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P. W. D. HANDBOOK

BOMBAY

CONTAINING

Specifications, Rates, Tables, Plates

AND

Notes on Work

ORIGINALLY COMPILED FOR THE USE OF THE P. W. DEPARTMENT IN THE BOMBAY PRESIDENCY

BY

CAPTAIN E. L. MARRYAT
Royal Engineers

VOL. I

(Sections I—III)

REVISED AND BROUGHT UP TO DATE UNDER THE ORDERS OF THE GOVERNMENT OF BOMBAY

NINTH EDITION

BOMBAY

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PREFACE TO THE NINTH EDITION.

First Edition (1876).—The first edition of Captain Marryat' s Specifications was published under Government Circular No. 178–E, dated 25th March 1876 with the principal object of laying down a good standard set of specifications for use in the Public Works Department in the Bombay Presidency for all ordinary works, and a series of rates for such specifications. In addition to this, sketches of masonry, brickwork, carpentry, etc., were added for the use of maistries and others by whom the Roorkee Treatise and other larger and practical books are unobtainable, and some practical notes on various subjects were compiled so as to form a handy note book.

The following were the principal sources from which the specifications were framed and notes compiled :—Standard specifications, Oudh, by Captain Peile, R.E.; for Rajputana, by Lieutenant-Colonel Forlong; for Bombay, by Colonel Fuller, R.E; Specifications of G. I. P. and B. B. & C. I. Railways; The Roorkee Treatise; The Chatam Course; Professional Papers on Indian Engineering; Engineer's Pocket Book; The Manufacture of Portland Cement, by H. Reid, C.S.

Second Edition (1877).—The second edition was issued in September 1877, with the following principal additions :—

1. Index.
2. Table of contents.
3. Tables on roofing by Major Seton, R.E.
4. Tables of scantlings for doors and windows by W. Howard, Esq., C.E.
5. Tables of timber topped culverts.

Third Edition.—The second edition of this compilation, which was published in 1877, was revised under the orders contained in Government Resolution No. 33–E.—185, dated 6th February 1882.

The matter contained in this edition, both new and old, was arranged somewhat differently to that of former editions. The specifications and rates followed each other instead of being separately massed together as in previous editions. The number of specifications and rates was largely increased, the most important addition being a set of standard specifications for use in the Irrigation Department furnished by the Chief Engineer for Irrigation.

Fourth Edition.—The third edition of this compilation, issued in 1883, was revised under the orders contained in Government Resolution No. 237–A.—1533, dated 16th September 1886. Some specifications which were somewhat incomplete were replaced by others taken from the " Standard Specifications in the Madras Presidency." A new sub-head " Drains, Culverts and Bridges " was added. The average plans and tables of quantities of which it consists were published with the permission of J. H. E. Hart, Esq., M.Inst.C.E., Chief Engineer for Irrigation. This section was a reprint, slightly amended, of two very useful pamphlets " intended to facilitate the preparation of road projects in Executive Engineers' offices ", published by that officer in 1868.

Fifth Edition.—The fourth edition of this compilation, which was issued in 1887, was revised under the orders contained in Government Circular Memo. No. 52–E., dated 25th January 1896. Under the resolution, Mr. C. I. Burke, M.I.C.E., was put on special duty for the purpose of revision. This edition was entirely re-arranged so as to bring all information pertaining to each particular kind of work together in one place. A chapter on Irrigation Works including specifications for Earthen and Masonry dams was included and the information on Water-works was extended. A section on Fireproof floors was added. All rates were omitted, the materials and labour required for a given quantity of work only being shown, so that Executive Engineers might fill in for themselves the rates prevailing in their respective districts.

Sixth Edition.—This edition was revised in the Secretariat under the immediate supervision of Mr. R. W. Murphy. Some useful notes, recipes for preparing materials were added. On the suggestion of many officers, the rates for work (which were not given in the previous edition) were entered in this edition. The rate abstracts of works specified in each chapter were placed at the end of their respective chapters and numbered according to the specifications to which they related.

This edition was reprinted in the year 1916, with the addition of "Rules for blasting with dynamite and other high explosives" and "General rules to be observed in Government Magazines for explosives."

Seventh Edition.—This edition was thoroughly revised and brought up-to-date under the orders contained in Government Resolution No. 3225, dated 29th November 1922. Mr. N. N. Ayyangar, B.A., L.C.E., M.I.E. (Ind.), Executive Engineer, was appointed as Officer on Special Duty for the purpose. New chapters were added on Reinforced Concrete, Arboriculture, Hydraulic formulæ and data, Retaining walls, Sanitary. Engineering including drainage and sanitation, and notes on Mechanical and Electrical Engineering. In the chapter on Road work full notes were added on road construction and repairs, care of steam rollers and tarring of roads. In the section on drains, culverts and bridges, additional matter was introduced on high level causeways, temporary crossings and landing stages on tidal creeks. The chapters on irrigation works and water supply, as well as Chapters I, II and III, were revised and additional notes included. A large number of new tables, specifications, rate abstracts and plates were added. Some obsolete portions and plates were omitted.

The following books were consulted :—

1. Indian Woods and their Uses, by R. S. Troup, F.C.H.
2. A Handbook for Cement Works Chemist, by F. B. Gatehouse, F.C.S.
3. Reinforced Concrete, by Harrington Hudson.
4. Reinforced Concrete, by J. C. Gammon, B.Sc. (Lond.), A.C.G.I., O.B.E.
5. Reinforced Concrete, by V. M. Kothasthane, B.A., B.Sc., L.C.E.
6. Detail Design in Reinforced Concrete, by E. S. Andrews, B.Sc.
7. Reinforced Concrete, by Captain A. F. Day, R.E.
8. Reinforced Concrete Manual, by Marsh and Dunn.
9. London County Council Regulations.
10. Rivington's Series of Notes on Building Construction.
11. Manual of arboriculture.
12. Hydraulics, by Lieutenant-Colonel H. D. Love, R.E.

13. Treatise on Hydraulics, by Prof. Unwin.
14. Irrigation Pocket Book—Buckley.
15. Irrigation, Roads and Buildings—W. L. Strange.
16. Water Supply of Towns, by Prof. Burton.
17. Water Supply, by R. E. Middleton, M.I.C.E.
18. Surface Drainage, by H. A. Gubbay, A.M.I.C.E.
19. Sanitary Engineering, by Colonel E. C. S. Moore, R.E.
20. Drainage Problems of the East, by C. C. James.
21. Sanitary Engineering in India, by J. Wallace, C.E.
22. Manual of Vital Statistics and Public Health, by Dr. J. D. Munsiff.
23. Military Works Handbook.
24. Pocket Companion--Messrs. Dorman Long & Co.
25. Civil Engineer's Pocket Book—Merriman.
26. Pocket Book of Engineering—Molesworth and Hurst.
27. Kemp's Engineer's Year-Book for 1922.
28. Engineer's Pocket-Book—Trautwine.
29. Proceedings of the Bombay Engineering Congress.
30. Do. Institute of Engineers (India).
31. Publications of the Governments of India, Bombay and Madras.

Almost all the suggestions made by the P. W. D. Officers were given effect to and contributions were specially obtained from many Officers including several not in the P. W. D. It would be invidious to mention individual names among so many and grateful thanks are due to all of them for the ready and valuable help received.

The rates were revised and brought up-to-date. This edition was published in two volumes.

Eighth Edition.—This edition has been revised in the Secretariat. A number of additions in the form of notes, new specifications, additional tables and plates have been made in this edition. Exhaustive tables have been added in the chapter on reinforced Concrete with a view to facilitate the work of designing and to ensure as far as possible uniformity of practice in the same. Most of the useful suggestions made by the Public Works Department officers have been given effect to ; besides a number of additions and alterations have been made on the subject of cement concrete and the allied specifications to bring this section up to date and as accurate as possible and grateful thanks are due to the Concrete Association of India for suggestions and assistance in this matter.

In most cases the rates prevailing in the Poona District have been adopted and, in others, figures such as might be assumed as fair average have been entered. As the rates are so very fluctuating from place to place and from time to time, the figures are meant only as a guide and each item has to be worked out for each special occasion and purpose.

This edition too, as the previous one, is published in two volumes.

Ninth Edition (1949).—The eight edition of the P. W. D. Hand Book, which was published in 1931 was thoroughly revised in the P. W. D. Secretariat under the direct supervision of Mr. H. K. Thakore, L.C.E., J.P., B.S.E. (Retired Executive Engineer), who was specially deputed on this work. The two main characteristic departures over the previous edition of the Hand Book, introduced in the present edition, are :—

(*a*) Non-embodiment of the rates in the rate abstracts.

(*b*) Distribution of the entire Hand Book, which previously was in 14 chapters in 8 sections each section dealing extensively with the main subject as under :—

Section	I	... ... Materials.
,,	II	... ... Buildings.
,,	III	... ... Reinforced Concrete.
,,	IV	... ... Roads.
,,	V	... ... Hydraulic formulae and data, drains, culverts, etc. etc.
,,	VI	... ... Irrigation works and storage for Hydro-electric Projects.
,,	VII	... ... Water supply and sanitary Engineering.
,,	VIII	... ... Valuation tables, Mechanical and Electrical notes and tables and miscellaneous information.

Rates in the rate abstracts are not given in view of the fact that those entered in the Hand Book (previous edition) are nowhere near the current rates or rates which are likely to be obtained for some years to come. While compiling this edition no effort was spared to bring the existing matter up-to-date as is warranted by the present times. Besides many new items have been introduced such as Asbestos Cement sheets, Pile foundations, Lintels with their design with necessary tables, curves and superelevations etc. in connection with Roads. Also new specifications for many items, such as, Cement mortar, lime-cement mortar, cement concrete, cement rendering and guniting, Shahbad stone flooring, granolithic and Terrazo toppings, Sand clay roads, gravel roads and other improved types of surfaces, etc. etc. have been introduced in this publication.

Great care has been devoted in the compilation of this publication, which includes the latest available experience, so as to make it an extensive and the best guide for all concerned as far as possible.

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P. W. D. HANDBOOK

BOMBAY

Volume I

SECTION I

MATERIALS

1949

CHAPTER I—NOTES FOR GUIDANCE.

1. GENERAL.

1. **Procedure.**—In all cases the work shall be executed, in strict accordance, with the contractor's accepted tender and the specifications attached thereto, with this book of specifications and notes, and with such drawings, specifications, quantities and orders, as may from time to time be issued by the Executive Engineer or his authorised agent.

2. **Supply of Materials.**—In cases where the contract is for the supply of materials, the materials shall be of such quality as may be specified in the contract and the specifications attached thereto and shall be delivered in such quantities, at such places, and at such times as may be laid down therein. They shall also be neatly stacked and arranged in such a manner as may be ordered by the Executive Engineer or his authorised agent.

3. **Supply of Tools, etc.**—All tools, implements, materials and machinery that may be required by the contractor will be provided by him at his own expense and he will only be paid for the finished articles as scheduled in the contract and in the specifications attached to the contract. It is, however, open to the Executive Engineer to lend or supply to the contractor any tools. implements, materials and machinery that the Executive Engineer may consider desirable, but for any such tools, implements, materials and machinery that may be lent or supplied to the contractor by Government the contractor shall pay such deposit, hire, or purchase price as may be determined by the Executive Engineer.

All articles that may be so let or hired out to the contractor, shall be returned by him to the Executive Engineer or his authorised agent on completion of the work for which they were lent or hired out, or earlier if so ordered. The hire charges, and charges for any shortage or damage, shall be recovered in cash or from the contractor's bills as specified.

4. **Workmanship and labour.**—The quality of all materials, tools, apparatus and labour used on the work shall be subject to the approval of the Executive Engineer or his authorised agent who shall have the power to order the immediate removal by the contractor of any that may not meet with his approval.

In case of failure to carry out the order of removal within the time specified, the Executive Engineer or his authorised agent, shall get it removed at the contractor's expense.

5. **Keeping dry and pumping.**—Unless otherwise specially provided for in the contract, the contractor will, at his own expense, keep all portions of the work free from undue water whether due to springs, soakage or inclement weather and will use his own implements and machinery for this purpose, subject to the conditions in para. 3 *ante*. The decision as to what consists undue water rests with the Executive Engineer.

6. **Facilities for Inspection.**—The work shall at all times be open to inspection by the Executive Engineer or his duly authorised assistant and the contractor shall arrange easy access to every part of the work and shall provide such ladders, scaffolding and lifts for this purpose, as necessary, without payment.

7. **Delivery of work.**—The final bill will be prepared after the work is handed over to the Executive Engineer or his duly authorised representative in a thoroughly complete, clean, sound and workmanlike state.

8. **Extra Items.**—Whenever the contractor is ordered by the Executive Engineer or the person duly authorised by him, to execute any item of work which is not in his tender, it shall be the contractor's duty to see, that the order is duly entered in the order book on the work, unless a separate communication to this effect is received by him. It shall also be his duty, to get a rate sanctioned for the item by the appropriate authority. For any extra item of work not thus ordered, either by an entry in the order book or a separate communication, the contractor shall have no claim to payment. If a rate for the extra item is not got sanctioned as directed above, the contractor shall be bound to abide by the Executive Engineer's decision.

9. **Compliance with Bye-laws, etc., and protection against accidents, etc.**— Contractors are responsible for complying with all Acts, Bye-laws, Municipal and other Regulations for the provision and maintenance of night lights, fencing and any other protection that may be necessary and will be liable for all claims that may arise from accidents, or nuisances on or caused by the works.

10. **Disputes.**—Disputes on any points between the Executive Engineer and the contractor shall be referred to the Superintending Engineer whose decision shall be given in writing and shall be final.

11. **Tolls, etc.**—The contractor shall, unless otherwise specially stated in the contract, be responsible for the payment of all import duties, tolls, octroi duties, quarry fees, etc., on all materials and articles brought on site.

12. **Treasure Trove and materials found during the execution of the work.**— All materials or treasure trove obtained from excavations, demolitions or other work on the site, are the property of Government, and shall be disposed of as the Executive Engineer or his authorised agent may direct.

2. CLEARING OF SITES.

1. The site described and shown on the plan, to be cleared of all obstructions, loose stones and materials, rubbish of all kinds, as well as all trees and brushwood, the roots being entirely grubbed up.

2. The products of the clearing to be stacked in such a place and in such manner as ordered by the Executive Engineer or his agents.

3. In jungle clearing, all trees not specially marked for preservation, bamboos junglewood, and brushwood shall be cut down and their roots grubbed up. All wood and material from the clearing to be the property of Government, and to be arranged as the Executive Engineer may direct.

4. All holes or hollows, whether originally existing or produced by digging up roots, shall be carefully filled up with earth, well rammed and levelled off, as may be directed.

3. DEMOLITION.

1. The contractor may, at the Executive Engineer's discretion, be required to provide, erect and remove screens of canvas or other suitable material to minimise the nuisance from dust and to provide for watering as the work of demolition proceeds.

2. The contractor will, if ordered by the Executive Engineer, make good any walls or roads, etc., disturbed during demolition and will protect, as far as possible, all trees, shrubs, etc., near the work.

3. If sewers or drains are to be removed or disturbed, the contractor must at once remove all foul matter, but the rates for taking up and removing pipes of all kinds are, unless otherwise mentioned in the contract, exclusive of any excavation that may be necessary. This will be separately paid for as such.

4. Unless specially stated in the contract, no allowance will be made for shoring or underpinning.

5. All material demolished shall, unless otherwise laid down in the contract, be the property of Government to be disposed of as may be ordered by the Executive Engineer. Even though not specified in the item of the contract, the rate for any item shall always include the sorting out of any demolished material, the stacking of it anywhere within 300 feet of the place of demolition in accordance with the orders of the Executive Engineer and also the removal of any material that the Executive Engineer may order completely from the place of demolition and the further disposal of it by the contractor. In the latter case, however, the contractor may realise such profit as he can from the material so removed and disposed of, subject always to the condition that the method of disposal shall be approved of in writing by the Executive Engineer in the first instance

6. Precautions shall invariably be taken by the contractor to avoid breaking or damaging material that may be considered by the Executive Engineer as likely to be serviceable.

4. EXCAVATOR'S WORK.

1. Trenches for foundations, footings, cesspits, drains, etc., to be excavated to the exact width, length and depth shown or figured on the drawings or as may be directed by the Executive Engineer. The excavated material shall be used to fill in on each side of the masonry or to form the filling in of floors, or it shall be placed or spread elsewhere on or near the site of the work as may be ordered free of charge. The contractor shall at his own expense, make provision for all pumping, dredging, bailing out or draining water, and the trenches shall be kept free of water while the masonry is in progress and till the Executive Engineer considers that the mortar is sufficiently set. The sides of the trenches to be kept vertical and the bottom horizontal and to be run at the same level throughout or properly stepped as may be desired by the Executive Engineer. The contractor shall also, at his own cost, remove such portions of boulders or rock as are required to make the bottom of the trench level He shall also make level and hard the bed of all the trenches and consolidate the earth against all walls, pits, drains, etc. The foundation trenches to be inspected and passed by the Executive Engineer before any concreting or masonry work is commenced.

2. The contractor shall be paid for the quantity arrived at, by multiplying the exact length, width at the lowest step of the footing, and the depth measured, vertically, as shown on the drawings, or as executed under written instructions of the Executive Engineer or his authorised agent.

3. The Executive Engineer or his authorised agent shall decide as to the classification of any material to be excavated.

4. All grades of materials, whether in cut or fill, will be measured in the excavations. The usual classification is given below :—

(*a*) **Hard rock wedged or chiselled.**—This shall include all rock occurring in masses which could best be removed by blasting, but which owing to the proximity of buildings or for any other reason should be cut out by means of cold chisels or wedges.

(*b*) **Hard rock (blasted).**—This shall include all rock occurring in masses which, could best be removed by blasting and where, in his opinion, blasting is permissible.

(*c*) **Soft rock.**—This shall include all material which is rock but does not need blasting and could be removed with a pick, bar and shovel.

(*d*) **Hard murum and boulders.**—This shall include all kinds of disintegrated rock or shale or indurated clay interspersed with boulders less than 1 cubic yard and larger than 1 cubic foot which do not need blasting and could be removed with a pick and bar and shovel.

(*e*) **Hard murum**—This shall include all kinds of disintegrated rock or shale or indurated clay free from boulders larger than 1 cubic foot which do not need blasting and could be removed by means of a pick and shovel though not without some difficulty.

(*f*) **Average murum** shall be stuff which is intermediate between hard murum and soft murum.

(*g*) **Soft murum** shall include materials which can be easily removed with a shovel after loosening with a pick.

(*h*) **Earth or sand.**—This shall include any other material of an earthy or sandy nature as the case may be, not classified above, which can be easily ploughed.

Note.—The use of explosives in excavations will not be considered as a reason for other classification than the above unless clearly necessary in the opinion of the Executive Engineer.

5. Consolidation of fill shall be done by thoroughly rolling or ramming in 9" layers which shall be watered at the contractor's expense, according to orders from the Executive Engineer.

6. All shoring, sheeting, strutting, etc., that may be necessary shall be provided by the contractor at his own expense.

7. Unless otherwise specified and provided for in the contract, the price for excavation shall include the removal of all grass, trees or other vegetation necessary to enable the material to be excavated to be got at.

8. The rates for excavation shall include levelling or grading the bottom and dressing the sides of the excavation, also levelling and dressing off the spoil, if so ordered.

9. Excavation to dimensions greater than those authorised as above, shall not be paid for, and if so ordered by the Executive Engineer or his authorised agent the contractor shall have :—

(*a*) to replace the material removed to excess depth, and consolidate it as in para. 5 *ante*, or

(*b*) to fill up the excess depth with new earth, murum or sand, and consolidate it as in para. 5 *ante*, or

(*c*) to fill up the excess depth with lime or cement concrete or masonry

as directed by the Executive Engineer or his authorised agent, without extra payment for this filling.

5. CARRIAGE.

1. The rates for carriage shall include all cost of loading and unloading in ordinary cases, and also as a rule, of stacking the material in regular heaps on site of work.

2. Carriage may be contracted for by weight or bulk at a mileage rate or at a fixed rate between specified places. In the former case, the distance shall be measured by the nearest practicable route.

3. When carts are engaged by the day, the quantity of material to be conveyed, and the distance to be travelled, or number of trips to be made, will be fixed by the Executive Engineer or his authorised agent.

TABLES FOR ASCERTAINING COST OF CARRIAGE BY COOLIES AND CARTS.

Memorandum on Cost of Carriage.

When any quantity of materials of given weight or cubic content (L) has to be moved to any distance (d), in feet, by a succession of trips of a number of units of conveyance, whose load in lbs. or cubic feet is (l), then the cost of transport of (L) will depend :

1stly, on X, or the proportion of (L) to (l)—that is, the number of unit-loads or trips of a unit of conveyance, that will be necessary.

2ndly, on Y, or the fraction of a working day, taken by a unit to make one trip to (d) and back.

3rdly, on Z, or the hire of a unit of conveyance for a working day.

In fact the cost of transport will $= X \times Y \times Z$.

To make tables for all possible values of Z would be beyond the scope of this memorandum. The following tables, however, give some useful values of Y for various leads, also of $X \times Y$ for a few given values of X or L/l.

The calculation of Y requires the following data :—

M, the number of minutes in a working day.

t, the time in minutes taken to load and unload a unit.

*S, the average speed in feet per minute of a unit.

If also for convenience of notation—

T represent the time in minutes taken for a unit to make one trip to (d) and back ;

N be the number of such trips made in a working day,

then—

$$(1)\ T = \frac{2d}{S} + t$$

$$(2)\ N = \frac{M}{T} = \frac{M}{\frac{2d}{S} + t}$$

$$(3)\ Y = \frac{T}{M} = \frac{\frac{2d}{S} + t}{M} = \frac{1}{N}$$

*S, the average speed, is the harmonic mean between the observed or known speeds s' s'' of the unit when loaded and unloaded, respectively, *i.e.*, $= \frac{2s's''}{s'+s''}$

If T be observed as well as t, then from (1) $S = \frac{2d}{T-t}$

TABLE I.

COST OF CARRIAGE BY COOLIES.

When unit of conveyance=COOLY LOAD, or $l = \frac{1}{2}$ cubic foot.

DATA : M=500 minutes, $t = \frac{1}{2}$ minute, $s = 200$ feet, d as per column 1.

Formulæ : $T = \frac{2d}{s} + t$; $N = \frac{M}{T}$; $Y = \frac{T}{M}$; $X = \frac{L}{l}$; Z = daily hire of unit.

Cost of transport of quantity L to $d = X \times Y \times Z$.

8 feet of lift equals 100 feet of lead.

I.	II.	III.	IV.	V.	I.	II.	III.	IV.	V
Lead or distance in feet.	Time of a trip to d and back in minutes.	No. of trips to d and back in a day.	Fraction of a day taken to make one trip to d and back expressed in decimals.	X × Y when $l = \frac{1}{2}$ C. F. L=100 cubic feet, *i.e.*, X × Y =200 Y	Lead or distance in feet.	Time of a trip to d and back in minutes.	No. of trips to d and back in a day.	Fraction of a day taken to make one trip to d and back expressed in decimals.	X × Y when $l = \frac{1}{2}$ C.F. L=100 cubic feet, *i.e.* X × Y =200 Y
d.	T.	N.	Y.	X × Y	d.	T.	N.	Y.	X × Y
20	·70	714	·0014	·28	475	5·25	95	·0105	2·10
30	·80	625	·0016	·32	500	5·50	91	·0110	2·20
40	·90	556	·0018	·36	525	5·75	87	·0115	2·30
50	1·00	500	·0020	·40	550	6·00	83	·0120	2·40
60	1·10	455	·0022	·44	575	6·25	80	·0125	2·50
70	1·20	417	·0024	·48	600	6·50	77	·0130	2·60
80	1·30	385	·0026	·52	625	6·75	72	·0135	2·70
90	1·40	357	·0028	·56	650	7·00	71	·0140	2·80
100	1·50	333	·0030	·60	675	7·25	69	·0145	2·90
125	1·75	286	·0035	·70	700	7·50	67	·0150	3·00
150	2·00	250	·0040	·80	750	8·00	63	·0160	3·20
175	2·25	222	·0045	·90	800	8·50	59	·0170	3·40
200	2·50	200	·0050	1·00	850	9·00	56	·0180	3·60
225	2·75	182	·0055	1·10	900	9·50	53	·0190	3·80
250	3·00	167	·0060	1·20	950	10·00	50	·0200	4·00
275	3·25	154	·0065	1·30	1000	10·50	48	·0210	4·20
300	3·50	143	·0070	1·40	1050	11·00	45	·0220	4·40
325	3·75	133	·0075	1·50	1100	11·50	43	·0230	4·60
350	4·00	125	·0080	1·60	1150	12·00	42	·0240	4·80
375	4·25	118	·0085	1·70	1200	12·50	40	·0250	5·00
400	4·50	111	·0090	1·80	1250	13·00	38	·0260	5·20
425	4·75	105	·0095	1·90	1300	13·50	37	·0270	5·40
450	5·00	100	·0100	2·00	1320	13·75	36.5	·0275	5·50

N. B.—Quantity carried in a day is N unit loads.

Cost of carrying one cooly load to d=Y × hire of cooly; of 100 C. F. of any materials is X × Y × hire of cooly.

Example.

What would be the cost of removing 100 c.f. to 600 feet if coolies cost 10 annas a day ?

Ans. 2·6 × 10=26 annas.

TABLE II.

COST OF CARRIAGE BY CARTS.

When unit of conveyance=CART LOAD or l has the values in columns V to XII.
DATA : M=540 minutes, t=10 minutes, s=100 feet, d as per col. 1.

Formulæ : $T=\frac{2d}{S}+t$; $N=\frac{M}{T}$; $Y=\frac{T}{M}$; $X=\frac{L}{l}$; Z = daily hire of unit.

Cost of transport of quantity : L to d=X · Y × Z.

I.	II.	III.	IV.	V.	VI.	VII	VIII.	IX.	X.	XI.	XII.
Lead or distance in feet.	Time of a trip to d and back in minutes.	No. of trips to d and back in a day	Fraction of a day taken to make one trip to d and back expressed in decimals.	X × U FOR UNDERMENTIONED VALUE OF l.							
				L=100 CUBIC FEET.					L=1 TON.		
				l in C.F.	l in C. F.	l in C. F.	l in C. F.	l in C. F.	l in cwt.	l in cwt	l in cwt.
d.	T.	N.	Y.	6.	7.	8.	9.	10.	8.	9.	10.
400	18	30	·0333	·556	·476	·416	·370	·333	·0825	·0730	·0666
431	18·6	29	·0345	·575	·493	·431	·383	·345	·0863	·0766	·0690
482	19·6	28	·0357	·595	·510	·446	·397	·357	·0895	·0793	·0714
500	20	27	·0370	·617	·529	·463	·411	·370	·0925	·0826	·0740
540	20·8	26	·0384	·640	·549	·480	·427	·384	·0960	·0853	·0768
580	21·6	25	·0400	·666	·572	·500	·444	·400	·1000	·0889	·0800
625	22·5	24	·0416	·693	·594	·520	·416	·416	·1040	·0925	·0832
675	23·5	23	·0435	·724	·621	·544	·483	·435	·1087	·0966	·0870
730	24·5	22	·0454	·757	·649	·567	·504	·454	·1135	·1009	·0908
785	25·7	21	·0476	·793	·680	·595	·529	·476	·1202	·1068	·0952
850	27	20	·0500	·833	·714	·625	·555	·500	·1250	·1111	·1002
921	28·4	19	·0526	·877	·751	·657	·584	·526	·1315	·1169	·1050
1,000	30	18	·0555	·925	·793	·694	·617	·555	·1389	·1234	·1111
1,088	31·8	17	·0588	·980	·840	·735	·653	·588	·1470	·1307	·1176
1,188	33·7	16	·0625	1·042	·893	·781	·694	·625	·1560	·1390	·1250
1,300	36	15	·0666	1·111	·952	·833	·740	·666	·1666	·1480	·1330
1,428	38·5	14	·0714	1·190	1·020	·893	·793	·714	·1787	·1590	·1430
1,575	41·5	13	·0769	1·282	1·099	·961	·854	·769	·1925	·1710	·1540
1,750	45	12	·0833	1·389	1·190	1·042	·926	·833	·2080	.1850	·1660
1,955	49	11	·0909	1·515	1·299	1·136	1·010	·909	·2280	.2020	·1820
2,200	54	10	·1000	1·666	1·429	1·250	1·111	1·000	·2500	.2220	·2000
2,500	60	9	·1111	1·852	1·587	1·389	1·234	1·111	·2770	.2470	·2220
2,675	63·5	8·5	·1176	1·960	1·680	1·470	1·307	1·176	·2940	·2610	·2350
2,875	67·5	8	·1250	2·083	1·786	1·563	1·389	1·250	·3130	·2770	·2500
3,100	72	7·5	·1333	2·222	1·904	1·666	1·481	1·333	·3330	·2960	·2660
3,355	77	7	·1428	2·383	2·040	1·784	1·587	1·428	·3560	·3170	·2850
3,653	83	6·5	·1538	2·563	2·197	1·922	1·709	1·538	·3840	·3410	·3070
4,000	90	6	·1666	2·777	2·381	2·083	1·852	1·666	·4170	·3700	·3330
4,425	98·5	5·5	·1818	3·030	2·597	2·273	2·020	1·818	·4540	·4030	·3630
4,900	108	5	·2000	3·333	2·857	2·500	2·222	2·000	·5000	·4450	·4000
5,500	120	4·5	·2222	3·703	3·174	2·777	2·409	2·222	·5550	·4940	·4440
6,200	135	4	·2500	4·166	3·571	3·125	2·777	2·500	·6250	·5560	·5000
7,200	154	3·5	·2857	4·762	4·082	3·573	3·174	2·857	·7140	·6340	5710
8,500	180	3	·3333	5·555	4·762	4·167	3·704	3·333	·8330	·7410	·6660
10,300	216	2·5	·4000	6·666	5·714	5·000	4·444	4·000	1·000	·8890	8000
13,000	270	2	·5000	8·333	7·143	6·250	5·555	5·000	1·250	1·111	1·1000
17,500	360	1·5	·6666	11·111	9·524	8·333	7·407	6·666	1·670	1·480	1·3330
26,500	540	1	1·000	16·666	14·286	12·500	11·111	10·000	2·500	2·220	2·0000
53,500	1080	0·5	2·000	33·333	28·572	25·000	22·222	20·000	5·000	4·440	4·0000

Example.

Cost of carrying 100 cubic feet of metal 2,200 feet, if cart hired at Re. 1–8–0 a day, takes 8 cubic feet as its load=1·25 × hire of cart per day=1·25 × 1·5=Re. 1-14-0.

TABLE III.

TASK WORK FOR AN EXPERIENCED ARTISAN, AND LABOURER, PER DAY.

Serial No.	Item.	Task.
1	Ashlar fine	1¾ c. ft.
2	Do. rough-tooled	2⅔ ,,
3	Do. rock, rustic or quarry-faced	3 ,,
4	Do. chamfered	2½ ,,
5	Do. facing, rough-tooled	4 ,,
6	Do. do. rustic, with chisel draft ...	4½ ,,
7	Do. do. chamfered	4 ,,
8	Block in course	4 ,,
9	Coursed rubble, 1st sort	9 ,,
10	Do. 2nd do.	12½ ,,
11	Do. 3rd do.	20 ,,
12	Random rubble, 1st sort	6 ,,
13	Uncoursed rubble masonry	20 to 25 ,,
14	Stone and mud masonry	50 ,,
15	Dry stone masonry	33 ,,
16	Dry rubble retaining wall	25 ,,
17	Brickwork, 1st class	17 ,,
18	Do. 2nd do.	25 ,, (¾th of these for 9-inch brick walls).
19	Brick and mud work	25 c. ft.
20	Honey-comb brickwork	25 ,,
21	Ashlar in arches	1 to 1½ ,,
22	Block in course arching	2¾ ,,
23	Rubble arching	6 ,,
24	Circular or flat brick archwork	10 to 12½ ,,
25	Pointing (stonework)	66 sq. ft.
26	Pointing (brickwork)	50 ,,
27	Plastering (cement) ¾″ thick	33 ,,
28	Do. (lime), 1 coat	66 ,,
29	Do. (lime), 2 coats	33 ,,
30	Do. (lime), 3 coats	22 ,,
31	Do. (lime), rough cast	80 ,,
32	Stone paving (trap, dressed), 1st sort	3 ,,
33	Do. (do.), 2nd do. ...	4½ ,,
34	Do. (do.), 3rd do. ...	6 ,,
35	Brick on edge terracing	45 ,,
36	Flagged or Shahabad stone flooring	30 to 40 ,,
37	Plank ceiling	50 ,,
38	Cloth do. (including framework)	33 ,,
39	Fixing roof battens for Mangalore tiles ...	100 ,,

Serial No.	Item.	Task.	
40	Fixing roof battens for country tiles	60	sq. ft.
41	Country double tiling	50	,,
42	Do. single tiling	100	,,
43	Mangalore tiled covering	100	,,
44	Fixing corrugated iron roof covering	33	,,
45	Fixing Mangalore ridge tiles	50	r. ft.
46	Valley gutter	12½ to 16½	,,
47	Door panelled 4′ × 7′ (with frame)	10	days.
48	Do. do. and glazed 4′ × 7′ (with frame)	10	,,
49	Do. plain planked 2½′ × 2½′ (with frame) ...	4	,,
50	Do. battened 4′ × 7′ (with frame)	7	,,
51	Do. veneteined 4′ × 7′ (with frame) ...	12	,,
52	Windows glazed 4′ × 5′ (with frame)	6	,,
53	Do. with plank shutters 3′ × 4′ (with frame)	3	,,
54	Do. glazed and venetianed 4′ × 5′ (with frame and double shutters)	14	,,
55	Teakwood work (framing)	2	c. ft.
56	Do. do. (joinery)	1	,,
57	Painting, 3 coats	60	sq. ft.
58	Varnishing, 2 coats	100	,,
59	Distempering, 2 coats	200	,,
60	Whitewashing, 3 coats	400	,,
61	Trellis work with frame (hoop iron)	50	,,
62	Do. do (teak wood)	33	,,
63	Do. do. (expanded metal) ...	50	,,
64	Excavation in black or red soil (lift up to 5 ft.; lead up to 100 ft.)	75	c. ft.
65	Do. in soft murum (do.) ...	50	,,
66	Do. in average murum (do.) ...	35	,,
67	Do. in hard murum (do.) ...	25	,,
68	Do. in soft rock (including removal of stone to a distance of 50 ft.)	16	,,
69	Do. in hard rock (trap) (including removal of stones to a distance of 50 ft.) ...	8	,,
70	Breaking metal 1½″ (trap or granite)	10	,,
71	Do. 1½″ (quartz metal on quarry) ...	13	,,
72	Breaking laterite metal 2½″	20	,,
73	Conveying of metal by head load. Lead 100 ft.	85	,,
74	Do. do. 200 ,, ...	65	,,
75	Do. do. 300 ,, ...	50	,,
76	Do do 660 ,, ...	35	,,

Note.—In recent years, many reasons have combined to increase greatly the efficiency of labour, and in many cases, in work given out on piece work or contract, the turn out is very much higher, and may be double that given in the table.

CHAPTER II—MATERIALS.

Quarrying, blasting with powder and dynamite, and the principal stones.

PRINCIPAL STONES AND QUARRYING.

1. The principal stones used for building purposes in the Bombay Presidency are :—

BASALTS

Blue Basalt or Trap.—This varies much in quality. The best quality is hard, of a bright colour, breaking with a clean fracture, and ringing when struck with a hammer, and is well suited for paving and metalling roads. Weight per cubic foot about 187 lbs.

Bombay Basalt.—Dark blue trap gives a resistance to crushing of 10,200 lbs. and light blue 4,800 lbs. per square inch.

Inferior qualities are often much softer and easier to work, but in a few years become discoloured and decay rapidly. Stones from boulders sometimes peel after a few months' exposure to the weather.

Yellow Basalt, or Kurla stone, is obtained from quarries at Kurla and Malad. Its resistance to crushing is about 9,840 lbs. per square inch.

Red Basalt.—Obtained at Satri, or from near Talegaon in the Poona district.

SAND STONES

Himmatnagar.—Obtained about 55 miles from Ahmedabad. A moderately hard, fine-grained, silicious white sandstone. Resistance to crushing, 5,000 lbs. per square inch.

Badami.—Obtained from Alur and Badami quarries. Alur and Badami are stations on the Gadag-Hotgi branch line, and the quarries are not very far from the stations. The Alur stone of a pure white colour is much used for arches, corner stones etc. in the Dharwar and Bijapur districts. It is a fine grained silicious sand-stone and is obtainable in large sizes. Milestones are prepared from a coloured variety.

LIME STONES

Porbandar.—A calcareous grit, composed of foraminiferous shells and a few grains of quartz, joined by solution of shells and re crystallization. Porbandar stone is to be of fine grain, good colour and free from salt. No stone of doubtful quality, or of very coarse grain, or with black specks in it to be brought on the work, and if it has been at any time saturated with sea water, it will be rejected. Care should be taken to lay it on its natural bed in the work. Resistence to crushing, 2,120 lbs. per square inch.

Shahabad.—A splendid limestone obtained in layers from 3 inches to 15 inches thick is found at Shahabad and Tandur.

2. All stone to be sound, free from decay, flaws, cracks, veins or cavities and, so far as possible, of uniform colour and texture.

3. Blocks required for dimensioned stuff must be quarried true and square, and as near the dimensions given as possible.

4. Rubble stone will be as square and evenly bedded as possible, and in as large pieces as the quarry will permit consistently with facility of being handled. No irregularly-shaped or unevenly-bedded pieces shall be permitted, and no stone shall contain less than ⅓ of a cubic foot.

5. In quarrying stone for building purposes there should be as little blasting as possible, as it shakes the stone besides causing considerable waste. Care should be taken to cut the blocks so that they can be placed in the work for which they are intended with their natural beds at right angles to the pressure that will come upon them.

Granite.—Excellent granite is obtainable in the Nizam's Dominions, Gujarat and the Southern Maratha Country, but it is difficult and expensive to work. The durability of granite depends upon the quantity of quartz and the nature of the felspar; if quartz largely predominates, it will be hard to work, but, unless the felspar is of a bad description, it will weather well. Mica is easily decomposed, and it is therefore a source of weakness.

If the mica or felspar contains an excess of lime, iron, or soda, the granite is liable to decay. The conclusions drawn from a series of careful tests carried out by the Bombay Port Trust, on Indian granites, in connection with the new docks are as under.

The Indian samples, with one or two exceptions, are equal to or better than the standard samples in respect of their compressive strength, resistance to abrasion, absorption of water, and freedom from voids. In structure there are two characteristic differences. In the first place, none of the Indian samples contains muscovite or white mica; in every case the mica is of the dark variety (biotite); in the Aberdeen or Cornish samples muscovite is prevalent, but is absent in the Norwegian specimen. The fact that in the Indian granites the mica is solely biotite is not regarded as any mark of mechanical inferiority. Secondly, the dominant species of felspar in the standard samples is potash felspar, whereas soda felspar is more abundant in the Indian samples. The opinion is generally held that potash felspars are more resistant to weathering than soda felspars, and the Indian granites are in this respect less excellent than the standard samples. But having regard to the fact that a series of corrosion tests of a somewhat severe kind have been successfully resisted by the Indian specimens, it is considered that the deviation from the composition usually approved is not of serious significance.

The order of merit of the granite samples is indicated in table IV.

Laterite.—A clay-stone impregnated with iron in the form of red and yellow ochres, with a perforated and cellular structure, is obtained in Belgaum, Ratnagiri, Kanara, Dharwar and Mahabaleshwar. It is very easy to work, but care is required in selection of stone, as the inferior sorts, containing much clay, do not harden when exposed to the weather. The best varieties are those that are rich in red oxide of iron (Hæmatite, $Fe_2 O_3$).

Laterite should be compact in texture, and the mottled and streaked colours pervading it should not be very unevenly distributed. Those descriptions in which white clay occurs, should not be used as building material. Laterite being benefited by long exposure, should never be used when freshly quarried, especially from any depth. It should not be used where subject to any great pressure, and liable to be soaked with water.

TABLE IV.

ULTIMATE STRENGTH OF DIFFERENT STONES TO RESIST CRUSHING.

Description.	Source.	Weight per cubic foot in lbs.	Absorption per cent. volume.	Crushing strength tons per square foot.	Remarks.
Traps.					
Dark grey close grained trap.	Kole Kalyan (Thana). ...	188·4	0·75	3,490	
Light brown trap ...	Kurla ...	146·4	6·09	1,708	
Dark grey coarse trap ...	Satri ...	196·8	0·23	1,464	
Dark grey fine grained trap.	Kurla ...	176·5	0·20	1,078	
Very dark blue grey trap	Anik ...	186·8	0·39	1,479	
Very dark grey trap, coarse texture.	Ghatkopar ...	187·1	0·00	1,765	
Very fine grey blue trap	Bhandup ...	189·2	0·00	2,475	
Dark blue trap ...	Danda ...	179·8	0·00	3,675	
Ordinary dark blue trap	Bombay ...	...	...	656	
Ordinary light blue trap	Do. ...	...	...	309	
Ordinary yellow trap ...	Kurla ...	...	...	633	
Reddish trap full of amygdales.	Poona District ...	...	...	306	
Ordinary grey trap ...	Do. ...	...	...	426	
Dark grey trap fine and uniform grained, free from anygdales.	Do. ...	...	...	507	
Trap stones ...	Chinchwad (Poona)	...	...	426	
Granites.					
Granite (standard) ...	Aberdeen ...	164·6	0·16	1,800	
Do. ...	Cornish ...	165	0·41	1,402	
Do. ...	Norwegian ...	166	0·34	1,870	
Granite (specimen A) ...	Raichur, Deccan Hyderabad.	165·75	0·26	2,427 (3)	
Do. („ B) ...	Do. ...	166·3	0·10	2,085 (2)	
Do. („ C) ...	Do. ...	166	0·11	2,444 (1)	Best.
Do. („ A) ...	Munirabad, Deccan Hyderabad.	164·4	0·21	1,806 (6)	
Do. („ B) ...	Do. ...	165	0·14	2,048 (3)	
Granite ...	Shivapuram, Deccan Hyderabad.	164	0·11	1,504 (7)	
Granite („ A) ...	Khanapur, Belgaum District.	164·5	0·21	2,484 (4)	
Do. („ B) ...	Do. ...	165	0·18	2,012 (4)	
Granite ...	Nagargalli, Belgaum District.	167	0·15	1,870 (6)	
Granite („ A) ...	Karwar, Kanara District.	165·4	0·35	2,271 (5)	
Do. („ B) ...	Do. ...	164·4	1·11	1,303 (8)	Decayed and friable and weak.
Do. („ A) ...	Godhra (Panch Mahals).	165	0·18	1,606·4	
Do. („ B) ...	Do. ...	165	0·11	1,660·4	
Do. („ C) ...	Do. ...	165	0·20	1,820·8	
Granite ...	Pallavaram (Madras).	179	0·29	1,410	Charnokite (not a true granite).
Gneiss ...	......	164 to 167	...	203 to 1,602	

(Bracketed numbers in the crushing strength column: Order of merit of granite.)

TABLE IV—*contd.*

Description.	Source.	Weight per cubic foot in lbs.	Absorption per cent. volume.	Crushing strength tons per square foot.	Remarks.
Limestones.					
Limestone (Miliolite) ...	Porebunder ...	...	...	136	
Limestone ...	Do. ...	110·7	5·19	155	Loses 47 per cent. of strength when thoroughly wet.
Sandstones.					
Siliceous white sandstone	Himmatnagar ...	...	...	321	
Calcareous sandstone ...	Dhrangadra ...	...	...	365	
Sandstone strong ...	......	...	...	353	
Laterite ...	West coast ...	...	...	17·3 to 29·3	Loses considerably in strength on becoming wet, depending on the amount of clay contained in the stone.
Good laterite (ferruginous)	......	...	...	67·3	
Pot stone strong ...	Mysore and Dharwar.	...	...	340·2 to 457·6	
Red porphyry (ornamental stone).	Mysore ...	...	...	1,142 to 1,833	
"Slates" (black limestone).	Cuddapah ...	167·5	...	1,006 to 1,571	

Note.—Rubble masonry, about four-tenths of cut stone.

For weights of building materials, etc., *vide* Page 90.

TABLE V.

AVERAGE CRUSHING STRENGTH OF BUILDING STONES.*

Coarse porphyritic granites	average	700 tons	per	sq. ft.
Medium grained granites	,,	1,000 tons	,,	,,
Fine grained granites	,,	800 tons	,,	,,
Doleritic basalts	,,	1,000 tons	,,	,,
Ordinary Deccan traps	,,	400 tons to 500 tons	,,	,,
Epidiortes and diorites	,,	1,500 tons	,,	,,
Sandstones, coarse, hard	,,	600 tons	,,	,,
Sandstones, medium to fine, hard	,,	400 tons	,,	,,
Marble, coarse to medium	,,	80 tons	,,	,,
Marble, fine to medium	,,	300 tons	,,	,,
Limestones, hard	,,	400 tons	,,	,,
Limestones, soft or öolitic	,,	100 tons	,,	,,
Slate, fine hard	,,	800 tons	,,	,,
Clay slate, hard	,,	600 tons	,,	,,
Clay slate, normal	,,	400 tons	,,	,,
Brick, good	,,	100 tons	,,	,,
Cement (neat)	,,	350 tons	,,	,,
Concrete, (cement) 1 : 2 : 4, 6 to 10 months old	,,	180 tons	,,	,,
Cement mortar 1 to 3 months old	,,	150 tons	,	,,
Brick work, in cement	,,	50 tons	,,	,,
Lime mortar	,,	40 tons	,,	,,
Brick work, ordinary	,,	25 tons	,,	,,

N.B.—The pressure applied perpendicular to the plane of foliation, bedding or lamination. Stones generally begin to crack or split under about ½ their crushing loads. In practice, neither stone nor brickwork should be trusted with more than $\frac{1}{10}$ to $\frac{1}{20}$ of the crushing load, according to circumstances.

*Fresh undecomposed specimens only.

TABLE VI.

STONE BEAMS.

Table of safe dead extraneous loads for beams of good building granite, one inch broad, supported at both ends and loaded at the centre. Factor of safety 10. Weight of beams allowed for at 170 lbs. per c.ft.

DEPTH IN INCHES.	CLEAR SPANS IN FEET. 1	2	3	4	5	6	7	8	10	12	15	20
	SAFE CENTRE LOADS IN POUNDS.											
1	10	5	...	...	...	...	...	...	...	...	...	...
2	40	20	13	10	...	...	...	...	...	...	...	...
3	90	45	29	21	17	...	...	...	...	...	...	...
4	160	79	52	39	31	26	21	...	...	...	...	...
5	250	124	82	61	48	40	34	...	...	...	...	...
6	360	179	119	89	70	58	48	42	32	...	...	...
7	490	244	162	120	96	79	67	58	45	36	27	16
8	639	319	212	158	126	104	88	76	59	47	36	22
10	999	499	331	248	197	163	139	120	94	76	58	38
12	1439	718	478	357	284	236	201	174	137	111	85	53
14	1959	978	650	487	388	322	274	238	188	153	118	81
16	2559	1278	850	636	507	421	359	312	246	201	157	109
18	3239	1618	1077	806	643	534	455	396	313	257	200	141
20	3999	1998	1329	995	794	660	563	490	388	319	249	176
22	4839	2417	1609	1205	961	800	682	594	470	387	303	216
24	5758	2877	1916	1434	1145	951	813	708	562	463	362	260
27	7288	3642	2425	1815	1450	1205	1030	898	713	588	462	332
30	8998	4496	2995	2243	1791	1489	1273	1110	882	728	573	415
33	10888	5441	3624	2714	2168	1803	1542	1345	1069	883	696	505
36	12958	6476	4314	3231	2581	2147	1836	1603	1275	1054	832	606

Note.— 1. If uniformly distributed over the clear span, the safe extraneous loads will very nearly be twice as great as those in the table.

2. To find the bearing strength of a slab, multiply the figures in the table by the width of the slab in inches.

3. In the above table the breaking load for a beam one inch square, and one foot clear span is taken to be 100 lbs. concentrated at the centre.

4. For good slate *on bed* the safe loads may be taken at about 3 times;

5. For good sandstone *on bed* at about ½; and

6. For good marble or limestone *on bed* at about the same as those in the table.

BLASTING WITH POWDER.

1. Blasting operations must be in charge of competent persons and be carried out during fixed hours of the day, preferably during the midday luncheon hour or at the close of the work. The Sub-divisional officer should fix the hours in written orders.

2. Red danger flags should be prominently displayed and all the people, except those who have actually to light the fuses, must be removed to a safe distance, not less than 200 yards as a rule. For special cases, suitable extra precautions must be taken.

3. All fuses must be cut to the lengths required before being inserted into the holes.

4. The number of charges to be fired and the actual number of shots heard, must be compared, and the person responsible must satisfy himself by examination that all the charges have exploded, before work-people are permitted to approach the scene. The withdrawal of a charge which has not exploded is under no circumstances to be permitted; but the tamping and charge should be flooded with water, and the hole marked in a distinguishing manner. Another hole should be jumped at a distance of about 18 inches from the old hole and fired in the usual way. The results to be carefully examined by the person in charge of the blasting, and the operation continued, until the original charge is exploded.

5. Where it is not practicable for the subordinate in charge to supervise the blasting operations in person, select men from amongst the quarrymen, should be appointed as special *mukadams* to supervise the operations.

6. In the case of works executed by contract, the contractor or any competent person the contractor may place in charge of blasting operations shall be held responsible for strictly observing the rules.

7. A copy of the rules in English and in the appropriate Vernacular must be posted in a conspicuous position on each work, and the contractors must initial the copy of the orders, which should be shown to them when they receive orders to commence work.

8. All sub-divisional officers must see that these orders are carried out strictly, and they will also be held responsible for the safe custody and storage of the powder or dynamite or other explosives brought for use on the work.

9 Blasting powder when stored in a Government magazine or issued for the work must be kept separate from the fuses and detonators.

NOTES ON DYNAMITE.

1. Dynamite is procurable made up in cartridges of two kinds—one $\frac{7}{8}$ inch diameter, $3\frac{1}{4}$ inches long, each weighing 2 ounces; the other 1 inch in diameter, $3\frac{1}{2}$ inches long, each weighing $2\frac{1}{3}$ ounces. The cartridges are made up in 5-lb. packages, and 10 of these packages are packed in a wooden case. A ton of dynamite = 2,000 lbs.

2. Dynamite is exploded by means of detonators, which are procurable in tin boxes and are laid in sawdust, which should be blown out with a dry blow of the mouth before using. A detonator consists of a capsule containing an explosive

priming substance, and its purpose is to set off a high explosive. Mercury fulminate, still remains the principal ingredient of most detonators.

The contact between the detonator and the explosive should be as close as possible, as even a space interval of 0·04″ greatly diminishes the effect.

The most common types of detonators in use, are blasting caps, and electric blasting caps.

Blasting caps are fixed by means of a safety fuse. For ordinary quarry work a medium grade fuse is satisfactory. The rate of burning of the fuse must be definitely known to permit such a length being cut as will permit sufficient time to firer to reach safety.

One end of a Bickford's fuse cut square is pushed into the detonator till it touches the white fulminate within it. The open end of the cap is then pinched with pincers to grip the fuse, care being taken not to break the powder core of the fuse by pinching too tightly. If the detonator is to be used in damp or wet places the junction should be made water-tight with grease, white lead or tar. A primer i.e. a dynamite cartridge used for priming, is then opened at one end, and the detonator gently pushed into the dynamite, leaving about ⅓rd of the copper tube exposed outside. The paper of the cartridge is then closed up and securely bound with wire or twine to prevent dislocation of the detonator. Avoid pushing the detonator too far into the cartridge, otherwise there is a risk of the fuse burning up the cartridge releasing fumes.

The premier (that is the cartridge with the detonator and attached fuse), is then gently inserted on the top of the charge. The space for about 8 inches above the charge is then gently filled with dry clay pressed home and the rest of the tamping is formed of any convenient material gently packed with a wooden rammer.

3. In blasting rocks with dynamite, the following general principles should be observed :—

The mode of proceeding is very much the same as for powder, but the holes should be further apart, of similar depth but of smaller diameter. The following are the diameters of drills used for different depths of bore hole :—

From 3 to 6 feet	...	... 1 inch in	diameter.
„ 6 to 11 „	...	... 1½ to 2 inches	„
„ 11 to 15½ „	...	... 2 to 2½ „	„

The depth of the bore hole should be about the same as length of the line of least resistance, and, if possible, the bottom of the holes should never descend below the face of the rock. The bore holes should generally be not more than 5 feet deep, and the distances apart should be from one and a half to twice their depth.

If the required charge is so great that it cannot be held in a hole 5 feet deep, two or more holes should be made close together, the total charge being slightly increased, and all charges exploded simultaneously.

Cracks and fissures in the rock to be blasted, should be carefully studied to ascertain the best position for the bore holes. The charge should always be placed in a sound piece of rock and if possible, not nearer to a crack than 1 foot.

If it is desired to shatter rock, close connection between the dynamite and the rock is essential, and points of contact should be multiplied as much as possible. For this reason, several bore holes of moderate diameters, are preferable to one hole of a large diameter.

In case of a gently sloping rock with no face, dynamite should be used very much as powder is, only with fewer and shallower bore holes. As the line of least resistance is not so important in dynamite as in powder, the necessity for sloping the holes is not so great. But if a face is required on an almost level rock, sloping holes must be used.

4. *Tamping.*—Water, sand, and clay, are the best materials for tamping, the first two being the easiest to use. Soft *muram* is also suitable. If water is used, the junction of the fuse with the detonator must be made water-tight. This can be done by means of coal tar thickened with quicklime. A piece of cloth can then be wrapped round the joint and kept in position with a few turns of yarn. In case of a mis-fire with clay tamping, the old charge must not be removed, but a fresh hole should be bored not less than 6 inches from the old one, loaded and fired in the usual way. The explosion of the charge in the new hole will almost always explode the first charge. Should the first hole be of considerable depth, it will only be necessary to make the new hole 6 inches lower than the top of dynamite in the old hole.

5. When dynamite is used for blasting, the person in charge must himself superintend the loading of the holes and must see that all charges have exploded.

6. Other directions, same as described for "blasting, with powder".

7. *Charges.*—In calculating the charges required to blast rocks the following formula should be used :—

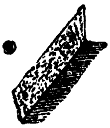
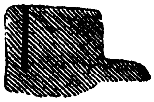
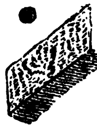
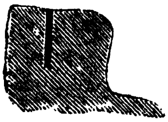
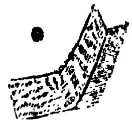
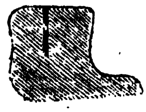
W, Explosive charge in ounces avoirdupois $= A X^2 + B X^3$ where A and B are co-efficients to be determined by direct experience, and x is the line of least resistance, *i.e.*, the distance from the centre of the charge to the nearest surface of the rock.

Table VII gives charges for gneiss rocks under the conditions assumed.

TABLE

EXPLOSIVE charges of dynamite in ounces avoirdupois to blast gneiss rocks
W=charge in ounces = A X^2 + B X^3 for solid rock—for boulders by

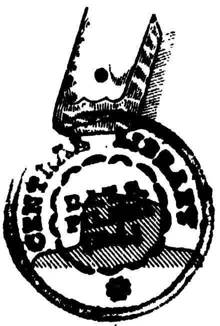
ILLUSTRATIONS.

Explosive employed.										
	Solid attached rocks.	 			 			 		
	Different conditions of rock blasting.	Only one face and that not clear; footings of rock requiring bore-holes to be below bottom of face.			Only one clear face, bottom of bore-hole being above foot of face of rock.			Two clear faces.		
	FORMULA WITH VARYING CO-EFFICIENTS.	$W = A(x^2) + B(x^3)$ $A = 1 : B = \frac{1}{8}$ W = Charge in ounces.			$W = A(x^2) + B(x^3)$ $A = \frac{5}{12} : B = \frac{1}{4}$ W = Charge in ounces.			$W = A(x^2) + B(x^3)$ $A = \frac{5}{12} : B = \frac{1}{9}$ W = Charge in ounces.		
	LINE OF LEAST RESISTANCE OR L.L.R. IN LINEAL FEET.	Explosive charges. Avoirdupois.		Fraction of x^3 in lb.	Explosive charges. Avoirdupois.		Fraction of x^3 in lb.	Explosive charges. Avoirdupois.		Fraction of x^3 in lb.
		Ozs.	lbs.		Ozs.	lbs.		Ozs.	lbs.	
Noble's dynamite No. 1.	1	1¼	·08	$\frac{1}{12}$	¼	·04	$\frac{1}{25}$	½	·03	$\frac{1}{33}$
	1½	3	·17	$\frac{1}{20}$	1½	·09	$\frac{1}{30}$	1⅓	·08	$\frac{1}{42}$
	2	5⅓	·33	$\frac{1}{24}$	3	·19	$\frac{1}{45}$	2½	·16	$\frac{1}{50}$
	2½	9	·56	$\frac{1}{28}$	5¼	·33	$\frac{1}{48}$	4⅓	·27	$\frac{1}{56}$
	3	13½	·84	$\frac{1}{32}$	8½	·52	$\frac{1}{52}$	7	·43	$\frac{1}{63}$
	3½	19½	1·21	$\frac{1}{36}$	12¼	·76	$\frac{1}{56}$	10	·61	$\frac{1}{70}$
	4	26⅔	1·66	$\frac{1}{39}$	17½	1·09	$\frac{1}{59}$	14	·86	$\frac{1}{74}$
	4½	35½	2·21	$\frac{1}{41}$	23¾	1·48	$\frac{1}{62}$	18⅓	1·16	$\frac{1}{78}$
	5	46	2·88	$\frac{1}{43}$	31⅓	1·96	$\frac{1}{64}$	24½	1·53	$\frac{1}{82}$
	5½	58	3·63	$\frac{1}{46}$	40⅓	2·52	$\frac{1}{66}$	31	1·94	$\frac{1}{86}$
	6	72	4·5	$\frac{1}{48}$	51	3·19	$\frac{1}{68}$	39	2·44	$\frac{1}{88}$
	6½	..	..	..	63½	3·96	$\frac{1}{70}$	48	3·01	$\frac{1}{91}$
	7	..	..	..	78	4·85	$\frac{1}{71}$	59	3·66	$\frac{1}{94}$
	7½	..	..	..	94	5·86	$\frac{1}{72}$	71	4·40	$\frac{1}{96}$
	8	..	..	..	112	7·00	$\frac{1}{73}$	84	5·21	$\frac{1}{98}$
	8½	..	..	..	133	8·28	$\frac{1}{74}$	99	6·14	$\frac{1}{100}$
	9	..	..	..	156	9·71	$\frac{1}{75}$	115	7·18	$\frac{1}{102}$
	9½	..	..	..	181	11·28	$\frac{1}{76}$	133	8·30	$\frac{1}{104}$
	10	..	..	..	209	13·01	$\frac{1}{77}$	153	9·54	$\frac{1}{106}$

VII

under the various conditions shown. Charges calculated from the formula: ounces to square feet of least vertical section.

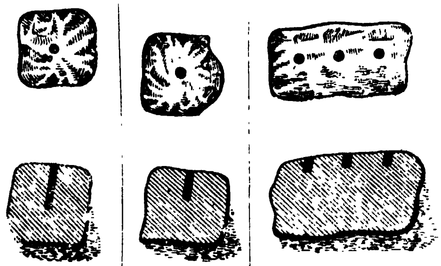
ILLUSTRATIONS.



Three clear faces.

Loose detached rocks.

Different conditions of boulder blasting.



Vertical hole bored in detached boulder to proper depth, *i.e.*—⅔ height of rock.	Vertical hole bored ½ height of rock in depth.	Several vertical bore-holes ⅙ height of rock in depth and 3 feet apart.	Dynamite laid on rock with no bore-hole and covered with clay, etc.	Dynamite laid on rock and exploded without being covered.

$W = Ax^2 + B \times ^3$
$A = \frac{1}{2}:\ B = \frac{1}{14}$
W = Charge in ounces.

Explosive charges			BOULDERS.	EXPLOSIVE CHARGES OF DYNAMITE IN OUNCES AVOIRDUPOIS.				
Avoirdupois.		Fraction of X^3 in lb.	AREA OF LEAST VERTICAL SECTION IN SQUARE FEET.	ONE ounce of DYNAMITE to every 4 square feet of least vertical section.	One ounce of DYNAMITE to every 2 square feet of least vertical section.	One ounce of DYNAMITE to every square foot of least vertical section.	Two ounce of DYNAMITE to every square foot of least vertical section.	Four ounces of DYNAMITE to every square foot of least vertical section.
Ozs.	lbs.		Sq. ft.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.
¼	.03	$\frac{1}{88}$	..	....	....	....	..	..
1	.06	$\frac{1}{84}$	2	½	1	2	4	8
2	.13	$\frac{1}{64}$	4	1	2	4	8	16
3½	.20	$\frac{1}{78}$	8	2	4	8	16	32
5	.31	$\frac{1}{86}$	12	3	6	12	24	48
7½	.45	$\frac{1}{96}$	16	4	8	16	32	64
10	.63	$\frac{1}{101}$	20	5	10	20	40	80
13½	.83	$\frac{1}{116}$	24	6	12	24	48	96
17½	1.08	$\frac{1}{116}$	28	7	14	28	56	112
22	1.38	$\frac{1}{121}$	32	8	16	32	64	128
27½	1.72	$\frac{1}{125}$	36	9	18	36	72	144
34	2.10	$\frac{1}{136}$	40	10	20	40	80	160
41	2.56	$\frac{1}{134}$	44	11	22	44	88	176
49	3.06	$\frac{1}{138}$	48	12	24	48	96	192
58	3.62	$\frac{1}{141}$	60	15	30	60	120	240
68	4.25	$\frac{1}{145}$	70	17½	35	70	140	280
79	4.94	$\frac{1}{148}$	80	20	40	80	160	320
91	5.69	$\frac{1}{151}$	90	22½	45	90	180	360
104	6.50	$\frac{1}{154}$	100	25	50	100	200	400

Data for blasting 100 cubic feet of Rock.

	Rs.	a.	p.
1 lb. of dynamite @ Rs. 2-4-0 per lb.	2	4	0
4 men boring @ Rs. 1-2-0 each	4	8	0
4½ coolies removing rock @ As. 10 after blasting	2	13	0
6 running feet fuse @ As. 12 per 24 feet	0	3	0
3½ detonators	0	2	5
Sundries			
Carriage			

8. The following articles are required for this work :—

	Rs.	a.	p.
Noble's No. 1 dynamite, per lb.	2	4	0
Treble detonators, per box of 100	4	4	0
Nippers for fastening detonator 9 annas to	3	0	0
Red tape, safety fuse, per coil of 24 feet	0	12	0
Or white tape do. do.	1	0	0

RULES FOR BLASTING WITH DYNAMITE AND OTHER HIGH EXPLOSIVES.

I.—The jamadar in charge, hereafter mentioned as the jamadar, must show that he is thoroughly acquainted with all blasting operations, and that he understands the rules herewith laid down. He will be held responsible for any accident that may occur.

II.—Bore holes must be of such a size that the cartridge can easily pass down them.

III.—The position of all holes to be drilled must be marked out with white paint thus ⊙, and the jamadar must take particular note of these positions.

IV.—The drilling operations being finished, the jamadar must make a second inspection and satisfy himself that the bore holes marked out by him have been drilled.

V.—The jamadar himself must prepare all charges necessary for the bore holes.

VI.—Only ten holes may be loaded and fired at one time, and the charges should be fired as far as practicable successively and not simultaneously. Bore holes must be thoroughly cleaned before a cartridge is inserted.

The loading is to be done by the jamadar himself, and the position of the charge holes carefully noted by him. Wooden tamping rods only to be used in charging holes (not pointed but cylindrical throughout): one cartridge at a time must be inserted and gently pressed home with the tamping rod.

VII.—Immediately before firing a blast, due warning must be given and the jamadar must see that all the coolies have retired to safety.

VIII.—The safety fuses of the charged holes are to be lighted in the presence of the jamadar, who must see that the fuses of the holes charged have properly ignited.

IX.—Careful count must be kept by the jamadar and others of each blast as it explodes.

X. After the blast, the jamadar must carefully inspect the work and satisfy himself that all the charges have exploded.

XI *Missfires.*—Missfires are a source of great danger. If it is suspected that part of the blast failed to fire or is delayed, allow sufficient time to elapse before entering the danger zone. When fuse and blasting caps are used, a safe time, at least an hour should be allowed.

XII.—None of the drillers are to work near this hole until one of the two following operations have been done by the jamadar.

XIII.—(*i*) Either the jamadar should very carefully (when the tamping is of damp clay) extract the tamping with a wooden scraper and withdraw the fuse with the primer and detonator attached, after which a fresh primer and detonator with fuse should be placed in this hole and fired ; or

(*ii*) the hole may be cleared of one foot of tamping and the direction then be ascertained by placing a stick in hole. Another hole may then be drilled 6″ away and parallel to it ; this hole to be then charged and fired, when the other charge should explode.

XIV.—Before leaving his work, the jamadar should inform the jamadar of the relieving shift of any case of miss-fire, and should point out the position of the red cross denoting the same, also stating what action, if any, he has taken in the matter.

XV.—The jamadar should also at once report at the office all cases of miss-fire, the cause of the same, and what steps were taken in connection therewith.

XVI.—Names of night and day shift jamadars, must be sent in daily to the office.

Precaution against miss-fire.

1. The safety fuse (lighting end) should be cut in an oblique direction, with a knife.

2. All saw-dust must be cleared from the inside of the detonator ; this can be done by blowing down the detonator and tapping the open end. No instrument must be inserted into the detonator for this purpose.

3. After inserting the fuse in the detonator, it should be fixed by means of the nippers.

4. If there is water present, or if the bore hole be damp, the junction of the fuse and detonator must be made water-tight by means of tough grease, white lead or tar.

5. The detonator should be inserted into the cartridge, so that about one-third of the copper tube is left exposed outside the explosive. The safety fuse outside the detonator, should be securely tied in position in the cartridge. Waterproof fuse only to be used in damp bore holes, or when water is present in the bore hole.

6. If a miss-fire has been found to be due to defective fuse, detonator, or dynamite, the whole quantity or box from which the defective article was taken, must be returned to the office for inspection.

GENERAL RULES TO BE OBSERVED IN EXPLOSIVES MAGAZINES OWNED BY GOVERNMENT.

1. The magazine should at all times be kept scrupulously clean. High explosives like dynamite should be stored in a dry, clean, well-ventilated, bullet proof and fireproof building, on an isolated site.

2. No unauthorized person is at any time to be admitted into the magazine.

3. The person in charge of the magazine is to take care that the magazine is well and securely locked.

4. The magazine is on no account to be opened during, or on the approach of, a thunderstorm, and no person should remain in the vicinity of the magazine during such storm.

5. Magazine shoes without nails should be kept at all times in the magazine, and a wood tub or cement trough, about one foot high and eighteen inches in diameter, filled with water should be fixed near the door of the magazine.

6. Persons entering the magazine, must put on the magazine shoes provided for the purpose, and be careful—

(*a*) not to put their feet on the clean floor unless they have the magazine shoes on ;

(*b*) not to allow the magazine shoes to touch the ground outside the clean floor ;

(*c*) not to allow any dirt or grit to fall on the clean floor.

7. Persons with bare feet will, before entering the magazine, dip their feet in water, and then step direct from the tub over the barrier (if there is one), on to the clean floor.

8. A brush or broom should be kept in the lobby of the magazine, for cleaning out the magazine on each occasion it is opened, for the receipt delivery or inspection of explosives.

9. No matches or inflammable materials should be allowed in a magazine. Light should be obtained from an electric storage battery lantern.

10. No person having articles of steel or iron on him is to be allowed to enter the magazine.

11. Oily cotton rags, waste, and articles liable to spontaneous ignition, should not be taken into the magazine.

12 Workmen or menials should be examined before they enter the magazine to see that they have none of the articles mentioned in rules 9, 10 and 11 on their person. All other persons shall have no such articles on their person.

13. No tools or implements other than those of copper, brass, gunmetal or wood should be allowed inside the magazine. Tools should only be used with great gentleness and care.

14. Boxes of explosives should not be thrown down or dragged along the floor, and should be stacked on wooden trestles. Where there are white ants, the legs of the trestles should rest in shallow copper, lead or brass bowls containing water. In hot countries open boxes of dynamite should never be exposed to the direct rays of the sun.

15. Empty boxes should not be kept in the magazine, nor any loose packing material.

16. If the magazine has a lighting conductor it should be tested at least once a year.

17. Blasting caps and electric blasting caps should never be stored in the same box, magazine or building with other explosives.

18. The following should be hung up in the lobby of the magazine:—

(*a*) A copy of these rules.

(*b*) A statement showing the stock in the magazine.

(*c*) Certificate showing the last date of testing of the lightning conductor.

Note.—In order to prevent accidents full precautions for the security and efficient supervision of magazines should be adopted, and the above general rules have been framed for this purpose.

2. These rules do not apply to—

(*i*) Magazines used for storage of ammunition only (such as Police and Jail magazines and those belonging to Volunteer and District Levy Corps), or

(*ii*) Magazines in which the explosives stored do not exceed the quantities shown below:—

(*a*) Sixty pounds of any explosive, not being a fulminate, or

(*b*) two hundred pounds in all of gunpowder and small arm nitro-compounds, or

(*c*) two hundred pounds of manufactured fireworks, or

(*d*) sixty pounds in all of gunpowder, small arm nitro-compounds and manufactured fireworks.

3. All magazines which contain more than 250 lbs. of high explosives should be inspected at least twice a year by the officer in direct charge thereof and other magazines at least once a year. High explosives are those which are habitually fired by detonation and used where a destructive rather than a propellent effect is aimed at, and include such explosives as—

Blasting Gelatine, Carbonite, Celtite, Dynamite, Gelignite, Monobel Powder, Phœnix Powder, Negro Powder, Roburite, Tonite and Ammonal.

TIMBER.

1. The principal uses and strengths of the important timbers in the Bombay Presidency are given in the following tables and in the notes :—

TABLE VIII.

STRENGTH AND WEIGHT OF SOME TIMBERS.

No.	Local names.	Botanical names.	Wt. in lbs. of a c. ft. of seasoned wood. W	Coeff. of elasticity lbs. per sq.inch. E	Constant of strength in lbs., *i.e.*, the concentrated load at centre that would break a piece 1″×1″ supported 1 ft. apart p	Representative fig. of fissibility.
1	2	3	4	5	6	7
1	Ain (M), Matti (K), Sagada (G).	Terminalia tomentosa.	53 to 60	4,412	864	3·28
2	Anjan ...	Hardwickia binata ...	82	4,579	942	...
3	Arjun (M), Holematti (K).	Terminalia Arjuna ...	54	4,094	820	...
4	Babul (M), Jali (K)	Acacia arabica ...	54 to 59	4,111	876	...
5	Ber. The Jujube tree	Zizyphus Jujuba ...	48	3,584	583	...
6	Bilimatti (K), Kindal (M).	Terminalia paniculata.	58	3,417	588	...
7	Bilidevdari (K), White cedar.	Dysoxylum malabaricum.	48	4,140	666	...
8	Chanangi (K), Kakaria (G), Bonda.	Lagerstroemia parviflora.	48 to 52	4,120	908	3·62
9	Dhamani (M), Dadsal (K).	Grewia tilliaefolia ...	45	2,876	803	...
10	Dhupada (K) ...	Vateria indica ...	47	3,120	428	...
11	Golden Teakin ...	Hopea odorata ...	48	4,610	833	...
12	Haiga ...	Hopea Wightiana ...	65	...	830	...
13	Heddi (K), Haldu (M), Haladwan (G), Honangi.	Adina cordifolia ...	45	...	616	3·67
14	Honne (K), Bibla (M), Bia (G).	Pterocarpus Marsupium.	46 to 56	3,300	752	11·33
15	Ippi (K) ...	Bassia longifolia ...	60 to 63	3,174	730	...
16	Jack ...	Artocarpus integriplia	33	......	378	...
17	Jamba (K), Ironwood.	Xylia xylocarpa ...	58 to 69	3,400	653	...
18	Jambul (M), Nerale (K), Black plum.	Eugenia Jambolana	47	...	585	...

TABLE VIII—*contd.*

No.	Local names.	Botanical names.	Wt. in lbs. of a c. ft. of seasoned wood. W	Coeff. of elasticity lbs. per sq. inch. E	Constant of strength in lbs., *i.e.*, the concentrated load at centre that would break a piece 1″ × 1″ supported 1 ft. apart. P	Representative fig. of fissibility.
1	2	3	4	5	6	7
19	Kalamb (M), Kadawa (K).	Stephegyne parvifolia	42	...	664	...
20	Kaimuttal (K), Tewas (M).	Ougeinia dalbergioides.	56	...	835	44·78
21	Khair, The cutch tree.	Acacia Catechu ...	66	...	847	2·98
22	Mango ...	Mangifera indica ...	42	3,710	632	...
23	Mashwal (K), Satin wood.	Chloroxylon Swietenia.	60	4,163	870	10·25
24	Mohwa (M) ...	Bassia latifolia ...	66	3,420	700	...
25	Nagasampige (K) ...	Mesua ferrea ...	70	5,910	1,010	...
26	Nandi (K), Nana (M), Benteak.	Lagerströmia lanceedata	44	2,438	695	...
27	Nim ..	Melia Azaderachta, Melia indica.	30	2,516	596	...
28	Owli (M), Bakul (K), Borsali (G).	Mimusops Elengi ...	61	3,653	632	...
29	Rayani (G) ...	Mimusops hexandra	70	3,948	944	...
30	Sawari (M), The cotton tree.	Bombax malabaricum.	23	...	630	5·84
31	Shiwani (K) ...	Gmelina arborea ...	31	3,430	588	6·17
32	Siris, Indian Walnut.	Albizzia Lebbek ...	55	3,502	532	...
33	Shisham Blackwood	Dalbergia latifolia ...	40 to 50	...	765	14·00
34	Sissu, Tali (S) ...	Dalbergia Sissoo ...	50	4,022	807	8·00
35	Surhonne, Shrihonne (K), Poon Spar tree.	Calophyllum tomentosum.	36	4,250	825	...
36	Tamarind, Hunase (K), Chinch (M).	Tamarindus indica	79	3,145	864	...
37	Teak, Sagwan (K) ...	Tectona grandis ...	41 to 45	3,978	683	1·75
38	Tun, Tippa devdar (K), Red ceder.	Cedrela Toona ...	31	2,684	560	4·25

1. **Ain (Terminalia Tomentosa).**—Wood of a reddish brown colour, hard, heavy, durable under water, rather coarse in fibre, and difficult to work. In seasoning, the grain is apt to open. Requires 12 to 15 months to season ; is not readily touched by white ants. It makes an excellent fuel and forms good charcoal. The timber has a remarkable power of absorbing water rapidly, and consequently it takes creosote oils well, a fact that should make it a useful long service sleeper when so treated. It makes fine furniture. A large tree.

2. **Anjan (Hardwickia binata).**—A large tree growing in the Godavary forests and elsewhere, very tall and straight. The wood is dark coloured, heavy, and of excellent quality for posts. It is very difficult to work, is liable to split, but does not warp. This is perhaps the hardest and heaviest wood to be found in India. Khandesh and Dharwar grow it. Excellent when hard wood bearings for machinery are required.

3. **Arjun (Terminalia Arjuna).** A large tree widely diffused, often found in company with teak, and growing to a very large size. It furnishes a dark brown, heavy, very strong wood, suitable for masts and spars, beams and rafters. The wood is apt to split in seasoning and is not easy to work.

4. **Babul (Acacia arabica).**—The tree seldom attains a greater height than 50-60 feet, or a greater thickness than 2 feet. The heartwood is of a dark red brown colour, close-grained, hard and tough, and though rather heavy, is preferred for many purposes on account of its durability. It is used for wheels, both for the naves, spokes and felloes, also for the handles of agricultural implements, and in Sind for boat-building. It makes an excellent fuel.

5. **Ber (Zizyphus Jujuba).**– A moderate sized tree ; wood reddish, hard tough, durable, taking a polish : Wood used for well-curbs and agricultural implements.

6. **Bilimatti (k), Kindal (m), (Terminalia paniculata).**—A strong, stringy, serviceable all-round wood of great strength and comparatively cheap ; does not warp or crack readily, and consequently should be excellent in concrete constructions ; does well for all kinds of house building work, and is particularly useful in ceiling planks. Resists white ants quite satisfactorily. A large tree.

7. **Bildevdari (k), White cedar (Dysoxylum Malbaricum).**—This very large tree is found in the ever green forests of the Gersoppa country. It is hardly known at all in Bombay, but in Southern India yields a well-favoured, superior timber ; good in grain, texture, appearance and durability. Logs of this timber have been known to lie in the forests for 20 years untouched by insects, and sound then when wrought upon. "The timber is a superior one in every way."

8. **Bonda (Lagerstroemia parviflora)**— The wood is tough, elastic and seasons well. It is very hard, grey or greyish brown in colour, darker coloured near the centre. Has been used for sleepers with good results, also for shafts of carriages. A large tree.

9. **Dhamani (Grewia Tiliaefolia).**—This is the timber when elasticity is required. It is fibrous and durable and works easily. Unfortunately it contracts and expands in dry and wet. For cart shafts it is excellent, also for tool handles and golf clubs.

10. **Zhupada (Veteria Indica).**—The "Vellapine" of Malbar. Large tree, with light grey moderately hard wood : The planks are used for floors, ceilings and concrete forms, and for making teaboxes.

11. **Golden Teakin (Hopea Odorata).**—This tree grows in the forests of Siam and Burma. This wood is yellow in colour, close and even grained. It is more difficult to work than teak, and is said to be durable and white-ant proof. It weighs 48 lbs. per cubic feet. The wood takes a beautiful polish, and is used for house building, cabinet work, carriage and boat

Note.—**Nos. given refer to Table VIII, Column I.**

building; but when exposed to rain or otherwise wetted during the execution of the work in which it is used, it is liable to stain any lime plaster with which it may be in contact.

12. Haiga (Hopea Wightiana).—A large tree wood, brown hard, close grained, smooth, and is much used for building purposes in Kanara.

13. Heddi (k), Honangi (k), (Adina cordifolia).—This is a nice, very fine, soft, close, even-grained wood. It is most useful when carefully seasoned and that ordinarily takes a very long time. It can be made to yield superior tongued and grooved planks and boards. When the tree is in the pole stage, it gives useful rafters. The carpenter bee is rather fond of this timber, if it is in exposed situations. The cabinet maker will find this one of the best woods to ebonize, as its texture and that of ebony are alike. It is very susceptible to alterations of temperature. It is esteemed as an ornamental wood for cabinet purposes.

14. Honne (Pterocarpus Marsupium).—A pretty wood and easily worked; used in the interior of houses; not durable when exposed. A large tree.

15. Ippi (k) (Bassia Longifolia)—This is a large tree with red wood, moderately hard, close grained, durable and very flexible. It is especially used for all wood-work below the water-line.

16. Jack (Artocarpus Integriplia).—The common jack-fruit tree is of rapid growth and reaches a very large size. It is found all over India and is esteemed both for its fruit and timber and with its abundant dark foliage and numerous pendant fruit is a handsome object. The wood when dry is brittle and has a coarse and crooked grain. It is, however, suitable for some kinds of house carpentry and joinery, tables, musical instruments, cabinet and marquetry work etc. The wood when first cut is yellow, afterwards changing to various shades of brown

17. Jamba (Inga xylocarpa).—This valuable timber tree, known as the iron wood of Arracan, is found throughout Southern India and Burma, furnishing a wood of very superior quality, heavy, hard, close-grained and durable, and of a very dark-red colour: it is, however, not easily worked and resists nails. It is extensively used for bridge-building, posts, piles, etc., and is a good wood for sleepers, and paving blocks. Plentiful in Kanara.

18. Jambul (Eugeina Jambolana).—A large tree, with reddish brown, moderately hard wood, durable under water and therefore used for well curbs.

19. Kalamb (Stephegyne parvifolia).—A large fine timber tree with a wood of fine grain, easily worked, used for flooring planks, packing boxes and cabinet purposes; it is much used by the wood carvers of Saharanpore.

20. Karimuttal (k), Tewas (m), (Ougeinia dalbergioides).—Its timber is of a very high grade. It is to be had from the Dangs and part of Kanara. There is no Indian timber more difficult to split, and it has its special uses consequently. This timber is held to be more valuable than teak for local purposes. It is of a handsome grey colour, close-grained, very elastic, tough and hard. Tree moderate sized.

21. Khair (Acacia Catechu).—The wood seasons well, takes a fine polish and is exceedingly durable. Is not attacked by white ants. Has been found useful for railway sleepers and would probably be used much more but for the smallness of the tree and the consequent waste in cutting. There are supposed to be two varieties or this tree which have dark and light heart-wood respectively. It is used for wheels.

Note.—Nos. given refer to Table VIII, Column I.

22. Mango (Mangifera indica).—The mango is generally diffused all over the warmer parts of Asia, and is much esteemed for its fruit. Its wood, however, is of inferior quality. coarse and open-grained, of a deep grey colour, decaying if exposed to wet, and greedily eaten by white ants. It is, however, largely used, being plentiful and cheap, for common doors and door posts, boards and furniture, and also for firewood. It should never be used for beams, as it is liable to snap off short.

23. Mashwal (k) Satin Wood (Chloroxylon Swietenia).—A moderate sized tree with wood of a yellow colour very hard and close grained and with a beautiful lustre. The wood is used in cabinet work, furniture, axle-trees etc. and is very durable.

24. Mohwa (Bassia latifolia).—A large tree with reddish brown heartwood. The wood is strong, close and even grained, tough and durable, seasons well. Used for door panels, well curbs and carved work.

25. Nagasampige (Mesna ferrea).—A large tree with wood of a dark red colour. The wood is extremely hard, strong and durable, and lasts well in ground. Very good for big construction work, bridges, sleepers, paving blocks etc.

26. Nandi (Legerstromial Lanceolata).—A large tree. Plentiful in Kanara. It yields a valuable sound all round building timber, with a good straight grain, easy to work. The dark reddish brown wood is the best. If seasoned with care, the timber lasts well in whatever situation it is placed. White ants are slow to attack it. It is a timber less strong than teak, but on the other hand it splits much less easily.

28. Bakul (k) Owli (m) Mimusops Elengi).—This tree grows in South India and Gujarat and furnishes wood heavy, close and even-grained, of a pink colour, standing a good polish: used for cabinet making purposes and ordinary house building and bridges. This must be useful for piles also.

29. Rayani (Mimusops hexandra).—A moderate sized tree with very hard red coloured wood. The wood is close and even-grained, tough, very durable and is used for big beams in houses; also used for piles, agricultural implements and in turning.

30. Sawari (Bombax Malabariacum).—The silk cotton tree with soft wood much used in making match-boxes and match sticks.

31. Shiwani (k), (Gmelina arborea).—This is pre-eminent for use in such structures as lock and sluice gates and in situations where it is alternately in and out of water, a most exacting test for any wood. This very useful timber is to be had principally from Guzerat and Khandesh. The wood is light, even-grained and difficult to split. It is remarkably durable, and once seasoned, does not shrink. If it were more plentiful, it would be an ideal wood in concrete construction, as it does not warp.

32. Siris (Albizzia Lebbek).—The siris is a common tree throughout India, and with its rapid growth, its large head of handsome foliage and sweet scented flowers, is a good avenue tree. It grows to 40 or 50 feet in height and to 5 to 6 feet in girth. The heart wood is hard, strong and durable, never warping or cracking, and is used by the natives of South India for naves of wheels, pestles and mortars. and for many other purposes.

33. Shi sham Black Wood (Dalbergia Latifolia).—This is rather a special timber; very handsome, somewhat expensive, seldom found long enough to serve well as scantlings but most excellent for small work and furniture. The timber is close grained, flexible, fibrous and of great strength. It neither warps nor splits however much exposed, and stands either damp or dry situations equally well.

Note.—Nos. given refer to Table VIII, Column I.

34. Sissu (Dalbergia Sissoo).—From upper Sind is obtainable another dalbergia, D Sissoo, the tali. It is used with complete satisfaction for big beams in house construction in Shikarpur and Sukkur and is reputed to be white-ant proof.

35. Surhonne (k). The poon spar.—These perfectly straight trees are sometimes 150 feet high, with a girth of 15 feet. The wood is tough and elastic, easy to saw and work and holds nails well. Most useful for masts and the like. Yields large mahogany-like level planks. A timber with a future.

36. Tamarind (Tamarindus indica).—The tamarind is a very handsome tree for avenues, gardens, etc., of very slow growth, but attaining a great size, and much valued for its fruit. The heart wood is very hard, close-grained, dark-red and very hard to work; used for turnery, also for oil presses and sugar crushers, mallets, and plane handles; it is a very good brick-burning fuel.

37. Teak Sagwan (Tectona grandis).—Is found in Southern India, Pegu, Java, Siam and Burma. The best teak in the Bombay market comes from Moulmein; the heaviest and strongest from Johore; and the most handsomely figured varieties from the Vindhyan forests. The Malabar teak forests are nearly exhausted. The timber form these forests is darker and stronger than that from Moulmein, but very full of knots. The great durability of teak is ascribed to the presence of an aromatic oil, which largely preserves it from the attacks of white ants. Thana district produces plentifully good pole teak. Very fine teak is obtainable from the Dangs.

38. Tun Tippa Devdar (k) Rodceder (Cedrela Toona).—A large tree with a brick-red coloured, soft even grained wood. The wood is handsome and is used after seasoning well for panels, ornamental work, furniture etc.

Australian gum.—It is a pity that more of this class of wood is not imported as its properties of lasting under water are stated to be far superior to those of any Indian wood, teak not excepted.

Cedar.—Singapore. A reddish wood, not unlike benteak in appearance; very light; obtainable in Bombay market about the same price as American pine.

Pine.—American, obtainable in the Bombay market.

2. CHARACTERISTICS OF GOOD TIMBER.

Good timber should be from the heart of a sound tree, the sap wood being entirely removed, the wood uniform in substance, straight in fibre, free from large or dead knots, flaws, shakes, or blemishes of any kind.

The colour of good timber should be uniform throughout; and among coloured timbers, darkness of colour is said to be in general a sign of strength and durability.

3. SEASONING.

The object of seasoning timber is either to expel or to dry up the sap remaining in it, which otherwise putrefies and causes decay.

Tredgold calls timber *seasoned* when it has lost $\frac{1}{5}$th of its weight, and says that it is then fit for carpenter's work and common purposes. He calls it *dry*, fit for joiner's work and framing, when it has lost $\frac{1}{3}$rd of its weight.

Timber should be well seasoned before being cut into scantlings. The scantlings should then be further seasoned, and should be left as long as possible to complete the process of seasoning before being used.

4. DECAY OF TIMBER.

To preserve timber from rot or decay it should be kept constantly dry and well ventilated.

It should be kept clear of damp earth or damp walls, and free from contact with mortar, which hastens decomposition.

Rot in timber is decomposition or putrefaction, generally occasioned by damp and which proceeds by the emission of gases, chiefly carbonic acid and hydrogen. There are two kinds of rot, *dry rot* and *wet rot*. Timber exposed to confined air alone, without the presence of any considerable quantity of moisture, decays by *dry rot*, caused by a fungus, which finally converts the wood into a fine powder. *Wet rot* occurs when the gases evolved cannot escape, and the tissues of the wood, especially the sappy portions, are decomposed.

Wet rot may occur while the tree is standing, whereas dry rot takes place only when the wood is dead.

5. PRESERVATION OF TIMBER.

Amongst the most efficient means of preserving timber are good seasoning and the free circulation of air.

Protection against moisture is afforded by oil-paint, provided that the timber is perfectly dry when first painted; otherwise, the filling up of the outer pores only confines the moisture and causes rot. The paint should be renewed from time to time.

A coating of pitch or tar may be used for the same purpose.

The lower ends of posts, put into the ground, are generally charred with a view to preventing dry rot and the attacks of worms.

Protection against dry rot is afforded by saturating the timber with solutions of particular metallic salts, and *creosoting*, known as Bethell's process which protects the timber not only against wet and dry rot, but also against white ants and sea worms.

The process is effected by extracting the moisture and air from the tubes of the timber, and then forcing in *creosote* (oil of tar) at a high pressure.

Creosote has been fairly satisfactory, but after some time in exposed situations the creosote tends to leach out. In houses creosote treated wood cannot be used as creosote has a strong smell, and besides the woodwork treated cannot be painted or polished.

A new preservative, called Ascu has been developed at the Forest Research Institute, Dehra Dun. It is made up of three chemicals proportioned as under :--

One part by weight of $As_2O_5\ 2H_2O$
Three parts by weight of $CuSO_4\ 5H_2O$
Four parts by weight of $K_2Cr_2O_7$

It is in powder form, and six parts weight of the powder dissolved in a hundred part by weight of water gives a solution for ordinary use. The solution is odourless and wood treated with it can be painted, varnished polished or waxed. Ascu solution can be applied or sprayed on in two coats, or the wood pieces can be soaked in the solution tank, or the wood pieces impregnated with the solution under pressure. The method to be adopted depends on the degree of immunity required and the nature of the wood; the last method being the most effective, and the first the least.

Shakes and checks.—Round, ring or cup shakes shall not occupy more than one-fourth the least dimension on either end of a timber, measured on their vertical projections. Any combination of checks or shakes which would reduce the strength to a greater extent than the allowable round shakes shall not be permitted. Shakes must not show on any face of a timber.

Borer holes or worm holes capable of having greater weakening effect than that of allowable knots, shall not be permitted. Timber containing active borers must not be used.

Angle of grain.—Beams shall not have diagonal or spiral grain in volumes 1 and 2, with a slope steeper than 1 in 20 ; in struts the slope shall not be steeper than 1 in 15.

In hardwoods, or timbers of trees of the deciduous varieties, rapid growth is not commonly an indication of weakness, but extremely slow growth is likely to produce inferior material. The timber shall be considered " dense " if it shows more than 20 annual rings per inch, and is not obviously lighter in weight than the average for that species, moisture contents being equal. Structural timbers shall be of " dense " wood.

The requirements given above apply generally to No. 1 structural timber only.

Stresses.—The accompanying tables give the results of tests on some Indian timbers and suitable, working stresses for the same. In side locations are barracks, warehouses, dwellings, etc. ; outside locations are bridges, viaducts, and the like where the timber is exposed to the action of weather ; and wet locations are piling, very damp foundations, etc.

In structures where the timber is to be continuously subjected to the maximum computed load, the modulus of elasticity shown in table IX should be divided by 2. Where the values are required for timber used in pure tension, the values under " static bending, extreme fibre stress " should be used. For pure shear in timbers, such as in joints, etc., the value given for a horizontal shear may be increased by one-half.

The value given for compression along the grain should be used for end bearing and for short columns. For compression members, with an unsupported length, greater than about ten times their least side, these values should be reduced according to the accepted column formulæ.

TABLE

WORKING

Grade.	No. 1 Structural,			
	M. of E. 1,000's lbs. per square in.	Bending. Extreme fibre stress.		
		Inside locations.	Outside locations.	Wet locations.
Tectona grandis (Teak), Burma and Malabar ..	1,600	2,200	2,000	1,570
Tectona grandis (Teak), C. P.	1,207	1,820	1,650	1,300
Terminalia tomentosa (Matti)	1,600	2,250	2,050	1,610
Pinus longifolia (Chir)	1,500	1,570	1,430	1,120
Pseudotsuga mucronata (Douglas fir)	1,700	1,630	1,490	1,170
Pinus Palustris (Southern yellow pine)	1,630	1,740	1,580	1,240
Picea Morinda (Spruce)	1,400	1,380	1,250	980
Abies Pindrow (Silver fir)	1,500	1,390	1,260	990
Pinus excelsa (Kail)	986	950	860	680
Cedrus Libani (Deodara)	1,348	1,740	1,580	1,240
Pterocarpus macrocarpus (Burma Padauk) ..	2,000	2,260	2,240	1,750
Do. dalbergioides (Andaman Padauk) ..	1,564	2,250	2,040	1,600
Do. Marsupium (Honne)	1,470	2,330	2,110	1,660
Shorea robusta (Sal)	1,920	2,120	1,930	1,510
Eucalyptus Marginata (Jarrah)	1,500	2,300	2,090	1,640
Dipterocarpus alatus (Kanyin)	1,478	1,880	1,710	1,340
Do. turbinatus (Gurjun)	2,020	2,205	2,005	1,575
Do. tuberculatus (In)	1,754	2,320	2,110	1,655
Anogeissus latifolia (Bakli)	1,501	2,280	2,080	1,640

Note.—Requirements given in paragraph 5 generally

IX

STRESSES.

pounds per square inch.

Horizontal shear, all locations.	Compression.					
	Parallel to grain—" short struts ".			Perpendicular to grain.		
	Inside locations.	Outside locations.	Wet locations.	Inside locations.	Outside locations.	Wet locations.
125	1,700	1,580	1,230	700	520	420
120	1,380	1,280	1,000	670	500	400
155	1,680	1,560	1,210	790	600	480
95	1,250	1,160	900	500	380	300
100	1,230	1,150	890	360	270	210
120	1,350	1,250	980	400	300	240
90	840	780	600	320	240	190
70	840	780	600	230	170	135
110	970	900	700	170	125	100
100	1,370	1,270	990	440	330	260
220	2,200	2,140	1,660	....	....	....
220	1,490	1,380	1,080	....	....	....
150	1,420	1,320	1,020	....	....	....
175	1,510	1,400	1,090	....	....	....
....	870	810	630	....	....	....
120	1,390	1,290	1,000	510	380	300
105	1,805	1,675	1,305	635	475	380
140	1,735	1,610	1,255	815	610	490
160	1,590	1,480	1,150	785	590	470

apply to No. 1 structural timber.

Recent experiments have given the following test results at the Forest Research Institute, Dehra Dun.

TABLE X.

—	*Strength* Safe fibre stress lbs. per square inch.	*Stiffness* Modulus of Elasticity in lakh lbs. per square inch.	*Shear* Safe Horizontal lbs. per square inch.
Ainior Matti	2,150	15	105
Axle-wood	2,400	16	165
Benteak	2,050	16	140
Bija Sal	2,100	14·5	135
Chir	1,200	14	90
Deodar	1,450	13·5	100
Gurjun	2,000	18	120
Hopea	2,650	18·5	185
Irul	2,300	16·5	180
Jarul	1,700	13	125
Kindal	1,850	15	130
Kokko	1,900	16	155
Laurel	2,200	16	145
Mesua	3,300	23	175
Pudauk (Andamans)	2,450	16	145
Poon	1,900	14	120
Sal (United Provinces and Bengal)	2,800	20	165
Sisso	2,150	12·5	165
Sundri	2,350	19·5	180
Teak (Burma and Malabar)	2,200	16	125

Factor of Safety.—5 for hardwoods and 6 for conifers, applied to the ultimate strength *in bending.*

For horizontal shear—10.

The depth : breadth ratio of a beam should be kept below 3 unless suitable stiffening is provided, as otherwise the beam may fail by buckling or horizontal shear.

The physical and mechanical properties of woods grown in India (Indian Forest Records, Vol. XVIII, Part V).

Suitability tables :—For comparison with teak as a standard, values of eight of the most important properties are given in this table. These values are called " suitability figures ". The calculation of each figure is based on all the strength functions bearing on the particular purpose under consideration. Taking for instance the property " strength as a beam ", three functions *viz.* Modulus of rupture and fibre stress at elastic limit in static bending and fibre stress at elastic limit in impact bending, are combined, after multiplying them by adjusting and weighting factors—the values obtained being index numbers with teak as 100. It must be remembered also that although strength is an essential quality, there are others such as seasoning properties, easy workability, durability, appearance, availability, cost etc. which should also be studied. The table of suitability figures enables the best selection to be made, with regard to strength, from among the available species which are satisfactory in other respects.

TABLE XI.

—	Locality.	Weight.	Stiffness as a beam.	Suitability as a post.	Shock resisting ability.	Retention of shape.	Shear.	Hardness.	Strength as a beam.
Teak—Tectria-Grandis ..	Burma and Malabar.	100	100	100	100	100	100	100	100
Babul—Acaria Arabiea ..	Sind ..	120	95	105	170	70	180	185	120
Haldu—Adina Cordifolia	Madras ..	100	80	75	85	85	100	100	75
Axle—wood-Anojeissees Latifolia.	Do. ..	140	105	95	..	65	135	175	105
Mahuda—Bassia Lati-folia	Central Provinces.	135	80	75	100	50	120	165	75
Poon—Callophyllum-tomritosum.	S. Kanara ..	95	90	85	80	65	85	95	90
Do. do. .. Wightiaran.	Do. ..	100	80	80	90	65	110	110	80
Satinwood—Chloroxylon Swiotinia.	Madras ..	155	110	105	115	115	70	180	195
Dhaman—Grewia Tilaefolia.	Do. ..	115	125	125	145	60	140	155	110
Anjan—Hardwickla Binata.	Central Provinces.	125	60	70	125	90	145	180	75
Beneteak—Legcrstixmia Microcoupa.	West Kanara	105	105	95	100	60	115	120	95
Mango—Mangifera-India	Puri ..	95	80	75	100	95	105	90	75
Padauk—Ptarocaipa-dalbergioida.	N. Andaman .	105	105	105	100	105	115	130	100
Bijasal—Ptarocaipa-Marsupian.	Belgaum ..	115	95	95	135	75	115	135	105
Sal—Shorea Rabusta ..	Central Provinces.	120	110	105	115	60	110	120	105
Arjon—Tercuindia Arjuno	Bihar and Orissa.	115	70	70	135	65	140	135	75
Kuidal—Tercuindia Paniwlata.	East Kanara .	110	100	85	90	65	105	110	85
Irul—Xylia Xylocupe ..	North Kanara	125	105	105	90	65	155	195	100

WOOD-WORK.

General.

1. "Carpenter's work" includes all timber in roofs, floors, verandahs, staircases, door and window frames, bridges, centerings, coff rdams, curbs of wells, shores, struts, large gates, and generally all wood-work of which the scantling exceeds three square inches except in the case of battens used in roofing trellis-works etc. which is not specially moulded or carved.

2. When the thickness of carpenter's work does not exceed two inches and at the same time the width exceeds twice the thickness, it is called "planking".

3. "Joiner's work" includes furniture, doors and windows, and turned, carved, or moulded work of all kinds.

4. Carpenter's work is rated per cubic foot, except planking, which is rated by the square foot of a specified thickness, or per 100 running feet with specified breadth and thickness and batten work which is rated by the hundred square feet. Doors, windows and similar work, and panelled work generally, are rated per square foot ; other joiner's work at special rates, according to the nature of each case.

5. The timber generally used for carpenter's work in the Bombay Presidency is teak, and, except, where other kinds of wood are distinctly specified, teak alone is to be used.

Specification No. 1.

1. The source from which the timber is procured is to be approved by the Executive Engineer. The timber is to be of the best quality, well seasoned, felled not less than two years before use for carpentry and four years for joinery and free from large or loose knots and from shakes or defects of any kind. Sap-wood will be rejected unless it is thoroughly impregnated with creosote or some other approved preservative. Any timber so rejected shall be removed at once from the site of the works, and not again brought thereon unless with the express written permission of the Executive Engineer.

2. The Executive Engineer may inspect all logs previous to use, and reject any which he considers defective.

3. Carpenter's work is ordinarily specified as "wrought" or "wrought and put up," or "wrought, framed and fixed".

4. The rate for wrought timber includes carriage to, and delivery at, the site of the works, the fair rendering of all surfaces, chamfering of angles, etc.

5. The rate for timber "wrought and put up" includes all that is specified in the preceding paragraph, and in addition, all work required for fixing the timber in its proper position in a building, bridge centering, or other construction. The rate includes all special scaffolding, labour, materials, and apparatus for lifting and fixing in position according to the drawing or other instructions furnished by the Executive Engineer.

6. The rate for framed wood-work to include all sawing, planning, jointing, framing, labour and materials for raising and fixing, and also, the fitting, fixing, and supply, of all straps, bolts, nails, trenails, spikes, screws, etc., necessary for the framing and fixing.

7. All workmanship is to be of the best description and all joints must fit accurately without wedging or filling. After the wood-work has been erected, if any undue shrinkage or bad workmanship is discovered, the contractor shall forthwith amend the same, without any extra charge.

8. Planking is to be supplied with straight square edges, or rebated, plougheed, tongued, or dowelled as may be directed.

9. All carpenter's work shall be paid by net measurement, no allowance being made for wastage or for dimensions supplied beyond those specified, but the length of each piece shall be taken over all, so as to include projections for tenons or scarfs.

10. The contractor shall give due notice to the Executive Engineer when any timber is to be covered up in the ground, or in the walls of a building, or otherwise; failing which it shall be optional with the Executive Engineer to order it to be uncovered at the contractor's expense, or to measure and pay for only so much as is uncovered.

11. No timber work shall be painted, tarred, or oiled without the previous written permission of the Executive Engineer.

12. The Executive Engineer may order any truss or other framed work to be put together on the ground, and submitted to suitable tests before being placed in position.

13. When unwrought timber is supplied by a contractor, the rate paid will in all cases include carriage to, and delivery at, the place where it is required for use.

14. Timber in the log, or wholly or partially wrought, may be supplied to the contractor from Government stores or from a dismantled building. In such case the value of the timber so supplied, at the rate payable to the contractor for similar material, will be deducted from the price of the finished work. Where the contract schedule contains no rate for similar material, the value to be deducted will form the subject of special agreement.

15. A separate rate will be required when material thus supplied has to be re-framed, re-fitted or reworked in any manner.

16. When material is supplied to the contractor under either of the two preceding paragraphs, he shall be charged for its full dimensions, no allowance being made for wastage in working or altering it; and all of such material not used and charged for as finished work shall be the contractor's property, but the contractor shall be entitled to appeal to the Superintending Engineer, if required to utilise such material, as is in his opinion, unsuited to the purpose intended, in consequence of excessive wastage or other cause.

17. The conditions detailed above will apply to joiner's as well as to carpenter's work, except where they are plainly inapplicable.

18. All timber-resting on or bedded in masonry must be well coated with boiling coal tar.

19. The ends of all timbers set in masonry shall have as air space left on end and sides to allow of free circulation of air round it.

20. Glue shall not be used in joints which are exposed to the weather, and in such exposed work any hard stopping shall be done with tight driven plugs.

21. No wood-work of any sort shall be set within 2 feet of a fireplace or flue.

22. The contractor will be responsible for the easing or otherwise of all doors etc., and the closing of all open joints which may occur within six months of the completion of the work and which, in the opinion of the Executive Engineer, should be attended to.

23. The rate for all wood-work includes oiling with either linseed or sweet oil as ordered by the Executive Engineer.

BRICK MAKING.

BRICKS.

Specification No. 2.

General :—(1) The operations necessary for the production of bricks and tiles are classifiable under the following heads :—

(1) Selection or preparation of brick earth.
(2) Tempering.
(3) Moulding.
(4) Dying.
(5) Burning.

Earth Selection :—(2) It rarely happens that earths occuring in nature are suitable for making first class bricks. Pure clays require the addition of loam, sand, etc., whilst looms may be so loose as to require the addition of clay or binder.

The earth for bricks shall be carefully selected good firm loam. All gravel, coarse, sand, *kankar* and roots of grass or plants shall be completely removed by washing or other means; two or three sorts of clay can often be found, which, when mixed, make better bricks than loam. Specimen bricks made in the neighbourhood and the localities in which they were made should be examined before selecting the earth. The Executive Engineer must, however, in all cases select the earth or the mixture of earths proposed for brick manufacture.

N. B.—Where a large number of bricks has to be made, it would be well to mould and burn a small number on trial, so as to ensure the certainty of the quality before starting operations on a large scale.

3. The earth or mixture, as selected and approved, shall be repeatedly turned over and thoroughly tempered. When practicable, it should be dug up before the rains set in, and left to weather for a few months; but when this cannot be done, it must be thoroughly watered, turned over for at least 48 hours before use, and tempered until stiff enough for moulding. The tempering should be done in a pug mill, or by treading with the feet. The earth thus treated should be homogeneous throughout, and sufficiently stiff for moulding.

4. No earth or clay must be taken from localities where salt water is found, and any containing the slightest trace of salt, must be rejected for brick-making purposes.

5. In moulding, the stuff shall be dashed firmly into the moulds, which should be kept well sprinkled with clean sand. The earth must be used as dry as possible, and proper moulding blocks and pallet boards employed in all cases; but a brick table is better than blocks and should, where practicable, be employed. The mould requires washing for every 4 or 5 bricks moulded. Strikes or floats should also be used.

6. The bricks must be turned out with clean sharp edges, well and squarely shaped, and must be carefully handled in stacking to prevent their becoming distorted. Iron brick moulds (¼ inch plate), with the top and bottom edges steeled, are the only moulds that keep their shape, and with a few repairs turn out 500,000 bricks. The chief cause of cracking in bricks being exposure to wind, protection should be given by mat screens or sheds.

7. The bricks, if not otherwise specified, to be $9'' \times 4\frac{1}{4}'' \times 2\frac{1}{2}''$. The necessary allowance for shrinkage in drying and burning must be determined by actual experiment for each brick-yard, and the moulds should be made larger than the finished bricks to the extent of this shrinkage.

8. All fuel for brick-burning should be as dry as possible, and used when comparatively fresh. Tamarind or *babul* is the best wood to use in burning. Too much attention cannot be given to the proper regulation of the fire in the kiln.

9. The burnt brick shall be well but not overburnt, sound, hard, free from cracks, flows, stones, or lumps of any kind and of regular size and shape to ensure uniform courses..

A sound well burnt brick should give out a clear ringing sound when struck, should be of a uniform deep red or copper colour, and should not absorb more than one-fifth its dry weight of water.

Note.—(1) In Europe where bricks are more carefully prepared it is generally specified that the absorption of water should not exceed *one-sixth* the dry weight of the brick. In India generally for reasons of economy the best available local material in a district, is used.

For Rate Abstract *see* pages 102 and 103.

N. B.—For *rapid* brick-making, Bull's trench kilns are used, and are found satisfactory, if made in dry ground.

When the supply required is not large, local practice may be advantageously followed in the selection of kilns or clamps.

9. **Colouring by dipping.**—Bricks or tiles coloured this way, are said to stand any amount of exposure to the weather without losing their colour, and the surface resists the growth of moss when exposed to a damp atmosphere. The materials for the colouring liquid are turpentine, linseed oil, and litharge, with colouring matter as may be required.

An earthenware box is provided, a few inches larger each way than a common brick, and it is half filled with liquid of about the consistency of thick cream. The bricks to be coloured are laid upon an iron plate with a fire underneath, and heated, not to a great heat, but too great to admit of their being handled. They are then taken one at a time and dipped into the liquid for a few seconds, then placed on a table to dry, which they do in a few minutes. They are then lightly washed in cold water, and placed aside to dry. In porous bricks, the colouring matter will penetrate about $\frac{1}{8}$ of an inch. The following are the proportions used for some of the colours :—

I.—For dark red bricks—

$1\frac{1}{2}$ pints of turpentine.

$1\frac{1}{2}$,, linseed oil.

$\frac{1}{4}$ lb. of litharge.

$\frac{1}{2}$ oz. of Indian red.

Mix well together and use as above.

II.—For blue bricks—

1 pint of turpentine.

1 ,, linseed oil.

$\frac{1}{2}$ oz. of litharge.

1 lb. of French ultramarine.

III.—For black bricks—

2 ozs. of litharge.

6 ,, manganese.

4 ,, linseed oil (boiled).

6 ,, turpentine.

IV.—For grey bricks—

3 ozs. of white lead.

1 oz. of litharge.

1 ,, manganese.

2 ozs. of boiled linseed oil.

4 ,, turpentine.

These colours may also be applied to walls already built. In such a case the bricks are carefully cleaned, and the liquid is laid on hot with a brush.

BRICK BURNING IN BULL'S TRENCH KILN.

1. **Brick burning.**—Details of Bull's pattern kiln are shown in plate I.

A circular plan is the best, but kilns can also be made straight or oval.

The dimensions given are for the most suitable size of small kiln, capable of burning 10,000 bricks daily, divided into 20 sections containing 14 concentric walls of bricks, and requiring one chimney.

Where it is required to turn out a large number of bricks, a broader kiln (up to 30′) may be built, requiring two chimneys.

2. **Construction of kiln.**—In hard soil the trench may be unlined, with the bottom, sides and top edges dressed off to a true surface. In soft soil the walls will be of burnt brick of the dimensions shown in the figure.

In damp sandy soil the excavation should not exceed 4′, leaving 3′-6″ to bank up.

The damper spaces and combustion chambers as shown in figure 3 must be carefully marked out on both walls.

3. The chimney is 35′ high, mounted on a cast iron base plate on wheels, the axles of which radiate so that they will travel round the wall. They should run on a sheet iron path-way, and the gaps at the chimney openings require to be bridged as shown in figure 4.

4. When two chimneys are used, the chimney openings on the inner sides will be opposite those on the outer but will be only 2′-6″ in width, and the chimney will be only 25′ high.

5 The upper outlet into the chimney is controlled by an adjustable damper.

In the lower outlet from the kiln to the chimney the arch and its backing project 5″ to prevent the earth, used for closing the outlet while working, going into the kiln too far and thereby interfering with the draught.

6. Cross dampers, figure 5, are required to divide off the various sections of the kiln. These should be made 2″ smaller than the width of trench to prevent the centre key jamming. When fixing the cross dampers, great care must be taken to make them fit tightly. It is a good plan to drop a little dust or fine earth down behind them to close up any possible interstices owing to irregularities on the floor.

7. **Loading.**—The bricks should be thoroughly dried before being loaded. The method of setting the bricks is shown in figure 6. Care should be taken when loading to leave a space between the bricks except those spanning the combustion chambers. This space should not be less than ½″ in the bottom courses, decreasing to ¼″ in the upper ones.

The draught passages between walls increase as they get further away from the centre. The setting out is done with the aid of a templet such as shewn in figure 7.

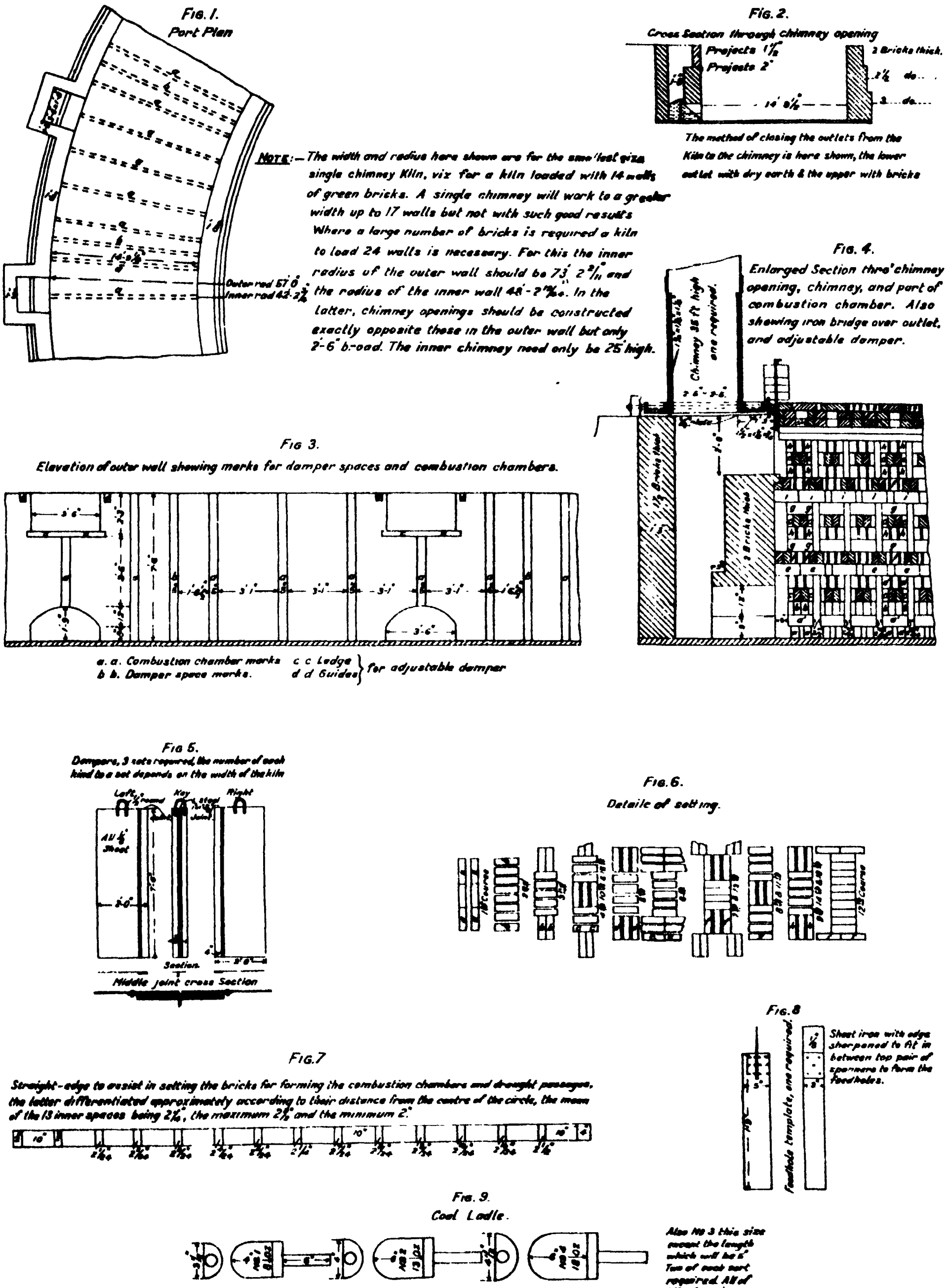
Only one wall can be exactly like the details shown, owing to the decrease in the distance between the lines of feed holes from the outer to inner walls of the kiln.

The bricks next to the chambers from bottom to top and from side to side should, however, be exactly as shown.

8. There are five combustion chambers to each damper length. As each length is completed it is covered except over the combustion chambers, with two layers of bricks laid flat breaking joint.

The feed holes are then formed with the aid of the templates shewn in figure 8 : there should be a feed hole over each of the two outer walls, after that over every alternate wall.

BULL'S IMPROVED BRICK KILN. *Plate I.*



To face page 30.

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Nine inches of earth is then evenly spread to the top of the brick temporarily placed over the feed holes. This earth should be made as tight and impervious to air as possible.

9. Between the second and third and all subsequent lines of feed holes level bricks for ascertaining the settlement should be fixed. There should be one level brick for each pair of feed holes and from the settlement of each level brick will be known when to close the pair to feed holes in front of it. The level bricks should be firmly bedded in the earth covering.

10. **Firing.**—To start the firing a temporary cross wall, z, see figure 1, is built, with furnaces for bottom firing.

The chimney opening of the first section (a_1) is closed and the chimney fixed at the second opening (b^1). Cross dampers are put down at b_2 and c_2 ; and the chimney opening C, closed with a sheet iron cover, provided for the purpose.

11. About 150 maunds of clean rubble coal is required for starting the fire of a 14 wall kiln and 250 for a 24 wall kiln. For top firing good dust coal is required and should have a certain proportion of nuts or small rubble in it.

12. To meet all the varying conditions of temperature, damp floor or bricks, four sizes, of ladle are required for top firing. These are given in figure 9.

13. When the fine coal will burn freely in the first line, it can be started, coal being given with No. 1 ladle at regular intervals of 15 minutes.

When there is a good bottom heat in the first line, fire the second with No. 1, ladle and the first with No. 2. When there is a good bottom heat in the second line fire the third line with No. 1 ladle, the second with No. 2, and temporarily stop firing the first, except the two outer feed holes. Take on the 4th line in the same way temporarily dropping the 2nd. When there is a good bottom heat in the fourth line, take on the 5th with No. 1 ladle and fire the whole of the other four with No. 2 ladle.

Up till this the bottom firing should under no circumstances be pushed, but now it should be cautiously increased. This, being the critical time, should, if possible be in the day time.

If No. 2 ladle does not seem to give sufficient heat after closing the bottom firing, use No. 3 or even No. 4 ladle : this will only be necessary in cold rainy weather.

14. If intelligence is used, by the time there is a good bottom heat in the fifth or front line, the second line from the front will be the hottest, and the back line can, all but the two outer feed holes, be closed.

If at the same time there is a settlement between the first and second lines, or between the second and third of, say, an inch or an inch and a half, slacken down the bottom firing but do not close it altogether until two or three lines are closed finally.

For opening a fresh line in front two conditions should always be fulfilled there must be a good bottom heat in the front line, and the heat in the second line from the first must be greatest.

At this time, with the bottom firing slackened down and one line of feed holes closed, great judgment should be used as to the sufficiency or otherwise of the way of heat. If from a deficiency of settlement or from the appearance when looking down the feed holes there seems to be insufficient heat to thoroughly burn the bricks the firing should be increased. As long as the bottom firing is still going on absolute control is retained.

15. Having, by the time the 2nd of 3rd line is closed, got a thoroughly sufficient wave of heat, stop the bottom firing entirely. Close the furnace mouths entirely and the ashpit mouths rather loosely, leaving interstices in the latter equal, in the aggregate, to 3 square inches in each.

When a line in front is opened, one behind should be ready to close. If, however, it is seen from the settlement that this is not the case there is no harm in delaying the opening a little.

The kiln will now be in full working order, the chimneys and dampers having been moved on as required.

16. Take out the first cross damper when there is a good bottom heat in the first line *i.e.*, the 8th from the chimney, and fix it in next vacant line. The chimney is moved on when the bottom heat has got as far as the fifth row from it.

17. The adjustable damper should be lowered three bricks. when the bottom heat is 7 lines from the chimney, and all but one brick removed, when the bottom heat reaches 6 lines from the chimney.

It is closed down entirely when the chimney is moved, and the outlets are blocked.

After moving the chimney, the upper and lower outlets being open, a strong draught is created which prevents the bricks vitrifying owing to stoppage of draught at the current when heat is maximum, and the draught at the combustion chamber is kept uniform.

18. It is important that the working of the kiln should be regular as far as possible, and a five line chamber should be worked to daily.

19. **Unloading.**—When twelve damper lengths have been burnt off, the temporary cross wall can be taken down and unloading commenced. Before doing this cross damper should be fixed at two damper lengths from the end.

20. **Finishing burning.**—When it is desired to finish off burning, a cross wall similar to that constructed at starting but without the furnaces should be run up at the end of any convenient chamber 6″ from the bricks.

Resting half on this and half on the green bricks, build two dummy chimneys 5′ long and 6′ high of bricks and plastered with mud.

When the time for moving the chimney from its last possible position has arrived these two dummy chimneys, which up to this should have been closed at the top, should be opened and will finish off the burning.

21. **Wood fire kiln.**—These are worked in a somewhat different way. No furnaces are required for starting, wood is packed to a depth of 3′ in a combustion chamber 1′ wide, and lit through fire holes 9″ square at the bottom of the wall.

Every alternate feed hole only goes down half the depth of the kiln, the object being to increase the heat near the top. The feed holes should be not less than 14″ square.

22. When a sufficient length has been loaded, the wood in the combustion chamber is lighted. When the wood is nearly burnt away, top firing is started into this chamber only, and continued until the bricks forming the first line of feed holes are sufficiently hot, when regular top firing will be commenced.

The chimney can be kept two or three lines further away from the burning, than in the case of coal firing.

23. When dry wood is procurable this method of starting a kiln may be used with advantage for a coal fired kiln, and the furnace bars saved.

TABLE XII.

Crushing strengths of bricks.

Locality.	Absorption after 16 hours immersion in water per cent.	Cracking loads in tons per square foot.	Crushing loads when dry in tons per square foot.	Remarks.
Sand and lime bricks (Marve, Bombay).	12·16	....	153·7 tons	Decrease in strength when soaked in water thoroughly, 24 per cent.
Kalyan bricks (earth) ..	17·2	....	44·75	
Do. ..	17·4	....	61·15	
Do. ..	17·1	....	47·90	
Do. ..	16·4	....	42·76	
Do. ..	21·5	....	41·15	
Average for Kalyan bricks ..	17·9	....	47·50	
Billimora bricks (earth) ..	16·5	....	74·5	
Do. ..	16·0	....	68·2	
Do. ..	19·1	....	76·1	
Average for Billimora bricks ..	17·2	....	72·9	
Madras Government bricks ..	....	....	19·1 to 143	
Bangalore water supply ..	....	19·8 to 20·8	78·2 to 98·0	
Mysore Palace division ..	....	9·3 to 12·7	38·6 to 60·6	
Pondicherry ..	....	10 to 15·2	50 to 105·5	
Cuddalore chimney bricks ..	....	34·7	85·5	
		28·6	118·9	
Bombay Development Department ordinary bricks, burnt as a trial.	24	....	38	Free from soluble salts.
New Delhi bricks	....	....	186	Average four experiments.

Note.—The ratios of strength of brickwork to strength of single bricks are—

For mortar of	1 lime, 2 sand	.. ..	0·44
Do.	7 lime, 1 cement, 16 sand	.. ..	0·48
Do.	1 cement, 6 sand	.. ..	0·55
Do.	1 cement, 3 sand	.. ..	0·63

At New Delhi, a brick pillar 9″ × 13½″×22½″, laid in mortar 1 cement to 3 sand, failed at 37 tons per sft. the bricks being crushed. Another pillar 9″ × 4½″ × 14½″ with bricks laid in similar mortar, failed at 111 tons per sft.

TILES.

Specification No. 3.

1. The process of tile manufacture is similar to that of brick manufacture. Since the tiles are thinner however the clay must be purer and stronger and all the processes of manufacture must be much more carefully carried out.

2. All tiles must be thoroughly well burnt throughout, of regular shape and uniform size, sharp, even and free from twists, bends or flaws. They must be of a deep red colour, and ring clearly when struck.

For Rate Abstract *see* page 103.

Note on Mangalore tiles.

1. Mangalore tiles are made of the best Malabar clay, well dried and thoroughly burnt in patent kilns.

The tiles are arranged in layers in the kilns, and when the burning has been completed, are taken out and assorted, generally, into three classes. All those that are thoroughly and satisfactorily burnt are classed as 1st class; those that are insufficiently burnt are classed as "*nakari*" or 2nd class; while vitrified or over-burnt tiles are classed as 3rd class, and are much used for roofing chawls and buildings of that class.

Each tile covers $12\frac{1}{2} \times 8\frac{1}{4}$ inches. Making allowance for laps, about 150 tiles are required for each 100 square feet of roofing. 1,000 tiles weigh about $2\frac{1}{2}$ tons and 250 tiles make a cart-load.

The gauge for battening is $12\frac{1}{2}$ inches, centre to centre.

Tiles weigh about $5\frac{5}{8}$ lbs. dry and $6\frac{9}{16}$ when soaked, *i.e.*, they absorved 16·7 per cent. of water.

Each ridge tile is about 16 inches in length, weighs when dry $7\frac{1}{2}$ lbs. and 150 tiles make a cart-load.

On broad gauge lines 4,800—5,000 flat tiles make a truck load of 12 tons, and half the number on narrow gauge lines, of 6 tons.

Asbestoes cement slates flat sheets, and corrugated sheets.

General Remarks.—These asbestos cement products are made by a combination of Portland cement with asbestos fibres. The fibres act as a sort of reinforcement and the products are stronger and more resilient than pure cement slates or sheets.

The British Standards Institution has issued a specification [No. 690-1936] for these products, the main points of which are reproduced below :—

Colouring Matter.

Pigments that are embodied in the asbestos-cement for colouring purposes, shall be of permanent colour. They shall not consist of nor contain, substances deleteriously affecting cement, such as lead oxide. The proportion of water soluble chlorides (expressed as chlorine), and of water-soluble sulphates (expressed as sulphuric anhydride), shall not together exceed 2·5 per cent. by weight of the pigment.

Freedom from Defects.

The finished products when delivered shall be free from visible defects, and shall have been manufactured for at least four weeks.

Manufacture.

7. (a) **Slates.**—Slates shall be consolidated under pressure, and shall be smooth on both sides.

(b) **Flat Sheats.**—Flat sheets shall be rectangular, have a plain surface on one side, and shall have neatly trimmed edges.

DIMENSIONS AND TOLERANCES.

8. (a) **Dimensions of Slates and Flat Sheets.**—The slates, (rectangular for laying straight-cover, diamond and honeycomb pattern for laying diagonally), and Flat Sheets, shall conform to standard dimensions.

(b) **Tolerances** (i) **Slates.**—The permissible tolerance on the thickness of slates shall be less than 5 per cent.

(ii) **Flat Sheets.**—Flat sheets shall not vary from the linear dimensions specified by more than one quarter of one per cent. They shall be tested for thickness, by stacking 20 sheets together, and the difference between the actual height and the theoretical height, shall not exceed ± 10 per cent.

TRANSVERSE TEST.

9. (a) **Average Breaking Load.**—The average breaking load of six square specimens measuring 10″ by 10″ cut, from slates or flat sheets, when tested wet over a 9 inch span in the manner prescribed, shall not be less than the values given in the following table :—

Breaking Load in Pounds.

TABLE XIII.

Type.	Thickness.	Treated with the fibres running parallel to the bearers.	Tested with the fibres running at right angles to the bearers.
		lbs.	
Slates	3·8 to 4·2 mm. ..	53	75
	4·3 to 4·7 mm. ..	68	97
	4·5 to 4·9 mm. ..	73	105
Flat Sheets	5/32 in ..	34	48
	3/16 in ..	49	69
	1/4 in ..	88	123
	5/16 in ..	137	192
	3/8 in ..	196	276

Note.—In the case of slates from which a 10″ by 10″ specimen cannot be obtained, a specimen 10″ by 5″ shall be used and tested with the same ⁰ inch span. The breaking load obtained shall be not less than one half the value for the appropriate fibre direction, given in the Table above for the 10″ by 10″ specimen, of the same thickness.

(b) **Uniformity.**—If the breaking strength of any specimen, is less than 70 per cent. of the average breaking strength of the six specimens tested, a further six specimens shall be tested, and the results combined with those of the previous five results, the lowest result having been eliminated. The breaking strength of any one of the eleven specimens, shall not be less than 70 per cent. of the average breaking strength of the specimens.

CORRUGATED SHEETS.

General.

10. Corrugated Sheets shall be classified according to the size and form of the corrugations as follows :--

TABLE XIV.

Type of Sheet.	Depth of Corrugation.	Centres of Corrugations.
Small Section	Under 2 in	$2\frac{7}{8}$" and 3".
Large Section	2 in and over	$5\frac{3}{4}$" and 6".
Alternate Flat and Corrugated Section.	2 in and over	$13\frac{1}{3}$" usually.

The sheets shall be corrugated in a true and regular manner.

DIMENSIONS AND TOLERANCES.

11. (a) **Dimensions.**—The corrugated sheets shall within the limits of tolerance specified, conform to the linear dimensions given in Standard tables. The thickness shall not be less than that specified.

(b) **Tolerances.**—Corrugated sheets shall not vary from the standard dimensions for length and width specified, by more than one quarter of one per cent.

TRANSVERSE TEST.

12. (a) **Average Breaking Load.**—When tested wet in the manner prescribed the average breaking load of 3 specimens, shall not be less than the values in the following table :—

TABLE XV.

Class of Sheet.	Span at which tested.		Minimum width of sheet tested.		Minimum average breaking load per inch width of specimens tested.
	ft.	in.	ft.	in.	lb.
Small section	2	6	2	..	12
Large section	3	6	3	..	26
Alternate flat and corrugated section ..	3	6	3	6	26

(*b*) **Uniformity.**—If the breaking strength of a specimen is less than 70 per cent. of the average breaking strength of the three specimens tested, a further three specimens shall be tested, and the results combined with the results of the two previous tests, the lowest result having been eliminated.

The lowest breaking strength of any one of the five specimens shall not be less than 70 per cent. of the average breaking strength of the specimens.

METAL WORK.

General.

1. As commonly interpreted, the term "steel structure work" includes all material covered by cast iron, wrought iron and steel, employed for structural, purposes. Each material has various grades and all differ from each other mainly in the amount of carbon contained, and the degree to which other elements such as sulphur, phosphorus, silicon and manganese enter into its constituents.

2. Wrought iron comes nearest to pure iron, and good grade material contains little or no carbon, in any case rarely exceeding 0·025 per cent. On the other hand, cast iron contains the greatest amount of carbon 5 per cent. being a common grade. Steel is intermediate between the wrought and cast irons, the quantity of carbon contained varying from 0·4 to 1·5 per cent. Its grading depends upon the purity of the materials used, and the processing during manufacture. Low, medium and high carbon steels are manufactured for innumerable purposes, which grouping includes special service steels, differing from the common classes only by reason of specific elements contained, or in some other desired change brought about through the process of manufacture.

3. When conditions arise which necessitate local purchase of steel in particular, it should not be overlooked, that Indian markets are often stocked with considerable quantities of inferior material, distributed and sold by metal merchants, who possess little or no technical knowledge of the material sold. The necessity for efficient inspection and for obtaining guarantees of manufacture will, therefore, be obvious. All good grade work should be covered by material coming under British Engineering Standards, and it is advantageous to give consideration only to such tenders as fully comply with the conditions covered by contract clauses to that effect.

CAST IRON.

Notes of castings.

1. Castings may be of cast iron, of malleable iron, or of steel. Taking the first it will be recognised that the first process of iron casting is usually performed at the smelter, with resultant products in the form of pig iron. Commercial castings, however, are the product of the foundry, where the operations of melting and moulding the metal into shapes and forms, as desired for practical purposes, are carried out. Such castings are produced from mixtures of several brands, giving a superior product to that obtainable from the blast furnace as normally manufactured.

2. The quality of material may be fairly well judged from the appearance of the fracture. It is made either as a grey or as a white iron. Grey, being the strongest, is in demand the most and should invariably be used where strength is desired. Hard and brittle material is commonly light grey in colour, having little or no lustre. A tough iron is marked by a uniformly diffused dark grey colour having a good lustre, mottled colour and lack of lustre, shows that the material is weak. A light grey

colour with pronounced lustre indicates a hard and tenacious iron, and when a fracture shows up a *much* mottled dark colour with an entire absence of lustre, the suitability of the iron should be suspected, with a view to rejection.

3. The common cast irons do not pass through any heat treatment after casting, so that the weakness of the material or imperfections of the process conditions are ever present. Good grade material is most suitable for withstanding compressive stresses, which very largely accounts for its common use in the base plates and framing, which form the stationary parts of machines.

4. The ultimate strength of good grade material in compression, averages 40 tons per square inch of section, and working strengths frequently used in compression, free from flexure, are, one-sixth of this for dead weights, one-eighth for columns free from vibration, and one-fourteenth for arch-work. The average tensile strength of cast iron is however low, being but about six tons per square inch of section. It should, therefore, never be used horizontally for either heavy or variable loads, nor where the slightest liability to shock exists, for experience teaches us that cast iron gives little or no warning of approaching failure due to tensile stresses.

5. For all close fitting work, the nature of cast iron necessitates a close attention being paid to detail and if for any specific purpose there exist elements of doubt in relation to size or shape, a pattern or template should be forwarded to the supplier. The grade of material and purpose for which it is designed are both factors which re-act upon the cost of any machining which may be necessary after the casting has been made and, therefore, attention should be given to an adherence to stock or standard designs as much as possible, to reduce cost.

6. For all practical purposes of importance, steel has entirely displaced cast iron in structural engineering, but owing to its relative cheapness and the ease with which it can be cast in moulds to almost any desired shape, there are still many uses to which it is put.

Brazing and riveting are inadmissible operations where cast iron is concerned and grey iron is much cheaper to machine than white iron which is not easily worked.

Specification No. 4.

1. All castings shall be of the best tough close-grained grey metal, of such a strength that a bar one inch thick by two inches deep placed upon bearings three feet apart, will sustain, without fracture, a weight of 27 cwt. placed at the centre with a deflection of not less than one-third inch.

2. Castings having wearing surfaces shall be made from cold blast pig. All castings shall be clear sound and without admixture of deleterious matter, true and out of winding, free from airholes and flaws and with the arrises clean and sharp.

3. The British Admirality specify that cast iron must have an ultimate tensile strength of not less than 11 tons per square inch and that the load in transverse tests must not be less than 2,000 lbs. applied centrally, on cast bars one inch square in section when suspended on supports placed one foot apart.

Malleable iron is formed from iron castings of suitable composition, carefully watched for soundness during casting, subjected to a partly thermal and partly chemical change producing a material very ductile and tough. The resultant product is vastly superior to ordinary commercial cast iron and is used extensively.

WROUGHT IRON.

Notes on wrought iron.

1. The use of wrought iron for structural purposes has been practically superseded by steel. Some grades however being less susceptible to corrosion than steel, have been frequently used on hydraulic and marine works for special purposes such as lock gates, etc. Apart from the extensive manufacture of galvanized iron sheeting, its more general utilities are to be found in operations performed at the smithy and the forge where it is supplied as bar or sheet material.

2. Good quality wrought iron is tough, ductile and fibrous. A short blackish fibre indicates imperfect material, and a very fine grained iron is likely to prove cold-short. Cracks developed on surface or edges indicate hot-short material.

3. Galvanized iron corrugated sheeting is made in lengths from three to ten feet in length.

Specification No. 5.

(1) Wrought Iron shall be of the grade A, B or C as specified.

(2) It shall be well and cleanly rolled to the dimensions specified and shall be sound and free from flaws, laminations, cracks or other defects.

(3) The weight shall be calculated on the basis of $3\frac{1}{3}$ lbs. per square inch area, a foot long.

(4) The Iron shall not contain more than 0·10 per cent. of manganese for Grade A and not more than 0·15 for grade B.

5. The results of tensile tests for Grade A and B should give a tensile strength of 21 to 24 Tons per square inch for rounds and squares up to 2″ diameter or side and flats and angles, and 20 to 24 tons for rounds and squares $2\frac{1}{2}$″ diameter or side and over, and plates with the grain. For plates across the grain, these figures should be 17 to 21 tons per square inch. For Grade C, the tensile strength of rounds and squares upto 2″ diameter or side should be 21 to 25 tons per square inch and the same strength for flats 4″ wide and up to $\frac{1}{2}$″ thick and angles up to $\frac{1}{2}$″ thick. For higher sizes and plates along the grain, the tensile strength should be from 20 to 24 tons per square inch. For plates across the grain this strength should be from 17 to 21 tons per square inch.

The grades vary in elongation per cent. under test the grade A giving the greatest minimum elongation per cent. and the greatest minimum reduction of area per cent. of original area, and Grade C the least.

Cold bend Tests : -

The test piece shall without showing signs of fracture on the outside of the bend, withstand being bent cold through an angle of 180° round a former having a diameter equal to the diameter or thickness of the test piece, until the limbs of the test piece are parallel, for grade A. For Grades B and C the former shall have a diameter equal to $1\frac{1}{2}$ times the test piece thickness, and for grade C with the same former thickness the bend will be through 90° only for all round and square bars and for flats up to $1\frac{1}{4}$″ thick .For flats over $1\frac{1}{4}$″ thick the. former, is twice the thickness of the test piece and the bending through an angle of 135°.

For Plates—the bending is round a former of 1″ diameter, and the angles of bending as under :—

TABLE XVI

Thickness of plate.	¼″	⅜″	½″	⅝″	¾″	⅞″	1″
Withgrain.—							
Grade A	90°	62°	45°	34°	28°	23°	20°
Grade B	80°	58°	42°	32°	25°	22°	..
Grade C	70°	50°	35°	27°	21°	17°	..
Acrossgrain.—							
Grade A	40°	28°	20°	14°	12°	9°	6°
Grade B	35°	25°	17°	13°	10°	8°	..
Grade C	30°	20°	15°	12°	10°	7°	..

Nick and Bend test.

In Grades A and B a test piece lightly and evenly nicked on one side, and bent steadily should show fibres free from slag, dirt or coarse crystalline spots or streaks.

There are other tests viz. welded for test, the Quench test, and Ram's Horn test, to judge the quality.

STEEL.

Notes on steel.

1. For structural steel the latest British Standard Specifications as revised are in general use. Stock material should invariably be adhered to when indenting, since this ensures prompt deliveries at lower cost. In general, sections made up as bridge rails, steel joists, channels, angles tees, rolled edge steel flats and plates of common widths and thicknesses are stocked in lengths ranging from 18 to 40 feet, advancing in steps of two feet.

2. Round bars for solid steel columns are not usually stocked over 30 feet in length.

3. Owing to the advantages which the use of broad flange beams offer for many purposes, as an alternative to built up or compound girders, the use of the former is extending and reputable makers now manufacture them in sections up to 16″ × 12″ × 107 lbs. per foot.

EXTRACT SPECIFICATION FROM B. S. S. STRUCTURAL STEEL FOR BRIDGES, ETC., AND GENERAL BUILDING CONSTRUCTION.

Specification No. 6.

1. The steel shall be made by the Open Hearth Process (Acid or Basic) or Acid Bessemer Process unless one of these processes is specially required or specified, and shall not show on analysis, more than 0·06 per cent. of sulphur or of phosphorus.

QUALITY OF FINISHED STEEL.

2. All finished steel as sent from the mills shall, subject to permissible variations in length, weight and cross-sectional dimensions as laid down, be well and clearly rolled to the dimensions, sections and weights specified or required. It shall be sound and free from cracks, surface flaws, laminations, rough-jagged and imperfect edges, and all other defects, shall be finished in a workmanlike manner, and shall in all respects comply with the tests and requirements herein mentioned, applicable to the description of material (e.g., plates, sections, bars, rivets, etc.) required or specified.

5. The tensile breaking strength of all steel, determined from the Standard Test Pieces hereinafter referred to, shall be as follows : –

(a) Plates, Sections (e.g., Angles, Tees, Beams, Channels, etc.) and Flat Bars. – The tensile breaking strength of all plates, sections, (such as angles, tees, beams, channels, etc.) and flat bars, shall be between the limits of 28 and 33 tons per square inch of section. The elongation measured on the Standard Test Piece, shall be not less than 20 per cent. for steel of 0·375 inch in thickness and upwards, and not less than 16 per cent. for steel below 0·375 inch in thickness.

For plates, sections, and flat bars, under 0·25 inch in thickness, bend tests only shall be required.

(b) Round and Square Bars.—The tensile breaking strength of round and square bars (other than rivet bars) shall be between the limits of 28 and 33 tons per square inch of section, with an elongation of not less than 20 per cent. measured on the Standard Test Piece, with gauge length not less than 8 times the diameter or side, or not less than 24 per cent. measured on the Standard Test Piece, with gauge length not less than four times the diameter or side, for bars above 1″ diameter or side. For bars under 0·375 inch diameter or thickness, for concrete reinforcement, the elongation measured on the former test piece shall be not less than 16 per cent. For bars under 0·375 inch diameter or thickness for other purposes, bend tests only are required. The bars may be tested the full size as rolled.

(c) Rivet Bars.—The tensile breaking strength of rivet bars, shall be between the limits of 25 and 30 tons per square inch of section, with an elongation of not less than 26 per cent. measured on the Standard Test Piece, with gauge length not less than eight diameters or not less than 30 per cent. measured on Standard Test Piece with gauge length not less than four diameters. The bars may be tested the full size as rolled.

9. **Cold Bend Test.**—For cold bend tests, except in the case of round bars 1 inch in diameter and under, the test piece shall withstand, without fracture, being doubled over either by pressure or by blows from a hammer until the internal radius is not greater than 1½ times the thickness of the test piece, and the sides are parallel.

In the case of round bars, 1 inch in diameter and under, the internal radius of the bend, shall be not greater than the diameter of the bar.

For sections having flanges less than 2 inches (50·80 mm.) wide these bend tests may be made from the flattened section.

10. **Number of Tests.**—For every 5 tons or part of 5 tons, of material presented for inspection, the following cold bend tests shall be taken from the material from each cast, included therein :—

From each type of section and from flat bars.	From plates.	From each diameter of round and each thickness of square bars.
1 lengthwise	1 lengthwise and 1 crosswise.	1 lengthwise.

Except that for the first 5 tons, or part of 5 tons, one additional test shall be taken from each type of section and from flat bars, and from each diameter or thickness of square bar.

For rivet bars bend tests are not required.

Number of Tensile Tests.—One for each different type of section from each cast, for any quantity up to 25 tons, and an additional test for each type, if the quantity exceeds 25 tons.

For rivet bars, one tensile test shall be made from the finished steel from a cast for any quantity up to 10 tons.

NUMBER AND KIND OF TESTS OF MANUFACTURED RIVETS.

1. Manufactured rivets selected from the bulk, in such number as may be specified, shall withstand the following tests :—

(*a*) The rivet shanks shall be bent cold, and hammered until the two parts of the shank touch, without fracture on the outside of the bend.

(*b*) The rivet heads shall be flattened, while hot, without cracking at the edges. The head shall be flattened until its diameter is $2\frac{1}{2}$ times the diameter of the shank.

NOTES FOR GUIDANCE IN CONNECTION WITH STEEL STRUCTURE BUILDINGS.

When calling for designs and estimates for steel frame buildings, workshops, engine or pump houses, etc., delays and misconceptions likely to arise will be greatly minimised, if care is taken to furnish *the people from whom tenders are invited*, with such information, as the requirements of the case demand.

1. A plan of site, showing the location of proposed structure, position of adjacent buildings, roadways, waterways or other physical conditions, having a bearing upon either the erection or completed work proposals.

2. Sketches showing the proposed building dimensions ; height to eaves, lengths, widths, number of floors, heights of same from floor level to underside of floor above, and any other dimensional information, which being specified, may be incorporated in a design, *otherwise*, left to the designer's judgment.

3. If more than one bay in width is required, state width of each and the number of bays, also advising whether the number and positions of stanchions can be left to the designer's discretion. Where special circumstances, such as the placing of machinery, shafting, or cranes, rule the positions of internal stanchions, this should be clearly stated, with preferably a lay-out drawing for guidance.

4. State any preference held for floor construction, giving the load per super foot which the floors will be called upon to support, exclusive of individual dead weights.

If machinery is to be supported, the positions and weights should be shown on the lay-out drawing. Concentrated loads on either floors or roofs, should be clearly specified, likewise all openings, or channeling, through and along either the walls or floors.

5. State whether roof is required flat, ridged or curved.

6. State wall and roof material desired, and for sheeting, state whether the sheets are to be supplied galvanised or black painted, with gauge, end laps, etc

7. State whether the use of timber is permissible or not, for supporting sheeted walls, and roof covering ; also for roof purlins.

8. If shafting has to be supported by the roof, this should be stated, giving the length and diameter of the same, together with particulars of the load, and positions of concentration.

9. **Doors and staircases.**—If required in steel, state the number, position, size and type.

10. **Crane Runways.**—Where a crane runway is desired, state the centres of the supporting stanchions, the type, the span, the wheel-base, and the load of the crane, together with the end and overhead clearances.

11. **Gutters and pipes.**—If not left to the discretion of the designer, state material for the same, *i.e.*, cast iron or galvanised iron, etc., giving particulars of position.

12. **Concrete work.**—The steel used for reinforcement should comply with quality A, B. S. S.

13. State any known conditions on site, which may assist or retard (if ignored), either the erection work, or the local delivery of material, during the progress of the work.

14. Where building design is largely determined by a conformity to local Government or Municipal bye-laws, a copy of the bye-laws should accompany the specification.

15. When the progress programme of the erection work is largely determined by the demands of internal plant contracts, carried out at the same time as the building work progresses, the full programme requirements should be stated in specification.

16. **Workmanship.**—On all permanent works the whole of the workmanship should be of first class character throughout, and true to dimensions.

All sheared edges should be planed or machined, where stress is transmitted, and all holes in girders and columns must be drilled. Machine riveting should be stipulated for wherever practicable, and all connections on the site should preferably be bolted, unless otherwise agreed upon in the contract.

NOTES ON THE INSPECTION OF IRON AND STEEL SUPER-STRUCTURES.

1. Contract drawings and specifications should be read, studied and so examined, that the whole contract is thoroughly known. Ordinarily when drawings, etc ,

are received, it is assumed that they will be complete and accurate. It is however, unwise to take too much for granted, the prevention of errors or omissions *before* they can affect the progress of work should invariably be aimed at.

2. Two classes of drawings are usually supplied on erection site, namely, general and detail drawings. The general drawings constitute plans, elevations and sections, and serve to show the proper relationship borne by structural members to each other. To facilitate assembly work, the drawings usually show a marking system, from which the fabricated steel material can be readily identified and checked. Detail drawings are generally shop drawings. As they are usually on a scale large enough to give machinists and other workmen, the exact knowledge for cutting, shearing, drilling, planing, milling and riveting, finishing with an erection mark, it follows the supply of these drawings to erectors, facilitates the identification of details common to the connections of members.

3. Conduct all the inspection duties, so as not to interfere unnecessarily with the progress programme in operation.

4. When unusual circumstances require an explanation of the plans, or some variation from the specified procedure, take the necessary action at once.

5. See that all the erection tackle supplied for use on site, is of a quality and in a condition, as will enable all parts of the structure to be properly assembled and aligned, with perfect freedom from the liabilities of structural distortion or accident to workpeople, etc.

6. See that all levelling and setting out for foundations is carefully carried out.

7. Give special attention to the requirements of specification where foundations are concerned. This is of the utmost importance, since the stability and life of the structure, will largely depend upon the uality of the material used and the manner in which it is handled.

8. See that all material arriving on site is so unloaded, handled and stored, as will safeguard against any distortion or other damage to members, noting it is bad practice to have such quantities on the site, as may result in expense for moving operations and its consequent delays.

9. During erection prevent any abuse or rough usage of the material, such as bending, straining, or pounding with sledges.

10. Carefully watch the use of fillers, washers, and threaded members of all classes, with a view to preventing both misuse and abuse. The use of shims of any kind for plumbing up purposes, should not be allowed.

11. Examine castings carefully for blow-holes and other imperfections, and exercise discretion in rejecting castings as unfit for use.

12 See that all tie-rods, anchor bolts, connection bolts, plates (base, wall and connection), bushings, collars, keys, or other miscellaneous parts required in assembly, are properly checked and safeguarded against loss, or any substitution by inferior grade material arising through same.

13. Remember that *field* riveting requires a more stringent attention than is the case with shop riveting, which usually permits of whole time attention. No *covered* riveted or bolted work should ever be passed, without having been thoroughly inspected *prior to covering up,* and any defective work rectified.

14. Machine riveting should be adhered to wherever possible, owing to accessibility requirements, however, the majority of field operations usually involve *some* hand riveting, and this should be carefully watched so as to guard against loose rivets, underheating, overheating, and other imperfections of workmanship.

15. Loose rivets should *always* be cut out and replaced by new ones, care being taken to prevent injury to the metal during the cutting out.

16. Sometimes the use of bolts is resorted to, where riveting was originally intended, owing to the want of space for driving. This of course should never occur where any important connection is concerned. In such a case, care shou d be taken to ensure the use of material, of such a standard Whitworth size, that will provide for a force fit when bolt is in place.

When in place and the nut is screwed home as tightly as possible, the screw end should be reveted cold by hammering threads into deformation, which prevents the nut from working loose through possible vibration, etc.

17. Whenever possible during the progress of the work, secure photographic records.

18. Make such weekly progress reports, as readly lend themselves to the making up of a final report on completion, which will show the cost of erection in sections, the cost of correcting any errors which may have arisen, and any other information likely to prove useful at a future date, when estimating for similar works.

TABLE XVII.

BREAKING AND WORKING STRESSES FOR MATERIALS FOR DEAD LOAD.

Material.	Breaking stresses in tons per square inch		Working stresses in tons per square inch.		Factor of safety.
	Tension.	Compression.	Tension.	Compression.	
Cast-iron	9	48	1½	8	6
Wrought-iron	23	18	5	4	4½
Steel	30	30	7½	7½	4
Timber, fir	4½	3	½	⅓	9
Do. oak or teak ..	6½	4½	⅔	½	9

TABLE XVIII

FACTORS OF SAFETY.

The following table shows the factors of safety recommended for application in several cases that arise in practice.

Authority.	Nature of structure.	Nature of load.	Factor of safety.	Remarks.
Various authorities quoted in the Rivington's series of Notes on Building Construction.	*Cast iron.*			
	General ..	Dead ..	4	
	.... ..	Live or varying ..	6	Stress of one kind only.
	.... ..	Do. ..	10	Equal alternate stresses of different kinds.
	.... ..	Varying with shocks ..	15	
	Water tanks ..	Dead ..	4	
	Pillars ..	Do. ..	6	
	Pillars subject to vibration.	Live ..	8	
	Pillars subject to transverse shock.	Do. ..	10	
	Wrought iron.			
	General ..	Dead ..	3	
	.... ..	Live or varying ..	5	Stress of one kind only.
	.... ..	Do. ..	8	Equal alternate stresses of different kinds.
	.... ..	Varying with shocks ..	12	
	Girders ..	Dead ..	3	
	.... ..	Live with shocks ..	6	
	Bridges ..	Mixed ..	4	
	Riveted joints ..	Dead ..	4	
	Roofs ..	Do. ..	4	
	Tension and compression bars.	Live with shocks ..	6 to 7	
	Compression bars ..	Dead ..	4	
	Steel.			
	General ..	Dead ..	3	
	.... ..	Live and varying ..	5	Stress of one kind only.
	.... ..	Do. ..	8	Equal alternate stresses of different kinds.
	.... ..	Varying and shocks ..	12	
	Bridges ..	Mixed ..	4	
	Timber.			
	General ..	Dead ..	7	
	.... ..	Live and varying ..	10	Stress of one kind only.
	.... ..	Do. ..	15	Equal alternate stresses of different kinds.
	.... ..	Varying with shocks ..	20	
	Exposed to weather ..	Dead ..	10	
	For temporary purposes	Do. ..	4	
	Brickwork and masonry.			
	General ..	Dead ..	20	4 to 10 (Rankine).
	Do. ..	Live ..	30	
	Arches ..	Dead ..	20	
	Do. ..	Live ..	30	

Note.—The above figures are for general guidance only; the factor of safety, determined upon for any particular case, will depend upon what is acurately known of the strength and quality of the particular material to be used, upon the importance of the structure, etc.

The following is an approximate list of sections and sizes of round, square, flat and tee bars, etc., which are usually available for immediate delivery in the bazar :—

SIZES :—ROUND, SQUARE AND FLAT BARS.

Round bars, $\frac{3}{16}$, $\frac{1}{4}$, $\frac{5}{16}$, $\frac{3}{8}$ and $\frac{1}{2}$ inch.
Do. $\frac{5}{8}''$ to 2 inches, rising by eighths.
Do. $2\frac{1}{4}$ to 4 inches, rising by quarters.
Do. $4\frac{1}{8}$, $4\frac{5}{8}$, $5\frac{1}{4}$, $6\frac{1}{4}$, $7\frac{1}{4}$ and $8\frac{1}{4}$ inches.
Square bars $\frac{1}{4}$ to $1\frac{3}{4}$ inches rising by eighths.
Do. 2 to 4 inches rising by quarters.

Flat bars,	$\frac{1}{2}$ to 1 inch	$\times \frac{1}{8}$ inch thick, width advancing by $\frac{1}{8}$ths.			
Do.	$1\frac{1}{4}$ to 3 inches	$\times \frac{1}{8}$	,,	do.	do.
Do.	1 to 4 ,,	$\times \frac{1}{4}$	,,	do.	do.
Do.	1 to 6 ,,	$\times \frac{3}{8}$	,,	do.	do.
Do.	1 to 6 ,,	$\times \frac{1}{2}$	,,	do.	do.
Do.	1 to 6 ,,	$\times \frac{5}{8}$	,,	do.	do.
Do.	$1\frac{1}{2}$ to 6 ,,	$\times \frac{3}{4}$	,,	do.	by $\frac{1}{2}$ inch.
Do.	$1\frac{1}{2}$ to 6 ,,	$\times \frac{7}{8}$	,,	do.	do.
Do.	$1\frac{1}{2}$ to 6 ,,	$\times 1$	,,	do.	do.
Flat girder bars,	6 to 12 inches wide	$\frac{1}{4}''$ in 30-feet lengths.			
Do.	6 to 16 ,,	$\times \frac{3}{8}''$		do.	
Do.	6 to 16 ,,	$\times \frac{1}{2}''$		do.	

ANGLE BARS, VARIOUS SECTIONS.

Angle bars, $\frac{3}{4}'' \times \frac{3}{4}''$, $1'' \times 1''$ and $1\frac{1}{4}'' \times 1\frac{1}{4}'' \times \frac{1}{8}''$.
Do. $1'' \times 1''$, $1\frac{1}{4}'' \times 1\frac{1}{4}''$, $1\frac{1}{2}'' \times 1\frac{1}{2}''$ and $1\frac{3}{4}'' \times 1\frac{3}{4}'' \times \frac{3}{16}''$.

ANGLE BARS, VARIOUS SECTIONS.

Angle bars, $1'' \times 1''$, $1\frac{1}{4}'' \times 1\frac{1}{4}''$, $1\frac{1}{2}'' \times 1\frac{1}{2}''$, $1\frac{3}{4}'' \times 1\frac{3}{4}''$, $2'' \times 2''$, $2\frac{1}{2}'' \times 2\frac{1}{2}''$ and $3'' \times 3'' \times \frac{1}{4}''$.
Do. $2'' \times 2''$ and $2\frac{1}{2}'' \times 2\frac{1}{2}'' \times \frac{5}{16}''$.
Do. $2'' \times 2''$, $2\frac{1}{2}'' \times 2\frac{1}{2}''$, $3'' \times 3''$, $3\frac{1}{2}'' \times 2\frac{1}{2}''$, $3\frac{1}{2}'' \times 3\frac{1}{2}''$, $4'' \times 3''$, $4'' \times 4''$, $5'' \times 3''$, $6'' \times 3''$ and $6'' \times 4'' \times \frac{3}{8}''$.
Do. $2\frac{1}{2}'' \times 2\frac{1}{2}''$, $3'' \times 3''$, $3\frac{1}{2}'' \times 3\frac{1}{2}''$, $4'' \times 3''$, $4'' \times 4''$, $5'' \times 3''$, $6'' \times 3''$ and $6'' \times 4'' \times \frac{1}{2}''$.
Do. $3'' \times 3''$, $4'' \times 4''$, $5'' \times 5'' \times \frac{5}{8}''$.

TEE BARS, VARIOUS SECTIONS.

Tee bars, $1\frac{1}{4}'' \times 1\frac{1}{4}''$, $1\frac{1}{2}'' \times 1\frac{1}{2}''$, $2'' \times 2''$, and $2\frac{1}{2}'' \times 2\frac{1}{2}'' \times \frac{1}{4}''$.
Do. $2\frac{1}{2}'' \times 2\frac{1}{2}''$, $3'' \times 3''$, $3'' \times 4''$, $3\frac{1}{2}'' \times 3\frac{1}{2}''$, $4'' \times 3''$, $4'' \times 4''$, $5'' \times 3''$, $6'' \times 3''$ and $6'' \times 4'' \times \frac{3}{8}''$.
Do. $3'' \times 3''$, $3'' \times 4''$, $3\frac{1}{2}'' \times 3\frac{1}{2}''$, $4'' \times 3''$, $4'' \times 4''$, $5'' \times 3''$ and $6'' \times 3'' \times \frac{1}{2}''$.

Note.—**Angle and tee bars are available in lengths of 24, 25 and 30 feet, these being the usual lengths imported.**

SHEETS AND PLATES.

Sheets 18 to 24 B. W. G. size 4′ × $2\frac{1}{2}$′.
Sheets $\frac{1}{16}$″ and $\frac{1}{8}$″ thick, 6, 8, 10 and 12 feet long × 3′ and 4′ wide.
Plates $\frac{3}{16}$″ to $\frac{5}{8}$″ thick, 6, 8, 10 and 12 feet long by 3′, $3\frac{1}{2}$′ and 4′ wide.
Plates $\frac{3}{4}$″ to 1″ thick, 6 and 8 feet long × 3′ and 4″ wide.

Note.—When the weight of iron is determined by measurement the following weights should be allowed :—

Wrought iron	40 lbs.	per foot superficial an inch thick.
Steel	40·8 ,,	,, do. do.
Cast iron	37·5 ,,	,, do. do.

TABLE XIX.

SECTIONAL AREA AND WEIGHT OF SQUARE AND ROUND BAR IRON.

Diameter or side in inches.	Square bars.		Round bars.		Diameter or side in inches.	Square bars.		Round bars.	
	Sectional area in sq. inches.	Weight per lineal foot in lbs.	Sectional area in sq. inches.	Weight per lineal foot in lbs.		Sectional area in sq. inches.	Weight per lineal foot in lbs.	Sectional area in sq. inches.	Weight per lineal foot in lbs.
$\frac{1}{4}$	·063	·209	·049	·164	$2\frac{1}{8}$	4·516	15·08	3·546	11·84
$\frac{5}{16}$	·098	·326	·076	·256	$2\frac{1}{4}$	5·062	16·91	3·976	13·27
$\frac{3}{8}$	·141	·470	·110	·369	$2\frac{3}{8}$	5·640	18·84	4·430	14·79
$\frac{7}{16}$	·191	·640	·150	·502	$2\frac{1}{2}$	6·25	20·87	4·908	16·39
$\frac{1}{2}$	·250	·835	·196	·656	$2\frac{5}{8}$	6·891	23·11	5·411	18·07
$\frac{9}{16}$	·316	1·057	·248	·831	$2\frac{3}{4}$	7·562	25·26	5·939	19·84
$\frac{5}{8}$	·391	1·305	·306	1·025	$2\frac{7}{8}$	8·265	27·61	6·491	21·68
$\frac{11}{16}$	·473	1·579	·371	1·241	3	9·00	30·07	7·068	23·60
$\frac{3}{4}$	·563	1·879	·441	1·476	$3\frac{1}{4}$	10·562	35·28	8·295	27·70
$\frac{13}{16}$	·660	2·205	·518	1·732	$3\frac{1}{2}$	12·25	40·91	9·621	32·13
$\frac{7}{8}$	·765	2·556	·601	2·011	$3\frac{3}{4}$	14·06	46·97	11·04	36·89
$\frac{15}{16}$	·878	2·936	·690	2·306	4	16·00	53·44	12·56	41·97
1	1·000	3·34	·785	2·62	$4\frac{1}{4}$	18·06	60·32	14·18	47·38
$1\frac{1}{8}$	1·266	4·22	·994	3·32	$4\frac{1}{2}$	20·25	67·63	15·90	53·12
$1\frac{1}{4}$	1·563	5·25	1·227	4·09	$4\frac{3}{4}$	22·56	75·35	17·72	59·18
$1\frac{3}{8}$	1·890	6·35	1·484	4·96	5	25·00	83·51	19·63	65·58
$1\frac{1}{2}$	2·250	7·51	1·767	5·90	$5\frac{1}{4}$	27·56	92·46	21·64	72·30
$1\frac{5}{8}$	2·640	8·82	2·073	6·92	$5\frac{1}{2}$	30·25	101·03	23·75	79·35
$1\frac{3}{4}$	3·062	10·29	2·405	8·03	$5\frac{3}{4}$	33·06	110·43	25·96	86·73
$1\frac{7}{8}$	3·515	11·74	2·761	9·22	6	36·00	120·24	28·27	94·43
2	4·000	13·36	3·141	10·49	..	..	..	..	..

NOTE :—To obtain weights of mild steel bars of the same diameter or scale add 2 per cent. to the above weights for the bar size concerned.

TABLE XX.

FLAT IRON BARS, WEIGHT PER LINEAL FOOT.

[Width in inches.]

Thickness in inches.	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3
$\frac{1}{16}$	·208	·260	·313	·365	·417	·469	·521	·573	·625
$\frac{1}{8}$	·417	·521	·625	·729	·833	·938	1·04	1·15	1·25
$\frac{3}{16}$	·625	·781	·938	1·09	1·25	1·41	1·56	1·72	1·88
$\frac{1}{4}$	·833	1·04	1·25	1·46	1·67	1·88	2·08	2·29	2·50
$\frac{5}{16}$	1·04	1·30	1·56	1·82	2·08	2·34	2·60	2·86	3·13
$\frac{3}{8}$	1·25	1·56	1·88	2·19	2·50	2·81	3·13	3·44	3·75
$\frac{7}{16}$	1·46	1·82	2·19	2·55	2·92	3·28	3·65	4·01	4·38
$\frac{1}{2}$	1·67	2·08	2·50	2·92	3·33	3·75	4·17	4·58	5·00
$\frac{9}{16}$	1·88	2·34	2·81	3·28	3·75	4·22	4·69	5·16	5·63
$\frac{5}{8}$	2·08	2·60	3·13	3·65	4·17	4·69	5·21	5·73	6·25
$\frac{11}{16}$	2·29	2·86	3·44	4·01	4·58	5·16	5·73	6·30	6·88
$\frac{3}{4}$	2·50	3·13	3·75	4·38	5·00	5·63	6·25	6·88	7·50
$\frac{13}{16}$	2·71	3·39	4·06	4·74	5·42	6·09	6·77	7·45	8·13
$\frac{7}{8}$	2·92	3·65	4·38	5·10	5·83	6·56	7·29	8·02	8·75
$\frac{15}{16}$	3·13	3·91	4·69	5·47	6·25	7·03	7·81	8·59	9·38
1	3·33	4·17	5·00	5·83	6·67	7·50	8·33	9·17	10·00

IRON WORK

Specification No. 7.

1. All headed bolts passing through plates to be accurately fitted to the holes, with the heads lying squarely and closely on the plates. The heads to be forged in one piece with the plates. Rivets must be tightened and drawn closely home, and the heads spread equally, and properly hammered and set down all round.

2. All screws to be cut to a full thread without taper, and to an accurate fit.

3. Nuts, when measured across the flats, to be at least twice the diameter of the bolt, and to be at least equal in depth to the diameter of the bolt.

4. All iron work during the whole course of manufacture and testing, shall be subject to the inspection of the Executive Engineer or his representative.

5. All iron work to be coated while hot with boiled linseed-oil or painted with two coats of red lead, as the Executive Engineer may direct.

6. No iron work shall be painted, before it has been examined by the Executive Engineer or the Inspecting Officer.

ERECTION.

7. The Executive Engineer may order the completion and fitting together on the ground, of such portions of the work as he may deem expedient, and may cause the same to be subjected to a proper test before it is put into position.

8. In putting iron work together, the greatest care is to be taken to fit the plates and bars accurately in contact, and to see that rivet and bolt holes correspond before riveting up. All joints to be perfectly cleaned and freed from rust. Should any parts be bent or injured, they are to be repaired according to the instructions of the Executive Engineer.

In case holes do not exactly correspond, they shall not be slotted out to fit, but shall, with the permission of the Executive Engineer, be enlarged with a circular bit and larger rivets or bolts used to fill the holes.

9. Rivets shall, if possible, be heated uniformly throughout their whole substance in an air furnace, the rivets being kept clear of the fuel. Great care is necessary in heating rivets, to prevent the iron from burning and becoming brittle.

10. In erecting girders, the different parts are to be fitted together with service bolts and packed up to camber, before riveting is completed; care to be taken to keep the girders laterally straight.

11. In fixing bed-plates, special care must be taken to put the holding down bolts exactly in position, so that the nuts may bear square, and firmly grip the plate below. The upper surface of the bed-plates or rollers, must be exactly at the level given by the Executive Engineer. The bed-plates to be set in mastic or cement as the Executive Engineer may direct, the cost of which must be included in the rate for fixing.

LIMES, CEMENTS, MORTAR, etc.

LIME.

Specification No. 8.

1. Limes are divided, generally, into three classes—(*a*) Fat limes, (*b*) poor limes, (*c*) Hydraulic limes :—

Fat lime gains no consistency under water but remains in a state of paste, dissolving slowly in pure water frequently changed.

Poor lime contains fat lime and sand.

Hydraulic lime has the property of hardening under water, the smaller the time of setting the greater the Hydraulicity. In India, generally speaking, all *kankar* limes are more or less hydraulic, and these should be used, when available, for all building work, fat limes being used for plaster and whitewash only.

2. The *kankar* shall be broken to a uniform size not exceeding 1½ inch gauge carefully freed from all impurities, and burnt with a sufficiency of coal, charcoal, wood or screened cinders.

3. The lime shall be properly slaked with water, not less than one week or more than three weeks before use. The slaking shall be carried out on a slaking platform of concrete, rubble or burnt brick set in mortar. The lime after slaking shall be screened through one-eighth inch mesh screens, and the refuse will be rejected if over-burnt. If under-burnt, it may be used for placing on the top of the kiln. If the slaked lime is stored, it must be properly covered over. As a rule, the lime shall be used within 14 days after removal from the kiln.

4. All lime that has been in any way damaged by rain, moisture, dirt or any other cause will be rejected and all material that has been rejected must be removed from the site of the work within 24 hours of its rejection.

HYDRAULIC LIME.

1. This is largely used on all ordinary buildings, when they are not likely to be exposed immediately to the action of water, and when its action is not very sever.

In using hydraulic limes, moreover, there is far less danger than in the case of cements of an unskilled or careless bricklayer spoiling the work.

2. Natural hydraulic limes vary much in character, containing from 8 to 30 per cent. of clay.

3. When naturally hydraulic limestone is not procurable, fat lime may be rendered hydraulic artificially ; but ordinarilly natural is preferable to artificial hydraulic lime.

Lime is considered to be hydraulic when it sets within seven days under water, as tested by Vicat's needle.

ARTIFICIAL HYDRAULIC LIME.

Specification No. 9.

1. Artificial hydraulic lime may be made by moderately calcining an intimate mixture of fat lime with as much clay as will give the mixture a composition similar to that of a good natural hydraulic limestone, of which the product should be a successful imitation.

2. After burning such lime shall be ground dry in a lime mill and passed through a sieve having 150 meshes to the square inch. It should then be left under cover till wanted.

3. When required for use small quantities of the lime mixed with the specified proportion of sand shall be wetted with sufficient water to make a thick paste, and shall be ground for such length of time as the Executive Engineer may order, as described in the specification for mortar. The proportion of sand may be 1, 2 or 3 to 1 of lime, according to the quality of the lime, but the exact proportions should be specified by the Executive Engineer.

4. Large quantities of artificial hydraulic lime have been successfully used on the Karachi harbour works and on irrigation works in Sind.

In the manufacture 5½ parts by measure of ordinary slaked lime in paste are mixed intimately with 1 part of clay. The mixture is made into balls which, when thoroughly dried, are burned in a kiln. One part of this lime may be mixed with 2 parts of sand for superstructure work, or with 3 parts for mortor in concrete and footings.

[Full description and details of the process and cost will be found in the Roorkee Manual on "Limes, Mortars and Cements".]

PORTLAND CEMENT.

Specification No. 10.

British Standard Specification.

(*Revised.*)

Composition and manufacture of cement.

1. The cement shall be manufactured by intimately mixing together calcareous and argillaceous and/or other silica and alumina or iron oxide bearing materials,

burning them at a clinkering temperature and grinding the resulting clinker so as to produce a cement capable of complying with this Specification.

No addition of any material shall be made after burning other than calcium sulphate, or water, or both.

No cement to which slag has been added or which is a mixture of Portland Cement and slag shall be deemed to comply with this Specification. For a Specification which admits of added Slag *see* British Standared Specification for Portland-Blast-furnace Cement (B. S. S. No. 146).

Samples for Testing and by whom to be taken.

2. A sample or samples for testing may be taken by the purchaser or his representative or by any person appointed to superintend the works for the purpose of which the cement is required, or by his representative, or by any expert analyst employed or instructed by such purchaser or person, or by the representative of such purchaser or person.

Samples for Testing and how to be taken.

3. Each sample for testing shall consist of approximately equal portions selected from at least twelve different positions in the heap or heaps when the cement is loose, or from not less than twelve different bags, barrels or other packages, when the cement is not loose, or, where there is a less number than twelve different bags, barrels or other packages, then from each bag, barrel or other package. Every care shall be taken in the selection, so that a fair average sample shall be taken. Such final sample shall weigh at least 10 lbs (4·54 kg.).

Sampling Large Quantities.

4. When more than 250 tons (560,000 lbs. = 254,012 kg.) of cement is to be sampled at one time, separate samples shall be taken, as provided in Clause 3, from each 250 tons or part thereof.

Not more than 250 tons shall be stored in such a manner that it cannot be separately identified and sampled in accordance with the provisions of this clause and Clause 3, and separated in bulk from the remainder. If more than 250 tons of cement is stored in a silo, provision shall be made by which each 250 tons, or any part of 250 tons in excess thereof, shall be isolated from the remainder and sampled at different points.

As there are silos in existence with capacities greater than 250 tons and which cannot be sub-divided without danger to the structure, sampling from such silos shall be permitted provided the Purchaser or his representative agrees and is satisfied that a proper and representative sample can be obtained of each 250 tons discharged into the silo. Such samples can be obtained either from suitable sampling holes in the walls of the silo or by automatic means at the point of discharge into the silo.

In the event of any such sample representing a 250-ton portion not complying with the requirements of this Specification, the Purchaser or his representative may refuse to accept any cement from the particular silo from which the sample was drawn.

It is, however, the intention of this Specification that wherever possible each 250 tons shall be isolated.

Facilities for Sampling and Identifying.

5. The vendor* shall afford every facility, and provide all labour and materials for taking and packing the samples for testing the cement and for subsequently identifying the cement sampled.

Cost of Tests, Analyses and Samples.

6. The tests and chemical analyses hereinafter mentioned, other than those referred to in Clause 15, shall (unless otherwise provided in the contract between the Vendor and the Purchaser) be made at the expense of the Purchaser, but no charge shall be made by the Vendor for the cement used for samples or for carriage thereon.

* The term " Vendor " throughout this Specification shall mean the seller of the Cement, whether he be the manufacturer of the cement or not.

TESTS.

7. The sample or samples shall be tested in the manner hereinafter mentioned for :—

(*a*) Fineness.

(*b*) Chemical composition.

(*c*) Tensile strength (cement and sand).

(*d*) Setting time.

(*e*) Soundness.

Test for Fineness.

8. The cement shall comply with the following conditions of fineness :—
100 grammes (or say 4 ozs.) of cement shall be continuously sifted for a period of 15 minutes on a sieve of British Standard Mesh No. 170 and the residue for a period of not less than 5 minutes on a sieve of British Standard Mesh No. 72 and in the order of succession given below with the following results :—

(1) The residue by weight on a sieve of British Standard Mesh. No. 170, shall not exceed 10 per cent.

(2) The residue by weight on a sieve of British Standard Mesh No. 72, shall not exceed 1 per cent.

Air-set lumps in the samples may be broken down with the fingers, but nothing shall be rubbed on the sieve.

The sieves shall be prepared from wire-cloth complying with the requirements of Table I of the British Standard Specification for Test Sieves (B. S. S. No. 410). The wire cloth shall be woven (not twilled) and carefully mounted on the frames without distortion. The sieving surface shall be not less than 50 square inches (322·58 cm. 2) and the depth of the sieves shall be not less than 2¾ inches (69·85 mm.) measured from the surface of the wire-cloth.

The nominal dimensions and tolerances for wire cloth for sieves for testing cements are given in the table below :—

TABLE XXI.

Dimensions of Standard Wire Cloth for Sieves for Testing Cement.

British Standard Mesh No. (Nominal meshes per lineal inch).	Nominal size of Aperture (side of square).		Nominal diameter of Wire.			Approximate. Screening Area.	Tolerance on Average Aperture *plus* or minus.
	in.	mm.	in.	mm.	Standard Wire Gauge.	per cent.	per cent.
170 ..	·0035	·089	·0025	·061	46	35	8
72 ..	·0083	·211	·0056	·142	38½	36	6

The maximum tolerances for occasional large apertures, if present, expressed as percentages of the nominal dimensions for side of aperture in either direction shall not exceed 50 per cent. for the sieve of B. S. Mesh No. 170, and 35 per cent. for the sieve of B. S. Mesh No. 72.

Test for Chemical Composition.

9. The cement shall comply with the following conditions as to its chemical composition. The proportion of lime, after deduction of the proportion necessary to combine with the sulphuric anhydride present, to silica and alumina when calculated (in chemical equivalents) by the formula $\frac{CaO}{SiO_2 + Al_2O_3}$ shall be not greater than 3·00 nor less than 2·0.* The percentage of insoluble residue shall not exceed 1·0 per cent., that of magnesia shall not exceed 4 per cent., and the total sulphur content calculated as sulphuric anhydride (SO_3) shall not exceed 2·75 per cent. The total loss on ignition shall not exceed 3 per cent.

* EXAMPLE.—In the case of a cement containing 63·28 per cent. of lime, 21·6 per cent. of silica, 8·16 per cent. of alumina and 2·00 per cent. of sulphuric anhydride, the proportion of lime, after deduction of the proportion necessary to combine with the sulphuric anhydride present, to silica and alumina would be as follows :—

Molecular weight of Lime	= 56
,, ,, Silica	= 60
,, ,, Alumina	=102
,, ,, Sulphuric Anhydride	= 80

Lime combining with 2·00 per cent. of Sulphuric Anhydride $= \frac{2·00 \times 56}{80} = 1·40$ per cent.

63·28—1·40 = 61·88 per cent. Lime.

Lime (CaO) $= \frac{61·88}{56} = 1·10$

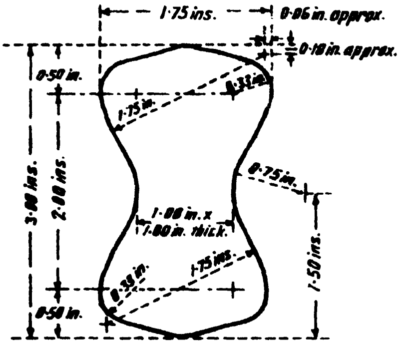
Silica (SiO2) $= \frac{21·6}{60} = 0·36$

Alumina (Al_2O_3) $= \frac{81·6}{102} = 0·8$

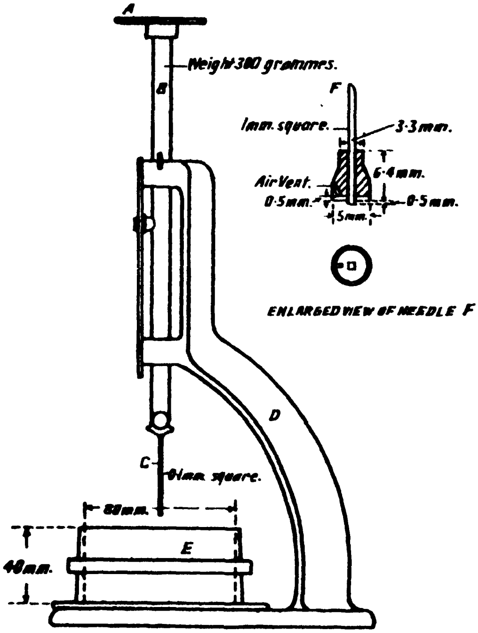
Then $\frac{CaO}{SiO_2 + Al_2O_3} = \frac{1·10}{0·36 + 0·08} = 2·50$

Plate II.

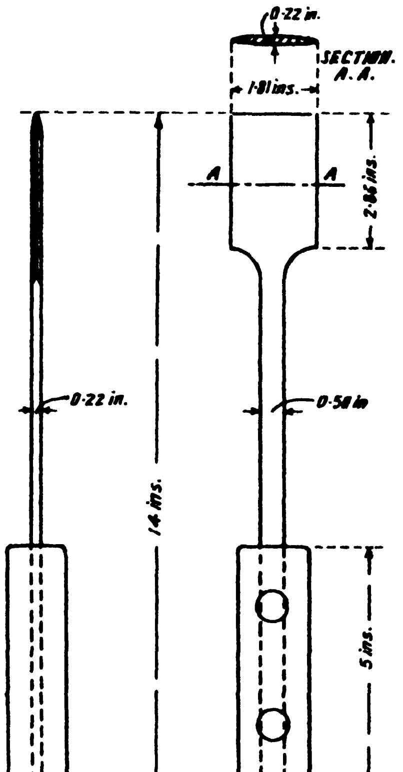
DIMENSIONS OF STANDARD BRIQUETTE.



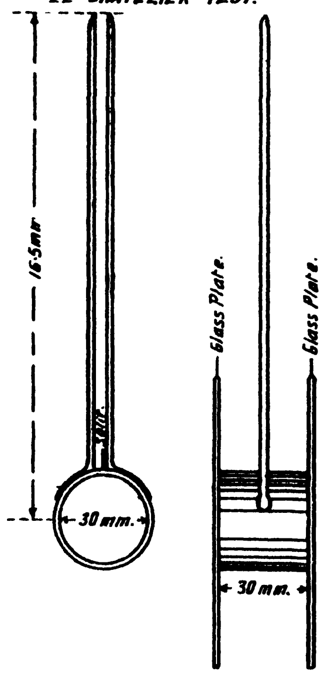
VICAT NEEDLE APPARATUS FOR ASCERTAINING SETTING TIME OF CEMENT.



STANDARD SPATULA.



APPARATUS FOR CONDUCTING THE "LE CHATELIER" TEST.



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Determination of Normal Consistency of Cement Paste.

10. Cement Paste of normal consistency shall be used in the tests for soundness and setting time, and also as a guide to the amount of water required for the gauging of cement and sand briquettes for the test for tensile strength as described in Clause II.

For the purpose of arriving at the normal consistency of cement paste the Vicat apparatus, shown on plate II, shall be used, the plunger (G), I cm. in diameter, being substituted for the needle there shown in position.

The quantity of water required to produce a paste of normal consistency shall be 0·78 of that required to give a paste which will permit of the settlement of the Vicat plunger to a point 5 to 7 mm. from the bottom of the Vicat mould when the cement paste is tested as hereafter described.

The time of gauging, that is the time elapsing from the moment of adding the water to the dry cement until commencing to fill the mould, shall be not less than three minutes nor more than five minutes. Where a quick setting cement has been specially specified or required, the time of gauging shall be not less than two minutes nor more than three minutes and the filling of the mould shall be completed within five minutes. In either case the gauging shall be completed before signs of setting occur.

The cement paste is filled into the Vicat mould (E), Plate 3, the mould resting upon a non-porous plate. The mould shall be completely filled and the surface of the paste shall then be smoothed off level with the top of the mould.

In filling the mould the operator's hands and the blade of the ordinary gauging trowel shall alone be used. The trowel shall weigh about 7½ oz. (213 g. approx.). The mould after being filled may be lightly shaken to the extent necessary for expelling the air.

Test for Tensile Strength (Cements and Sand).

11. The breaking strength of cement and sand shall be ascertained from briquettes also of the shape shown in Fig. 1, Plate II. The briquettes shall be prepared in the following manner :—

Preparation of Briquettes.—A mixture of cement and sand in the proportion of one part by weight of cement to three parts by weight of the standard sand shall gauged with water, the percentage of water to be used being determined by the following formula :—

$$1/4P + 2 \cdot 50.$$

where P is the percentage of water required for the preparation of neat cement briquettes as specified in Clause 10.

The mixture, gauged as above, shall be evenly distributed in moulds of the form required to produce briquettes of the shape shown in Fig. 1, Plate II, each mould resting upon a non-porous plate. After filling a mould, a small heap of the mixture shall be placed upon that in the mould and beaten down with the Standard spatula shown on Plate II until the mixture is level with the top of the mould. This last operation shall be repeated on the other side and the mixture patted down until water appears on the surface; the flat only of the Standard spatula is to be used, and no other instrument or apparatus is to be employed for this operation. The briquettes, shall then be finished off in the moulds by smoothing the surface with the blade of a trowel.

Clean appliances shall be used for gauging, and the temperature of the water and that of the test room at the time when the above operations are being performed shall be from 58 to 64 degrees Fahrenheit (14·4 to 17·8 degrees Centigrade) Subject to the provisions of Clause 17.

The briquettes shall be kept in atmosphere of at least 90 per cent. relative humidity for 24 hours after gauging, when they shall be removed from the moulds and immediately submerged in clean fresh water, and left there until taken out for breaking. The water in which they are submerged shall be renewed every seven days, and maintained at a temperature of between 58 and 64 degrees Fahrenheit (14·4 to 17·8 degrees Centigrade.) Subject to the provisions of Clause 17. After they have been so taken out and until they are broken, the briquettes shall not be allowed to become dry.

Breaking.—The briquettes shall be tested for breaking strenght at 3 days (72 hours) and 7 days respectively after gauging, six briquettes for each period. The breaking strength shall be the average tensile breaking strength of the six briquettes for each period. The briquettes to be tested shall be held in strong metal jaws of the standard shape *and the load steadily and uniformly applied, starting from zero, and increased at the rate of 100 lb. per square inch of section (7·03 kg. per $cm._2$) in 12 seconds.

The breaking strength of the briquettes at 7 days after gauging shall show an increase in the breaking strength at 3 days and shall be not less than 375 lb. per square inch (26·37 kg. per $cm._2$) of section.

Standard Sand.—The standard sand shall be obtained from Leighton Buzzard, shall be of the white variety and shall be thoroughly washed and dried. Its loss of weight on extraction with hot hydrochloric acid shall be not more than 0·25 per cent.†

The sand shall pass through a sieve of B. S. Mesh No. 18, and be retained on a sieve of B. S. Mesh No 25. The sieves shall be prepared from wire-cloth complying with the requirements of Table I of the British Standard Specification for Test Sieves (B. S. S. Mo. 410). The wire cloth shall be woven (not twilled) and carefully mounted on the frames without distortion.

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*In order to distribute the stress set up by the pressure of the jaws over as large a surface of the briquette as possible, it is recommended that rubber or greased paper be inserted between the sides of the briquette and the jaws of the machine.

†To carry out the test, dry the sand at 100° Centigrade for 1 hour, weigh out 2 grammes into a porcelain dish, add 20 c.c. of hydrochloric acid of specific gravity 1·1Q and 20 c. c. of distilled water. Heat on the water bath for one hour, filter, wash well with hot water, dry and ignite in a covered crucible.

The nominal dimensions and tolerances for wire cloths for sieves for preparing standard sand are given in the table below :—

TABLE XXII.

Dimensions of Standard Wire Cloths for Sieves for Preparing Standard Sand.

British Standard Mesh No. (Nominal meshes per lineal inch).	Nominal size of Aperture (side of square).		Nominal diameter of Wire.			Approximate Screening Area.	Tolerance on Average Aperture *plus.* or minus.
	in.	mm.	in.	mm.	Standard Wire Gauge.	per cent.	per cent.
25 ..	·0236	·599	·0164	·417	27	35	5
18 ..	·0336	·853	·022	·559	24	36	5

The maximum tolerances for occasional large apertures, if present, expressed as percentages of the nominal dimensions for side of aperture in either direction shall not exceed 20 per cent.

Tests for Setting Time.

12. *Vicat Needle Apparatus.*—The initial and final setting times of the cement shall be determined by means of the Vicat needle apparatus shown on plate II.

For the purpose of carrying out the tests, a test block shall be made as follows :—

Neat cement shall be gauged in the manner and under the conditions referred to in Clause 10, and the gauging shall be completed before signs of setting occur. The test block shall be made by filling the cement, gauged as above, into the Vicat mould shown at E, Plate II, the mould resting upon a non-porous plate. The mould shall be completely filled, and the surface of the paste shall then be smoothed off level with the top of the mould.

Clean appliances shall be used for gauging, and the temperature of the water and that of the test room at the time when operations are being performed shall be from 58 to 64 degrees Fahrenheit (14·4 to 17·8 degrees Centigrade), subject to the provisions of Clause 17.

The test block confined in the mould and resting on the plate shall be placed under the rod bearing the plunger, the latter shall then be lowered gently into contact with the surface of the test block and quickly released and allowed to sink into the same.

Trial pastes shall be made up of varying percentages of water until the amount necessary for determining the normal consistency as defined above is found. This amount of water used shall be recorded and expressed as a percentage by weight of the dry cement.

Determination of Initial Setting Time.—For the determination of the initial setting time the test block confined in the mould and resting on the plate shall be placed under the rod bearing the needle C ; the latter shall then be lowered gently into contact with the surface of the test block and quickly released, and allowed to sink into the same.* This process shall be repeated until the needle, when brought into contact with the test block and released as above described, does not pierce it completely. The period elapsing between the time when the water is added to the cement and the time at which the needle ceases to pierce the test block completely shall be the initial setting time above referred to.

Determination of Final Setting Time.—For the determination of the final setting time the needle (C) of the Vicat apparatus shall be replaced by the needle (F), shown separately on Plate II. The cement shall be considered as finally set when, upon applying the needle gently to the surface of the test block, the needle makes an impression thereon, while the attachment shown in the figure on Plate II fails to do so. In the event of a scum forming on the surface of the test block, the underside of the test block may be used for determining the final set.

Normal Setting Cement.—Unless a quick setting cement is particularly specified or required, the initial setting time of the cement shall be not less than 30 minutes and the final setting time not more than 10 hours.†

Quick Setting Cement.—If a quick setting cement is particularly specified or required, the initial setting time of the cement shall be not less than 5 minutes, and the final setting time not more than 30 minutes.

Test for Soundness.

13. The cement shall be tested for soundness by the " Le Chatelier " method. The apparatus for conducting the " Le Chatelier " test is shown on Plate II. The moulds shall be kept in good condition, having the jaws not more than 0·5 mm. (0·02 in.) apart.

In conducting the test the mould shall be placed upon a small piece of glass and filled with cement paste of normal consistency gauged in the manner and under the conditions referred to in Clause 10, care being taken to keep the edges of the mould gently together whilst this operation is being performed. The mould shall then be covered with another glass plate, upon which a small weight shall be placed, and the whole shall then be immediately submerged in water at temperature of 58 to 64 degrees Fahrenheit (14·4 to 17·8 degrees Centigrade) subject to the provisions of Clause 17, and left there for 24 hours.

The distance separating the indicator points shall then be measured, and the mould again submerged in water at the temperatures above mentioned, which shall be brought to boiling point in 25 to 30 minutes, and kept boiling for 6 hours. The mould shall then be removed from the water and allowed to cool and the distance between the points again measured; the difference between the two measurements represents the expansion of the cement, and shall not exceed 10 millimeters. In the event of the cement failing to comply with this test, a further test shall be made from another portion of the same sample after it shall have been aerated by being spread out to a depth of 3 inches (76·20 mm.) at the temperatures before mentioned for a total period of 7 days when the expansion determined as above shall not exceed 5 mm. (0·20 in)

* The Vicat apparatus may, if desired, be fitted with a mechanical attachment such as a " dash-pot ", so as to ensure the steady and gentle application of the point of the needle to the surface of the test block, and thereby render the test independent of the hand of the operator.

Care must be taken that the needle rests with its full weight upon the surface of the test block.

† Cement intended for use in tropical or other hot climates, when tested at any higher temperature up to 95 degrees Fahrenheit (35 degrees Centigrade), shall comply with these requirements. In other climates special arrangements between Vendor and Purchaser must be made unless the temperatures herein stated can be artificially obtained in the laboratory or other place where the tests are made.

Non-compliance with tests.—

14. Any cement which does not comply with the whole of the tests and analyses hereinbefore specified or which has not been stored in the manner provided in Clause 4, may be rejected as not complying with this specification.

Note.—The effect of higher Indian temperature on test results.—In India the temperature at which tests of cements can normally be carried out ranges between 80 and 90 F., an average of about 30 F., higher than those laid down by the British standards specifications.

The principal variations due to the higher temperature are in the setting time and the tensile strength. The setting and hardening of cement, involving as it does chemical action, is accelerated by heat. Hence the samples tested show a quicker set than would have been the case had the tests been made at 58° to 64° F. In the tensile strength the effect of heat is not necessarily to make the cement pass the specification easier. Increase of strength takes place more rapidly at first, and, therefore, although the results at 7 days will be higher, the strength at 28 days demanded by the specification will also be higher. For example, supposing a sample tested at 60° F., attained a strength of 600 lbs. at seven days and 700 lbs. 28 days margin over required increase 33 lbs.). If tested at 90° F., it might attain strengths of 637 lbs. and 705 lbs. respectively showing a margin of increase at 28 days of only 5 lbs. over that required by the specification, and the sample would appear to be of lower quality than it really is. The effect of higher temperature at the time of test is, it would appear, to favour the sample slightly in regard to sand-cement tests and to make the neat cement tests appear a little less favourable to the sample.

"It should also be noted that cement manufactured in India is manufactured and tested in these higher temperatures so as to conform at those temperatures with the requirements of the British Standard Specification and therefore, when using cement of Indian manufacture, the allowance mentioned need not be taken into account."

Copies of Vendor's Tests and Analyses, etc.

15. The Vendor shall, if required, furnish free of cost a copy of any document in his possession showing the result of any tests or analyses made for him, or for any other person, of any cement sold or offered for sale to the Purchaser or of the lot from which the cement so sold or offered for sale has been or is to be taken. The Vendor shall, if required at the time of purchase furnish, free of cost, a certificate that the cement so sold or offered for sale has been tested and analysed, and that such tests and analysis comply in al respects with this Specification. The furnishing of such copies of documents or the giving of such certificate shall not preclude the Purchaser from rejecting any cement which does not comply with this Specification.

Delivery.

16. Cement shall be delivered in bags, wooden casks or steel drums bearing the Manufacturer's name or recognised mark. A Purchaser desiring to have the cement delivered in bags, wooden casks or steel drums sealed or of any particular size must so specify at the time of ordering.

Unless otherwise agreed between the Purchaser and the Vendor the cement shall be packed in bags containing 112 lb. (50·8 kg.) net or in wooden casks or steel drums containing 375 lb. (170·1 kg.) net. These weights shall be legibly marked upon the packages and shall indicate the contents within reasonable limits of accuracy.

Cement in Hot Climates.

17. The temperatures specifically mentioned in Clauses 10, 11, 12 and 13 are applicable to temperate climates. For cement intended for use in hot climates the cement may be tested at any higher temperature up to 95 degrees Fahrenheit (35 degrees Centigrade) and shall comply with the requirements of this Specification.

18. The strength of gauged Portland cement increases with age up to a certain time: good cement never deteriorates, after it is put into the work.

The strength of cement decreases rapidly as the proportion of sand mixed with it increases.

19. The chemcial composition of a typical cement is as under:—

				Minm. Maxm.	
Soluble silica (SiO_2)	... 22·0	per cent.,	variation	12 and 37	per cent.
Insoluble silica	... 1·0				
Alumina (Al_2O_3)	... 7·5	,,	,,	5 and 10	,,
Ferric oxide (Fe_2O_3)	... 3·5	,,	,,	0 and 7	,,
Lime (CaO)	... 62·5	,,	,,	58 and 67	,,
Magnesia (MgO)	... 1·0	,,	,,	0 and 3	,,
Sulphuric anhydride (SO_3)	... 1·0	,,	,,	0 and 2·75	,,
Loss on ignition (CO_2)	... 0·5	,,			
(H_2O)	... 0·5	,,			
Alkalies and loss (K_2O) (Na_2O)	... 0·5	,,	,,	0 and ·2	,,
Total	100·0				

Strength increases with increase of lime from 58 to 67 per cent. Alumina makes it rapid setting. Iron gives it dark colour, and increases its liability to make clinker.

Optional Tensile Test on Neat Cement.—The following tensile test on neat cement is suggested where, because standard sand is not available, or for other reasons, the Purchaser wishes to use it. Failure to pass it shall not in itself involve rejection, but such failure indicates that the cement may not comply with the test requirements of this Specification, and that further investigation is desirable.

Cement paste of normal consistency shall be filled into moulds of the form required to produce briquettes of the shape shown in Fig. I, Plate I, each mould resting upon a non-porous plate. In filling the moulds the operator's hands and the blade of the ordinay gauging trowel shall alone be used. The trowel shall weigh about 7½ ozs. (213 g. approximately). No ramming or hammering in any form will be permitted, nor shall any instrument or apparatus other than the trowel before described be employed for this operation. The moulds after being filled may be shaken to the extent necessary for expelling the air.

Clean appliances shall be used for gauging, and the temperature of the water and that of the test room at the time when the above operations are being performed shall be from 58 to 64 degrees Fahrenheit (14·4 to 17·8 degrees Centigrade) subject to the provisions of Clause 17.

The subsequent treatment of the briquettes shall be as described for cement and sand briquettes.

Six briquettes shall be tested for breaking strength at 7 days after gauging in the manner described for cement and sand briquettes. The breaking strength shall be the average tensile breaking strength of the six briquettes and should be not less than 600 lb. per square inch of section (42·18 kg. per cm. 2).

NOTES ON THE USE OF PORTLAND CEMENT IN INDIA.

The cement manufactured in India is made by the same process, with similar machinery, and is equal in all respect to the best imported cements.

The number of brands of cement now being imported from abroad is legion. Many of them are of good quality, but a large number show important defects, and only well known and tested brands in original intact barrels, clearly marked with labels showing not only the brand name, but the place of origin and the name of the manufacturer, should be accepted.

The refilling of barrels with inferior cements or mixtures of lime and cement is very extensively resorted to, and great care should be exercised, if cement is purchased from bazar dealers, or any but the accredited agents of well known manufacturers.

All users should note the importance of watching the setting time of cement used, especially during the hot season. The effect of higher temperatures is greatly to accelerate the setting time. Moreover it sometimes happens that cement becomes quicker setting with age and storage. At the same time, it is to be noted that alteration in properties, if it takes place at all, does so much more slowly in the bag or barrel than in a sample of small bulk. It sometimes happens, therefore, that a small sample, which has been kept well, shows a quick set whilst the bulk is quite satisfactory in this respect.

It is very necessary that mortar or concrete is settled in place well within the time taken for initial setting to commence.

It should, therefore, be seen that the following precautions are taken :—

(1) That no time is lost between making the concrete and using it.

(2) That concrete that has "dried" is not rewetted and used in important work.

(3) That different mixes of concrete made at different times are used separately and not mixed together for use.

(4) Take a small quantity of concrete made at different times when mixed, and observe the time taken for initial setting to begin.

(5) That the materials should be so thoroughly mixed together on a concrete, wooden or paved area of water-tight platform that every particle of fine and coarse material is coated all over with a film of cement, the mixing being done either by hand when small quantities are used or by machine when large quantities are used. Mixing should be done for from ¾ths of a minute to 2 minutes, the latter period giving the strongest concrete.

(6) That neither too much nor too little water should be used in mixing. It is most important that the correct quantity should be used.

(7) That the concrete is properly cured and matured.

Note.—The continued chemical reaction upon which the increase in strength depends requires the presence of water and favourable temperatures. The term "curing" is used with reference to the continuing of these chemical reactions.

To test the initial setting time.—First of all careful observation should be made of the time taken on the work to mould the concrete or mortar, counting from the time of adding water, till the mass is lying undisturbed in place.

At regular intervals during the progress of the work a rough setting time test should be done in the following manner :—

To about 3½ parts by volume of the cement add one part by volume of water, the mixture being quickly trowelled, and also preferably kneaded with the hands, into a plastic mass. (A cigarette tin or other similar article is a convenient measure.) Should this amount of water prove insufficient to produce a plastic mass, this fact, in itself, suggests that the cement is quick setting; if, in addition, much heat is evolved the evidence is strengthened.

Fill the neat cement thus prepared into a tin, pressing it down with the thumb, and turn out the mould on to a non-porous plate or thoroughly wetted board.

If the mass is too soft, a further sample may be taken, and slightly less water (or more cement) used.

The commencement of setting cement can be roughly estimated by pressing the uncut end of a lead pencil into the mass; it will be found that the resistance to piercing rather suddenly increases when setting begins.

Note the time taken, counting from the addition of water to the dry powder. This is the initial setting time. It should not be less than 20 minutes, or less than the time taken to mould the actual work.

Aeration unnecessary.—The adverse effect of exposure or long storage on cement is insufficiently appreciated by many users. On the contrary there are many engineers who, when doing important work, spread the cement in shallow layers in the open to aerate it. This is an expensive, unnecessry and bad practice which deteriorates the modern cement. Modern rotary kiln cement does not, except in very rare instances, contain free lime and when used direct from the package is perfectly sound; aeration is, therefore, unnecessary.

Cement exposed to the atmosphere becomes hydrated and loses strength. Heat and humidity accelerate hydration. Special care is, therefore, necessary in India during the rainy season. It is better at all times to use cement as soon as possible after receipt and to avoid long storage, especially of cement stored in bags.

Cement stored in bulk or in airtight containers does not deteriorate; cement stored in covered barrels in a dry place retains its properties well, but special care is necessary in the case of cement packed in bags both because the surface exposed to air action is relatively high compared with the volume, and because the cloth readily absorbs moisture.

The Storage of Portland Cement.—The storage of Portland cement has never been free from difficulties, and as the cement of to-day is more finely ground than ever, the difficulties of storing without damage are increasing. Portland cement has a great avidity for water and will readily absorb moisture from the atmosphere, or from damp materials in contact with it. The absorption by cement of 1 per cent. or 2 per cent. of water has no appreciable effect, but further amounts of absorption, retard the hardening of the cement and reduce its strength. If the absorption exceeds 5 per cent., the cement is, for all ordinary purposes, ruined. The more finely a cement is ground the more active it is, and consequently the more rapidly does it absorb moisture from damp surroundings, so that, as previously mentioned, the finely ground modern cements are more susceptible to damage, than the cements of twenty years ago.

The best method of storage is that adopted by the cement manufacturers, viz., in bulk; and bins of loose cement 6 feet or more in depth can lie for longer than a year, with no more damage than the formation of a crust on the surface about 2 inch thick, which must be removed before the cement is taken for use. It need hardly be added, that the walls and floor of the cement bin must be damp-proof. Hence, if prolonged storage of cement is seen to be unavoidable, it is better to empty it from the sacks and stack it in as deep a heap as possible in a building of which the walls and floor are non-porous, the latter being preferably concrete, or of timber raised from the ground a foot or so with an air-space below.

When cement is stored in sacks, absorption takes place from the air through the sack on all sides which are not in contact with other sacks. It is then only a matter of time, before sufficient water is absorbed to injure the cement.

Indications of damage by storage are given by the cement becoming lumpy, and when this happens, the lumps should be screened out unless they are soft enough to be crumbled in the fingers.

When stored in sacks in a shed such as would be used by a contractor, the strength (as averaged at all ages) decreases as follows, the figures showing the percentage compressive strength (of a mixture of 1 part of cement to 5 parts of aggregate) as compared with the cement before storage.

Cement as received	... ...	100 per cent.
,, after 3 month's storage	... ...	80 ,, ,,
,, ,, 6 ,, ,,	... ...	72 ,, ,,
,, ,, 1 year's ,,	... ...	60 ,, ,,
,, ,, 2 years' ,,	... ...	46 ,, ,,

Thus the cement after two years' storage has less than half the strength of the original cement. Multiply paper sacks have been found quite suitable for transport and are strong enough for shipping in ocean liners, while as a means of protection from atmospheric moisture they are superior to jute sacks.

The following precautions should be taken if sacked cement has to be stored in sacks :—

(1) Reduce the time of storage as much as possible.

(2) Stack the sacks as closely as possible on a damp-proof floor or on timber raised a foot or so from the ground with air space below. There should be a similar air space between the stack and walls and roof of the building, which should have sound weather-proof walls and roof.

PORTLAND BLAST FURNACE CEMENT.

Specification No. 11.

1. This cement shall consist of a mixture of Portland cement clinker and granulated blast furnace slag. These two materials shall be mixed together in such proportions that in no case shall the proportion of slag exceed 65 per cent. of the total quantity. The mixture shall be ground together so that the two constituents shall be thoroughly and intimately mixed.

2. **Chemical composition.**—The percentage of insoluble residue shall not exceed 1·5 per cent.; that of magnesia shall not exceed 5 per cent. Sulphur present as and determined as sulphuric anhydride shall not exceed 2 per cent. and sulphur present as sulphide shall not exceed 1·2 per cent. sulphur, these being equivalent to a maximum total of 5·00 per cent. of sulphuric anhydride. The total loss on ignition shall not exceed 3 per cent.

3. The remaining specifications are the same as those given above for Portland cement.

Rapid-Hardening Portland Cement.—Rapid-Hardening Portland cement is a true Portland cement complying with the British Standard Specification, but made with such refinements in manufacture as to produce superlative quality. Not only is it notable for high early strength, but its ultimate strength is considerably greater than that of ordinary Portland cement. For this reason, when buying rapid-hardening Portland cement users should require that the strength at 7 days is at least 70 per cent. above the requirements of the British Standard Specification for ordinary Portland Cement.

In view of the additional strength of concrete containing rapid-hardening cement it can be stressed to a higher degree than ordinary concrete without reducing the factor of safety, and this advantage has been recognised in some specifications for concrete, including those of the Ministry of Transport, by increasing the permissible compressible strength of 1 : 2 : 4 : concrete to 750 lbs. per square inch.

Rapid-hardening Portland cement of good quality may be expected to possess a tensile strength of 400 lbs. per sq. inch at 24 hours, when mixed with three parts of standard sand, and 650 lbs. at 7 days. Laboratory concrete tests of the usual 1 : 2 : 4 mixture (clean and well-graded aggregate) give about 2,000 lbs. per sq. inch in compression test at 24 hours, and 5,000 lbs. at 7 days. These figures substantiate the claim that concrete made with rapid-hardening cement is as strong at two or three days as ordinary concrete at 28 days.

Aluminous Cement.—Aluminous cement is manufactured by melting a mixture of bauxite (a mineral composed largely of alumina) and lime. The fused material is ground to the usual cement fineness. Aluminous cement complies with the tests of the British Standard Specification for Portland cement, except that its proportion of lime is below the prescribed limit. This, of course, does not imply that aluminous cement is inferior, but merely that it is in a different category. A good aluminous cement may be expected to possess a tensile strength (3 parts sand to 1 part cement) of at least 450 lbs. per sq. in. at 24 hours, and a compressive strength of 5,000 lbs. at the same age. These figures show that an aluminous cement concrete only a day old, has the strength of a fully matured concrete made with ordinary cement. Piles made of aluminous cement have been successfully driven when only 24 hours old.

A valuable quality of aluminous cement is its comparative immunity from attack by frost during setting.

Aluminous cement is used in the same way as ordinary cement, but as contamination with Portland cement or lime is liable to cause flash setting it is necessary to employ mixers, barrows, shovels, and other accessories that have been carefully cleaned of any trace of ordinary cement or concrete; also, as soon as the cement is set usually within four to six hours the concrete should be kept moist for about 24 hours, in order that the water evaporated by the heating of the concrete may be replaced.

White Cement.—This cement is a true Portland cement, complying with the requirements of the British Standard Specification for ordinary Portland cement, and possessing the same properties. The only difference is in colour, which is pure white. On account of its colour it is finding increasing favour with architects as a rendering for concrete buildings, and also for structures built of other materials. It is also necessary to use white Portland cement for the lighter shades of coloured concretes and mortars.

A cream-coloured cement is also marketed, this is understood to be white cement ground with a small proportion of mineral pigment, and is acquiring popularity among architects seeking for variety of colour in surfaces.

Coloured Cements.—The introduction of colouring matters into concrete has been practised for some years. With the exercise of care, the results have been satisfactory, but it is not at all easy to obtain an even distribution of the colouring matter, and unless this is done the surface is liable to be streaky and irregular in shade. It is, however, now possible to purchase cements of several colours and shades, and with such cements the risk of irregularity of shade is removed, because the mixing is done by grinding and other machinery which ensures perfect results. For the more delicate shades, white Portland cement is used as the basis.

Strength of Ordinary Portland Cement Concrete at Various Ages.—Approximate percentage of strength of ordinary Portland cement concrete at different ages in comparison with the strength at 1 year :—

28 days old	... ...	60 per cent.
3 months	... ...	85 ,, ,,
6 ,,	... ...	95 ,, ,,
1 year	... ...	100 ,, ,,

Strength of Rapid-Hardening Portland Cement Concrete (Laboratory cubes).

Age 3 days	... ...	3,853 Lb. per square inch.
,, 7 ,,	... ...	5,360 ,, ,, ,, ,,
,, 28 ,,	... ...	6,810 ,, ,, ,, ,,
,, 12 months	... ...	7,490 ,, ,, ,, ,,

Strength of Aluminous Cement Concrete (Laboratory cubes).

Age 7 hours	... ...	3,700 Lb. per square inch.
,, 12 ,,	... ...	5,700 ,, ,, ,, ,,
,, 24 ,,	... ...	7,430 ,, ,, ,, ,,
,, 3 days	... ...	7,580 ,, ,, ,, ,,

Specification No. 12.

Fine aggregate (1).—shall consist of sand, stone screenings, or other inert material with similar characteristics, or a combination of these. The grains of particles should be clean, hard, strong and durable.

(2) The aggregate shall not contain, injurious amounts of dust, lumps, soft or flaky particles, shale, alkali, organic matter, loam or other deleterious substances.

(3) The size of grains shall be such that they will pass through a 1/4″ sieve.

Notes.—When the aggregate is to be used with cement as a binder, special care is necessary to have it in a clean state. If there is too much fine sand or stone dust, additional water is necessary for wetting it, and the concrete is weaker. It is therefore generally laid down, that on sifting the material through a sieve of 50 meshes to the inch, the matter passing through should not be more than 10 per cent. of fine and coarse aggregate combined.

Clay or loam adhering to the aggregate particles, prevents cement from coating them, and the mud mixing with the cement prevents the latter from setting and hardening. Organic matter is particularly objectionable, on account of its later decomposition. It is not inert material and changes in it, injure the matter or concrete.

Note.—Specifications for mortar and concrete generally lay stress on sharp sand, and cubical angular aggregate. The insistance on angularity, probably arose from rounded aggregate being usually mixed up with other deleterious matter, but with cement concrete precautions are generally taken to have clean aggregates. In this case, insistence on angular aggregates is unnecessary. In deep rounded aggregates pack much easier, and requires less water to work in. The concrete produced is therefore stronger than concrete with the same proportion of cement and angular aggregate.

Specification No. 13.

(1) *Coarse aggregate.*—shall consist of crushed stone, gravel, or other approved, inert material, or combinations of these.

(2) The pieces of aggregate shall be clean, hard, strong and durable.

(3) The aggregate shall not contain soft friable thin or elongated pieces, alkali, organic matter, or other deleterious substances.

(4) The aggregate shall contain such proportions of the various sizes, as have been specified.

Note.—When the aggregate is to be used with cement as a binder, special care is necessary to see that it is perfectly clean, because if there is a film of clay or loam on it, the cement will not come into intimate contact with it, and the strength of the concrete (depending on the adhesion between the stone and clay or loam) will be much decreased. The clay or loam will also hinder setting of cement and hardening.

SURKHI.

Specification No. 14.

1. *Surkhi* should always be made from fully but not necessarily over-burnt bricks, or from broken tiles and pottery, except when required for use in situations, where there is much salt in the soil, in which case it shall be made from overburnt bricks.

2. The bricks, tiles, or pottery shal be broken, and pounded or ground, to produce a powder passing through a screen with 64 meshes to the inch.

3. *Svrkhi* shall be free from admixture of any foreign matter, and shall be perfectly clean.

N.B.—Smiths' ashes and coal-dust are used to make the "black mortar" used for pointing slating and for some kinds of rubble masonry.

Note.—It was formerly a controversial point whether the best *surkhi* was obtained from under burnt, well burnt or overburnt bricks. A long series of experiments carried out at the Government Test House, Alipore, on lime *surkhi* morta's (*surkhi* being ground fine in a cast iron ball mill) proved that overburnt bricks are the best. The tests were on lime *surkhi* mortar in a 1 : 3 proportion, (by volume) and revealed that overburnt brick *surkhi* gave the best results as shown by the table below :—

Degree of burning.	Tensile strength in lbs. per square inch.			
	14 days.	28 days.	3 months.	6 months.
Under burnt	110	189	275	317
Well burnt	138	236	356	386
Over burnt	143	244	419	457

The *surkhi* in the experiments was ground so fine as to pass fully through a B. S. Sieve No. 30.

LIME MORTAR.

Specification No. 15.

1. *Ghani.*—For works costing over Rs. 10,000 the *ghanies* must be paved with solid stone or brick-on-edge paving. For those costing less than Rs. 10,000 a flat paving may be made of selected rubble or brick-on-edge set on concrete with lime mortar. In both cases the sides must be formed of *khandkies* or bricks set in mortar, and the sides must be maintained in good order.

2. *Proportion.*—Mortar must consist of such proportions of slaked lime and sand as may be specified for each particular class of work, usually 2 of sand to 1

of lime. The mortar shall be ground in a bullock mill, fitted with Beale's tell-tale. All lime mortars shall be such as set in 48 hours and not weaker than 1:3 for structural work.

3. *Preparation.*—The slaked lime is to be first placed in the mill trench in an even layer and ground for 180 revolutions with a sufficiency of water.

Thoroughly wetted sand is then to be added evenly and the mixture ground for another 180 revolutions. When two stones are used the number of revolutions for each stone must be 90 for each portion of the grinding.

The mortar must be stirred continuously during the process, particularly in the angles of the *ghani*. Water may be added during the grinding as required, care being taken not to add more water than will bring the mixed materials to be the consistency of a stiff paste.

4. All mortar shall be used as soon as possible after grinding. As a rule it should be used on the day on which it is made, but in no case should mortar made about 36 hours previously be permitted to be used or remain at the site of the work. For all cases the mortar must be kept damp, and must always be protected from the sun and rain. All mortar more than 36 hours old or damaged mortar, shall be removed and if it is not so removed by the contractor, a sufficient sum will be deducted from the contractor's bill, to cover the cost of removal by Government.

5. The Executive Engineer or his representative has the power to reject all mortar, which after a test with hydrochloric acid, is found to contain a larger percentage of sand, than that specified for any particular work.

6. If on testing the lime to be used with hydrochloric acid, a residue of more than 10 per cent. by weight is found, the Executive Engineer or his representative will order the removal of the whole of the lime from which the sample is taken, and if it is not removed within 24 hours it will be removed departmentally at the contractor's risk and cost.

Note.—(*a*) Fat lime mortars, unless improved by adding pozzuolana and similar substances, are so wanting in strength that any precautions in using them are but of little avail. Fat lime should therefore only be allowed for inferior or temporary work.

(*b*) For ordinary buildings not very much exposed slightly hydraulic limes will suffice to form a moderately strong joint and to withstand the weather.

(*c*) For masonry under water an eminently hydraulic lime, or cement mortar will be necessary.

(*d*) If the work be required to set very quickly Roman cement or a cement of that class would be used, whereas if quick setting be not necessary but great ultimate strength is required, Portland cement should be adopted.

(*e*) In using hydraulic limes and cements, it should be remembered that the presence of moisture favours the continuance of the formation of silicates, etc., commenced in the kiln, and that the setting action of mortars so composed is prematurely stopped, if they are allowed to dry too quickly.

(*f*) It is, therefore, of the utmost importance, especially in hot climates, that the bricks or stones to be imbedded in the mortar should be thoroughly soaked, so that they cannot absorb the moisture from the mortar; and also in order to remove the dust from their surface, which would otherwise prevent the mortar from adhering.

(*g*) Mortar should be used as stiff as it can be spread; the joints should always be well filled.

(*h*) *Grout* is a very thin liquid mortar sometimes poured overc ourses of masonry or concrete, etc., in order that it may penetrate into empty joints, left very often in consequence of bad workmanship. It may also be necessary in deep and narrow joints between large stones. It is deficient in strength, and should not be used where it can be avoided.

(*i*) Mortar for plastering must be ground a second time after an interval so as to ensure thorough slaking of the lime. The mortar should then be used at once.

(*j*) The crushing strength of mortar composed of 3 parts of sand to 2 of lime, ground in bullock mill, has been found to be 425 lbs. average per square inch or 27·33 tons per square foot after six months; 544 lbs. per square inch or 35 tons per square foot after 12 months; and 754 lbs. per square inch or 45·5 tons per square foot after 24 months.

PUMICE MORTAR.

Specification No. 16.

Shal' be made as described for lime mortar, except that it shall have Aden pumice mixed with it in the proportion of one or ha f part of ground pumice to one of lime, or such other proportion as the Executive Engineer may direc . The pumice shall be dried and ground in a flour mi l so fine that it will pass through a screen of 50 B.W.G., about 2,000 meshes to the square inch ; it is then to be added to the lime and ground and mixed. Pumice mortar must be used within 48 hours after it leaves the mill

CINDER MORTAR.

Specification No. 17.

As cinder (engine clinker) can often be obtained from railways, pumping installations, etc., at a very small cost, it can be used for preparing mortar. Only clean cinder should be used. The cinder will be ground fine in a mill and screened through a sieve containing at least 64 meshes to the square inch. Cinder mortar is usually composed of one part of s aked lime, one to one-and-half sand, and one to one-and-half crushed cinders. Sometimes no sand is used.

Note.—It is believed that a thin layer of cinder and coal tar well rammed under a tiled floor prevents the rise of "damp" and "kalar" or efflorescence.

Cinder obtained from brick-kilns should not be used, as it is not practicable to screen out the wood ashes.

CEMENT MORTAR.

General.—Owing to the standardized nature of cement, and the facility of obtaining it, cement mortar is now being used for a variety of purposes, for which lime mortar was previously used. It is extensively used in masonry work, in many places, e.g., Ratnagiri Division uses 1: 5 Cement Mortar for masonry, and in Gujrat Brick-work is laid in cement mortar, even as weak as 1 : 8. It has been found that even 1 : 8 cement mortar is stronger than 1 : 3 lime mortar by 50 per cent., and attains that strength earlier, provided the work is kept well-watered. For foundation concrete 1 : 4 cement mortar is very often used, and is stronger than the usual 1 : 2 lime mortar.

CEMENT MORTAR.

Specification No. 18.

(1) Cement mortar shall be prepared with good undamaged cement, clean fine aggregate, and good potable water.

(2) The proportions of cement and fine aggregate shall be as specified for the kind of wo k for which the mortar is to be used. Only sufficient water shall be used to enable the mixture to be worked up to the required consistency.

(3) The cement and fine aggregate will first be mixed dry in the specified proportions, till a homogeneous mixture is obtained, and the necessary water will then be gradually added through a fine rose. The mortar will then be worked up to the required consistency.

(4) Only sufficient mortar shall be prepared at a time, as can be used up within a period which is not more than that at which the initial set occurs in the cement.

(5) The work in which the mortar is used shall be kept well shaded and watered for at least 7 days.

CEMENT-LIME MORTAR.

General.—A portion of the cement in the mortar is replaced by hydrated lime in the case. It has been found, that if the hydrated lime replaces not more than 15 per cent. of the cement, the effect may even be slightly beneficial. The most pronounced effect of hydrated lime added to cement mortars and concretes, is the production of a more plastic better-working material. The cement-lime mortar spreads more easily under the trowel, and in concrete, the addition of hydrated lime in the mortar, tends to produce a material of greater uniformity.

Specification No. 19.

(1) The proportion of hydrated lime to the cement in the mortar, shall be as specified, but in no case the hydrated lime shall be more than 18 per cent. of the total cementing material.

(2) The hydrated lime powder and the cement will be mixed together dry, till a uniform tint prevails in the whole mixture.

The other items in the specification shall be as for cement mortar.

LIME-CEMENT MORTAR.

General.—This type of mortar is prepared, by replacing a certain proportion of the lime in the mix by cement. The idea is to make the mortar stronger and earlier setting, than would be the case with pure lime mortar, and more plastic and workable than weak cement mortars. For ordinary masonry work, 10 to 15 per cent. of the lime in the mortar is replaced by cement. For concrete in wet foundations, the cement may be 20 to 25 per cent. of the lime in the mortar, and for pointing 33½ per cent.

Specification No. 20.

(1) The proportion of the lime in the mortar, replaced by the cement, shall be as specified.

(2) The lime and sand will be ground into mortar as for lime mortar, and the cement will be added immediately before the mortar is to be used, in masonry or concrete.

(3) Watering shall be more carefully done where lime-cement mortar is used than with pure lime mortar, and special care must be taken for the first two days to see that the work is kept well-wetted.

SURKHI MORTAR.

Specification No. 21.

One part well burnt surkhi to 1 part of slaked lime (fat) and one part sharp clean sand, all measured in bulk dry.

To assist this mortar to set, add a little Portland cement.

NEERU.

Specification No. 22.

Neeru to be made of the best description of lime slaked with fresh water and sifted. The lime to be reduced to a fine powder by grinding it on a stone or in a handmill, with a thick solution of " mussala " to be made as may be desired by the Executive Engineer. The Neeru thus prepared to be kept moist until used and no more than can be consumed in 15 days to be prepared at a time.

TABLE XXIII.

STRENGTH OF LIME MORTARS.

Lime.	Proportion of lime to sand (trap).	Strength in tons per sq. foot after intervals of			
		One month.	Three months.	Nine months.	Twenty-seven months.
Deccan kunkar hydraulic lime ...	1 to 1	30	71	95	107
Do. ...	1 to 1½	28	66	103	104
Do. ...	1 to 2	28	64	92	118
Do. ...	1 to 2½	20	52	78	104
Do. ...	1 to 3	15	46	75	85
Shahabad stone fat lime and sand (trap).	1 lime to 2 sand.	18·8	48	83·2	
Shahabad stone fat lime and Bamburda brick surkhi and sand	2 : 1 : 6	20·6	59·2	...	
Shahabad stone fat lime and black soil surkhi and sand	2 : 1 : 6	19·6	48·5	94·4	

NOTE ON THE MANUFACTURE OF HYDRAULIC LIME IN THE NASIK, LAKE WHITING AND AHMEDNAGAR DISTRICTS.

I.—Kunkar.

Kunkar is obtained in two ways :—

(1) Collecting nodules lying on the surface of the ground.

(2) Quarrying or digging from the ground.

Kunkar which has any other colour than white, shews a bluish-grey, or brown fracture and is not too fine grained, and as far as possible free from glitter which denotes the presence of sand, is good. An easy test to decide whether the kunkar is fit for use, is to burn a piece and see if it slakes ; if so, it may be used with care subject to the further trials given below.

The outer colour of the kunkar depends upon the soil in which it is found, and is of no consequence. The presence of clay is perceptible to the taste and is detected also by smell after wetting.

The presence of sand can be best detected by breathing on a freshly broken fracture when the glitter of the sand shews out against the lime stone.

A comparatively easy test for ascertaining whether kunkar is hydraulic is the following :—

(1) To burn a small quantity of it.

(2) To select good pieces out of the burnt kunkar.

(3) To slake the pieces selected for five hours, and stir up the quick-lime so formed for three hours. Good sand in the proportion of 1 : 1 should then be mixed, and the mortar stirred for a further period of two hours.

(4) To make a briquette of the mortar 2 inches cube, leaving it damp in the mould for 24 hours. The briquette should be then removed from the mould, and immersed in wet sand kept damp for a further period of 24 hours.

(5) After the lapse of 48 hours as above, the briquette should be placed in water. If it keeps its shape, the lime is good and hydraulic ; if not, it is either overburnt or non-hydraulic ; if overburnt, pieces of clinker would be seen in the briquette.

After immersion in water for 10 days, the briquette should be capable of bearing a minimum crushing load of 50 to 70 lbs. per square inch, or 3·2 to 4·5 tons per square foot.

II.—Prospecting for kunkar.

Nodular kunkar.—Nodular kunkar is met with in all classes of soils either on the surface of fields or a few feet below ground in the low-lying portions of the catchments of nallas and rivulets. Surface kunkar however is not so hydraulic in quality as that found under the ground. Generally speaking, nodular kunkar is much superior to block or quarried kunkar, on account of its easier collection, additional hydraulic properties due to the larger percentage of clay, and its ability to withstand exposure to sun and rain without disintegrating.

Quarried or block kunkar.—This sort of kunkar is found on the banks of rivers and nallas and in the tributaries leading to them ; generally in fields possessing a light red brown soil and not in rich black soil ones. It is also found in the depressions at the foot of hillocks, *i.e.*, at heads of nallas, the variety found in such situations is better than that found in "shadu" or sandy soils. At the outset kunkar in the form of nodules is generally met with a few feet below ground surface mixed up with earth, and then lower down, in blocks 2 inches to 12 inches in thickness, alternating with sand or layers of silty soils. Generally no large deposits are found in black soil fields.

III.—Impurities found in kunkar.

On the banks of a nalla consisting of silty soil and "shadu", etc., the kunkar nodules or layers are generally free from muram and sand. They, however, contain veins of clay, or clay adhering to the surface (the former is common in surface kunkar). The presence of clay is not injurious, but adds to the hydraulicity, for it burns with the kunkar and turns into something like surkhi; on the other hand the presence of clay affects the slaking of the limes. In places where muram is met with below the layers of silty soil etc., the kunkar underneath the muramy layers, is found to have muram veins or muram adhering to it on the outside. Muram is also sometimes found in surface kunkar in minute pieces in the hollows. Sometimes a small piece of muram forms the core, round which the calcium deposits are laid. Generally the pieces of muram in the kunkar do not change their colour when the kunkar is burnt; in some cases however they turn reddish; they are of no consequence if found in minute quantities.

Sand is also sometimes present in kunkar as an impurity. If only a small quantity of sand is intimately mixed in the kunkar, it has not the glossy flintlike fracture, and is rough to the touch. If the quantity of sand be small, the kunkar is useful. Loose sand adhering to the outside of the nodules is very injurious as it vitrifies or runs to slag in the kiln.

IV.—Quarrying kunkar.

All the soft surface stuff and "shadu" etc., is removed from the quarry, and the hard layers or nodules of kunkar are dug out and spread on the ground to dry for about a week. They are then screened and broken to the required size. This breaking and drying, knocks and shakes off most of the impurities sticking to the kunkar. The kunkar is then carted to the site for burning.

V.—Preparing kunkar and fuel for burning.

Kunkar.—The kunkar should be hard, and in size generally not larger than what can pass through a ring of 2 inches diameter. It should be screened so as to remove all dust.

Engine Ash.—The ash should be screened well and all overburnt stuff to be picked out as far as possible; all dirt, sand, etc., to be removed.

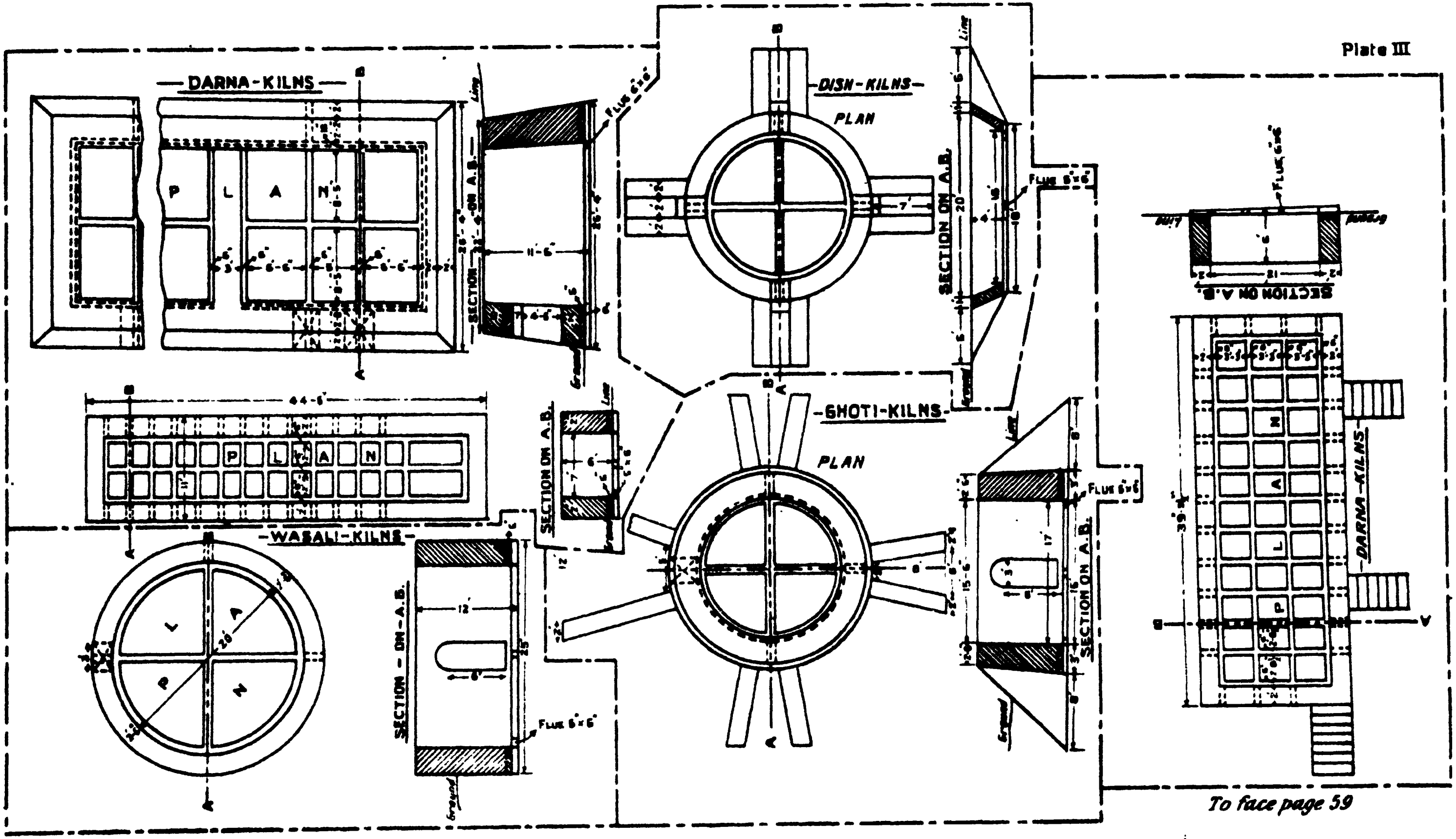
Coal.—All large lumps of coal, should be broken to the same size as that of kunkar. It should not be damp, nor and shou d be in the form of nuts. The coal should have a sh ning fracture. No dust should be allowed on any account.

Charcoal.—Charcoal shou d be free from any admixture of earth; any large lumps to be broken to he required size.

Wood.—Green wood not to be more than 3 feet in length and 1 foot in diameter.

LIME — KILNS.

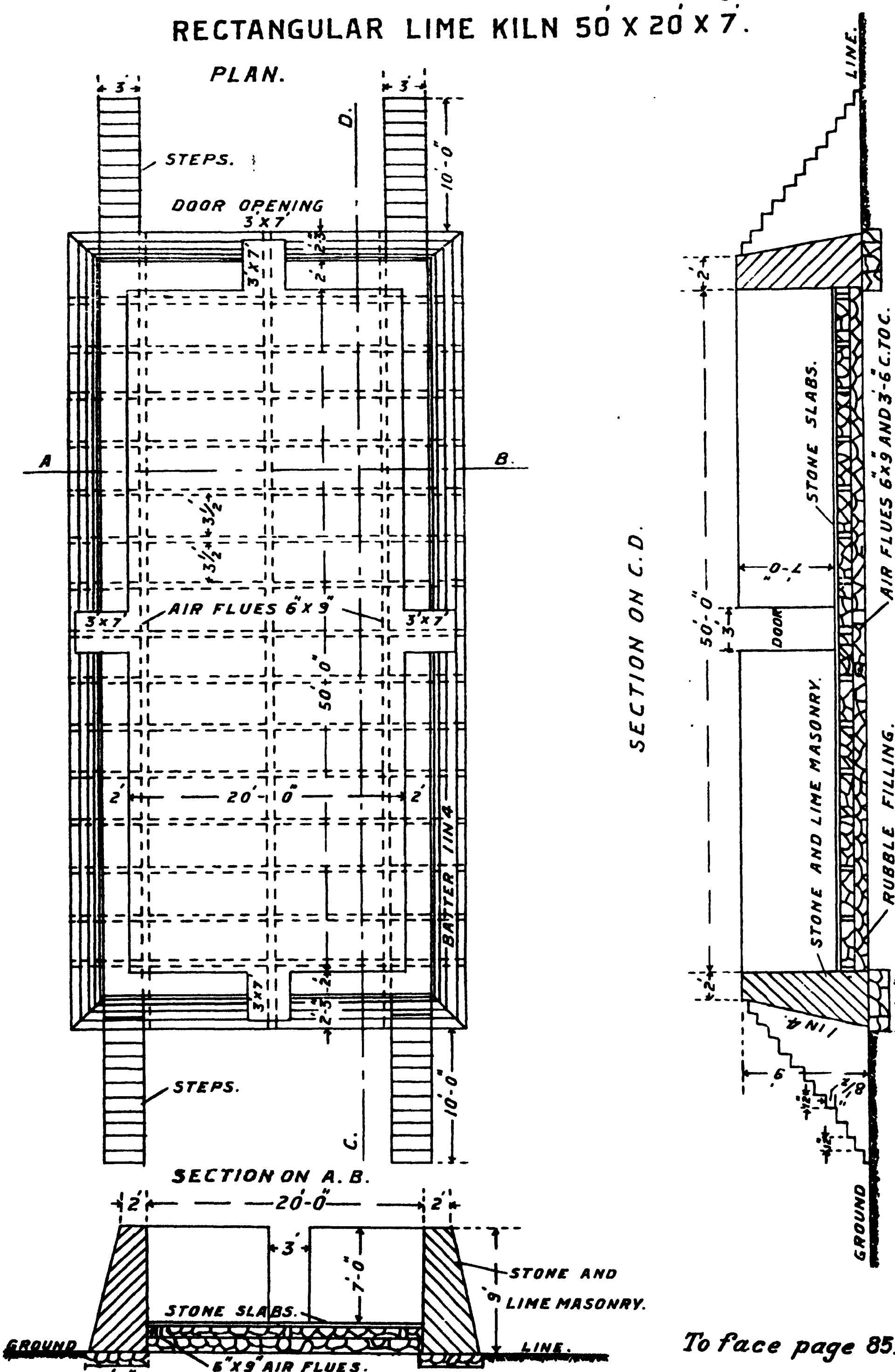
Plate III



To face page 59

G. P. & P. Poona, 1944

Plate IV.



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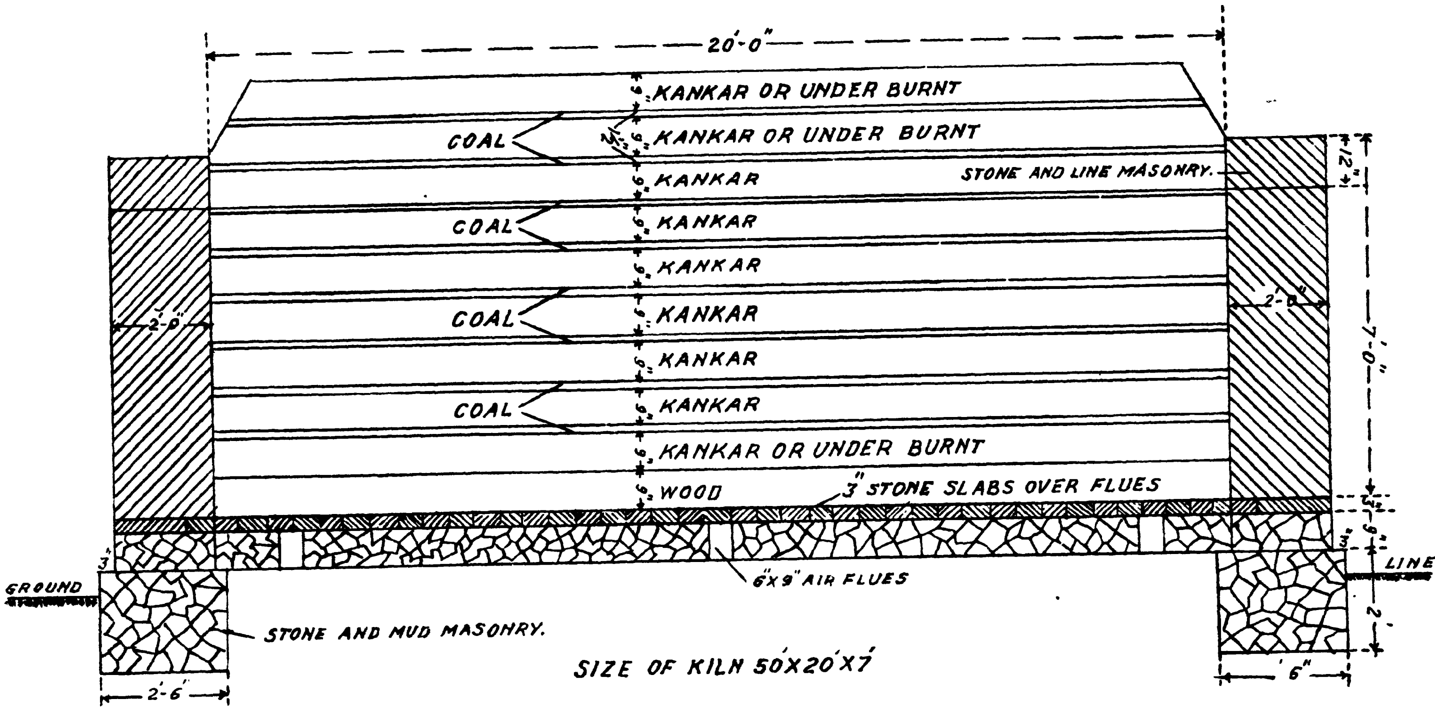
G. P. Z. P. Poona, 1918.

Plate V

SECTION THROUGH RECTANGULAR KILN.

SHOWING HOW IT IS FILLED.



SIZE OF KILN 50'X20'X7'

To face page 61.

G. P. Z. P Poona, 1946

VI.—Kilns.

Sites for kilns are selected generally on the banks of rivulets and na'las 'n which the water equired for slaking s available all the year round. As far as possible the site should also be close both to a railway station and the kunkar quarries, for facility of carriage of lime, coal, ashe , kunkar. The site should, however be away from human habitat ons. Kilns should be built partly in the ground and partly above as is convenient. The edge of a nalla or rivulet is a very convenient site for their construction. Kilns in such situations need not have any lining of stone and mud, if the sides of the excavation are hard enough to stand without upport. The bottom flues of the ki ns should be above the H. F. L. of the nalla. The ordinary diameter of kilns is 20 feet, with a depth of 12 feet, and hav ng wo doorways 6'×3' (arched over) facing the iver, where platforms for slaking the burn lime are usually made. In kilns of sm ller dimensions, proportionally more surfac area is exposed, wherefrom heat is lost by conduction, and these should therefore be avoided as far as possible. The doorways should not be slabbed over, as slabs crack owing to the excessive heat developed in the burning. Where necessary, the lining, of he kilns should be of quarried stone and mud masonry, (wherever the rainfall is moderate) about 3' wide, the inside fa e should have a batter on the inside, so that the charge as it sinks down, falls away from the sides, thus inducing a draught which allows the kiln to burn well at the sides. If the inner face of the kiln lining is made vertical, then, as the fuel in the kiln burns, the charge sinks down and jams against the sides preventing the kiln from burning well at the ides.

Arrangements for the uniform circulation of air and consequent uniform burning, are made by constructing central, crosswise, and circular horizontal flues, 6" × 9" preferably with dry quarried rubble.

Sometimes kilns shallow and rectangular or in the form of a dish, 3' to 6' deep, are constructed with similar arrangements of flues, etc., (see plate III).

In the Lake Whiting district, the s andard type of kiln for bu ning lime on a large scale, is an oblong overground one 50' × 20' × 7' in size. The length of the kiln is in the direction of the prevailing wind, as it is found by experience, that such kilns burn and cool more quickly and yield better outturn. Previous y circular underground kilns were used. The flues of these kilns being very deep below the surface cannot get a sufficient draft of air, and consequently they burn very slowly and unevenly, and yield a comparatively low outturn. They required about 30 to 40 days to burn and cool, while the oblong kilns require on 15 to 20. The outturn of the oblong kilns is also 25 per cent. more, than that of the circular underground type. Experience in this district shows, that the oblong overground type is the best cheapest and most convenient, for burning lime on a large scale.

VII.—Slaking platforms.

Where lime burning operations are to be continued for a number of years, it is advisable to have level concrete platforms large enough to accommodate the quick lime taken out of the kiln, in a 6 inches layer, with additional space for screening lime and stacking underburnt kunkar, etc.

VIII.—Procedure of filling kilns.

A. Filling kilns in layers.—The first and most essential item before filling a kiln, is to get all flues cleared of debris and covered in such a way, as to allow uniform circulation of air. All the space between the lines of flues should be filled in level with quarried rubble.

If there are cracks in the walls of the kilns, they should be repaired.

A layer of wood 12 inches thick or some light fuel such as cowdung cakes, etc., should be laid over the bottom well packed with chips of wood and large lumps of kunkar, and covered over with a thin layer of ash or coal as convenient. Kunkar and engine ash should be screened separately, and then lightly laid in the kiln in layers.

On the average the proportions of fuel for 100 cubic feet of kunkar are as follows :—

(1) 50 to 60 c. ft. of ash or charcoal.
or
(2) 25 to 30 c. ft. of coal,
or
(3) 12·5 to 15 c. ft. of coal and 25 to 30 c. ft. of ash.
or
(4) 50 to 60 maunds of green firewood.

About 6 maunds of wood for 100 c. ft., are required in every case for the bottom layer.

The above proportions vary according to the kind of kunkar used, the state of the weather, type of kiln, and the dryness of the materials.

8 inches to 9 inches layers of kunkar, varying in thickness (according as coal, ash, or charcoal are used) are to be laid lightly not thrown down, alternately over the bottom layer of wood. This filling should be continued to within two feet of the top of walls, leaving five vertical flues about 9 inches in diameter, one in the centre, and four round the sides.

The vertical flues should be located over the cross flues so as to get a continuous draught. These flues are sometimes built up with selected long pieces of kunkar as the filling of the kiln progresses; sometimes, chips of wood or cowdung cakes are used instead, but these get burnt before the kiln is well kindled, causing the sides to tumble in and choke the flues.

To prevent under-burning at the sides, a ring of about 3 inches of ash is laid along the inside lining of the kiln, for the whole height of the kiln, as the work of filling goes on. This ring should on no account be thicker than 3 inches, as it damages the stone lining of the kiln.

The kiln should be ignited with pieces of wood, cowdung cakes, etc., immersed in kerosene oil, some oil being also poured down the flues. When the firewood at the bottom is well kindled, the vertical flues should be slabbed over with quarried stone slabs. In cases when lime is urgently required, the kiln may be ignited when half full, to save time.

Instead of putting on slabs over the vertical flues at the centre and along the sides, they are sometimes filled in with ash and large pieces of kunkar, and plugged with a log of wood projecting upwards, to facilitate the passage of air up to the top of the conical portion.

Only light fuel is to be used around the vertical flues, as there is a likelihood of the kunkar in its vicinity being overburnt. It is also advisable that the layer of kunkar, should be thicker near the flues than at the sides; it should consist of big lumps of kunkar, specially selected for that purpose. After the vertical flues are closed, the remaining portion of the kiln up to the top of the walls, and the conical layers over it, are to be similarly filled in. If there is any underburnt kunkar available, it may be laid in layers after the flues are slabbed over; but as it requires less heat, it is better to lay it just above the bottom layer of wood. The covering to the conical portion (or if required the whole of the conical portion), should be without any fuel and should be of underburnt kunkar only, to prevent loss of heat.

When the burning reaches the top of the kiln, the doors of the kiln already closed with dry rubble, should be plastered with mud. The flues at the bottom of the kiln, which are left open till then, should also be closed or regulated, according to the draught required while the kiln is burning.

During strong winds, the bottom flues and the doors of the kiln have to be closed very carefully with mud; and any cracks in the mud plaster should be repaired at once. Unless this is done, the strong draught makes the fire in the kiln burn furiously, and overburns the charge of kunkar. For this reason kilns which are in a sheltered position are more satisfactory. Underburnt kunkar in the form of a cone, should continue to be laid over the top of the kiln as the charge sinks down while burning. This occurs to a considerable extent when charcoal or wood is used as fuel. A kiln having a capacity of 1,000 to 4,000 cubic feet, requires 15 to 30 days to cool sufficiently before it can be emptied. A practical test to see whether a kiln is well burnt or not, is to insert an iron rod or thin stick from the top and if it passes down easily, the kiln is well burnt and ready for unloading.

B. Filling kilns with a mixture of fuel and kunkar.—The kunkar should be screened and restacked, the ash after being screened, should be stacked over the clean kunkar heap, with the required amount of coal, if used; the whole should then be mixed with a phaora. The mixture should then be finally screened, and laid in the kiln in 9 inches layers; all other operations being similar to those described under "Filling kilns in layers."

IX.—Slaking operations.

Quicklime should not be slaked a long time before use as it deteriorates. Mortar made of freshly slaked lime is stronger.

When the kiln is ready for emptying, the doors should be opened, out, and the quicklime spread over a clean platform in a 6-inch layer for slaking. It should be wetted with the necessary amount of sweet water, and allowed to stand for about 6 to 12 hours. The slaked lime should then be worked up with a phaora (more water being added if necessary), and kept in closely packed heaps or rows. Later on it should be screened for the first time as required. The residue from the first screen should be screened again after a couple of days, on screens with smaller meshes. Expanded metal screens with ⅜ inch meshes are used for the first screening of the slaked lime; those with ¼ inch meshes are used for the second screening of the slaked lime. Sometimes the residue is screened a third time, before it is used for reburning. This screening removes any lime still remaining in the residue, and prevents the kiln in which the residue is reburnt, from choking.

Any useful underburnt kunkar should be burnt again, together with the new kunkar, but the vitrified clinker must be thrown away. No useful underburnt stuff should ever be wasted. As far as possible the operation of screening slaked lime should not be done after 15th April, as much good lime is blown away and wasted, owing to the strong winds prevailing then.

X.—General information.

(1) Very-hard block kunkar, lying on the topmost layer of heaps, when exposed to sun and rain for a season, is found to disintegrate. In fact all the materials, kunkar, coal, ash, charcoal, etc., deteriorate, more or less, if not used within a year from the time of collection. Earth, 'shadu', and other dust varying from 15 to 20 per cent., is present even on freshly supplied lime kunkar, and the careful screening of all the materials to be put into the kilns is required, to prevent the kilns choking which results in a considerable waste of fuel. Kunkar of ordinary size should not be mixed with pearl kunkar (small pieces of ¼ inch diameter).

(2) The size of the materials used in the kiln must be as uniform as possible to secure good burning.

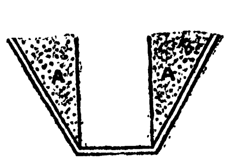
(3) Sometimes, kunkar nodules, owing to the dark colour of the fracture, appear to be like stone metal; but on burning a specimen, they are found to contain good hydraulic lime. Such nodules require more fuel, but yield a good outturn.

(4) Surface kunkar is found on the banks of rivers in light brown soil fields, and in the "Man and Chopan" soils on the Nira Left Bank Canal, from its headworks at Vir down to the 12th mile of the canal, near the Nira station of the Madras and Southern Maratha Railway. This class of kunkar is said to be very hydraulic. The quicklime obtained from such kunkar nodules slakes very slowly and imperfectly, with very little generation of heat, disintegration, or increase of the bulk. Some of the nodules contain a large proportion of earth, and when these are well burnt they slake very imperfectly and only turn soft. If wetted continuously afterwards, they go on hardening instead of slaking. If ground, when in soft condition, the resulting mortar is of a darkish brown colour, and begins to set very soon. Mortar made from such lime should be used within 24 hours of mixing. With this class of kunkar it is very difficult to distinguish burnt from underburnt pieces.

(5) Kunkar burnt with coal alone, is better than that burnt with ash, as the kiln fires more quickly and thoroughly; moreover the quantity of coal required to burn a given quantity of kunkar, is half that required with ash, and naturally the kiln accommodates more kunkar, and the result is a greater outturn; also the underburnt stuff remaining over from such kilns, is free from the admixture of clinker always found when ash is used. Coal containing an abnormal quantity of dust should be rejected altogether. A kiln loaded with such coal has been a complete failure.

(6) The loss on account of dirt, etc., in the fresh engine ash purchased from the Great Indian Peninsula Railway Company amounts to about 25 per cent.

(7) Dish kilns are only useful for burning small quantities of kunkar where time is short, but are of no use for burning large quantities of kunkar. A large proportion of the contents of these kilns is exposed to the open air, and during strong winds the fuel is consumed rapidly without burning a commensurate quantity of kunkar, owing to which the outturn is less. In any case, the kunkar and fuel at the sides of the kiln marked A, do not burn well owing to there being no draught.



(8) The outturn from kilns when the masonry is green, or from those filled with wet materials, is always unsatisfactory.

(9) It is preferable to fill kilns with alternate layers of kunkar and fuel, as makes it easy to check the amount and proportion of the materials while the kiln is being loaded.

(10) In using a mixture of fuel and kunkar for filling kilns, it is necessary that all the materials used must be of uniform size and well mixed.

(11) In large kilns when the contents are required quickly, one more layer of green wood, 12″ thick, should be laid at about half the height of the kiln, particularly in the month of November, when the kunkar is not properly dry and most of the other materials damp. When burning lime after the monsoon, it is advisable to place a layer of stones, 12″ thick, to drain off the water at the bottom of the kiln and to put the bottom layer of wood over it, and then kunkar, etc. This first layer of kunkar is however, generally found to be underburnt.

(12) As the heat in the kiln while it is burning is more intense at the top it is necessary to reduce the proportion of fuel in the uppermost layers gradually, or the height of the layers of kunkar should be increased as the filling reaches the top.

(13) If underburnt coal and other fuel, ash, etc., are found mixed with the kunkar while emptying the kiln, it indicates a want of draught, probably caused by some obstruction such as vitrified kunkar, etc., in the flues. The presence of vitrified kunkar itself, points to an unequal distribution of fuel and probably defective draught.

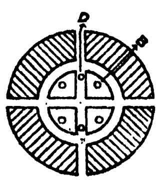
Increase in the number of flues at the bottom of kilns admits more draught and leads to quick burning and cooling of a kiln.

(14) One of the largest kilns, 27′ (diameter)×14′, with a capacity of 9,600 c. ft. (including the conical portion), burnt satisfactorily, giving an outturn of 10,900 c. ft. of lime.

(15) After the vertical flues are closed with slabs, the layer of kunkar directly over its top, should contain no fuel for some distance around it, even when the kiln is being filled in layers of kunkar and fuel.

(16) Sometimes for firing the kiln, charcoal or coal is kindled outside it, and allowed to burn for half an hour until red hot and is then thrown down the vertical flues. At first, until the wood forming the bottom layer gets well alight, there is much smoke ; when the smoke stops altogether, more coal is thrown down the flues, and after half an hour they are slabbed over, and the layers of kunkar laid over them.

(17) When the vertical flues are located over the cross horizontal flues, as shown in sketch at D, there is a through passage for the air which enables the kiln to both fire and cool more quickly. Such however is not the case when the vertical clues are placed between the cross clues as at B.



(18) If a kiln is filled in very soon after it has been emplied, the fuel may be kindled by the heat of the sides. Similarly, if there are two kilns side by side, one being burnt and the other loaded, the fuel in the latter may be ignited by the heat of the former.

(19) It is almost impossible to burn the contents of a kiln quite uniformly; generally, portions at the top and bottom of a kiln, are slightly over or underburnt. Slightly overburnt kunkar (not vitrified) slakes thoroughly within a day or two after its removal from the kiln, if covered over with well burnt quicklime and wetted. The colour of the lime is grey, and mortar made with it usually stands a good pressure under test. If proper care is taken in regulating the draught, there should be very little overburnt kunkar and the little there is, can be easily picked out, slaked, and well screened.

Overburnt kunkar slakes after a considerable time and should not be used until thoroughly slaked.

(20) The quantity of water required for slaking, is in general from 25 to 40 per cent. by volume of quicklime obtained from quarried kunkar, and from 40 to 60 per cent. for surface kunkar. The lime made from the latter increases in bulk on slaking and diminishes in weight.

(21) There is a loss of lime in transit (40 miles by railway on an average and 21 miles by country carts, including evaporation, loading and unloading, etc.) of 10 per cent. roughly by weight. The lime also gets more compact in transit, 6 c.ft measuring 4 c.ft.

(22) A bag (measuring 44″ × 26″) used for conveying lime by rail and road, last for 5 or 6 trips; when well packed it contains about 5 c.ft., so that for every 27·5 c.ft. of lime one bag is totally used up, or 4 bags for every 100 c. ft. nearly.

(23) About 150 bags full of lime make up a 16-ton waggon load.

(24) The lime produced from nodules of kunkar containing veins of earth or clay inside, or clay adhering to the outside, when well burnt, is not so reddish as that obtained from similar nodules partially burnt or rather underburnt. In the latter case, burnt earth or surki of red colour preponderates and hence the reddish colour. This lime weighs more than white lime, owing to the presence of burnt earth of a higher specific gravity. Lime taken out from the 2nd or 3rd burning of underburnt kunkar, is much whiter than that obtained from the first burning of new kunkar, as the underburnt stuff is then quite free or almost so of clay, etc.

(25) Lime is screened twice as mentioned under "IX Slaking operations". A bag containing 5 c.ft. of lime obtained by screening the residue from the first screening, weighs more than that containing lime from the first screening, as the former contains much granular stuff (small light lumps of burnt lime), while the latter is mostly in a powdered state. The weight of green slaked lime is reduced by 7 per cent., within two months on account of the lime getting dry.

(26) **Average weights of materials—**

Name of material.			C.ft.	Weight in maunds (Bengal).
Kunkar of usual size	...	...	1	1 (nearly).
Firewood, green	...	...	50	20 (roughly).
Ashes	...	...	2	1
,, Charcoal	...	...	4	1

Name of material.	C.ft.	Weight in maunds (Bengal).
Coal	1·5	1
Coal	30 to 40	1 ton=27¼ maunds.
Lime	1	50 to 55 lbs. The weight varies according to the dryness and fineness of the stuff.
New empty bag		1½ seer.

(27) Four khandies of green babul wood yield one khandie of charcoal.

(28) It is injurious to the health of persons to remain long by the side of a burning kiln, for they swoon by inhaling Co_2 gas ; they recover quickly in the open air.

(29) When the rainfall is moderate and the kilns are well drained, lime in excess of the requirements of one working season can be stored in kilns, by covering the conical portion with overburnt stuff and "chopan" earth. The kilns can be emptied after the monsoon and the lime slaked then.

The outturn of lime from such kilns, is more in comparison with that from kilns unloaded in the working season, before they are sufficiently cool. At times quicklime stored in such kilns is found to be still hot, and slakes with the same intensity as if taken out from a freshly burnt kiln.

(30) Generally a good bullock cart can carry the following load on ordinary metalled roads, on task work:—

15 maunds firewood in logs.
20 c.ft. coal.
25 c.ft. ashes.
35 c.ft. charcoal in bags.
15 to 20 c.ft. lime kunkar.
20 to 25 c.ft. lime in bags.
3 Nos. cement casks.

A JOINT NOTE BY THE EXECUTIVE ENGINEERS, RIGHT AND LEFT WORKS DIVISIONS, ON THE MANUFACTURE OF ARTIFICIAL HYDRAULIC LIME AT SUKKUR FOR THE LLOYD BARRAGE.

The limestone available is partically pure calcium carbonate, the impurities—iron, alumina, magnesia and silica only amounting to 1·45 per cent.

This is burnt in continuous kilns with alternate layers of Bengal Slack Coal of which 25-30 cft. is required to burn 100 cft. of selected limestone of a size varying from 2″ to 5″ ; the amount of coal varies with the strata from which the stone is obtained, some strata being much harder than others. The coal which is found to be the best for burning fat lime is the ruble coal from the Bengal Mines which usually comes in pieces not bigger than 2″ and does not contain much dirt which tends to choke the kilns. Any pieces bigger than 2″ are broken to that size. When lime has to be manufactured on an extensive scale, the kilms can be built adjoining each other in order to reduce loss of heat by radiation. To supplement these kilns at rush times ordinary country kilns are also used which require about 36 maunds of firewood per 100 cft. of stone ; these give a very uniform and good fat lime.

In either case 100 cft. of stone yields about 85 cft. of unslaked lime which on slaking gives 117 cft. of screened lime from the continuous kilns or 140 cft. from the counrty kilns, the larger output in the latter case being due to more thorough burning.

To render this lime hydraulic as soon as it has been slaked and screened it is ground wet for 20 minutes in power driven mills with 25 per cent. of its volume of clay. This has the following analysis :—

Loss on ignition	8·60 per cent.
Silica	58·94 per cent.
Oxide of iron	3·52 per cent.
Alumina	16·48 per cent.
Lime	7·67 per cent.
Magnesia	3·57 per cent.
Alkalies and loss	1·22 per cent.

The resulting slurry which is of the consistency of thick cream is then run out on to drying grounds and allowed to stiffen in the sun until it can be cut into lumps of 4″ to 6″ in size by means of spades. These lumps are then spread out and when completely dry are ready for final calcination.

This is carried out in large intermittent kilns or in ordinary country kilns. In the former case 10-12 per cent. of Bengal Coal is used in alternate layers, with the addition of 30 cft. of firewood per 100 cft. of dried slurry for initial ignition. The country kilns consume 150 cft. of firewood for every 100 cft. of dried slurry. In either case 133 cft. of dried slurry yield 100 cft. hydraulic lime. The hydraulic lime on removal from the kilns consists of lumps and powder and is placed without breaking or screening in bins until required. In about 7 days it will have slaked to powder or, if left in the open, only 3 days will be required.

The continuous kilns for fat lime burning are shown in the sketch on Plate V-A. The stone is put in in 12″ layers alternating with about 3″ or 3½″ of coal as required. Each kiln gives a daily output of ¼ to ⅕ of its total capacity.

Intermittent kilns for burning hydraulic lime.—These are shown in the sketches on Plate V-B. The cakes are loaded in 12″ to 15″ layers with the required thickness of coal in between. Each kiln holds 1,200 c. ft. of cakes and can be loaded, burned and unloaded in 3 days in the cold weather or 6 days in the hot giving a daily output of 300 c.ft. or 150 cft. of finished lime per day.

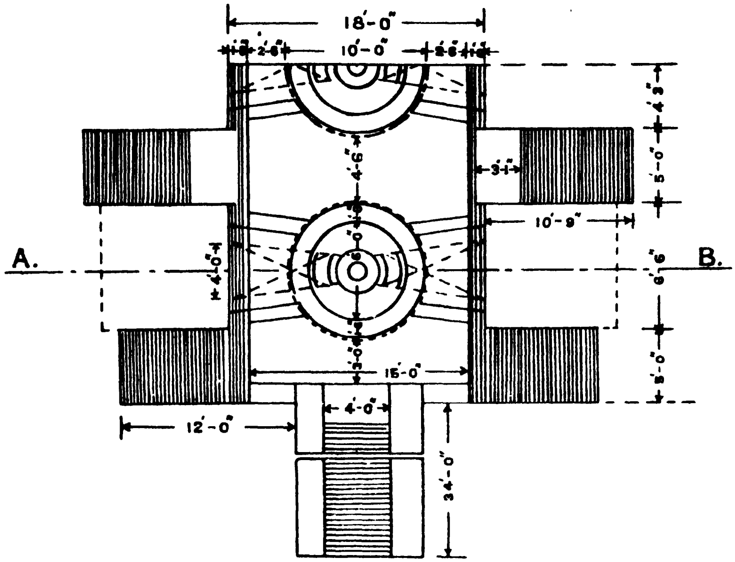
Country kilns for burning fat and hydraulic lime.—These are shown in the sketches on Plate V-C. The limestone or hydraulic lime cakes which are loaded as shown in the sketch (see Plate V-C) are covered by dry bricks before burning. Big pieces of stone are used to form a dome over the furnace and support the small lime-burning stone or hydraulic lime cakes. It takes one day to load, burn and unload one kiln. For fat lime burning they are made 150 c. ft. capacity and for hydraulic lime of 100 c. ft. capacity. As in these kilns the fuel does not come directly in contact with the stone or cakes, the resulting out-turn is free from impurities due to ashes, etc.

ANALYSIS OF COST OF MANUFACTURE.

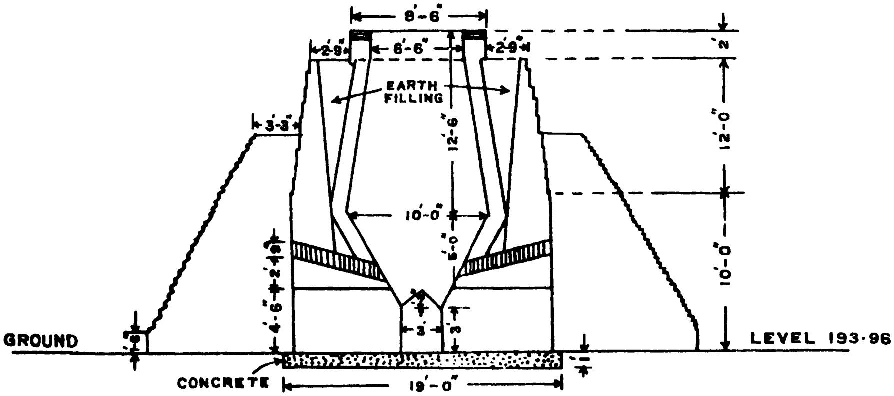
	Rs.	a.	p.
1st Process—			
Limestone at site of kilns 100 c. ft. at 9/-	9	0	0
Coal do. 25-36 ton at 23/-	16	0	0
Labour. Loading limestone and coal into kilns, sorting and stacking unslaked lime on measures, average load 100 c. ft.	4	8	0
Slaking and screening through ⅛″ mesh	2	8	0
Total cost of 117 c. ft. slaked lime	=32	0	0

FAT LIME KILN

CONTINUOUS ACTION KILN—TAJEWALLA TYPE WHOLLY ABOVE GROUND



PLAN



SECTION ON A-B.

NOTE—

1. QUANTITY OF STONE BURNT..........12000 CFT.
2. CAPACITY OF KILN.....................650 "
3. DAILY INPUT..............................150 "
4. " OUTPUT WITH COAL FUEL...90% OF INPUT.

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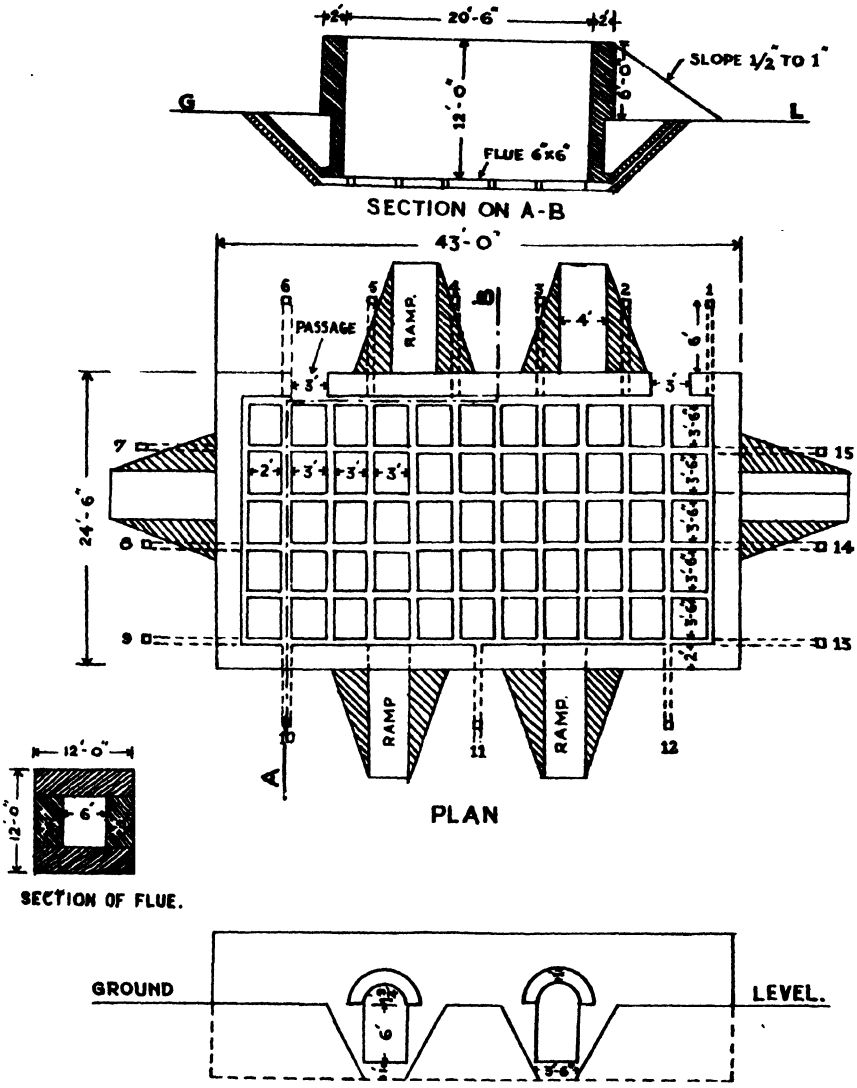
G. P. E. P. Poona, 1946.

PLATE V-B

LIME KILN

INTERMITTENT



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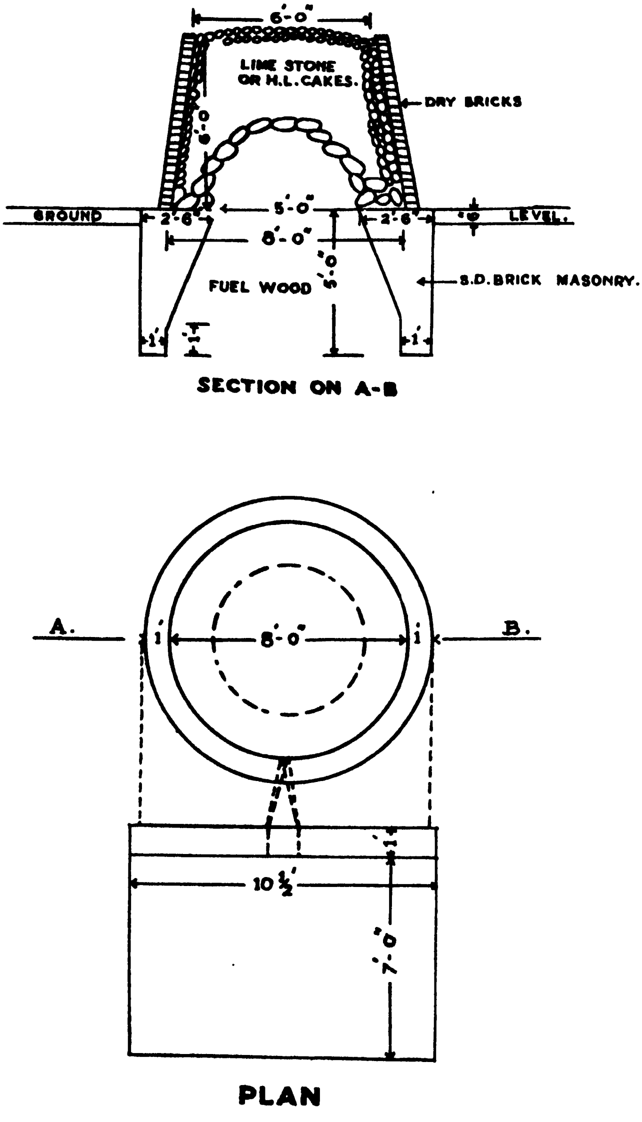
G. P. Z P. Poona. 1946.

PLATE V-C

PLAN OF COUNTRY TYPE KILN
100 CFT. CAPACITY



G. P. Z. P. Poona, 1946.

	Rs.	a.	p.
2nd Process—			
Fat lime 100 c. ft. at 27-6	27	6	0
Clay 25 c. ft. average lead 4,000′ at 1-8	0	6	0
Labour Grinding and mixing lime and clay, loading and unloading into tip wagons and depositing slurry in drying yard and cutting up when dry	3	0	0
Current charges for grinding mills	1	9	0
Coal 12 per cent. of dry lumps (= 85 per cent. of dry owing to shrinkage) $= \frac{106 \times 12}{100 \times 36}$ = ·353 ton at 23	8	2	0
Wood 32 c. ft. at 7-8 per 100 c.ft.	2	8	0
Labour Loading lumps and coal into kilns, burning, unloading and sorting out well burnt lumps and stacking in measures	3	10	0
Total yield = 80 c. ft. Total cost	=46	9	0
Cost for materials and labour for 100 c. ft.	=58	3	0
Add 5 per cent. for waste and contingencies	2	14	0
Service charges :—Water supply, oils stores and petty repairs to machines at 1 per 100 c.ft.	1	0	0
Work charged establishment	1	0	0
Depreciation charges and heavy repairs on Mills	2	2	0
Do. light track and tip wagons	2	0	0
Capital cost of kilns, bins and land	2	5	0
Maintenance of light gauge lines, tip wagons	0	8	0
	70	0	0

The following are typical results of tests for Tensile Strength, Compressive Strength Setting time and Hydraulicity :—

TABLE XXIV.

Tensile Test lbs.

	Seven days.	Fourteen days.	One month.	Two months.	Three months.	Four months.	Five months.
Neat hydraulic lime	51	87	133	171	185	204	211
Mortar 1 to 1½ ...	33	57	122	189	...	...	...

Compressive Tests lbs.

—	Ten days.	One month.	Two months.	Three months.	Four months.
Mortar 1 to 1½	121	205	268	421	459

Setting and Hydraulicity Tests.

—	In water.		In air.	
	Initial set.	Final set.	Initial set.	Final set.
	Hrs. mts.	Hrs. mts.	Hrs. mts.	Hrs. mts.
Neat lime	21 40	76 0	0 21	3 5
Mortar 1 to 1½ ...	22 15	77 30	5 0	21 0

Note.—The setting time is found to increase considerably with the age of the lime.

SAND-LIME (CALCIUM-SILICATE) BRICKS.

Specification No. 23.

1. **Definition.**—Sand-lime-bricks-consist essentially of an admixure of sand and hydrated lime, mechanically pressed together, and combined by the action of steam under pressure.

2. **Size.**—The size of the bricks shall be not more than 9″ long, 4⅜″ wide and 2 $\frac{11}{16}$″ deep, nor less than 8⅞″ long, 4$\frac{5}{8}$″ wide and 2⅝″ deep, or any other dimensions which may be agreed upon.

3. **Process of manufacture.**—The sand and lime shall be intimately mixed and moulded under mechanical pressure, and afterwards subjected to the action of steam in a closed chamber. The pressure on the bricks in the moulding machine is usually not less than 5,000 lbs. per square inch, nor more than 8,000 lbs. per square inch. The newly moulded bricks are usually subjected in the hardening chambers to steam, free from condensed water, at a pressure of 120 lbs. per square inch, for about ten hours, when the steam is exhausted and the bricks removed.

4. **Sand.**—The sand shall be mainly siliceous, and shall be free from any deleterious constituents. Salts in the sand, which are soluble in water, shall not exceed 0·5 per cent. The sand shall pass through a sieve having 2,500 meshes per square inch, about 85 per cent. being retained upon a sieve having 10,000 meshes per square inch. The sand should consist of grains of assorted sizes, and so graded as to give the greatest density of material.

5. **Lime.**—The lime shall be well-burned, free from ashes, over-burnt coal and any foreign matter. It shall be a high calcium lime, containing 90 to 95 per cent. of calcium oxide, and not more than 0·5 per cent. of magnesium oxide.

The ratio of the weight of dry hydrated lime, to the total weight of dry hydrated lime and dry sand, is usually not less than 7½ per cent., nor more than 12½ per cent.

6. **Water.**—Water used in the manufacture shall be free from oil and organic matter.

7. **Mixing.**—Whether the sand and lime be mixed by weight or by volume, care shall be taken to see (1) that the required ratio of lime to sand is constantly maintained, and (2) that the mixing shall ensure the lime being disseminated thoroughly throughout the mass.

8. **Classification.**—The bricks shall be classified as follows :—

Class A—Engineering bricks having a crushing strength, when tested dry (after being thoroughly dried to constant weight in a suitable oven at a temperature of from 225°to 250°F), not less than 2,800 lbs. per square inch, or 180 tons per square foot.

Class B.—Bricks for external walls—having a crushing strength not less than 2,000 lbs. per square inch, or 128·6 tons per square foot.

Class C.—Bricks for internal walls—having a crushing strength not less than 1,000 lbs. per square inch, or 64 tons per square foot.

9. **Wet test.**—The crushing strength, when tested wet after immersion in clean fresh water for 24 hours, shall not fall below the figures specified above for classes A and B, by more than 20 per cent., and for class C, by more than 30 per cent.

10. **Absorption.**—Dried bricks should be weighed and submerged in water at a temperature of from 60°to 80° F. The water containing the bricks should be raised to boiling point within one hour, kept boiling continuously for five hours, and then allowed to cool down to 60°or 80°F. The bricks should then be removed wiped clean and weighed. Increase in weight of each brick by absorption, should not exceed 10 per cent. of the original dry weight, for classes A and B.

PAINTS, VARNISHES, etc.

Paints.

1. Paints are used to preserve materials from the action of heat, gases, moisture, etc., and also to improve their appearance.

Ordinary oil borne paints consist of—

(*a*) a base,

(*b*) a vehicle or carrier,

(*c*) a drier,

(*d*) a colouring pigment,

(*e*) a solvent.

2. The base determines the character of the paint.

3. The following are the materials generally used :—

Bases.—White l·ad, red lead, zinc white, oxide of iron, tatanium oxide, etc., and metalic powders such as aluminium, copper, bronze etc.

Vehicles.—Oils, especially linseed and china wood or Tung oil, and white spirit,

Driers.—Litharge, acetate of lead, sulphate of zinc, red lead.

Colouring pigments.—Ochres, lampblack, copper sulphate and various metallic salts.

Solvents.—Spirits of turpentine.

4. **Bases.**—The base of all lead paints is either white or red lead. The former is a carbonate of lead, the latter an oxide of lead.

White lead paints are not suitable for delicate work as the lead becomes discoloured. White lead, is however, dense, of good body, and permanent, and is perhaps the base most largely used. It is obtainable in the market either dry or ground in oil.

White lead is frequently adulterated with sulphate of baryta, whiting, etc. The presence of sulphate of baryta, can be detected by the addition of nitric acid which will dissolve the lead, but not the baryta.

Red lead is very largely used for painting iron work, for the priming coat of wood work, and also as a drier. It is sometimes adulterated with brick-dust, the presence of which may be detected by heating in a crucible and treating with dilute nitric acid. The lead will be dissolved and the brick-dust remain.

Oxide of zinc, or zinc white, is the basis of most zinc paints. It has the advantage over lead paints that it is not liable to discolouration by sulphur, but it has the disadvantage that it has less body than white lead, is difficult to work and is less durable. Lead dries should not be used with zinc paint.

Oxide of iron forms the base of an important class of paints. The tints obtainable vary from yellowish brown to black. The best known paint of this class is Olphert's oxide of iron paint, which is now largely used for painting iron work.

Titanium oxide makes an excellent base for paint, unaffected to the same degree as lead by sulphur fumes, and having great powers of scattering light, and a little oxide goes a long way.

Aluminium paint, is very useful as a first coating for new woodwork. It keeps the moisture content of the wood practically constant and prevents warping and cracking. It has a very great covering power, 70 to 80 square yards per gallon.

5. **Vehicles.**—The oils generally used are linseed oil, poppy oil, and nut oil, china wood or Tungoli white spirit is also used.

Linseed oil is that most generally used, as it oxidises and becomes thick on exposure to the air. It is used either raw or boiled. Oil pressed out from green unripe seeds, always abounds with watery, acidulous, particles. The quality of the oil may be determined in the following manner—

Fill a phial with oil and hold it up to the light: if bad it will appear opaque, turbid and thick, taste acid and bitter to the tongue, and its odour will be rancid and strong. Such oil ought to be rejected. Oil from fine full-grown ripe seed, when viewed in a phial, will appear limpid, pale and brilliant is mellow and sweet to the taste, has very little odour, is specially lighter than impure oil, and when boiled or clarified dries quickly and firmly.

Raw linseed oil is paler in colour than boiled oil, and is used for inside work, but is inferior in drying qualities.

The drying of raw linseed oil, "may be improved by adding about 1 lb. of white lead to every gallon of oil, and allowing it to settle for at least a week."*

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Linseed oil can be clarified by mixing it with sulphuric acid, after which it is to be well washed with water, till quite free from the acid. The oil is, however, said to recover its original colour on drying.

Boiled linseed oil is thicker and more darkly coloured than raw oil, and cannot therefore, be used for delicate colours. When country linseed oil is used, it should be boiled for 2 or 3 hours with red lead and litharge in the proportion of 1 lb. of each to 1 gallon of oil.

Tung oil is much superior to linseed oil, and is used in making superior paints and varnishes.

Poppy oil is used for very delicate colours. It is inferior in drying qualities to linseed oil, though its colour stands longer. Nut oil is nearly colourless ; it dries very rapidly, but is not durable.

White spirit for paints.

Shall be wholly a petroleum product. It shall be clear, colourless and free from solid matter and from water.

Tests as regards Distillation ; freedom from grease, non-volatile residue etc. given in Br. Sl Sp. No. 244-1936.

6. **Driers.**—Litharge or oxide of lead is that generally used, the proportion being about ½ lb. to a gallon of oil. It has however, a tendency to injure the colour of paint, and is not therefore, generally used for the finishing coat.

Sulphate of manganese is frequently used with zinc paints, to avoid the danger of the discolouration of a lead drier. It requires, however, great care in mixing, otherwise the work will be spotted.

7. **Pigments.**—The following are the most common :—

Blacks.—Lampblack, vegetable black, ivory black.

Blues.—Prussian blue, indigo.

Yellows.—Chrome yellow, yellow ochre, raw sienna.

Browns.—Raw umber, burnt umber.

Reds.—Carmine, red lead, vermilion.

Green.—Copper sulphate.

8. **Solvents.**—Spirits of turpentine is used to thin prepared paints, to make them work more smoothly. If used in excess it flattens colours, which are not then durable, as the spirits evaporate, leaving an excess of colour not mixed with the oil. The best test of its purity is by evaporation, when it should leave practically no residue.

Note.—English turpentine is too pungent for in-door use.

9. **Preparation of paints.**—The base must first be thoroughly ground in oil, and mixed to the required thickness for work, with oil or spirits of turpentine. The pigment should then be ground on a flat stone or in a colour mill, with oil, until thoroughly mixed, and then rendered fluid by the addition of oil or spirits of turpentine and mixed with the base that has already been prepared.

Aluminium powder and paste.

(1) Should be in the form of a soft powder, the particles of which are in the form of flakes, when examined under the microscope.

(2) Shall contain not less than 95 per cent. aluminium and not more than 0·1 per cent. of copper and not more than 3 per cent. of grease.

(3) The paste is made by mixing aluminium powder with white spirit, and should contain not less than 65 per cent. of aluminium powder.

Tests as regards settling properties, colour, opacity, finish brightness etc. are laid down in Br. Sr. Specification No. 388 of 1938.

VARNISHES.

1. Varnishes are used to brighten the appearance of the grain in wood, to render painted surfaces more brilliant, or to protect them.

2. Varnish to be copal varnish or such other as may be specified by the Executive Engineer.

DISTEMPERS.

1. Distempers are paints in which clean water is used instead of oil as a carrier and whiting or chalk takes the place of white lead as a base, with some sort of size.

2. Distempers such as Hall's sanitary washable distemper, muraline, karsonite, shalimar, etc., are mixed ready for use, and, with the exception of muraline, require a priming coat to obtain good results.

3. Washable distempers are not really washable as a rule, until after they have had an opportunity of hardening for at least three months. After that time, they can be washed lightly with a soft damp cloth and plenty of water.

4. An advantage of using distempers is, that the Engineer has a number of exactly defined colours from which to choose, and the difficulty of obtaining a colour suitable for a particular room, is therefore reduced to a minimum.

5. Most of the manufacturers of distempers send out complete directions for use, and these should be explicitly adhered to. Variations are certain to give unsatisfactory results.

TABLE XXV.

AVERAGE WEIGHTS OF BUILDING MATERIALS.

Name of materials.	Weight per c. ft. in lbs.
Solid substances (non-metallic).	
Asphalt	144
Basalt	178
Bitumen	90
Bricks of burnt clay 12″ × 6″ × 3″	90
Chalk	121
Clay, ordinary	120 to 130
Concrete	120 to 150
Coke	62 to 103
Cuddappah slabs	170
Earth, vegetable	90

TABLE XXV—*contd.*

Name of materials.	Weight per c. ft. in lbs.
Solid substances (non-metallic)—*contd.*	
Earth, loamy	100
Do. semi-fluid	110
Granite	168
Gravel	110
Glass crown	157
Do. sheet and plate	155 to 175
Do. common, green	169
Limestone	139
Marble	169
Mortar	109
Mud (just dredged)	124
Paper (close packed)	55
Do. (loose records)	40 to 45
Pitch	72
Plaster of Paris	50
Portland cement	90
Pumice stone	50 to 70
Salt	43
Sandstone	137
Sand, quartz, pure, dry, slightly shaken	92 to 110
Do. river, dry (maximum)	117
Shingle	88
Slate	171
Sulphur (melted)	124
Do. (native)	127
Tar (coal)	63
Tile of burnt clay 12″ × 12″ × 2″	15 to 16
Do. 8″ × 8″ × 2″	7 to 8
Water pure at 39·9° Fah.	62·425
Timber.	
Chir wood	32
Deal do.	40
Sál do.	62
Teak do.	42 to 52
Metals solid.	
Aluminium	162
Brass Cast	504
Copper Cast	537
Do. Sheet	550
Cast-iron	450
Lead	710
Steel	490
Wrought iron	480

TABLE XXV—*concld.*

Name of materials.	Weight per c. ft. in lbs.
Liquids.	
Oil, linseed	59
Oil, turpentine	54
Stone and Brick work, etc.	
Burnt brick and lime concrete	115 to 120
Burnt brick and cement concrete	130 to 140
Lime mortar (old)...	90
Do. (new)	110
Do. (well tempered)	115
Brick work set in lime mortar	120
Do. sun dried	110
Masonry stone	156
Plaster (lime)	106
Reinforced concrete	150

Roofs, Sheeting, etc.

Name of item.	Weight per Sq. ft in lbs.
Single country tiling and battens	14
Double do. do.	24
9″ thatch and frames	10
6″ thatch and frames	$6\frac{1}{2}$
Felt asphalted	3
Rubberoid	$\frac{1}{3}$ to $\frac{1}{2}$
Lath and plaster ceiling	8
Double Allahabad tiling	34
First class mud roof	100
Jack arched roof	150
Single Allahabad tiling	17
Roof, Sind type terraced, consisting of 12″ square tiles 2″ thick, 4″ mud and 4″ ‘bhan’ in alternate layers of 1″ and mud plaster on top	65 to 70
Corrugated iron roofing sheets 24 B.W.G.	1
Do. do. 22 do.	$1\frac{1}{3}$
Do. do. 20 do.	$1\frac{1}{2}$
Do. do. 18 do.	2
Mangalore tiles and battens	14
Lime plaster ceiling on $\frac{3}{4}$″ wire netting	7
Asbestos roof sheeting $\frac{5}{32}$″	$2\frac{1}{2}$
Do. $\frac{1}{4}$″ corrugated	$3\frac{1}{4}$ to $3\frac{1}{2}$

TABLE XXVI.

LOADS FOR A TWO-BULLOCK CART.

Bricks (9″ × 4½″ × 2½″)	200 Nos.
Broken Stone	12 cubic feet
Muram	16 „
Gravel	12 „
Kunkar lime	13 „
Slaked lime	20 „
Sand stone	9 „
Earth	18 „
Mangalore tiles	250 No .
Mangalore ridge tiles	150 „

The average load of a two-bullock cart may be taken as 1,400 lbs. for short distances, say, up to 7 miles, and 1,000 lbs. for longer distances. On hard wall-made City pavements, and for short trips, the loads may be as big as 3,360 lbs.

Detail of rates of different items occurring in chapter II.

Rate Abstract No. 1.

Brick-making on tables.

Labour for 1,000 bricks.	Number.	Rate.	Per	Amount.	Artificers, labourers and materials for 1,000 bricks.	Number or quantity.	Rate.	Per	Amount.
Making bricks.		Rs. a.		Rs. a.	*Burning by kiln*		Rs. a.		Rs. a.
Moulder ...	1	...	...	...	Coolie for loading kiln ...	1	...	...	...
Coolies for digging, tempering, and conveying earth, etc. ...	2	...	...	...	Women for loading kiln ...	2	...	...	...
Women and boys for conveying moulded bricks and stacking dried ones ...	3	...	...	...	Firewood, dry, 28 maunds or ton ...	½	...	...	...
Bhistie for water ...	⅓	...	...	...	Coolie for firing kiln ...	1	...	...	...
Sundries, such as moulds, baskets, etc. ...	...	...	...	...	Coolie for unloading and stacking burnt bricks ...	1	...	...	...
					Sundries ...	...	...	...	...
	Total, making bricks					Toal, burning ...			
						Total, making ...			
	Allowance for unsound bricks and wastage ...								
	Total for 1,000 table-made bricks, 9 × 4½ × 2½ inches ...								

RATE ABSTRACT No. 2.

Brick-making on ground.

Labour for 1,000 bricks.	Number.	Rate.	Per	Amount.	Artificers, labourers, and materials for 1,000 bricks.	Number or quantity.	Rate.	Per	Amount.
Making bricks.		Rs. a.		Rs. a.	*Burning by clamp.*		Rs. a.		Rs. a.
Moulder ...	1	...	...	...	Coolie for loading clamp ...	1	...	...	...
Coolies for digging, tempering, and conveying earth.	2	...	...	...	Women for loading clamp ...	2	...	...	...
Women for turning and stacking dried bricks ...	2	...	...	...	Firewood, dry, 17½ maunds or ton ...	$\frac{5}{16}$	...	...	...
					Cowdung cakes ...	500	...	...	...
Bhistie for water ...	½	...	...	...	Rubbish, cart loads ...	2	...	...	...
Sundries, such as moulds, etc.					Rice husk or brush-wood, cart-load ...	¼	...	...	...
					Coolie for unloading and stacking	1	...	...	...
					Sundries ...	...	...	...	...
	Total, making bricks					Total, burning ...			
						Total, making ...			
					Allowance for unsound bricks and wastage ...				
					Total for 1,000 bricks, 9 × 4½ × 2¾ inches ...				

RATE ABSTRACT No. 3.

Tile-making (round tiles).

Materials for 1,000 tiles.	Number.	Rate.	Per	Amount.	Labourers for 1,000 tiles.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
					Moulder ...	1	...	...	...
Cart-loads of rubbish ...	1½	...	...	...					
Sundries ...	...	...	...	...	Coolies for earth, and heaping tiles, etc. ...	2	...	...	...
					Women for covering and cutting, etc. ...	2	...	...	...
					Sundries, such as water, etc. ...	...	...	...	...
	Total, materials					Total, labour ...			...
						Total, materials ...			...
						Total for 1,000 tiles ...			...

RATE ABSTRACT No. 4.

Lime-burning with charcoal..

Materials for 40 cubic feet slaked lime.	Number or quantity.	Rate.	Per	Amount.	Labour for 40 cubic feet slaked lime.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Limestone Cft.	30	...	...	...	Lime burners ...	½	...	...	...
Charcoal Lbs.	560	...	...	...	Coolies for bareking and loading	5	...	...	...
Ooplas (dried cowdung) No.	125	...	...	...	Women for breaking and loading	4	...	...	...
Basket ,, ...	1	...	...	...	Bhistie ...	¼	...	...	...
Sundries ...	...	...	...	...	Sundries ...	...	...	...	...
	Total, materials ...			...		Total labour ...			...
						Total, materials ...			...
					Total for 1 *khandi* or 40 cubic feet slaked lime ...				...

N.B.—Unslaked stone lime increases 1½ times in bulk when slaked and yields 1⅓ times in bulk of pure lime.

RATE ABSTRACT No. 5.

Lime-burning with English coal.

Materials for 435 cubic feet.	Number or quantity.	Rate.	Per	Amount.	Labour for 435 cubic feet.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Broken *kunkar* ... C.ft.	435	...	...	...	Lime-burners No.	6	...	...	...
English coal Tons ...	2¼	...	...	...	Watchmen ... ,,	6	...	...	...
Carting coal to kiln No. (carts)	2¼	...	...	...	Coolies for loading and unloading ... ,,	12	...	...	...
Babul firewood ...*Mds.	11	...	...	...	Women for loading and unloading ... ,,	4	...	...	...
Cowdung cakes ... No.	300	...	...	...	Coolies for preparing lime ... ,,	18	...	...	...
Sundries ...	...	...	...	...	Women for preparing lime ... ,,	18	...	...	...
					Bhisties ...	6	...	...	...
					Sundries ...	...	...	...	...
	Total, materials ...			...		Total, labour ...			...
						Total, materials ...			...
					Total for 435 cubic feet ...				...
					Or, for 1 *khandi* or 40 cubic feet of slaked lime ...				...

* 56 maunds = 1 ton.

RATE ABSTRACT No. 6.

Lime-burning with firewood.

Materials for 40 cubic feet slaked lime.		Number or quantity.	Rate.	Per	Amount.	Labour for 40 cubic feet slaked lime.	Number.	Rate.	Per	Amount.
			Rs. a.		Rs. a.			Rs. a.		Rs. a.
Limestone	C. ft.	30				Lime-burner ...	$\frac{1}{2}$			
Firewood, dry	*Mds.	28				Coolies for breaking and loading ...	6			
Cowdung cakes	No.	125				Women for breaking and loading	4			
Basket	,,	1				Bhistie ...	$\frac{1}{4}$			
Sundries	...	...				Sundries ...	...			
						Total, labour ...				
		Total, materials				Total, material ...				
						Total for 40 cubic feet of slaked lime				

*56 maunds 1 ton.

RATE ABSTRACT No. 7.

Grinding mortar.

Labour for grinding 100 cubic feet of mortar.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.
Pairs of bullocks	2			
Bhisty	1			
Coolies	2			
Women	5			
Sundries	...			
Total for grinding 100 c.ft. of mortar ...				

Rate Abstract No. 8.

Grinding mortar in power-driven iron mills (1 lime to 1½ sand for masonry).

Materials for 1,500 cubic feet.	Number or quantity.	Rate.	Per	Amount.	Labour for 1,500 cubic feet.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Sand C.ft.	1500				Oil-engine attendant No.	1			
Lime ,,	1000				Assistants ,,	2			
Crude oil Gls.	12				Fitter ,,	1			
Lubricating oil ,,	1				Assistants ,,	2			
Sundries (grease, nuts, bolts, etc.) ...	...				Men ,,	18			
					Women ,,	18			
					Mukadam ...	1			
						Total, labour ...			
	Total, materials ...					Total, materials...			

Total for 1,500 c.ft. ...

or for 100 c.ft. ...

Add (*a*) for water for 100 c.ft. of mortar ...
(*b*) depreciation charges for mills, engine shed, etc. ...

Total for 100 c.ft. ...

Note.—(*i*) Each mill turns out 250 cubic feet per day of 8 hours, or a battery of 6 mills turns out 1,500 cubic feet per day of 8 hours.

RATE ABSTRACT No. 9.

Grinding mortar in power-driven iron mills (1 *lime to* 2 *sand for concrete*).

Materials for 1,500 cubic feet.		Number of quantity.	Rate.	Per	Amount.	Labour for 1,500 cubic feet.	Number.	Rate.	Per	Amount.
			Rs. a.		Rs. a.			Rs. a.		Rs. a.
Sand	C.ft.	1500				Same as for grinding mortar (1 to $1\frac{1}{2}$ for masonry) in Rate Abstract No. 8	...	...	...	
Lime	,,	750								
Crude oil	Gls.	12								
Lubricating oil	,,	1								
Sundries	...	...								
							Total, labour ...			
		Total, materials ...					Total, materials ...			
							Total for 1,500 c.ft. ...			
							or for 100 c.ft. ...			
						Add (*a*) for water for 100 cubic feet of mortar ...				
						(*b*) depreciation charges for mills, engine shed, etc. ...				
							Total for 100 c.ft. ...			

P. W. D. HANDBOOK

BOMBAY

Volume I

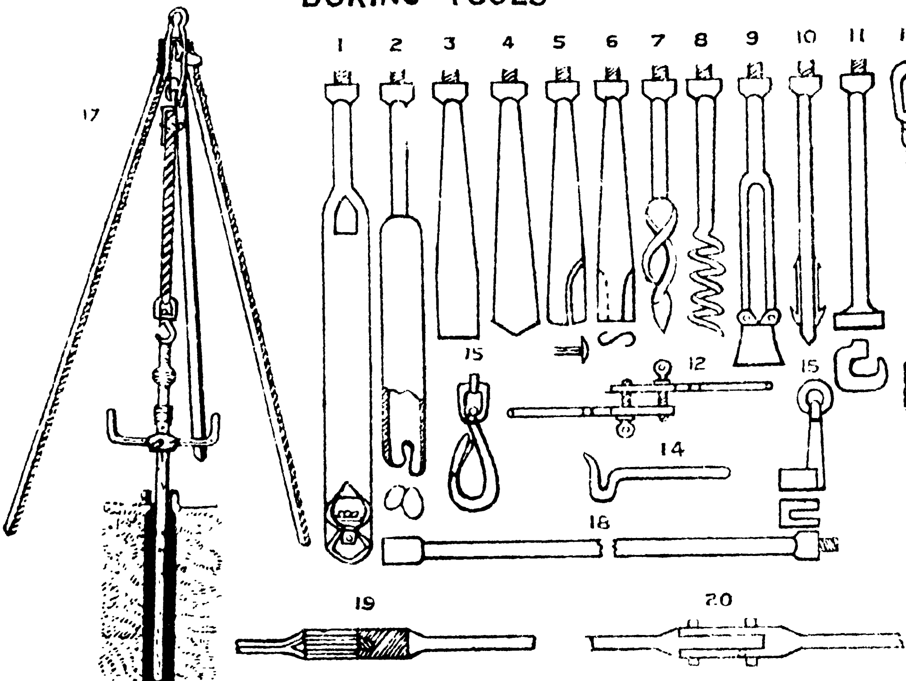
SECTION II

BUILDINGS

1949

Boring Tools

Plate VI



1 Shoe nose shell with valve, for bringing up loose stuff.
2 Open Auger for clay and stiff soil.
3 Flat Chisel for moderately hard ground.
4 V nose Chisel 3¼ inch, for hard ground.
5 T nose Chisel, 3¼ inch, for hard ground & rocky.
6 S nose Chisel 3¼ inch, for hard rock & flint.
7 Worm Auger 3¼ inch, for loosening stuff in bore-hole.
8 Spiral worm, for extracting broken rods.
9 Bell Box, for bringing up broken bits.
10 Spring Dart, for drawing pipes from bore-hole.
11 Crows foot, for extracting broken Tools.
12 Pair of Tillers, with screws for Working the rods.
13 Short Rod, with Swivel head to fit all rods.
14 Pair of Rod Wrenches for screwing & unscrewing rods
15 Swivel Spring Hook.
16 Lifting Dog for raising rods.
17 Rigger and Carriage.
18 Boring Rods, in 10 feet lengths, with screws joints.
19 Joint of Rods.
20 Do Do.

CHAPTER III—BUILDINGS.

FOUNDATIONS.

Nature of Strata.

TRIAL PITS AND BORINGS AND TEST PILES.

1. The first step in the design of a foundation, is a site investigation. This may be a surface inspection, to determine from the appearance of the soil at the site itself, and from any cutting, well, etc. in the vicinity, what the top surface and the substrata consist of. For more precise determination of the type of substrata at the site, it is necessary to dig trial pits, or sink bores. A trial pit can only be carried down economically to a moderate depth, but it affords an excellent opportunity of studying the strata in their undisturbed state, and of determining the difficulties in excavation. The chief objection to the trial pit, is the localised nature of the information, and the fact that a sufficient number of trial pits are costly. If supplemented by trial bores, however, a moderate number of trial pits may suffice.

2. The usual method of boring is as follows :—

The ordinary boring apparatus consists of a succession of iron rods in lengths of 10 feet each, 1 inch square in section, joined by screw threads ; the boring tool is attached to the lowest rod. The various parts of the apparatus are shown in plate VI.

Figures 19 and 20 represent the methods of jointing rods. In figure 19 the joint is liable to come undone if the rod is turned in the opposite direction to the thread.

Figure 1 shows the mudshell, a cylinder of strong sheet iron closed by a valve opening upwards or by a ball, used in quicksand and mud or earth so loose that it cannot be removed by the auger, and also for cleaning the hole where the chisels have been used.

Explanatory notes for other figures are given on the plate.

For deep borings a proper timber framework is erected, but for small boring this is dispensed with and a triangular gin is used for raising the rods. A pit 6 feet deep and 4 feet diameter at bottom and 6 feet at top is first sunk. The gin is then erected immediately over the centre, and a 12-inch diameter pulley called a rigger is attached to it. A small frame 12 inches square, called an auger board, having two flaps, is sunk in the bottom of the pit to prevent .loose stuff falling into the hole. In the auger board is a hole 2 inches diameter. A spar is lashed to two legs of the gin close to the ground, to which a snatch-block is fastened for taking the fall of the windlass, which is placed close to the spar and weighted with sand bags, etc. The fall being rove through the block, the lower end is attached to a short length (about 2 feet) of rod, having a swivel at the top (Fig. 13), which allows the rod to turn round without twisting the rope. A rod is next screwed on, and is raised vertically into its position over the intended boring and passed through a 3-inch hole in the centre of a plank laid across the pit. Two men descend into the pit and attach the boring tool, screwing it well by means of the pair of tillers (Fig. 12), which are used afterwards for turning the rods. The men above cover over the pit with planks, and slip on the four-handled lever. The men in the pit open the flaps of the auger board, lower the tool on the to ground, and man their double-handled lever, while the men above work their four-handled one, walking round with the sun. In this way the boring is continued, the tool being occasionally raised into the pit to clear it of earth or to change it, additional lengths of rod being added as required.

The chisel is worked by the men hauling on the rope and suddenly letting it go, the tool being partly turned between each stroke by the men in the pit. If the weight is too great it can be raised by the windlass, the man who hauls on the fall simply slacking it when the chisel is raised sufficiently and allowing the turns to slip round the barrel; he should only pay out enough rope to allow the chisel to fall the depth of its stroke; if too much rope be paid out, the head of the rod wobbles about and the rods get bent.

LIST OF EARTH-BORING TOOLS REQUIRED FOR VARIOUS DEPTHS.

(1) 30 Feet.

1 Clay Auger, 2 in.
1 Shoe Nose Shell, 2 in.
1 Flat Chisel, 2 in.
1 Worm Auger, 2 in.
1 Pair of Tillers.
1 Hand Dog.
1 Lifting Dog.
5 Five-feet lengths of ¾ inch Rods.
1 Short Swivel Rod.
1 Spring Hook and 20-feet Rope.
1 Gin Block.
1 Tripod with Shackle.

(2) 50 Feet.

1 Clay Auger. 2½ in.
1 Flat Chisel. 2½ in.
1 T Chisel, 2½ in.
1 Shoe Nose Shell, 2 in.
1 Worm Auger.
1 Pair Tillers.
2 Hand Dogs.
2 Lifting Dogs.
10 Five-feet lengths of 1-in. Rods.
1 Short Swivel Rod.
1 Gin Block.
1 Spring Hook and 30-feet Rope.
1 Tripod with Shackle.

(3) 100 Feet.

1 Clay Auger, each 3¼ in. and 4¼ in.
1 Shoe Nose Shell, each 3 in. and 4 in.
1 Auger Nose Shell, each 3 in. and 4 in
1 Flat Chisel, each 3½ in. and 4¼ in.
1 T Chisel, each 3¼ in. and 4¼ in.
1 Worm Auger.
1 Bell Box.
2 Hand Dogs.
2 Lifting Dogs.
1 Pair of Tillers.
1 Gin Block.
10 Ten-feet lengths of 1-in. Rods.
1 Short Swivel Rod.
1 Spring Hook and 30-feet Rope.
1 Auger Board.
1 Auger Cleaner.
1 Tripod with Shackle.

(4) 200 Feet.

1 Clay Auger, each 3¼. 4½ and 5¼ in.
1 Flat Chisel, each 3¼. 4¼ and 5¼ in.
1 T Chisel, each 3¼, 4¼ and 5¼ in.
1 V Chisel, each 3¼, 4¼ and 5¼ in.
1 Shoe Nose Shell, each 3, 4 and 5 in.
1 Auger Nose Shell, each 3, 4 and 5 in.
1 Worm Auger.
1 Bell Box.
2 Lifting Dogs.
2 Hand Dogs.
1 Pair Tillers with square screws.
20 Ten-feet lengths of 1¼ in. Rods.
1 Short Swivel Rod.
1 Gin Block.
1 Spring Hook and 30-feet Rope.
1 Auger Board.
1 Auger Cleaner.
1 Tripod with Shackle.

In firm ground no precaution are necessary to prevent the sides falling in, but if the boring passes through a stratum of quick sand, marshy earth, etc., a casing of pipes must be provided.

The pipes generally used are of wrought-iron, from 12 to 15 feet long, and of varying diameters, from 3 inches upwards, so as to pass one within the other. They are provided with bayonet joints. The largest pipes are first placed in the boring successive lengths being added at the top until the required length is got in, and are forced down, if necessary, by a monkey or small pile engine, acting on a block of "babul" fitting in the head of the pipe. When the resistance of the earth prevents the pipes being driven any further, another pipe whose external diameter is equal to the internal diameter of the pipe already placed is lowered, the boring for it being made by tools of proper diameter.

Samples of the various strata through which the boring passes should be preserved, their thickness and any other information likely to be useful being noted. Great care must be taken to prevent breaking of the boring rods, which is the most troublesome and expensive accident that can occur.

When the boring rods, from their great length, become too heavy to be lifted and allowed to drop with safety, a portion of their weight is generally taken by means of a counterpoise.

For deep borings the rods are now being replaced by a rope, one length of rod only being used next the chisel and boring being done entirely by jumping.

The "spring stroke" boring plant is designed to bore holes up to 4 inches diameter or larger in any strata such as hard rock, muram or soft soil to any depth up to 250 feet, or more if desired. It is specially suitable for sinking bore-holes in existing wells, or from the ground surface, to obtain water for drinking purposes, etc.

Test Piles.

Another way of obtaining this information is to drive test piles. These do not definitely indicate the kind of strata through which they pass, but the driving, and load bearing data, combined with local information are often sufficient guidance. Test piles are particularly valuable in determining the thickness of top crusts or the depth below poorer soils at which good bearing strata lie.

Pile-driving.

1. It is often necessary to drive wooden piles in order to serve as a support for the masonry work above or to compress the soil on which a building is to be erected.

2. Piles are generally driven by a falling weight sliding between upright guides.

3. Without a pile-driving engine; set an iron rod 2 inches in diamter and 7 or 8 feet long, about 1 foot into the centre of the head of each pile, truly parallel to the length. Up and down this guide rod is worked a wooden monkey, about 9½ inches diameter and 3 feet long, provided with 4 handles of ¾-inch iron secured by wood screws to the block under 2-inch iron rings shrunk on at either end. Down the centre of the monkey is a 2½-inch hole to allow it to slid freely up and down the guide rod. The monkey is worked up and down by men who stand on a platform fixed to the pile.

4. Piles are generally driven till they are able to bear 2,000-3,000 lbs. per square inch, with a very small movement, the working load being from 200-1,000 lbs. per square inch, depending on whether the pile is resting in soft ground or has penetrated soft ground and has its point resting on hard soil.

Notes on reinforced concrete pile foundations.

1. In all important cases the bearing power of piles should be determined by actual experiment.

2. Trial piles must always be driven to ascertain the length to which piles must be cast, as it is an expensive thing to lengthen of cut piles of reinforced concrete, so that advantage may be taken of this to test the bearing power. The superior bearing power of concrete piles arises from the fact that as pillars they are stronger and that they can sustain much heavier driving.

3. In deciding as to whether the pile is sufficiently driven, the rule is that the set under the last ten blows should not exceed ½ to 1 inch. The weight of the monkey and the fall are varied according to the load to be carried by the pile.

4. It is generally advisable to use a heavy monkey and a low fall for reinforced concrete piles. With a final set of ½ inch for 10 blows, a 2-ton monkey with a 1 ft. 3 in. fall, or a 30 cwt. monkey with a 2 ft. drop might be used, where the load on the piles would not exceed 30 tons. For piles designed to carry a load of up to 40 tons with the foregoing final set, a 1½ ton monkey with 2 ft. 8 in. drop, or a 2-ton monkey with 1 ft. 8 in. drop would be suitable.

5. Driving to refusal is sometimes required, or driving so that an exceedingly small set is obtained. Such extreme driving should be avoided. Occasionally piles which give a large set under the hammer will be found to acquire much greater resistance after a few days' rest.

Pumping.

1. In excavating foundations, pumping has frequently to be resorted to. In deciding on the kind of pump to be used, it should be remembered that the useful limits of a lift-pump is from 20 feet for hand pumps, to about 25 feet for centrifugal pumps.

2. The pumps generally used are:—

Lift pumps	... ...	(a) Contractor's pump. (b) Centrifugal pump.
Force pumps	... ...	(c) Pulsometer pump.

3. In both the contractor's and centrifugal pumps, care must be taken that the bottom of the suction pipe to which a screen is attached, is at least two feet from the bottom of the sump hole, since any gravel drawn u · the suction pipe will probably stop the discharge in a contractor's pump, by getting in the valve seating and in a centrifugal pump, by sticking between the vanes of the pump and destroying, the centrifugal motion of the water in the chamber.

4. The suction pipe should be as short as possible, with few bends and should be laid with a slight falling gradient from the pump to the sump. The velocity of flow should not exceed 2 feet per second. The screen or strainer fitted at the lower end, should have the sum of the areas of the holes in it not less than twice the area of the suction pipe. A foot-valve is required above the strainer.

5. In the contractor's pump, the principal points to be attended to are, that the plungers are properly packed and that the valve seatings are clear. Hemp twisted into a rope as required makes the best packing for the pumps.

6. In the centrifugal pump care must be taken, that the speed of the pump is sufficient. Though classed as a lift-pump, a centrifugal can also be used as a force-pump, the height to which water can be forced, depending on the velocity in the pump chamber—

$h = \left(\frac{s}{9 \cdot 82}\right)^2$, where h = height in feet to which water can be forced.

s = speed of periphery of pump in feet per sec.

Best duty occurs when s, exceeds velocity of falling body ($v = \sqrt{2g\,H}$) due to height of lift, by 6 to 8 ft. per sec.

7. The following may be taken as a fair estimate of the discharge and power required to drive the following sizes of pumps :—

	Discharge.			H.P. required.
6-inch,	700	galls. per minute	... ...	6
7-inch,	900	do.	... ...	8
8-inch,	1,100	do.	... ...	10

8. The pulsometer is a very convenient pump for foundation work, as it requires no staging and can be slung in any position, being attached to a boiler generating steam by a flexible steam pipe only. Its range of pumping is practically unlimited, depending only on the pressure at which steam can be delivered to the pump.

9. Generally it may be considered that for small lifts with large quantities of water, a centrifugal pump is likely to give the best results.

Cost of unwatering foundations of bridges and culverts.

1. In the case of larger bridges, whose foundations are in sand and gravel river-beds, charged with water even in summer time, the actual cost of unwatering foundations, of average depths varying from 6 to 22 feet below river-bed level, has been found to vary from 9 to 23 per cent. of the cost of the work. For average conditions, an average of 15 per cent. may be taken for estimating purposes.

2. In the case of smaller bridges and culverts across ordinary nallas, whose beds are more or less dry in summer, the actual cost of unwatering foundations, of average depths varying from 4 to 13 feet, has been found to vary from 1 to 9 per cent. of the cost of the work. For average conditions an average of 5 per cent. of the cost of the work may be taken for estimating purposes.

Nature of foundations.

The foundations of a structure may be of the open i.e., kind taken out as trenches, footings, and excavations to cover the whole area on which the structure stands as in the case of raft foundations, or they may be of the closed kind, in which case either piles are driven, or cylinders or caissons sunk. The choice of the type of foundation, depends on the nature of the surface at the site, and the loads to be carried by the foundations, but economy considerations consistent with sufficient strength finally decide the type.

Open foundations.

General.—As the foundation has to carry the whole load of the superstructure and carried loads, it is to be seen that it is carried to such depth, or so arranged, that the superstructure will not be damaged either through a large subsidence or unequal settlement.

It is also necessary that the foundation should be horizontal so that the loads coming on it will be applied normally. For this reason, rock should be properly dressed level and if necessary cut in horizontal steps, to receive the footings.

The loads safely permissible on different varieties of soil, are given in the table below, and the footing course shall be so designed, that the load on soil does not exceed the permissible limit. If the different parts of the superstructure bear different loads, the footing for each part must be designed separately, so that there is no large difference in the load per sft.

From the information as regards substrata gained from trial pits and borings, and from additional information which can often be obtained from structures in the neighbourhood, an idea of the bearing power of the soil at the site can be obtained, and the foundation trenches, footings, etc., designed.

Specification No. 24.

1. All foundation pits and trenches shall be taken down to such depths as are shown in the drawings or as directed by competent authority. They shall be taken out to the exact width of the lowest step of the footings; the sides shall be left plumb where the nature of the soil admits of it; but they must be sloped down, or shored up carefully where the soil appears treacherous or likely to fall in.

2. All foundation trenches shall be at one level, unless it is directed that they should be taken out in steps, when each step shall be level.

3. Pit holes and weak spots shall be dug out square, and filled with material approved by competent authority, properly consolidated.

4. The bottom of foundation pits shall be dressed perfectly level and, before any concrete or masonry is put in, shall be well watered and thoroughly rammed. No filling will be allowed in thus bringing the foundation bed to proper level throughout.

5. Before any filling of foundations with concrete or masonry is commenced, the foundations must be got passed by competent authority.

6. All foundation pits must be re-filled at the sides of the masonry or concrete to the original surface of the ground with approved material, well watered and rammed. The layers not exceeding 6″ in thickness.

7. No material excavated from foundation trenches, of whatever kind it may be, is to be placed nearer than 4 feet or greater distance prescribed from the outer edges of the excavation.

8. Near large towns and in all frequented places foundation pits, well-pits, and similar excavations, shall be strongly fenced, and, shall be marked at night by red lights in the charge of watchmen.

9. If work is done by contract, the contractor's rate shall include the cost of all shoring, pumping, dredging, baling out or draining; and the excavations shall be kept free of water while the masonry is in progress in such manner as the Executive Engineer may direct.

10. The rate paid will include lifting and removing soil to any distance within 50 feet of the centre of excavation. If the soil be removed to a greater distance than 50 feet, the extra schedule rate for increased lead of earthwork will be allowed. The rate will also include filling in again round the foundation walls, ramming, and securing in the ordinary manner. The measurement of the work shall be the exact length and width of the lowest step of the footing according to the drawing or the Executive Engineer's instructions, and the depth shall be measured vertically.

TABLE XXVII.

SAFE PERMISSIBLE LOADS ON DIFFERENT SOILS.

	Description of soil.	Safe load in tons per square foot.
1	Soft, wet, pasty or muddy clay, and marshy clay ...	0·25 to 0·33
2	Alluvial deposits of moderate depths in river beds ...	0·20 to 0·35
3	Diluvial clay in beds of rivers	0·35 to 1·00
4	Black cotton soil	0·50 to 0·75
5	Alluvial earth, loams, sandy loams (clay and 40 to 70 per cent. of sand) and clay loams (clay and about 30 per cent. of sand).	0·75 to 1·50
6	Moist clay	1·00 to 1·75
7	Compact clay, nearly dry	2·00 to 2·50
8	Solid clay mixed with very fine sand	4·00
9	Dry compact clay of considerable thickness	3·00 to 5·00
10	Loose sand in shifting river beds, the safe load increasing with depth	1·50 to 2·50
11	Silted sand of uniform and firm character in a river bed, secure from scour and at depths below 25′	3·50 to 4·00
12	Compact sand	2·00 to 3·00
13	Compact sand, prevented from spreading	5·00 to 7·50
14	Sandy gravel, or kunkur	2·00 to 3·00
15	Do. but compact, dry, and prevented from spreading	4·00 to 6·00
16	Very firm, compact sand at a depth not less than 20′, and compact sandy gravel	6·00 to 7·00
17	Firm shale, proctected from weather, and clean gravel ...	6·00 to 8·00
18	Red earth	3·0
19	Muram	4·0
20	Compact gravel	7·00 to 9·00
21	Rock	from laterite 2 tons to granite 25 tons and upwards.

TABLE XXVIII.

SAFE PERMISSIBLE LOADS ON MASONRY.

	Description of masonry.	Safe loads in tons per square foot.
1	Brick in mud	$1\frac{1}{4}$
2	Brick-bat concrete in lime mortar	2
3	Stone metal concrete in lime mortar	3 to $3\frac{1}{2}$
4	West coast laterite in lime mortar	2
5	Hard laterite in lime mortar	3
6	Random rubble in lime mortar	3
7	Ordinary country bricks in lime mortar	2 to $3\frac{1}{2}$
8	Good hard burnt bricks in lime mortar	4 to 5

	Description of masonry.	Safe loads in tons per square foot.
9	Coursed rubble in lime mortar	3·5 to 7
10	Coursed rubble (granite) in lime mortar	5
11	Country brick in cement mortar	4 to 6
12	Random rubble (grantite) in cement mortar	8
13	Good bricks in cement mortar	8
14	Coursed rubble (granite) in cement mortar	12
15	Granite ashlar	15
16	Ashlar masonry (trap)	20
17	Do. do. (Porebunder)	12
18	Cement concrete :—	
	1 : 12 mass concrete	5
	1 : 10 mass concrete	10
	1 : 8 mass concrete	15
	1 : 6 mass concrete	20
	1 : 2 : 4 Concrete	30
	1 : 1½ : 3 Concrete	35
	1 : 1 : 2 Concrete	40
19	Limestone and sandstone will bear almost any structure likely to be built and is quite safe	2·0 to 9·0

Note.—1. The factor of safety for items 1 to 13, 15 and 16 is 8.

2. The factor of safety for items 17 to 20 is 5.

3. In the case of isolated brick piers without proper lateral supports, the above stresses may only be used when the ratio of the height to the least dimension of the pier does not exceed 6. For higher values of the ratio of height to least dimension, the permissible pressures shall be those given above multiplied by the following reduction coefficients :—

Ratio of height to least dimension ...	8	10	12
Reduction coefficient	0·8	0·6	0·4

No isolated brick pier shall have a ratio of height to least dimension greater than 12.

Loading—Dead Loading.—In all cases of floors where the position and nature of the partitions are definitely shown in the design, the dead load shall be calculated and provided for. For all floors in which the partitions are intended but are not located on the plans, a uniformly distributed load at the rate of not less than 20 lb. per square feet of floor area shall be provided for as an allowance to cover partitions. The partitions erected should not exceed the allowance made.

TABLE No. XXIX.

SUPERIMPOSED LOADS FOR DIFFERENT TYPES OF BUILDINGS.

Slabs.			Type of building or floor.	Beams.		
Alternative minimum load.	Load lb. per sq. ft.	Span or panel width.		Load lb. per sq. ft.	Minimum area of floor carried. sq. ft.	Alternative minimum load.
		Ft. in.				
$\frac{1}{4}$ ton distributed.	112	5 0	Domestic rooms ...	40	56	1 ton distributed.
	94	6 0	Hotel bedrooms ...			
	80	7 0	Hospital rooms ...			
	70	8 0	Hospital wards ...			
	62	9 0				
	56	10 0				
	50	11 0 and over.				
$\frac{3}{8}$ ton distributed.	168	5 0	Offices: Upper floors	50	90	2 tons distributed.
	140	6 0	Offices: Entrance and below.	80	56	
	120	7 0	Churches ...	70	64	
	105	8 0	Schools ...			
	94	9 0	Reading rooms ...			
	84	10 0	Art galleries ...			
	80	10 6 and over.	Garages: cars less than 2 tons weight	80	56	
$\frac{3}{8}$ ton distributed.	200	4 3	Assembly halls ...	100	45	2 tons distributed.
	168	5 0	Drill halls ...			
	140	6 0	Dance halls ...			
	120	7 0	Gymnasia ...			
			Light workshops ...			
			Public spaces, hotels, etc.			
	105	8 0	Staircases and landings.			
	100	8 6 and over	Theatres ...			
			Cinemas ...			
			Restaurants ...			
			Grandstands ...			
$\frac{3}{8}$ ton distributed.	240	3 6	Warehouses ...	200	$22\frac{1}{2}$	2 tons distributed.
	200	4 3 and over.	Book stores ...			
			Stationery stores ...			
			Garages: cars more than 2 tons weight.			

Alternative load for heavy garages: 1·5 maximum wheel load but not less than 1 ton distributed over floor area 2 feet 6 inches square.

In any case where the superimposed loading on any floor, roof, or other part of the building is intended to exceed that specified hereinbefore, such greater load shall be provided for.

Notwithstanding the requirements specified above in this clause the beams, etc. slabs and other floor constructions shall be capable of carrying the following loading on an otherwise unloaded floor :—

Table No. XXX.
MINIMUM SUPERIMPOSED LOADS.

Type of Floor.	Minimum Superimposed Loading on an otherwise unloaded floor.	
	Beams, etc.	Slabs, etc.
Rooms used for domestic purposes, hotel bedrooms, hospital rooms and wards.	1 ton uniformly distributed.	$\frac{1}{4}$ ton uniformly distributed per foot width.
Offices, floors above entrance floor	2 tons uniformly distributed.	$\frac{3}{8}$ ton uniformly distributed per foot width.
Offices, entrance floor and floors below entrance floor ...		
Churches, schools, reading-rooms, art galleries and the like.		
Retail shops and garages for cars of not more than 2 tons dead weight.		
Assembly halls, drill halls, dance halls, gymnasia, light workshops, public spaces in hotels and hospitals, taircases and langings, theatres, cinemas, restaurants and grandstands.		
Warehouses, bookstores, stationery stores and similar uses.		
Garages for motor vehicles exceeding 2 tons dead weight	1·5 × maximum possible combination of wheel loads, but each wheel load not less than 1 ton.	

8 (b). Reduction of Superimposed Loading.—For the purpose of calculating the total load to be carried on foundations, columns and piers in buildings of more than two storeys in height, the superimposed loading for the roof and topmost storey shall be calculated on the loads given above, but for the lower storeys a reduction of the superimposed loading may be allowed in accordance with the following table :—

Table No. XXXI.

	Per cent. reduction of superimposed load.
Next storey below topmost storey	10
Next storey below	20
Next storey below	30
Next storey below	40
All succeeding Storeys	50

The above reductions may be made by estimating the proportion of floor area carried by each foundation, column, pier and wall. No such reductions shall be allowed on any floor scheduled for an applied loading of 100 lb. or more per square foot.

Wind.

9. The design shall allow for a wind pressure in any horizontal direction of not less than 20 lbs. per square foot of the upper two-thirds of the vertical projection of the surface of such buildings, with an additional pressure of 10 lb. per square feet upon all projections above the general roof level or ridge. On the sea coast and in similarly exposed situations a further provisions shall be made.

If the vertical projection of a building is less than twice its width, wind pressure may be neglected, provided that the building is adequately stiffened by floors and walls.

For roofs inclined at an angle with the horizontal of more than 20°, a minimum superimposed loading (deemed to include the wind load) of 20 lbs. per square foot of surface, shall be assumed, acting normal to the surface, inwards on the windward side, and 10 lbs. per square foot of surface, acting outwards on the leeward side, provided that this requirement shall apply only in the design of the roof structure. The stresses resulting from wind pressure shall be considered separately with or without suction.

In the case of any floor for which a superimposed loading is not specified herein, the superimposed load to be carried on such floor, shall be actually calculated and provided.

Pile foundations.—Piles are employed to carry the load, when the ground at a reasonably accessible depth is too poor in bearing power, to provide a bed without undue spreading of the footing area. The piles act in one of two ways, or a combination of both. The pile tip may rest on a hard substratum and the pile carry the load as a column, or the pile may penetrate some distance into a stiff material and so bear up by skin-friction—when it is partly a column, but is supported laterally, and is passing on the load to the surrounding ground at all points of contact. Ultimately the ground must carry the whole load, through friction at sides, and through bearing area at pile end. For this reason, for a definite unit bearing capacity, a definite area of ground will be required per pile (unless the pile tips rest on rock and the soil gives no friction support). This is the reason why piles should not be crowded so close together that the area affected by piles overlap, a contingency shown by the rising (however small) of the pile already driven, on driving a fresh pile. The minimum spacing of piles should be about 3′ centre to centre, with an absolute minimum of 2′ 9″ for small size piles. For heavier piles this should be increased to 4 feet centre to centre, the maximum spacing varying from 5 feet to 7 feet 6 inches according to conditions.

The piles may be of timber, steel, iron or reinforced concrete, and the latter may be precast or cast in situ.

Timber piles.—These piles if used below the ground water level last for a very long period,* but ordinarily they last not longer than 30 years or thereabouts, even if treated.

Timber piles should not be loaded above 15 to 20 tons and should be carefully driven. The set should not be exacting, and the specification should never lay down that they should be driven to *refusal*.

Wrought iron or steel screw piles, consist of a rolled iron or steel shaft, having at its end a cast iron or cast steel screw, with a blade 1 foot, 6 inches to 5′ diameter. These piles can be screwed down to a great depth in clay, etc., and

* Those under the campanite of St. Mark's Venice have lasted more than a thousand years.

penetrate through small broken stones. The base area of the screw does most of the weight bearing, and they were used formerly for bridges in river beds with deep clay foundations.

Reinforced concrete piles.—In recent years this type of pile has displaced timber and metal piles to a very large extent and the use is daily expanding. The two varieties of this type are (1) pre-cast piles and (2) cast in situ piles. The former are cast to the required shape and size, in forms on the ground and round the pre-arranged reinforcement, and are allowed to set and harden, before being used. They require ground space for laying out and also time for maturing. Cast-in-situ piles are free from these objections, but the systems of casting are patented, and usually special equipment is required. There are many patented systems, of which the Vibro and the Franki pile systems, have been used for building foundations in Bombay, and bridge foundations on rivers.

Driving of piles.—Timber piles, steel piles, and precast reinforced concrete piles are usually driven by a weight falling from a specified height, between guides. The driving is stopped at a specified set under a given number of blows, or when the pile tip reaches rock, the set depending on the bearing power required from the pile driven in granular material. A set of 1 inch or less is necessary for moderately or heavily loaded piles.

A heavy hammer not less than the weight of the pile, with a small drop of 3 or 4 feet, is preferable to a light hammer with a large drop, as being less damaging to the pile and more effective. The double acting steam hammer is quite satisfactory. The fairly heavy single acting steam hammer, is in some cases more efficient than the drop hammer (particularly in sand), on account of the higher blow frequency, which keeps the pile in motion, enlarges the hole, and minimizes resistance to driving. In pure sand and gravel, the steam hammer is generally more effective than the drop hammer. The choice of hammer and distance of drop, require experience in selection.

Formulae.—There are various formulae which connect driving resistance as given by the hammer weight, the drop, and the set,with the bearing power of the soil. In the case of soils easily permeable such as sand or gravel, a suitable formula intelligently used, is a good guide. In soils almost impervious to water such as fine-grained silt and soft clays, any formula is useless, because in these soils the values of skin friction on the sides, and pressure below the toe, when the pile is in motion, may differ tremendously from the values, when the pile is stationery. Dynamic resistance after the pile has started moving, is made up of a large toe resistance and a small amount of skin friction. Under static load the toe resistance is small and the skin friction quite appreciable. In the case of the second class of soils, test loading should be applied. For the former or permeable type of soils, the following Hiley formula is generally recommended :—

$$R2 = R + (W + P) = \frac{NW.h}{S + \frac{C}{2}} + W + P.$$

where R2 = Ultimate resistance of the ground.

R = Ultimate resistance of the ground less weight of pile and hammer.

P = weight of pile, shoe, helmet.

W = weight of moveable part of hammer.

N = efficiency of blow.

h = equivalent free fall in inches (take 90 per cent. of stroke H for single-acting steam hammer, 80 per cent. for drop hammer, 100 per cent. for drop hammers released by monkey trigger and for double acting steam hammers).

Value of $\frac{P}{W}$ ...	½	1	1½	2	2½	3	4	5	6	7	8
Efficiency N ...	0·69	0·53	0·44	0·37	0·33	0·30	0·25	0·21	0·19	0·7	0·15

For double acting steam hammers :—

$h = \frac{H (W + a.m.)}{W}$ where a is the piston area in square inches and m = mean steam pressure (80 per cent. of boiler pressure. i.e., 80 lbs. per square inch).

S = set in inches.

C = temporary elastic compression factor.

N depends on rates of $\frac{P}{W}$, and is given below.

Values of C are given below :—

Length of pile	10′	20′	30′	40′	50′	60′
Easy driving 500 lbs. per square inch	0·125	0·128	0·155	0·170	0·185	0·200
Medium driving 100 lbs. per square inch	0·205	0·235	0·265	0·295	0·325	0·365
Hard driving 1,500 lbs. per square inch	0·285	0·325	0·370	0·415	0·460	0·505
Very hard driving 2,000 lbs. per square inch	0·335	0·395	0·455	0·575	0·575	0·635

Safe load is taken as ⅓rd or ¼th of R2 as calculated above.

Raft foundations.—This type of foundation is used (1) when the trenches to receive the footing courses are so deep and wide, that only thin partitions of material are left, which would crumble down on weathering, (2) when columns are used and the column footing pits are so very close together that they almost cover the whole area, (3) where the soil is of such poor bearing capacity or whose capacity is so lowered by atmospheric influences, that even with moderate superloads, the area necessary to support load is equal to or exceeds the area of the building, (4) when piles are used, and the heads of piles are so close together all over, that it is inadvisable to use separate covering slabs.

For ordinary buildings of small height, the raft foundation may be filled in with mass lime cement or cement concrete but for structures of great height, or which bring heavy loads on the founds, it is generally necessary to use reinforceed concrete rafts. For covering and connecting together groups of piles also, a reinforced concrete raft properly tied in with the pile heads is required. For structures in black cotton soil or other similar clays also, the raft if used should be of reinforced cement concrete. In mining districts where soil settlement can be reasonably anticipated, reinforced concrete raft foundations should be provided for all major structures.

Caisson foundations and well foundations.—These consist of steel or concrete cylinders or brickwork wells resting upon a cutting edge. Excavation proceeds within the cylinder, which sinks under its own weight and the weight of any additional load that may be necessary. As sinking proceeds, the cylinder or well is gradually built up, and finally when the desired depth is reached, either it is filled up solid with concrete, or sand is filled in between a bottom plug and top cap of concrete. This type of foundation is usually restricted to works in river beds or the sea.

Notes on reinforced concrete pile foundations.

1. In all important cases the bearing power of piles should be determined by actual experiment.

2. Trial piles must always be driven to ascertain the length to which piles must be cast, as it is an expensive thing to lengthen or cut piles of reinforced concrete, so that advantage may be taken of this to test the bearing power. The superior bearing power of concrete piles arises from the fact that as pillars they are stronger and that they can sustain much heavier driving.

Supplementary Specifications for the item of un atering foundations.

(1) Adequate arrangements shall be made by the Contractor for unwatering the foundation trenches and excavations and keeping the same dry while the masonry or concrete work is in progress and till the Executive Engineer or his authorized agent considers that the mortar has sufficiently set.

(2) The rate of unwatering provided in the contract covers the cost of the complete bailing out of water required for all the items of works required to be carried out and up to the complete construction of the bridge or building or structure and also covering the time required for passing foundations and taking measurements of all works done.

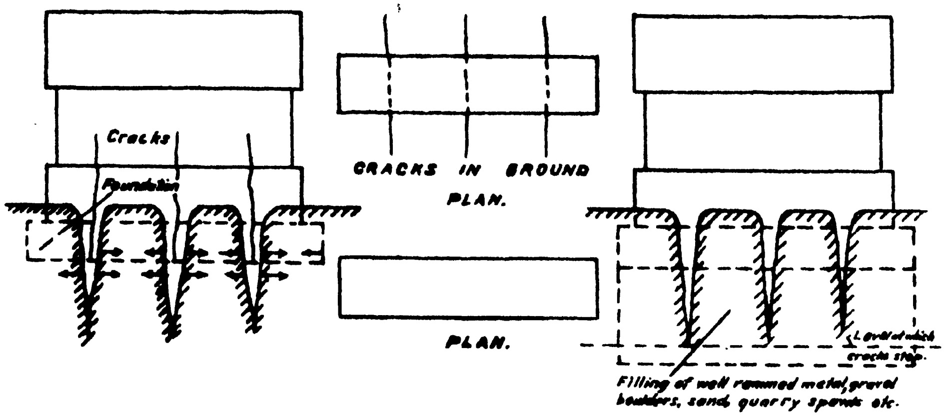
(3) The rate for the item includes the cost of the constructions and maintenance of any (*a*) shoring (*b*) cofferdams (*c*) bunds (*d*) dams (*e*) channels or other devices necessary for diverting the flow of water or any such items of any sort whatsoever required to prevent water entering the foundation trenches and excavations.

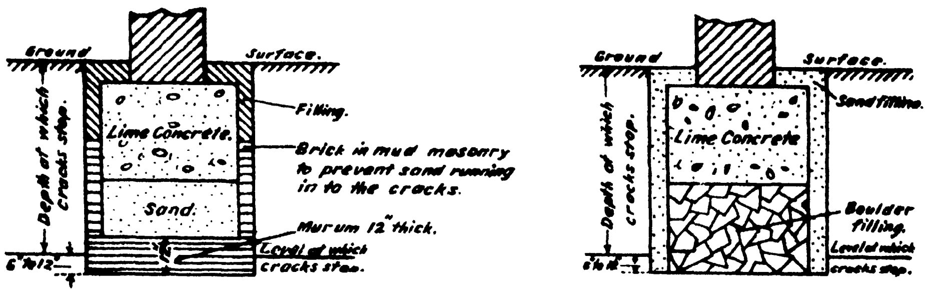
(4 No extra rate shall be paid for removing any stuff of any sort outside, which might find access, by blowing or for any other reason whatsoever from the sides or bottom of the foundation trenches and excavations or from elsewhere when the unwatering operations are in progress.

(5) The contractor must assure himself, by making the necessary investigations, regarding the depths to which the foundations are likely to go. No claim for extra payment for this item will be entertained on any account unless the depth of excavation exceeds that shown on the sanctioned plans. In case of any increase in the designed depth of founds in actual execution, any claim for extra payment will be subject to clause 14 of the contract.

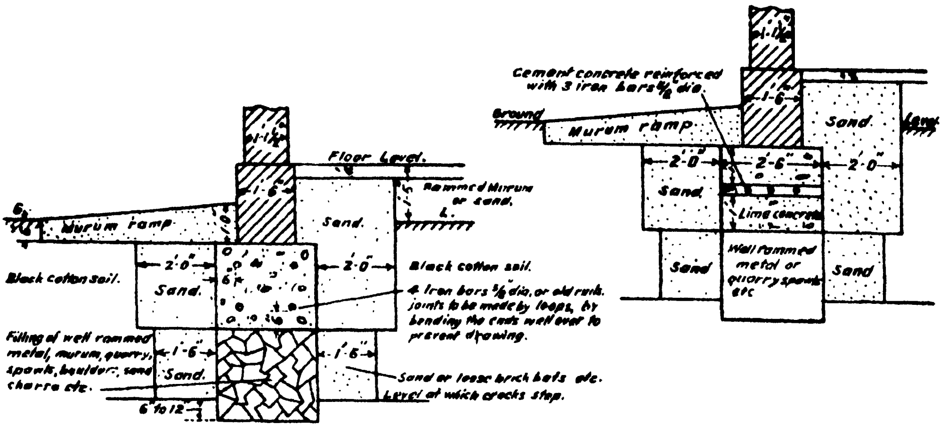
Plate VII

FOUNDATIONS IN BLACK COTTON SOILS.





SECTIONS OF FOUNDATION FOR COMPOUND WALLS ETC.



SECTIONS OF FOUNDATION FOR MAIN WALLS.

To face page 123

(6) The contractor will make his own arrangements for the necessary plant such as pumps, engines, other machinery and all other matters and materials required in this connection, but he may be supplied, on the usual terms and conditions with such machinery from Government stores as may be available, for which he will be charged at the rates laid down in the P. W. D. Manual or other relevant orders of Government operative from time to time.

Note on foundations in black cotton soils.

1. **Characteristics.**—Black cotton soil varies greatly in colour, in consistence and in fertility. It is highly clayey and somewhat loamy ; it becomes highly adhesive and very soft when wetted. It loses its bearing power considerably, some soils not being capable of taking more than 1,000 lbs. per square foot of load. It expands and contracts greatly when wet and dry to the extent of 20 to 30 per cent. of its original volume. In the dry weather, the whole area shrinks and spl ts up and large cracks, sometimes 3 to 6 inches wide at the suıface, and extending to 10 feet or so, where the soil is thick, are formed.

2. **Result.**—Any foundation embedded in such soil, being in intimate contact with it, has necessarily to move with the soil sideways, and thus tensile stresses are brought about in the concrete and masonry. Masonry and concrete, being weak against tensile stress, split easily, producing ugly cracks in the superstructure.

3. **Remedy.**—The following are the remedies to meet the characteristics of this soil.

(*a*) To make the load on foundations in these soils not more than, 1,000 lbs. per square foot, if water finds access to the foundations.

(*b*) To take the foundations to such depths to which the cracks do not extend.

To prevent the intimate contact of the black cotton soil with the concrete and masonry in foundations, by digging tr nches on either side of the concrete and filling them with sand or some loose material.

(*d*) To reinforce the concrete so as to enable it to withstand any tensile stress that may still come on it.

4. The figures in plate VII give the designs for foundations in black cotton soils.

5. It should be noted that a building constructed in the ordinary manner may remain undamaged for 10 or 15 years, and may then suddenly develop cracks. This may be due to a season of excessive drought, or excessive wet.

6. For compound walls and similar less important structures the foundation trench should be about 4′ wide and taken down to at least 6″ below the depth, at which the cracks cease.

The bottom of the trench to be well watered and thoroughly well rammed with heavy rammers. On the rammed bed a 12″ layer of good hard murum to be spread in 6″ layers ; each layer to be well watered and rammed.

On the top of the murum about 18″ of moist sand to be spread and well rammed ; but before spreading the sand and in order to keep it from running when dry into the cracks in the black soil, a half brick wall of bricks laid in mud or a thin skin of stone masonry, should be built along both sides of the trench as indicated in plate VI ı I. On the top of the sand the concrete foundation of the building to be laid ; the masonry to start 6″ below ground level.

7. During the past 35 years various devices for foundations have been tried on the G. I. P. railway. Some of the bungalows had been built on arches supported on masonry pil ars carried down below the black soil. In others, stone lintels had been tried in place of arches. Trenches had been cut to the depth of the black soil round bungalows and filled with coal ashes to isolate the site from the influence of cracks in the adjacent ground.

The results of these devices had been variable, and very conflicting,. In some cases they had held good for several years, in others they had failed after a few years, and there had been a few instances where cracks occurred in a building while it was under construction.

8. One means of getting over the difficulty was to interpose a continuous layer of reinforced concrete in the walls of buildings so as to tie all the alls together. Such a reinfored concrete layer would best serve its purpose, if placed in the foundations; but, where it would be of advantage to keep it under observation, it could be suitably placed at plinth level. A second course at some suitable level between the plinth and the top of the superstructure, would add materially to the efficiency of the first, and it would also help to resist unequal settlement.

9. Trials on the above lines have been made on the G. I. P. Railway and the practice now adopted by that railway in cases where black cotton soil is encountered and good foundation is at a greater depth than 4 feet below the surface is to put in shallow foundations and use two reingorced concrete courses of bands, each 4" thick, one at the plinth level and the other over the doors and windows. The top band may be at the lintel level, acting as a substitute for the lintels over doors and windows, but in that case its str ngth so far as portions over openings are concerned should be verified and, if necessary, additional reinforcement or depth should be provided for those portions. This prevents cracking of the masonry which might be caused by expansion and contraction of the black cotton soil in wet and dry weather and has been found very ffective and economical. This useful method of overcoming the difficulty of foundations in black cotton soil may be adopted in cases in which it is suitably and economically applicable.

10. **Measures adopted in the Sudan for buildings on cotton soil.**—This soil becomes badly fissured during the dry season, with large cracks reaching down 12 feet below the surface, and during the wet season the ground swells and rises. Many methods have been used to overcome the effect of these soil properties. They have tried piles, concrete rafts, excavating all round the foundations and replacing the soil with sand, covering the area round the plinth with a pucca platform 6′ to 8′ wide etc. No method is entirely satisfactory. A fairly efficacious and economical method is to provide light foundations only, but to insert steel tie-bars throughout the building at plinth and roof level.

Note.—The problem of foundations in black cotton has not yet found at solution. The object of these notes is to keep the problem in the forefront. It would lead to a great saving of money in the future, if really reliable information on the subject is collected and communicated by the officers of the department.

CONCRETE, GENERAL.

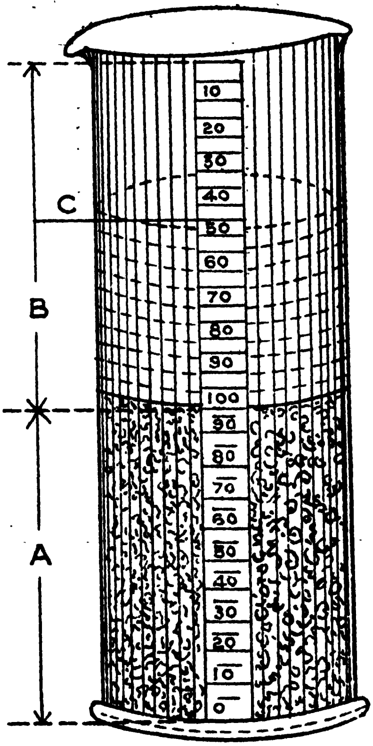
1. Concrete consists of an aggregate of clean broken stones or other hard inert substance, joined together by a matrix of mortar made of either cement or lime or both mixed with sand.

2. The proportions of the aggregate and matrix vary much with the different materials used. It is necessary that the matrix shall be in quantity rather more than

sufficient to fill the voids in the aggregate. The quantity of these voids can be ascertained by thoroughly wetting the aggregate, placing it in a water-tight container and noting the quantity of water necessary to fill the voids in the aggregate.

Note.—A more accurate test for voids is that recommended by the British Portland Cement Association and is as follows :—

Take a glass cylinder not less than 5" diameter and 12" in length, graduate it so that parts A and B contain equal volumes (a varnished paper scale will suffice. Stand the cylinder on a level surface and pour water in to fill part 'A'. Now pour the aggregate into the water, tapping the vessel on its support so as to compact the aggregate in the water. Sufficient aggregate must be put in so that it in its turn fills that part of the vessel marked A. The water surface will now rise to say 'C', dividing part 'B' into two portions, that filled by the water displaced by the aggregate and the upper part representing voids in the aggregate. If the scale is graduated as shown, the percentage of these voids to the volume of aggregate (A) can be read off directly. In the sketch this is 45 per cent. For the most accurate results damp aggregate should be used to prevent any absorption of the water in the cylinder.



The value of a knowledge of the specific gravity of a substance is in the fact that it offers an easy method of checking the voids in smaller or fine aggregates.

If W = the weight of a cubic foot of materials,
S = the specific gravity of the material,
the weight of a cubic foot of water is taken at 62·3 lbs. then the percentage of voids equals

$$\left(1-\frac{W}{62\cdot3\times S}\right)100$$

If the material contains moisture it should be first dried.

3. The aggregate frequently consists of a mixture of different sizes and shapes, the object being to lessen as far as possible the voids in the aggregate. It is thus important to specifiy clearly of what misxture the concrete shall consist. A specification of 6 to 1 concrete might mean the mixture of any aggregate, and sand 6 parts to 1 part of cement or lime. In specification the actual proportions of each type should therefore be clearly stated.

4. The aggregate is generally broken to pass through a specified gauge to $2\frac{1}{2}$ inches diameter, though with a proper admixture of materials this is not important. The size and shape of the pieces influence the void spaces and, therefore, the quantity of lime and sand that must be used.

5. Generally the voids amount to from 30 to 46% of the aggregate, if the aggregate is all of one size, but this may be considerably reduced by using aggregates of varying sizes and shapes.

TABLE No. XXXII.

Proportion of Solids and Voids in various coarse Materials.

Aggregates.	Solids.	Voids.
Sand, moist, fine, passing 18-mesh sieve (i.e. 324 meshes to the square inch)	·57	·43
Sand, moist, coarse, not passing 18-mesh sieve	·65	·35
Sand, moist, coarse and fine mixed ordinary	·62	·38
Sand, dry, coarse and fine mixed	·70	·30
Stone screenings and stone dust	·58	·42
Ballast, ¾ inch and under, 6 per cent. coarse sand	·67	·33
Broken stone, 1 inch and under	·54	·46
Broken stone, 2½ inches and under, dust only screened out ...	·59	·41
Broken stone, 2 inches and under, most small stones screened out	·55	·45

6. The proportions of the ingredients of the concrete must depend upon the nature of the materials used and the work for which the concrete is required. The chief point to consider is the quality of the mortar in the concrete; this should be a ranged so as to be good enough for the work in which it is to be used, and sufficient to thoroughly fill the voids of the aggregate, with a little to spare in case of imperfect mixing.

7. The following will give a good idea of proportions that may be adopted in various conditions :—

TABLE XXXIII.

———	Cement.	Lime.	Sand.	Broken stone.	Shingle.	Quarry lamps.
Ordinary situations ...	1	1	2 2½	4 to 5 2½ to 3	......	......
Concrete Blocks for:						
Manora breackwater ...	44	......	180	......	252	144
Bombay harbour works ...	1½	......	3	4	5	......
Sea works (according to Sir Alen Render).	1	......	2	3	......	Less than ½ T.
Rawalpindi Jail walls ...	......	12	29 (Surkhi).	......	100	......

8. The concrete shall be of such proportion and such nature as shall be specified by the Executive Engineer, with due regard to the propose for which it is to be used.

9. The concrete shall be mixed on a special platform floored with bricks, iron sheeting, etc., so as to keep the materials clean.

10. No more concerte shall be mixed than can be laid in place and rammed the same day, and when Portland cement is used it must only be mixed as it is laid, as the cement begins to set at once. It should be noted that the initial setting time for Portland cement according to the British Standard Specification shall not be less than 30 minutes and that most brands of cement manufactured in India have an initial setting time of 1½ hours to 2 hours under good conditions. Hot damp weather is liable to accel rate the setting.

11. The concrete shall be laid in the work in layers and shall be well rammed with heavy wooden or iron rammers, but not to such an extent as to bring the mortar upon the surface. Concrete should on no account be rammed after it had commenced to set. If one layer of concrete has set, it requires more than simply scoring with lines and wetting to give proper adhesion to the next layer. Before the next layer is laid on it, time must be given for the lower layer to set prop rly. When this is done the surface must be well picked over with a pick and all loose scum removed by brushing with a hard brush and plenty of water. Before laying the next layer of concrete a layer ½" thick of cement and sand mortar (proportions 1 cement, 2 sand) should be spread on the surface. It will be well also to test the concrete from time to time by picking up small portions to make sure that a proper set has taken place. Concrete shall not in any case be thrown from a height of more than 6 feet when depositing it, as it tends to cause the heavier materials to fall to the bottom.

12. If the lime does not fill all the spaces between the stones and cream to the surface, the top of each layer is to be grouted with thin mortar before the next layer is spread.

13. When concrete is used in a coffer-dam or trench full of water, it must not be shovelled in, as the lime will be washed out of it in its descent through the water, but lowered gently by means of a box or basket containing it, which can be overturned when it reaches the bottom so as to deposit the concerte.

14. Unless otherwise specified, the rates entered in the schedule are to include the cost of mixing, lifting, throwing, placing, ramming, watering, wheeling, planks, barrows, tools, and all appliances required to complete the concrete in position.

15. Any material pronounced to be inferior or worthless shall be removed at the contractor's expense from the site of the work within 24 hours after witten intimation to that effect has been given by the Executive Engineer.

CONCRETE OF LIME, MORTAR, SHINGLE AND BROKEN STONE.

Specification No. 25.

1. **Proportions.**—The mortar shall generally consist of two parts of sand to one of lime, and the usual proportions of concrete (unless otherwise specified) shall be :—

Metal or broken stone ...	...	... 2 parts	6 parts.
Shingle or large gravel	...	... 2 ,,	
Pebbles or small-sized gravel	...	... 2 ,,	
Mortar ...	...	... 3 parts.	

N.B.—In walls of buildings or superstructures the concrete of the walling shall be of the components specified, except at the faces where for two inches in thickness the broken stone should be omitted.

2. Mixing.—The broken stone and gravel must be perfectly clean and free from all impu ities, before being mixed with the mortar, and shall be thoroughly wetted before mixing. The matrials shall be thoroughly incorporated by being turned over and over backwards and forwards several times, or until every part of the stone and gravel is sufficiently coated with mortar.

3. Laying.—The concrete must always be used while quite fresh. It shall be *laid* (*not thrown*) in layers not exceeding six inches in thickness, and shall be well and quickly rammed with heavy wooden or iron rammers, until the mortar creams up to the surface.

The concrete laid should not be of too fluid a consistency; after it has been mixed, no more water should be added, but the surface during and after consolidation must be kept damp, and in laying consecutive layers, the lower course should be well watered and made rough before the upper is laid.

For Rate Abstract see pp. 333 and 334.

Lime concrete with broken brick aggregate.

Proportions.—(1) The usual proportions (unless otherwise specified) are :—

Slaked lime	... 1 part	Mortar.
Clear sand	...1¼ parts	
Broken brick aggregate	... 5 parts	

(2) Broken brick aggregate must be obtained from thoroughly burnt bricks. The size of the aggregate shall be from 1½″ to 2″ generally, and for mass concrete may be 2½″ gauge.

(3) Mixing as in specification 25.

(4) This concrete should not be rammed with heavy iron rammers as the brick aggregate is crushed into powder thereby.

(5) Additional water should be sprinkled on the concrete while ramming, as fresh fractures in ramming, cause absorption of water.

(6) The ramming must be lightly and rapidly done, as this concrete usually hardens quicker than metal aggregate concrete.

Lime-Laterite Concrete

Proportion.—(1) The usual proportions, unless specified otherwise, shal be :—

Lime slaked sand	... 1 part.
Sand	... 2 parts.
Laterite aggregate	... 3 parts.

(2) The aggregate shall be such as to pass through a 2″ diameter ring, and shall be broken from selected blocks or a red colour, hardened by exposure to the atmosphere, for say about a month or more if possible.

(3) Mixing and laying as for concrete of broken stone, gravel and lime mortar.

Lime-cement concrete.

Proportion.—The proportions of the mortar for this concrete shall be as specified, according to the purpose for which the concrete is to be used. Usually for moderately wet foundations the proportions of cement by volume is one-fifth that of the lime in the mortar. For stronger work as in arc ing, this proportion is one-third. The volume of the aggregate, is usually 2 to 2½ times the volume of sand in the mortar, and the aggregate may be hard-burnt brick, metal, or shingle as specified.

Mixing.—The aggregate previously wetted, shall be evenly spread over a clean non-absorbent level platform, and the mortar will be evenly spread on it. The mass will then be thoroughly mixed by turning over and over, till every piece of the aggregate is well-coated. Usually no extra sprinkling of water is necessary if the aggregate is well-wetted.

Keeping.—The concrete must be used generally immediately after mixing, but if for any reason this is not possible, it should be kept shaded and covered with damp gunny bags. No concrete which has begun to set shall be allowed to be used.

For other details of laying, ramming, etc., see general specification above.

Cement Concrete.

General observations.—Much greater care is required in the preparation of cement concrete than was considered necessary in the case of lime concrete. This is so, for the following reasons :—

(1) At best, lime is a non-standardized material and its qualities vary widely from place to place, so that for all but very important works such as reservoir dams, it was not worthwhile carrying out tests as regards its strength.

(2) Lime mortar sets slowly, and any slight variations in the interval between preparation of the mortar and mixing concrete, or in the amount of water used in mixing, had not any marked deleterious effect.

(3) Lime is fairly cheap and at small cost a larger quantity can be added to the aggregate to improve quality.

In all these respects, cement concrete differs markedly. Cement itself is a strictly standardized material, that can always be depended on to give a certain minimum strength at a certain age. It is also a very unstable material, extremely greedy for water and taking it even from the moist atmosphere, and its use, immediately after water is added, is important. It is a costly material, and it pays to take trouble over such factors as the exact amount of water for mixing, and the proper grading of the aggregates, curing, etc. It lends itself to a wide range of uses for which different strengths etc. are necessary, and different mixes have to be devised.

Good concrete has three fundamental characteristics namely, strength, durability and finally economy. The object of proportioning concrete mixes, is to secure *economical* concrete of the required strength and durability. Generally for any particular aggregates and methods of mixing, placing, and curing, the strength of the concrete depends solely upon the water-cement ratio, whereas economy depends, upon the amount of aggregate which can be added, whilst maintaining the consistency which renders the concrete workable.

Water-Cement ratio.—Laboratory experiments have demonstrated, that the quantity of water in a mix, determines its strength, and that there is a ratio of the volume of mixing water to the volume of cement which gives maximum strength to the concrete. This is the water-cement ratio theory and the curve below shows the effect of mixing water (in terms of water-cement ratio), on the strength of concrete. The right hand line is for concrete, where rigid control of the mixture is maintained, the other curve is for average conditions. For a desired strength of concrete the water cement ratio can be read off from the curve.

"Fineness modulus" method of proportioning aggregates.—With the water-cement ratio determined, the next step in the design of a mix is the selection of proper-proportions of cement and aggregates. This proportioning is for the purpose of obtaining the desired workability at the least cost. Grading of the aggregates is a prime requisite for economy as well as water tightness. The "fineness modulus" for a given aggregate, is the sum of the *percentages* left on each sieve (by weight). For sand or fine aggr gate, a 100 oz. sample is passed over a set of sieves of the following numbers and size of openings :—

Sieve No. ...	100	50	30	16	8	4
Clear opening (square mesh) in inches.	0·0059	·0117	0·0232	0·0469	0·0937	0·187

The ozs. left on each sieve are determined, and the total of all sieve leavings is divided by 100, to obtain the fineness modulus. For coarse aggregates a representative sample of 100 lbs. is used and similarly passed over sieves as above and in addition over sieves having square meshes and clear openings ⅜″, ¾″ and 1½″. The weights left on the sieves are ascertained and totalled as for sand and divided by 100 to obtain the fineness modulus.

Most aggregates with similar characteristics and same fineness modulus require about the same amount of water for the same workability, and produce concrete of the same strength. Since coarse aggregate exposes less surface, volume for volume, than fine aggregate, the greater the ratio of coarse aggregate to fine aggregate, consistent with the desired workability, the less the water required for the mix, and since the water-cement ratio is predetermined the less the cement necessary for the requisite strength. There is however a limit to which the coarse aggregate ratio and thus the fineness modulus can be increased and the table below indicates the maximum values for different conditions.

Cement to aggregate.	Size of aggregate.							
	No. 8 sieve.	No. 4 sieve.	⅜″	¾″	1″	1½″	2″	3″
1 : 9	2·45	3·05	3·85	4·49	4·75	5·15	5·55	6·00
1 : 7	2·55	3·20	3·95	4·50	4·90	5·30	5·70	6·15
1 : 6	2·65	3·30	4·05	4·60	5·00	5·40	5·80	6·25
1 : 5	2·75	3·45	4·20	4·75	5·15	5·55	5·95	6·35
1 : 4	2·90	3·60	4·40	4·95	5·35	5·75	6·15	6·60
1 : 3	3·10	3·90	4·70	5·25	5·65	6·05	6·45	5·90
1 : 2	3·40	4·20	5·05	5·65	6·05	6·45	6·85	7·30
1 : 1	3·80	4·75	5·60	6·25	6·65	7·10	7·50	7·95
	Sand or gravel.		Broken or crushed stone.					

If crushed stone screenings, are used for fine aggregate, deduct 0·25 from the values.

Workability.—The proportioning of aggregates was stated to be necessary, to obtain the desired workability at the least cost. This workability, is a relation between the nature of mixed concrete and the effort required to place and finish it so that a truly dense concrete is obtained, with the minimum cost of materials *and labour.*

Consistency.—Circumstances however dictate the consistency, that is, the fluidity of a mix. Thus for reinforced work the amount of water must be such that the mixture will flow easily under and around the metal reinforcement. Standards of consistency are indicated by the slump test.

Slump Test for Cement Concrete.

No definite measure of consistency and workability of concrete has yet been devised but the slump test affords a useful indication of both these properties. A slump test is no absoute measure of consistency because it does not distinguish between the character of mixes For example a harsh course misxture cannot be said to have exactly the same consistency as one with a large proportion of sand even though they have the same slump.

When the correct mixtures and proportions have been ascertained the slump test however will prove a useful indication on the work if any change has occurred in the character of the materials being used, and also any change in the water content of the aggregates.

The standard slump mould is shown in the diagram and also the size of the sheet of metal required to make the mould.

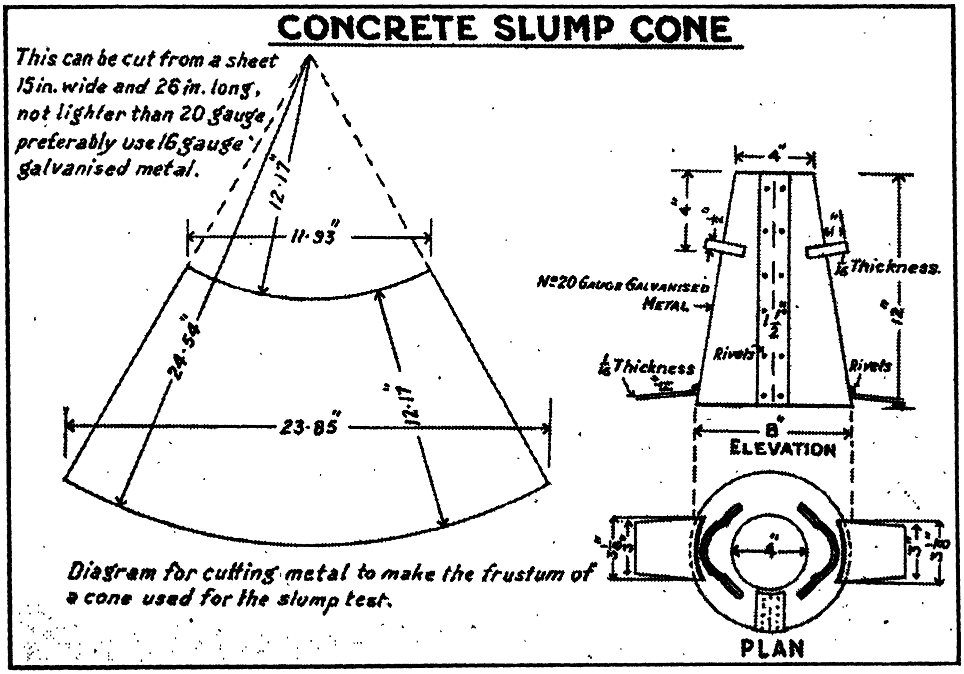


Diagram for cutting metal to make the frustum of a cone used for the slump test.

The method of carrying out a slump test should be as follows :—

The mould shall be placed on a flat non-absorbent surface such as a smooth plank or slab of concrete, and the operator shall hold the form firmly in place by standing on the foot pieces. The mould shall be filled to about one-fourth of its height with concrete which shall then be punned, using exactly 30 strokes of a ⅝ inch rod 2 feet long, bullet nosed at the lower end.

The filling shall be completed in successive layers similar to the first and the top struck off so that the mould is e actly filled. The mould shall then be removed by raising it vertically, immediately after filling. The moulded concrete shall then be allowed to subside and the height of the specimen measured.

The consistency shall be recorded in terms of inches of subsidence of the specimen during the test which shall be known as the slump.

Slump = 12 *minus* inches of height after subsidence.

The following slumps are recommended for different types of concrete :—

Class of Concrete.	Maximum Slump Inches.	Class of Concrete.	Maximum Slump Inches.
Mass concrete ...	2	Roads and Pavements—	
Reinforced Concrete—		Hand finished ...	4
Thin vertical sections ...	6	Machine finished ...	1
Heavy sections ...	2	Mortar for Floor Finishing	2
Thin confined horizontal sections ...	8		

Slumps recommended for different types of concrete :—

Mass Concrete :

Foundations	... 1″ to 2″
Piers (with plums)	... 1″ to 4″

Reinforced Concrete :

Beams	... 4″ to 6″
Slabs	... 4″ to 6″
Walls	... 5″
Columns	... 3″ to 5″

Road slabs :

Foundations	... 1″
Bottom layer	... ½″ to 1½″
Single layar	... 1″ to 2″

Bridge work :

Arches	... 4″ to 6″

Design of a Concrete mixture.

Date.—(1) Strength of concrete in compression at 28 days, is determ ned by the nature of the work. This in turn determ nes the water-cement ratio.

(2) The consistency of the concrete, is fairly indicated for each mix by the slump est. The slumps for the concrete, are determined by the nature of the work.

(3) The fineness moduli of the available materials : –For each type of cement-aggregate ratio, there is an optimum fineness modulus (combined) as shown in Fig. B.

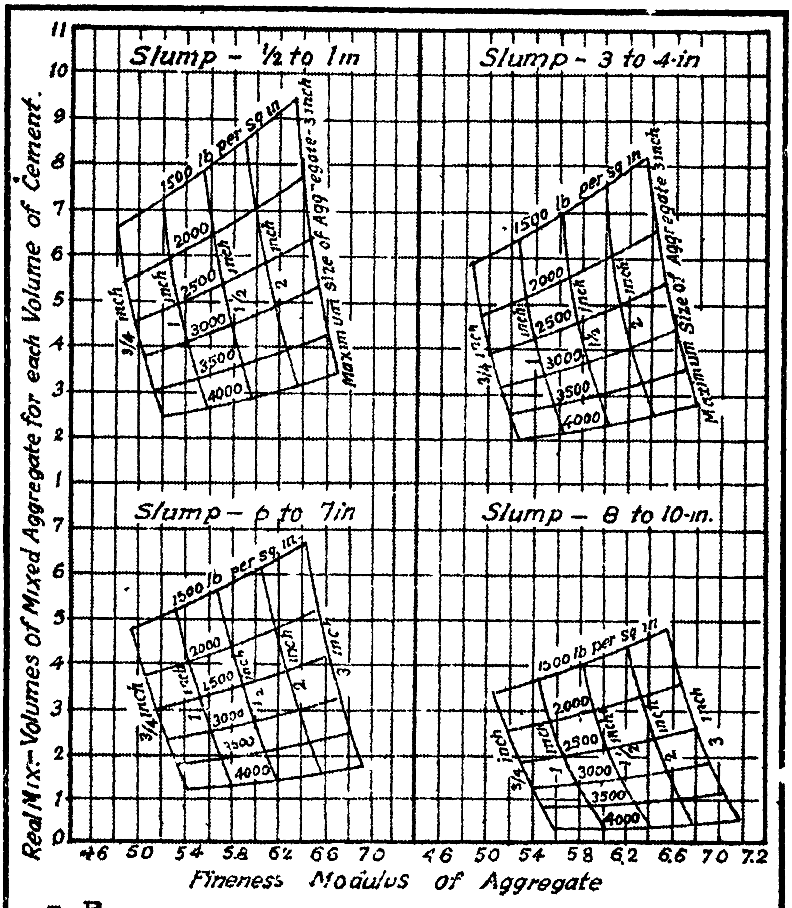


FIG. B.

Steps in design.—

Suppose that for the work in question, a concrete with a compressive strength of 2,000 lbs. per square inch at 28 days is required, and that consistency is represented by a slump of 6″ to 7″. From Fig. A (curve B) we see that a water cement ratio of 0·90 is indicated.

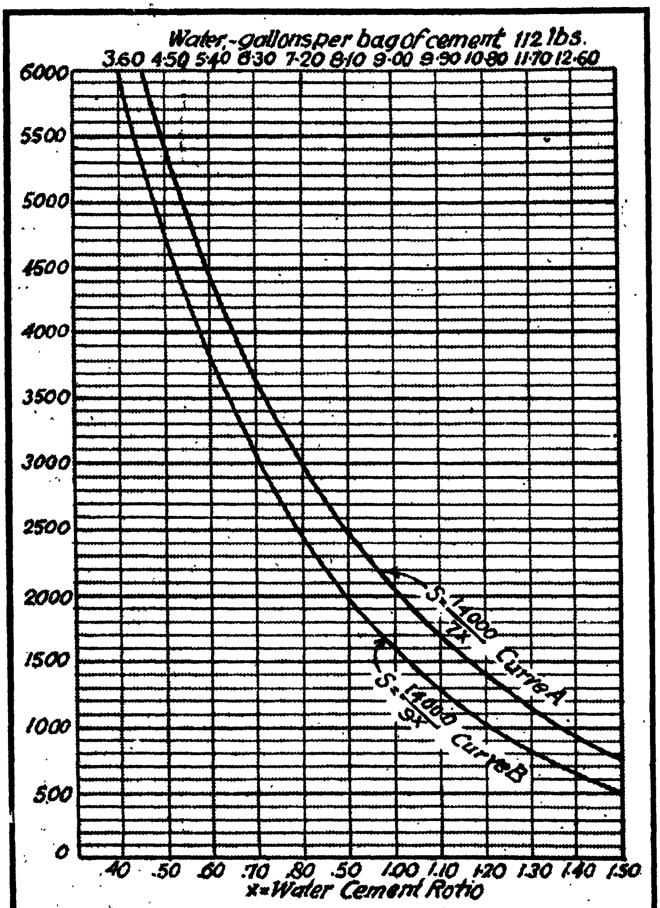


FIG. A

The sieve analyses of the available fine and coarse aggregate, are, say 2·57 and 6·90 respect vely. The sieve analysis also gives the maximum size of aggregate, (the maximum size of the aggregate is the coarsest size forming at least 15 per cent. of the total coarse aggregate). Suppose this size is 1½″.

Figure B shows that for the given conditions, i.e., a 2,000-16 concrete, 6″ to 7″ slump, 1½″ maximum aggregate size, the optimum fineness modulus 5·8, and the mix, i.e., volume of mixed aggregate to volume of cement, is 4·4 : 1.

The percentages of fine and coarse aggregates, to give a fineness modulus of 5·8 with the given materials, are :—

$$\text{Fine aggregate percentage :—}100 \times \frac{Mc\ M}{Mc\text{-}Mf} = 100 \times \frac{6\cdot 90-5\cdot 80}{6\cdot 90-2\cdot 57}$$

$$= 100 \times \frac{1\cdot 10}{4\cdot 33} = 25\cdot 4, \text{ say 25 per cent.}$$

and the coarse aggregate percentage = 75 per cent., by weight.

If the weight of a unit volume of dry coarse aggregate is say 110 lbs , and that of a fine aggregate 95 lbs., and that of a unit volume of the combined aggregate in the ratio 25 : 75 or 1 : 3 as obtained above is 120 lbs., the ratio of the volume of the mixed aggregate, to the sum of the volumes of the two aggregates is :—

$\frac{0\cdot25 \times 95 + 0\cdot75 \times 110}{120} = \frac{106}{120} = 0\cdot88$; and the mix 1 : 4·4 expressed in terms of volumes of cement, fine aggregate, coarse aggregate, is :—

$$1 : \left(\frac{4\cdot40}{0\cdot88} \times 0\cdot25\right) : \left(\frac{4\cdot40}{0\cdot88} \times 0\cdot75\right) \text{ or } 1 : 1\cdot25 : 3\cdot75.$$

The field mix will depend, on the amount of moisture present in the aggregates. If the unit weights of the field materials are say 90 lbs. for fine-aggregate, and 100 lbs. for coarse-aggregate, the field mix by volumes will be :—

$$1 : \frac{95}{90} \times 1\cdot25 : \ 1 \times \frac{110}{100} \times 3\cdot75 \text{ or}$$

$$1 : \ 1\cdot33 ; \ 4\cdot13.$$

The quantity of free water in the aggregates, (i.e., water remaining after the aggregates have absorbed to capacity), is to be deducted, from the quantity of water required according to the water-cement ratio.

Sometimes, the mixture as obtained above is too rough or harsh to work easily. A smoother mixture can be obtained, by additional sand or and also cement and water in the required ratio. In the next batch, the fine aggregate can be increased to the above extent.

For unimportant works where small quantities of concrete are used, the procedure of proportioning as above indicated, may be unnecessarily complicated. In such cases, a good rule for calculating the quantity of water required, is to take 28 per cent. by weight of cement, and 4 per cent. by weight of dry aggregates. Any free water in the aggregate, should be deducted from the quantity thus arrived at. In proportioning the materials, i.e., cement, fine aggregate, and coarse aggregate, (as available, without any sieve tests) a fairly useful method, is to find the voids in the coarse and the fine aggregates, and to fix the proportions in such a way, that the fine aggregate will be sufficient to fill the voids in the coarse aggregate, and the cement paste sufficient to fill the voids in the fine aggregate, with a margin for uneven mixing and variations in material. For example suppose the voids in the fine aggregate are 33 per cent., and in the coarse aggregate 45 per cent. The ratio should not be 1 : 3 : 6·7 but somewhere about 1 : 2½ : 5.

For absorbent coarse aggregates like broken brick, or when a dusty fine aggregate like stone dust is used, additional water will be necessary. It is better to wet the brick aggregate, the previous day, when it will be just damp next day, The quantity of stone dust should be strictly limited, and should not exceed 10 per cent., when the fine aggregate is sifted on a sieve of 50 meshes per inch.

If sand is used as fine aggregate in a cement mortar or cement concrete, care should be taken to see that it is dry, as any moisture in it affects the quantity of water to be used for forming cement paste. It also results in the sand ' bulking " i.e. increasing in volume, and thus disturbing the grading of aggregate. The bulking for fine sand may be as great as 33 per cent. and for ordinary sand 23 per cent. To determine the correct dry volume of damp sand, a sample is placed in a graduated container and well packed. It is then flooded, till, a film of water glistens at top, and the container gently shaken. The decrease in height gives a measure of the bulking in the sample.

On all important works test cubes of cement concrete are made, from the material prepared, as a check on strength. The method of preparing these test cubes is given in detail in the standard specifications and codes of practice for Road Bridges in India, prepared under the auspices of the Indian Road Congress.

Cement Concrete.

Specification No. 26

(1) The coarse aggregate and the fine aggregate for this concrete shall be the hardest, cleanest, and most durable, material available in the neighbourhood. and shall be free from all deleterious matter such as dust, lumps of clay, soft and flaky pieces, shale, alkali, organic matter, loam, etc. The materials shall be passed by the Executive Engineer or his agent.

(2) The proportioning of coarse and fine aggregates shall be that specified by the Executive Engineer, the proportions being determined by the ' fineness modulus " method on important works when a large quantity of concrete is necessary, or by the ' void " method when only small batches are to be used.

(3) The proportion of cement, and the proportion of water to the cement or the water-cement ratio, will be as specified or as ordered by the Executive Engineer, having regard to the nature of the work and the strength to be developed.

(4) **Mixing.**—For large quantities, mixing should be invariably done in concrete mixers. For small batches hand mixing may be permitted by the Executive Engineer. In the latter case mixing of the materials shall be done as quickly as possible, after water is added, so that every piece of aggregate is uniformly coated by cement paste.

(5) The concrete must be used immediately after it is prepared, and in no case shall it be used after the cement has attained a final set. If extra water has to be added to obtain the requisite workability, it may be taken that the cement has set. Generally concrete which has been standing more than an hour shall not be permited to be used.

(6) **Laying.**—The concrete must be laid gently, (not dumped from a height) so as not to permit of segregation of aggregates.

(7) **Consolidation** shall be rapidly carried out, sufficient labour being employed to permit of ramming, rodding, spading, etc., being completed within as short a time as possible, causing the mortar to cream up. In no case shall he ramming be prolonged after the cement has begun to take its initial set.

(8) **Curing.**—As soon as the concrete has set sufficiently i.e., after about an hour of laying, the surface must be protected from rapid drying out by being covered with wet sand, wet gunny or where possible by forming shallow pools of water on top. The setting shall be continued for at least 10 days, usually two to three weeks and where possible (as in precast articles) for longer periods.

(9) **Pointing and Patching.**—As soon as the concrete is exposed on removal of forms, the surface should be carefully examined, depressions filled up, and chipped portions remade. The mortar must be the same as used in the concrete, preferably being taken from a batch.

(10) Surface-treatment.—It is sometimes necessary to harden the surfacing of concrete, as in road slabs, footpath and floor slabs. etc., to increase the wear-resisting properties. After completion of the curing period, and as soon as the cement has sufficiently dried out, sodium silicate shall be applied. P. 84 grade sodium silicate shall be mixed with water, in the proportion of 1 part silicate to 4 parts water. This mixture, shall be applied with a soft broom or mop, evenly over the whole surface. Twenty-five hours after the first coat, a second coat shall be given, and after a similar interval a third coat.

(11) The decision of the Executive Engineer or his agent shall be final in all the matters specified above.

Specification for blocks of Portland cement concrete used on harbour works in Bombay.

The concrete blocks are to be of the dimensions shown on the drawings perfectly true, plumb, and square in the sides and angles.

Each block to be provided with through Lewis holes, with recesses for the Lewis properly protected with hard wood bearing pieces.

The concrete of which the blocks are made is to be composed of five parts by measure of shingle, four parts of broken stone trap or basalt of approved quality broken into cubes that will pass through a 2-inch ring, three parts of clean sand, and one and a half parts of Portland cement. All the ingredients should be measured separately in a frame or box.

The whole to be thoroughly incorporated and mixed by the addition of sufficient perfectly clean water to work the whole into a proper consistency to the satisfaction of the Engineer. The mixture to be turned over twice dry, and the water added through the rose of a watering can. The mixture is then to be turned over three times, wet, with a shovel.

All Portland cement to be used fresh, and any remaining over after the day's work shall not on any account be used on the work.

The concrete to be filled into the moulds and rammed as may be decided.

Specification for steam-ground mortar used for harbour works.

The mortar to be used in the work (unless where specially specified to be of Portland cement) is to be of two kinds, namely :—

Plain mortar,

and

Mixed mortar.

The plain mortar is to be composed of one part of lime and one part of clean sand, but hese proportions may be varied at the option of the Engineer so as to produce in his opinion a first class mortar.

The mixed mortar shall be composed as above with the addition of one-tenth dart of Portland cement before grinding.

In both cases the lime and sand are to be first gauged in boxes of a size and shape approved by the Engineer, then thoroughly mixed in a dry state on a clean platform, and then ground with clean water in pans driven by steam power for at least 200 revolutions.

Mixed mortar must be used within 24 hours of mixing, and, as far as practicable, well within the setting time of the cement used. Any left unused after that time must not be used in the work.

The Engineer shall decide what portion of masonry shall be built in plain and mixed mortar respectively.

Portland cement mortar shall be composed of one part of Portland cement and one part of sand, unless otherwise specified.

LATERITE CONCRETE.

Specification No. 27.

1. **Composition.**—The concrete shall be composed of 1½ parts laterite metal, broken so as to pass through a 2-inch ring, mixed with 1 part lime mortar of 1 lime to 2 sand.

2. **Mixing and laying.**—The mixing and laying shall be similar to that for concrete of broken stone and lime.

For Rate Abstract see p. 334.

STONE MASONRY.

General.

1. The stone to be used will be obtained from the quarries selected by the Executive Engineer. It shall be hard, durable and tough, and each stone must be laid, in the work, on its natural quarry bed.

2. Dumb-bell shaped bond stones or headers are useless and shall not be allowed on the work.

3. Jambs for door and window openings shall be formed with quoins of the full height of the course. The quoins shall be in breadth at least 1½ times the depth of the course, and in length at least twice the depth. For door openings 3, and for window openings 2, of these quoins shall be stones of the full thickness of the wall. Door and window frame posts shall be let into ½ inch chasis in the quoins.

4. All lintels and other stones, which are not to be plastered over, should be of the full width of the walls, including the thickness of the plastered face or faces.

5. Large flat stones are to be laid in all cases under the ends of girders, roof trusees, etc., their dimensions being invariably as specified by the Executive Engineer.

6. In all batter retaining, and breast walls, the beds of the stones, and the plan of the courses, to be at right angles to the batter.

7. Dowels and cramps to be of the hardest and toughest stone procurable, or of copper and also set in pure lime. Iron cramps are not to be used.

8. All mouldings to be worked to templates cut out of sheet zinc.

All cut stone work shall be moulded or chamfered as may be ordered.

All stone copings and cornices shall be paid for as cut stone work at so much per cubic foot.

All string courses and drip mouldings shall be moulded or chamfered as may be ordered.

9. All fine dressed work shall be protected by means of wood boxing immediately after fixing, at the contractor's expense.

10. By fine dressing is meant the finest surface which can be given to a stone with a chisel and without rubbing.

If there is any fine dressed work on the job a sample dressed stone should be prepared for approval and it will be kept on the work in charge of the maistry after being passed and initialled by the Executive Engineer or the Sub-Divisional Officer.

11. Samples similar to above should be prepared for medium and roughly dressed work also.

12. An average sample prepared face stone should also be supplied and kept on the work after being passed and initialled by the Executive Engineer or the Sub-Divisional Officer.

13. All copings to be dwelled or cramped, if so ordered or specified by the Executive Engineer, and the courses of pillars, skew-backs and similar work to be joggled to the stone below if specified.

14. The mortar shall be of proportions specified by the Executive Engineer.

15. The work is to be kept wet while in progress till the lime is properly set. On Sundays and other holidays the top of all unfinished masonry is to be kept flooded, and labourers are to be employed for the purpose. Watering is to be done carefully so as not to wash the lime out of the joints.

16. All masonry built with *surki*, or hydraulic mortar, or cement, shall be kept specially well watered.

17. Scaffolding will be double, but the ends of poles need not in this case be placed in the position of a header stone.

18. Should the mortar perish, that is, become dry, white, or powdery, through neglect of watering, the work must be pulled down and re-built at the contractor's expense, or, should the contractor fail to water the work to the satisfaction of the officer in charge of the work, the latter may supply the requisite men to water the work properly and charge the cost to the contractor.

19. Where practicable, the whole of the masonry in any structure will be carried up at one uniform level throughout, but where breaks are unavoidable, the joint will be made in good long steps, so as to prevent cracks arising between the new and old work. All junctions of walls to be formed at the time the walls are being built, and cross-walls to be carefully bonded into the main walls.

20. Where no definite mention is made of pointing, the exposed joints shall be finished as described on page 173 in paragraphs 1 to 4 under "pointing, general" and shall be well rubbed with a piece of bent $\frac{3}{8}''$ iron rod.

21. String-courses and drip mouldings shall be measured and billed at a rate per running foot.

22. All rates for arching shall include the cost of centerings for all spans up to 12 feet inclusive; for spans over that the centering shall be separately paid for.

23. The string courses shall tail at least 9″ into the work with a full bearing for at least 4″ and shall be paid for at a rate per running foot along the course. They shall also be throated on the underside, if so ordered.

24. Stone steps shall be measured and paid for as cut stone work, but only the stones forming the treads shall be so measured and paid for, the hearting being measured and paid for as uncoursed rubble.

25. All rates for masonry are inclusive of quoins and jambs.

26. All masonry shall be washed down on completion and all stains (lime or otherwise) removed from the face.

DETAILED SPECIFICATIONS OF STONE MASONRY.

Note.—*It will be necessary in utilizing the following specifications to add such paragraphs of the general specifications as may be required in each case, such as provision for watering, etc.*

ASHLAR-FINE.

Specification No. 28.

1. **Dressing.**—Every stone shall be fine-tooled on all beds, joints and faces, full true and out of winding if the surfaces are plane, or to uniform curves or twists if required by the design.

2. **Thickness of joints.**—The stone shall be set in fine mortar, the beds or joints being in no case more than $\frac{1}{8}$ inch in thickness, and all visible edges shall be quite free from unsightly chippings. Each stone will be struck with a maul, when laid, to bring it to a solid bearing, both as to bed and joint.

3. **Size of stones.**—The stones shall be laid in regular courses not less than 12 inches in height, and all the courses shall be of the same height unless otherwise specified, but no course shall be thicker than any course below it. No stone shall be less in breadth than in height, or less in length than twice its height.

Plate VIII

Ashlar Fine.

Fig. I

Elevation.

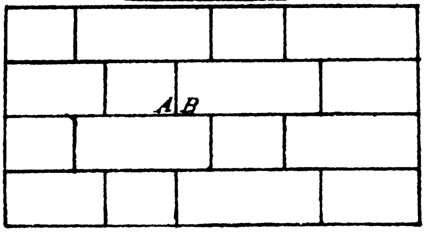


Fig. II

Section.

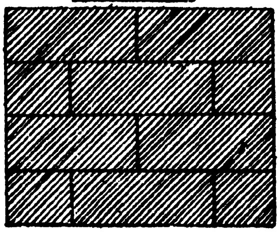


Fig. III

Plan, 1st Course.

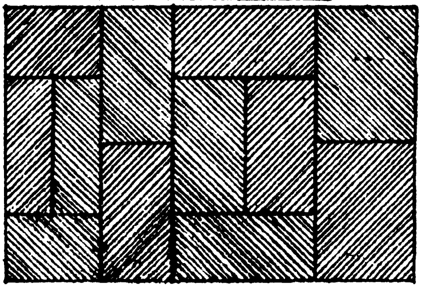
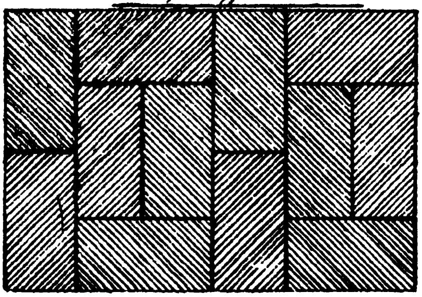


Fig. IV

Plan, 2nd " Course.



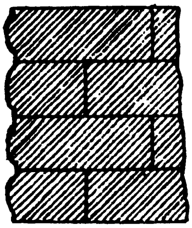
To face Page 140

Govt. Photozinco Office. Poona, 1949.

—Rock or Rustic Ashlar with Chisel draft—

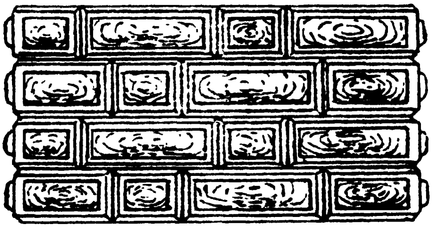
—Fig. I.—
—Elevation—

—Fig. II—
—Section—

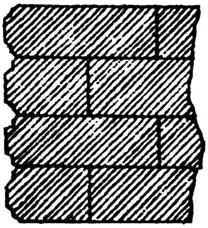


—Chamfered Ashlar—

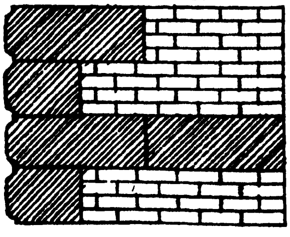
—Fig. III.—
—Elevation—



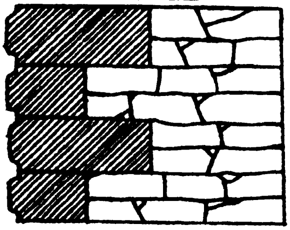
—Fig. IV.—
—Section—



-Ashlar facing-
-to Brick Work-
—Fig. V—
—Section—



-Ashlar facing-
-to coursed Rubble masonry-
—Fig. VI.—
—Section—



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4. **Bonds.**—The face stones shall be laid header and stretcher alternately (unless otherwise ordered), the headers being arranged to come as nearly as possible in the middle of the stretchers below, and the stones in adjacent layers shall break joint* on the face, for at least half the height of the course, and the bond shall be carefully maintained throughout the wall.

5. **Through stones.**—In walls 2½ feet thick and under, the headers shall run right through the wall.

6. **Courses.**—The course lines shall be horizontal, and side joints vertical throughout.

For Rate Abstract see p. 335.

ASHLAR, ROUGH-TOOLED, OR BASTARD ASHLAR.

Specification No. 29.

1. The faces exposed to view shall have a fine dressed chisel draft, 1 inch wide all round the edges, and be rough-tooled between the drafts, and on all beds and joints, which shall not exceed ¼ inch in thickness.

2. The stones shall be set in ordinary mortar. In other respects, with regard to size of stones, bond, etc., to be precisely the same as in specification for ashlar, fine.

For Rate Abstract see p. 336.

ASHLAR, ROCK, RUSTIC OR QUARRY-FACED.

Specification No. 30.

1. Shall be in all respects similar to No. 29, except that the exposed faces of the stone between the drafts shall be left rough as the stone comes from the quarry ; but no rock face or " bushing " to project more than 3 inches from plane or drafts

The drafts may be omitted altogether, except at quoins, if preferred.

For Rate Abstract see p. 336.

ASHLAR-CHAMFERED.

Specification No. 31.

Shall have the edges round the exposed face of each stone bevelled off to 45° for about a depth of 1 inch (or more, as may be specified) ; in all other respects shall be similar to No. 30.

N.B.—Nos. 28, 29 and 30 are suited for solid courses to run right through high piers or as the top of piers or abutments to carry large girders.

For Rate Abstract see p. 336.

ASHLAR FACING.

Specification No. 32.

1. The faces of stones shall be rough-tooled, rustic (with or without chisel draft, except at quoins), or chamfered, as specified for the particular work.

* Break of joint means the horizontal distance of the vertical joints of one course from the vertical joints in the courses above and below it, such as A-B, Fig. 1, plate VIII.

2. **Size of stones.**—In walls of rubble or concrete faced with ashlar, the dressing shall be as specified in No. 28, except the dressing for the backs of the stones, which may be left rough in the state they leave the quarry.

No course shall be less than 8 inches in height, or less than 18 inches in length. For courses less than 10 inches in height, the width of the stones shall not be less than 15 inches. For courses more than 10 inches in height, the width shall be not less than 1½ the height of course.

Headers shall not be less in length than the breadth of ashlar stones plus 18 inches. One-third of the length of each course to be headers, used at regular intervals.

The beds and joints of all ashlar stones to be dressed perfectly true, square and full.

The thickness of ashlar in plain walling to be as noted in the drawings, and to be measured one-third more to compensate for the extra length of headers.

3. **Dressing.**—The beds and joints shall be true and square for at least the same distance in from the face as the thickness of the course in which they occur, i.e., if 12-inch courses are specified, the beds and joints shall be dressed 12 inches; if 15-inch courses, beds, etc., shall be 15 inches.

4. **Bond.**—Bond stones shall run quite through the backing when work is no more than 2½ feet thick, or, if more, shall overlap at least 6 inches, and they shall be inserted between 5 and 6 feet apart clear in every course.

5. **How paid for.**—In work of this sort the face-work alone will be paid for as ashlar, and of those stones only so much as is dressed back, true and square on the beds and joints, ⅓ more being allowed for headers (i.e., in 12-inch courses a thickness of 16 inches from the face would be paid for as ashlar), the remainder to be paid for according to the character of the backing.

6. The height of the courses should equal an exact number of courses of brick or rubble with intermediate mortar joints, and the backing shall be carried up simultaneously with the face-work.

For Rate Abstracts see p. 337.

Note.—This class of work is suitable for face of piers and abutments of very large bridges.

ASHLAR BLOCK IN COURSE.

Specification No. 33.

Differs only from ashlar, rough-tooled, in the size of the stones. The height of the courses should not be less than 7 inches.

For Rate Abstract see p. 338.

Note.—Suitable for through courses in piers, abutments of large bridges, or for top courses of same in girder bridges, for verandah pillars, or in large buildings as barracks.

ASHLAR BLOCK IN COURSE FACING.

Specification No. 34.

1. **Size of stones.**—The height of the courses shall not be less than 7 inches and all courses shall be of the same height, unless otherwise specified, but no

course shall be thicker than any course beneath it. No stone shall be less in breadth than in height, or less in length than twice its height. All stones to be set full in mortar.

2. **Break of joint.**—Stones shall break joint at least half the height of the course.

3. **Face.**—The face of the stones to be left rough (but no projection to exceed 2 inches) without chisel draft, except at quoins, where a ½-inch draft shall be given.

4. **Joints and beds.**—The side joints and beds of all stones to be vertical and horizontal, respectively, and all stones to be rough-tooled true and square, for at least the same distance in from the face as the thickness of the course in which they occur, i.e., in a 7-inch course at least for 7-inch beds, etc., and are not to exceed ¼ inch in thickness. The back of the stones may be left rough as they come from the quarry.

5. **Headers.**—At least ⅓rd of the course shall be headers tailing into the work at least twice their height, and "through" stones shall be inserted 5 feet apart which shall run quite through the backing in walls 2½ feet thick and under for, thicker walls headers shall be laid from face to back which shall overlap each other at least 6 inches.

6. The course shall be equal in thickness to an exact number of courses of brick-work or rubble, including intermediate joints ; and the backing shall be carried up simultaneously with the face-work.

7. **How paid for.**—Only so much of the face stones as is dressed back, full true and square from face will be paid for as block in course, ⅓ being added for headers. The remainder to be paid for according to the character of the backing.

For Rate Abstract see p. 339.

FINE DRESSED CUT-STONE WORK.

Specification No. 35.

1. **Stones.**—The stones be of the kinds specified, of approved quality and colour, hard and free from defect of any kind.

2. **Dressing and joints.**—The stone shall be dressed full or to template, or as shown in working drawings. Exposed faces of the stones shall be fine chisel-dressed or rough-tooled, as may be ordered, and all joints shall be in line and close, and not more than ⅛ inch thick. All visible angles and edges to be free from unsightly chippings.

3. **Planking.**—The stones shall be covered with rough planking during the progress of the work, where exposed to damage.

SHAFTS, MULLIONS, ETC.

Specification No. 36.

The height of each stone in the column to be such as the Executive Engineer may direct, but in no case to be less than the diameter of the shaft. All joints shall be full and no hollow spaces shall be allowed. They shall be made with fine mortar, *neeru* or cement as may be ordered.

Copper pegs of adequate size to be provided at each joint where the stones of the shaft do not bind in the masonry of the walls.

STRING COURSES, COPINGS, ETC.

Specification No. 37.

(1) Copings shall be in as long stones as are easily obtained, and shall break joint with the stones of the course below. The minimum length of a coping stone, shall be 18 inches. The dressing shall be as specified.

(2) String courses shall tail into the work to such depth as is specified, or as directed by the Executive Engineer.

(3) Quoins shall be laid header and stretcher in alternate courses, and shall ordinarily be of the full height of a course, unless otherwise specified, or ordered by the Executive Engineer. They shall be fine-tooled, rustic-faced or rough-tooled, and shall be with or without chisel-drafts and chamfers as shall be specified or ordered by the Executive Engineer.

For Rate Abstracts see pp. 339 to 343.

STONE STEPS.

Specification No. 38.

1. **Dressing.**—Shall be of the exact size and shape ordered. They shall be fine chisel dressed or rough-tooled on exposed surfaces as may be directed.

2. **Support.**—Each stone shall rest at least 1½ inches on that below it. They shall have one end free or be supported at both ends.

For steps which have one end free contilevered i.e., which are out, the length fixed in the wall, shall be half the wall thickness with a minimum of nine inches. The length in the wall shall be set in cement mortar and firmly packed. Steps supported at both ends, shall rest at least six inches on the wall at either end.

3. **Centres.**—The steps should be laid on proper centres, which shall not be removed without permission.

4. Holes for balusters should be cut in the steps before they are laid.

5. **Proportion of tread and riser.**—The proportion of tread and riser should be as in the following table :—

With of tread.	Height of riser.	Width of tread.	Height of riser.
6″	8½″	11″	6″
7″	8″	12″	5½″
8″	7½″	13″	5″
9″	7″	14″	4½″
10″	6½″	15″	4″

For section of stairs, see plate XI.

For Rate Abstract see p. 343.

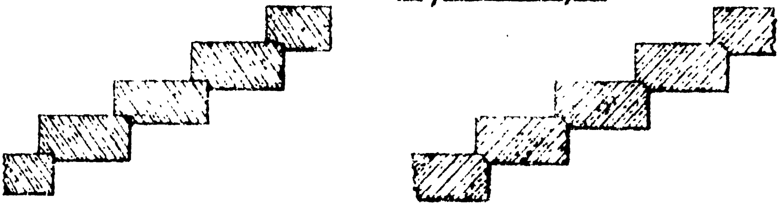
STONE STAIRS.

5. The cost depends very much on the length of the stone; only the part out of the wall should be paid for as stairs. The details for dressing and setting per running foot wil be somewhat as in Rate Abstract No. 32, p., 343, for steps of the section shown in plate X.

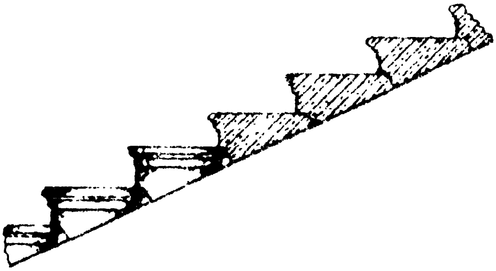
Plate X

— STONE STAIRS —

— *Square Steps* —

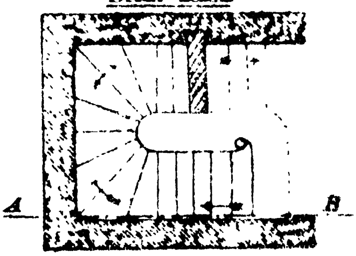


— *Spandril Steps* —

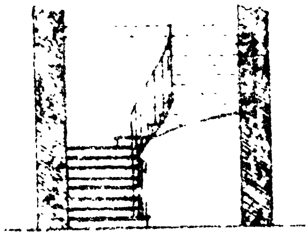


— *Step Stone* —

— *Sectional Plan of a Geometrical* —
— *Stair case* —



— *Elevation* —



— *Sectional Elevation* —
— *on line A B* —

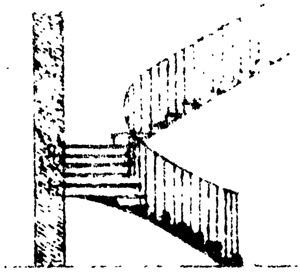


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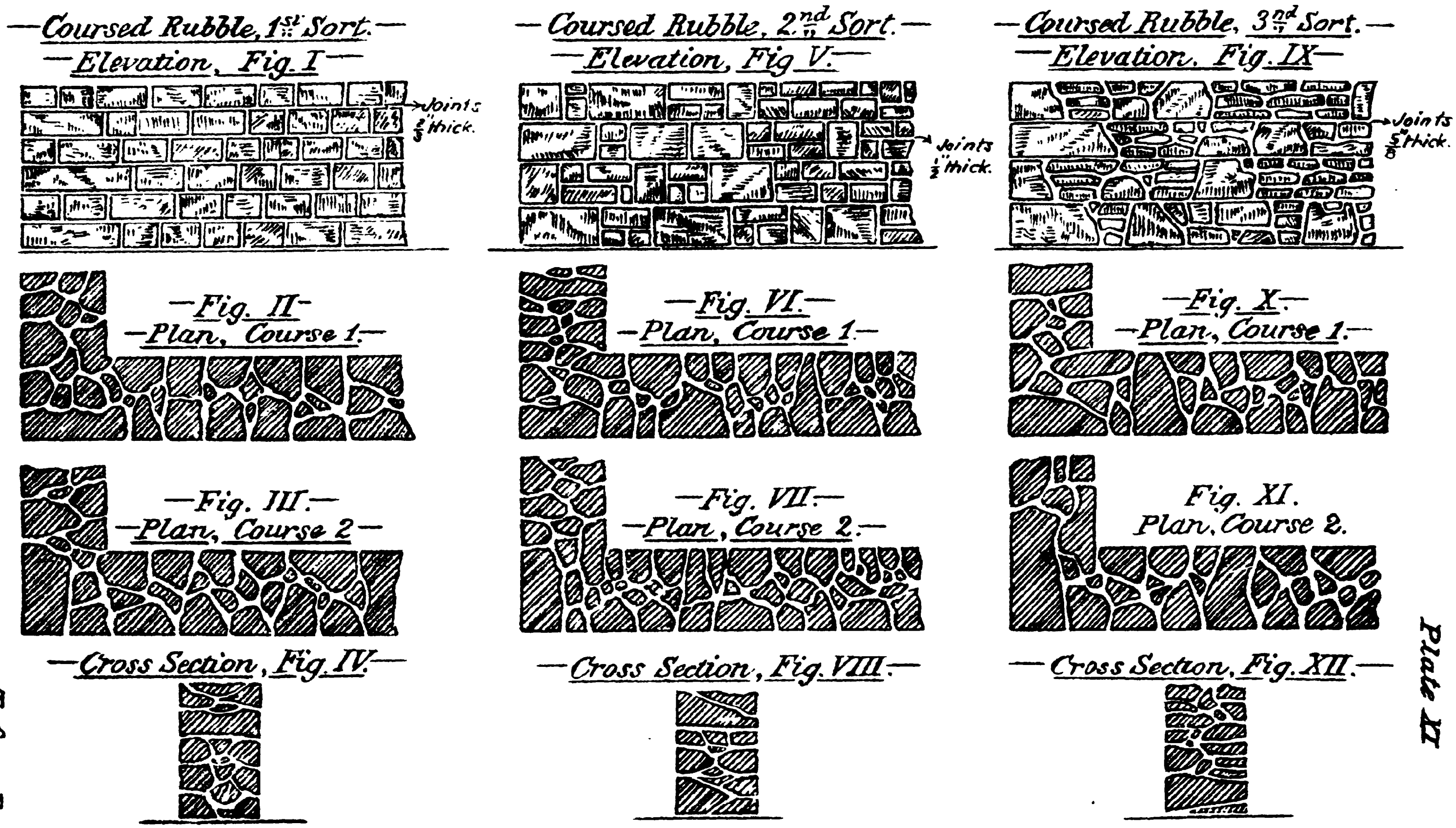
Plate XI



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RUBBLE MASONRY.

General.

The following points require special attention in all rubble work :—

(*a*) That the stones on the face have full joi ts for the s ecified distanec from the face. If not carefully superintended, masons will chip off the edges of the stones with a hammer, leaving a full joint for perhaps $\frac{1}{2}$ inch from the face only.

(*b*) That the backing is made ot fair-seized stones, and, in the case of thin walls with 2 faces, that the face stones from opposite faces bond together as far as possible. There should be more bond than is provided by the through stones. Also that the backing in thick walls bonds well with the facing. Without proper supervision the masons will build 2 face walls, each 6 to 8 inches thick, and fill in the middle with small stones.

(*c*) It is not advisable that the filling should be accurately made up to the level of each course by the use of chips. It is better that larger stones should be used in the filling, even if they are slightly thicker than the height of the course.

(*d*) Care is required to see that the proper number of headers is used in each course. It is better to specify that the headers shall be laid at certain distances in each course rather than that there should be one header to a specified area of face-work.

(*e*) Stones should be thoroughly wetted before being laid in the work and for this purpose each mason should be supplied with a vessel for wetting stone. The proper wateri g of all masonry should be carefully attended to.

(*f*) Tops of walls should be built right up to the upper surface of battens so as to leave no space for rats.

(*g*) Plinth offsets on the interior should be kept at least 6 inches below the floor level, to allow of the paving (if any) coming up to the face of the superstructure. As paving is done subsequently, this point should always receive attention.

DETAILED SPECIFICATIONS OF RUBBLE MASONRY.

COURSED RUBBLE, FIRST SORT.

Specification No. 39.

1. **Height of courses.**—The stones shall be laid in horizontal courses not less than 6 inches in height. The stones in each course shall be of equal height, and all courses of the same height, unless otherwise specified, but no course shall be thicker than any course below it. All stones to be set full in mortar.

2. **Dressing.**—The face stones to be squared on all joints and beds. The beds to be hammer or chisel-dressed, true and square, for at least 3 inches back from the face, and the joints for at least $1\frac{1}{2}$ inches. The face of the stones to be hammer-dressed, and "bushing" not to project more than $1\frac{1}{2}$ inches.

3. **Thickness of joints.**—No pinnings will be allowed on the face. All side joints shall be vertical and beds horizontal, and no joint shall be more than $\frac{3}{8}$ inch in thickness.

4. **Size of stones.**—No face stone shall be less in breadth than in height, or shall tail into the work to a length less than the height, and at least ⅓rd of the stones shall tail into the work at least twice their height, or in thick walls three times their height.

5. **Through stones and headers.**—Through stones shall be inserted between 5 and 6 feet apart in the clear, in every course, and shall run right through the wall when not more than 2 feet thick. When the work is more than 2 feet thick, a line of two or more headers shall be laid from face to back, which shall overlap each other at least 6 inches. A header shall have a length of at least thrice the height.

6. **Break of joint.**—Stones shall break joint at least half the height of the course.

7. **Quoins.**—The quoins, which shall be of the same height as the course in which they occur, shall be formed of stones at least 1½ feet long, laid stretcher and header alternately. They should be laid square on their beds, which should be fair dressed to a depth of at least 4 inches.

8. **Interior face.**—The work on the interior face shall be precisely the same as on the exterior face, unless the work is to be plastered, in which case the side joints need not be vertical.

9. **Hearting.**—Shall consist of flat-bedded stones carefully laid on their proper beds and solidly bedded in mortar, chips and spauls of stone being wedged in wherever necessary, so as to avoid thick beds or joints of mortar, care being taken that no dry work or hollow spaces shall be left anywhere in the masonry.

The face-work and backing shall be brought up evenly, but the backing should not be levelled up at each course by the use of chips.

For Rate Abstract see p. 344.

Note.—This class of work is suitable for the larger class of buildings, and for piers and abutments of ordinary bridges.

COURSED RUBBLE, SECOND SORT.

Specification No. 40.

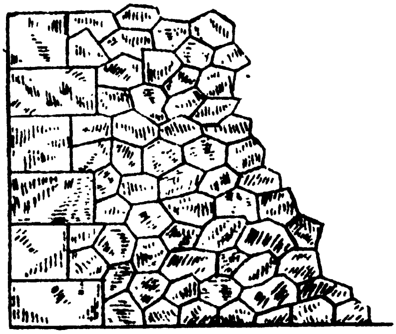
1. **Description of work.**—This description of masonry shall consist of a facing of hammer-squared stones, with a backing of rubble masonry built in courses to the same height as the facing, and bonding properly with it. All stones to be carefully set full in mortar.

2. **Face-work.**—The face-work shall be as specified for coursed rubble, first sort. The stones in each course *need* not, however, all be of the same height, but not more than two stones to be used in the height of the course, and the joints may be as much as ½ inch in thickness, the latter b ing the chief criterion for classification. No course shall be of greater height than those below it.

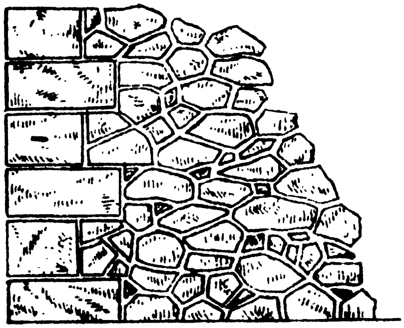
3. **Hearting or backing.**—The backing shall consist of uncoursed rubble masonry, which shall be carried up simultaneously with the facing, the face stones being backed as soon as laid, but each course need not be completely levelled off.

Plate XII

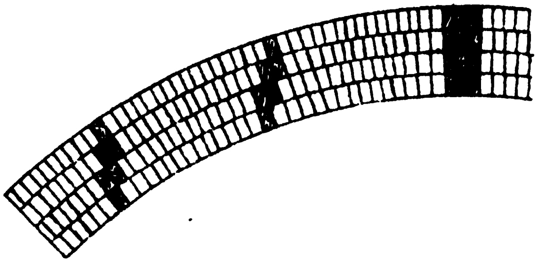
—*Elevation*.—
—*Random Rubble, 1st Sort*.—



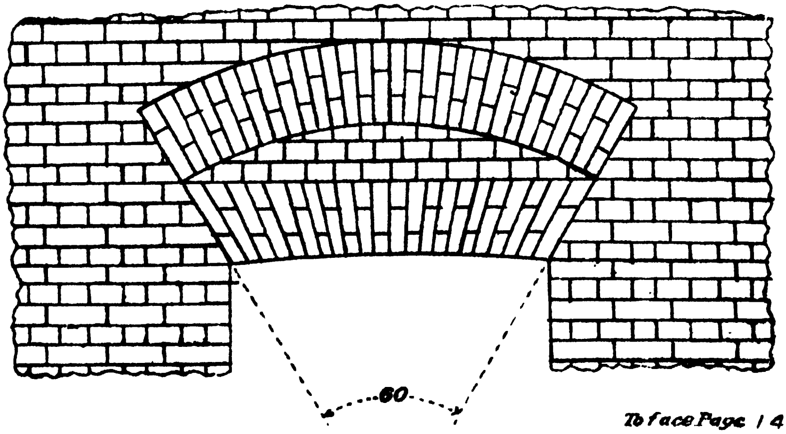
—*Elevation*.—
—*Random Rubble, 2nd Sort*.—



—*Brick Arch*.—



—*Flat and Relieving Arches*.—



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4. In all respects, other than those specified above, the facing and backing shall correspond with specifications for coursed rubble, first sort, and uncoursed ubble, respectively.

For Rate Abstract see p. 345.

COURSED RUBBLE, THIRD SORT.

Specification No. 41.

1. **Description of work : Headers and joints.**—In each course, headers hammer-dressed, of the entire height of the course are to be placed 5 feet apart, each header to be of a breadth not less than the height, and to tail into the work at least 3 times its height. Between the headers, each course is to be built of smaller stones not less than 2 inches thick, of which there may be two or three in the height of the course. These stones need not be dressed, but should be as flat-bedded as possible ; the side joints need not be vertical, but no side joint shall form an angle with a bed joint sharper than 60°. No stone shall be less in breadth or length than its height, and care must be taken to make the stones in the different courses break joint. All stones to be set full in mortar. The thickness of joints may be ⅝ inch.

2. **Through stones.**—In walls of two feet and under, the headers to be through stones. In thicker walls a line of headers to be laid from face to back which shall overlap each other at least six inches. Care should be taken not to place the headers of successive courses above one another.

3. Quoins etc., as in coursed rubble, first sort.

For Rate Abstract see p. 346.

Note.—This class of work is fitted for all minor and subsidiary buildings when the height of the walls is not very great, for enclosure walls, culverts, wing walls, etc.

RANDOM RUBBLE, FIRST SORT.

Specification No. 42.

1. **Fitting.**—The face stones shall be laid absolutely without pinnings on the face. Every stone shall be carefully fitted so as to form neat and close joints, and if necessary, the edges shall be dressed with a chisel so as to ensure close-jointed work. Joints not to exceed ¼ inch in thickness.

2. **Size of stones.**—The stones shall be roughly chisel-dressed and uniformly coloured and of pretty equal size on the face. They shall be carefully laid and solidly bedded in mortar, and shall tail back and bond well into the backing, and shall not be of greater height than either breadth of face, or length of tail into the work.

3. **Through stones.**—One header or through stone shall be inserted in at least every square yard of the face, and shall run right through the wall if it is not more than 2 feet thick ; if it is more than 2 feet thick, a line of headers shall be laid from face to back, which shall overlap each other at least 6 inches.

4. **Break of jounts.**—The stones shall be arranged to break joint as much as possible, and long vertical lines of joining shall be carefully avoided in the face-work.

5. **Quoins.**—Quoins to be as for coursed rubble, first sort.

For Rate Abstract see p. 346.

RANDOM RUBBLE, SECOND SORT.

Specification No. 43.

Same as above, but face and joints of stones to be only hammer-dressed, and joints may be ½ inch thick.

For Rate Abstract see p. 347.

Note.—Random rubble is most suitable for spandrils of arches.

UNCOURSED RUBBLE.

Specification No. 44.

1. **Dressing.**—The stones to be set in the work as received from the quarry, after merely knocking off weak corners and edges with the mason's hammer.

2. **Bond and laying**—The stones shall be carefully laid so as to break joint as much as possible, and shall be solidly bedded in mortar with close joints. No joint shall exceed half an inch in thickness. Chips of stone and spauls shall be wedged into the work, wherever necessary to avoid thick beds or joints of mortar. No dry work or hollow spaces shall be allowed ; every stone, whether large or small, shall be set flush in mortar, smaller stones used in the filling being carefully selected to fit snugly the interstices between the larger ones.

3. **Face stones.**—The face stone shall be selected from the mass of quarry stone for greater size, good beds, and uniform colour and shall be laid, as far as possible, without pinnings in front. They shall tail back and bond well into the work, and shall not be of greater height than either their breadth on face, or length of tail in the work. Fifty per cent. of the stones shall be one cubic foot in content, and twenty-five per cent. shall be headers tailing into the work at least 15 inches.

4. **Through stones.**—One through stone shall be provided for every square yard of facing. They shall be at least half a square foot in face area ; and shall run back into the work at least two feet, or the full depth of the work if it is less than two feet. If the wall be over two feet thick, a line of headers overlapping each other at least 6 inches, shall be laid right through the wall.

5. **Backing stones.**—A fair proportion of the stones used in the backing shall be of a large size. Thirty per cent. of them shall exceed three quarters of a cubic foot in content.

6. **Quoins.**—The quoins, unless otherwise specified, shall be of selected stone, neatly dressed with the hammer or chisel to form the required angle, and laid header and stretcher alternately. No quoin stone shall be less than one cubic foot in content.

7. **Pointing.**—The exposed face of the work shall be carefully and neatly pointed with mortar in all joints. The joints shall be raked out carefully at least one inch, and wetted and pointed with good fresh mortar, carefully inserted, and the joints neatly finished off with the trowel. At the back, the joints shall be finished off by being neatly struck and smoothed off with the trowel while the mortar is fresh.

For Rate Abstract see p. 347.

STONE AND MUD MASONRY.

Specification No. 45.

1. **Description of work.**—Shall be of the class and character of masonry designated, except that mud is used instead of mortar.

2. **Mud mortar.**—The mud used for this purpose shall be prepared from carefully selected earth of a tenacious nature. The earth to be well tempered by men's feet, and worked with water until it is perfectly free from lumps, and of the consistence of thick paste. Sand and chopped straw to be added in such proportions as the officer in charge of the work may direct.

3. When stone and mud masonry is specified to be lime pointed, the face stones should be set in mortar for 1½ inches from face.

Note.—When this description of masonry is used for supporting centerings, thin timber ties should be inserted at every three feet to bind the faces of the wall together. This object is equally gained by using split bamboos between the courses.

For Rate Abstract see p. 347.

DRY STONE MASONRY.

Specification No. 46.

Similar in all respects to coursed rubble, 3rd sort, but without the mortar. The work to be brought up with a batter of not less than 1 in 12.

For Rate Abstract see p. 348.

DRY STONE REVETMENT OR PITCHING.

Specification No. 47.

1. The stones to be perfectly sound, as regular in shape as possible, and their lengths about equal to the thickness of the required revetment without the backing.

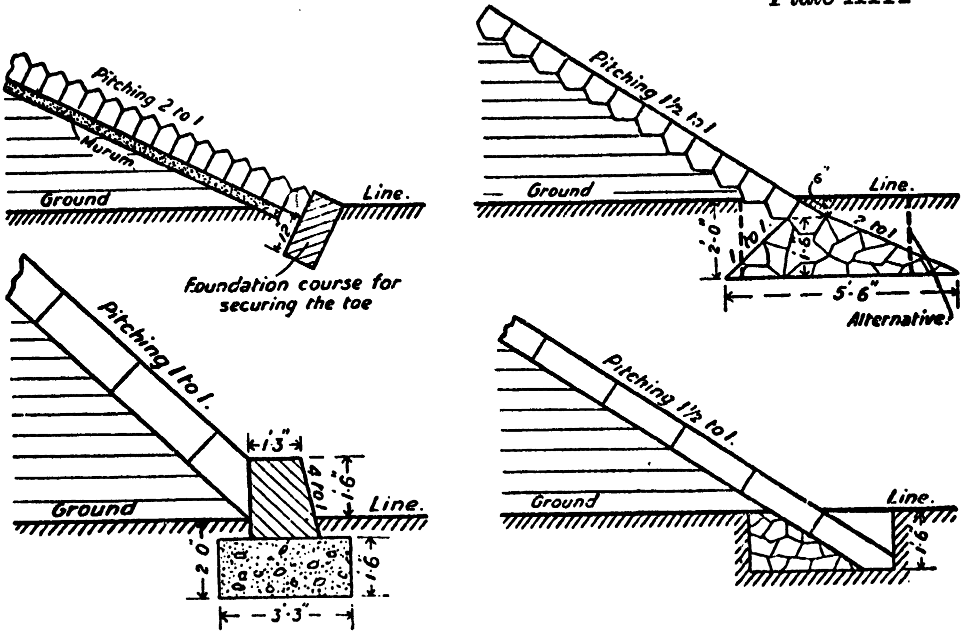
2. The sides of the bank to be trimmed to the required slope, and profiles put up at the required intervals, to ensure regular work and a uniform slope throughout.

3. The stones to be laid closely in position and firmly bedded, the length being made perpendicular to the face of the revetment.

4. The backing may consist of smaller stones closely packed, or gravel, or muram in layers of 6 inches, carried up simultaneously with the face-work and well watered and rammed.

5. For the stability of pitching it is essential that the toe should be thoroughly secured against slipping, being supported as shown in the sketches or in other specified ways.

Plate XIII



METHODS OF SECURING THE TOE OF PITCHING AGAINST SLIPPING.

ROUGH-STONE GHAT REVETMENT.

Specification No. 48.

1. The stone used to be perfectly hard, and as rectangular as can be found in the locality; and to be approved and passed before the work is put in hand.

2. The foundation to be carried down to perfectly firm and solid soil. The first course of stones, specially selected for flatness on one side, will be laid carefully in the bottom of the foundation trench, close together, side by side as headers, and the interstices carefully wedged up by packing with spauls. A slab, not less than 3 feet in length and not less than 6 inches thick, to be introduced in every 10 feet in this course, and in every course throughout the work. When this slab only reaches halfway through the course, two slabs to be laid abutting end to end, so as to bind the face and rear together. Above the first course, work will proceed with the front and rear facings of alternate headers and stretchers. All courses to break joint with the course immediately below, and to be laid perpendicular to the front batter. Every stone to be laid flat not on edge, and in close contact with neighbours. No projecting stones to be allowed.

3. Where the height of the revetment is 6 feet, or in the top 6 feet where the revetment is higher, no stone used in the work shall be less than 1'-6" in length. In the portion of the revetment below the top 6 feet, no stone used in the work shall be less than 2 feet in length. The stone shall be close-packed in the work by spauls.

4. The revetment to batter at 1 in 4 on the face and to be built in plumb steps at the back. Each step or offset to be 6 inches course and the courses above to be laid perpendicular to the front batter. Every stone to be laid flatwise, not on edge, and in close contact with its neighbours. No projecting stones to be allowed.

5. As the work proceeds, the wedging at the face and the back is to be attended to carefully.

6. The space between the rear face of the retaining wall and a vertical plane from the edge of the lowest offset, to be filled in with small stones or chips well hand-packed. The earth-filling behind to be brought up in 12-inch layers at a time and thoroughly consolidated dry with heavy rammers.

DRY RUBBLE RETAINING WALLS.

Specification No. 49.

1. **Foundations.**—The foundations, if in *muram*, to be carried down to a depth of from 2 to 3 feet below the hill slope at the outer side, and to be filled in with the largest blocks of stone procurable within a moderate distance, carefully laid and packed in by hand with stones of a smaller size. The bed of the foundation shall be excavated at right angles to the face batter and not horizontally.

2. **Stones.**—The stones used to be of the largest and best description procurable within a moderate distance, and to be roughly hammer-dressed, so as to secure as large bedding surfaces as possible. When laid, all hollow round them to be tightly packed with smaller stones.

3. **Section of the wall.**—These walls are to be built of dry rubble stone masonry and constructed with sound workmanship which should include the provision of suitable "headers" in adequate numbers in all cases. Under normal conditions viz., with a filling weighing not more than 100 lbs. per cft., and having a natural slope not flatter than $1\frac{3}{4}$ to 1 and with the top of the filling horizontal without any surcharge, the wall is to have a section of at least 2 feet width at the top, to be perpendicular at the back and to have a batter in front of 1 in 4 when the height does not exceed 15 feet.

For greater heights, either the top width of the wall may be suitably increased and the whole wall built of dry rubble stone masonry, or, alternatively, the upper 15 feet of the wall may be built of dry rubble stone masonry and the portion below this built in mortar with a suitable back batter.

Long lengths of dry rubble retaining walls should be divided into panels separated from one another by short lengths of walls of 5 to 7 feet long built in mortar at intervals of, say, 20 to 30 feet, in order to confine subsequent damage, if any, only to the panels affected and thereby to minimise the repairs required.

4. **Superstructure.**—The beds of the stones to be laid at right angles to the face batter. Each course to be built with proper bond and break of joint with the course below. The front and rear faces of the wall to be built precisely similar in all respects, and to be equally well bonded with the hearting.

5. **Through stones.**—Through-stones or headers, at least 3 feet in length, to be provided in each course at 5 to 6 feet apart on the face of the work, and continued through the whole width, with headers overlapping 9 inches, so as to tie the front and rear faces of the work together. These bond stones shall be of the full height of the course in the facing, as broad at least as they are high, and of the greatest length readily procurable above.

6. **Filling behind wall.**—The filling immediately behind the wall to consist, as far as possible, of stone refuse and chips. Earth not to be used for this purpose, if it can be avoided.

Note.—In masonry, by "hammer-dressed" is understood dressed with the "*sutki*" or Deccan mason's hammer.

For Rate Abstract see p. 348.

LATERITE MASONRY.

Specification No. 50.

1. **Stone.**—The stone shall be the best procurable in the vicinity, and shall be free from any admixture of white earth. If possible, it shall be dug from the quarry some time before use, and allowed to harden, before being placed in the work.

2. **Size.**—The stone shall be quarried true and square to the sizes ordered. The least thickness of stones shall be 7 inches, and the breadth shall be not less than the thickness, and the length not less than twice the thickness.

3. **Laying.**—The stone shall be laid in the work header and stretcher alternately, to break joint at least 3 inches, and shall be laid in good lime mortar. In other respects the masonry shall be similar to the same class of stone masonry.

For Rate Abstracts see pp. 349 to 351.

BRICK-WORK.

General.

1. Brick-work shall be of three classes. The *first* class to be constructed with table-moulded bricks free from any defects; the *second* class with ground-made bricks specially made for the work and of first class quality; the *third* class with bricks purchased in the market, sound and well burnt. In all cases, the bricks must be free from defects, and approved by the Executive Engineer.

2. In no case shall bricks of different dimensions be used in the same work, except when specially permitted by the Executive Engineer.

3. All the best shaped bricks and those most uniform in colour shall be reserved for face-work.

4. The bricks shall be well saturated with water, by immer ing for at least 2 hours before being put into the work; (the cessation of bubbles rising in the water is an indication of saturation being complete); every bricklayer shall be supplied with a tub or trough full of water in which the bricks shall be kept before using.

5. The bond used shall be English or such other as may be specified, and shall be carried throughout the wall.

At all corners, alternate courses of brick work shall be laid header and stretcher-wise, so as to bond the two walls well together.

6. No bats shall be permitted except where absolutely required for obtaining the dimensions of the different courses, or for obtaining the specified bond.

7. The mortar to be used shall be that specified and approved.

8. In first class work, no four courses of work, with three joints, shall exceed in thickness the same bricks piled one upon another without mortar, by one inch.

9. The bricks shall be thoroughly bedded and flushed with mortar, and shall be grouted full at every fourth course.

Plate XIV

ENGLISH BOND

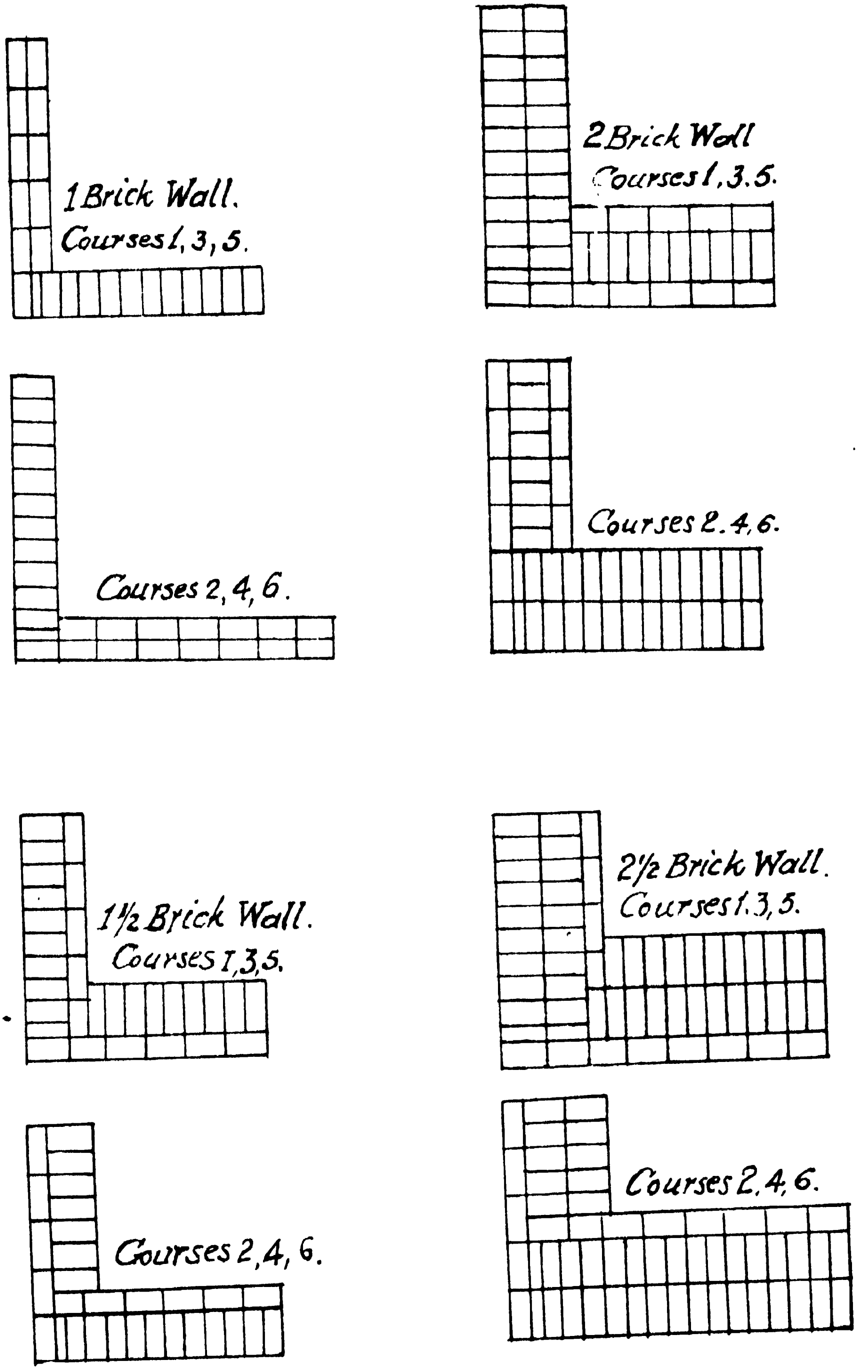


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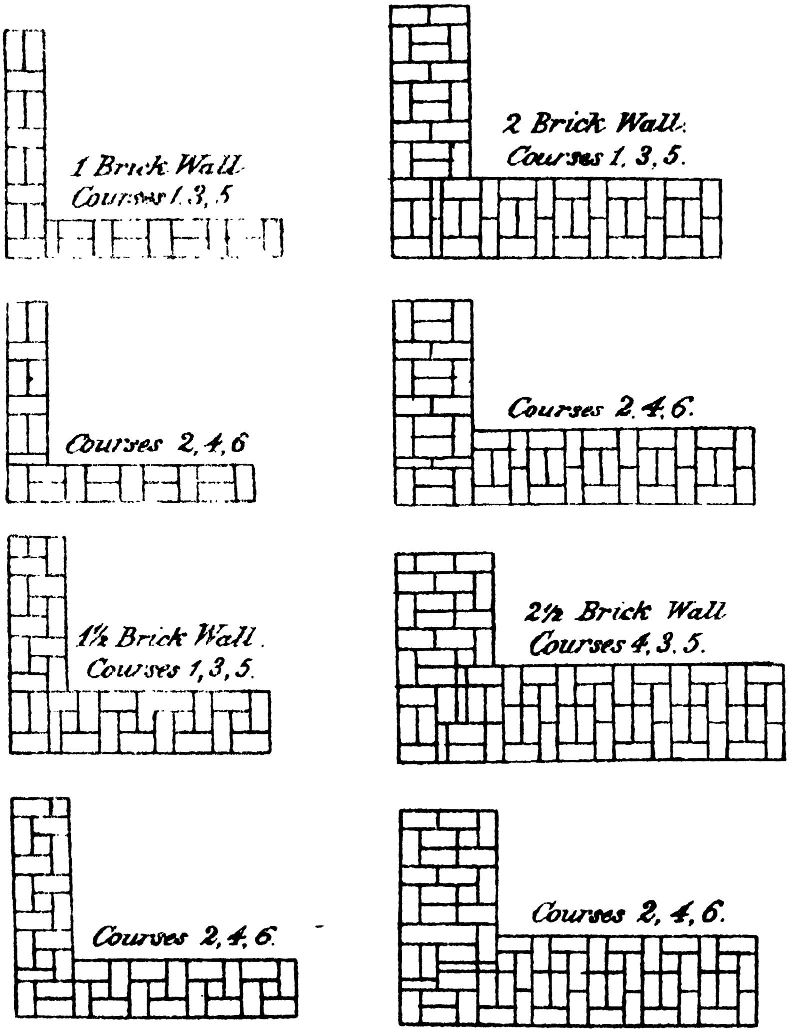
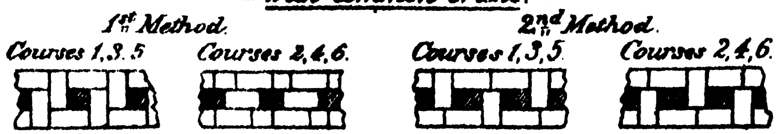
Plate XV

FLEMISH BOND.



Hollow Walls
with common bricks.



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G. P. Z. P. POONA, 1949

10. Every joint should be neatly struck at the close of the day's work and before the mortar has set.

11. All face-work must be finished with a neat drawn joint and pointed; but when the face-work has to be plastered, the joints shall be well raked out before any plaster is laid on. Should the plaster, for any reason flake off from the brick-work, the contractor if so ordered, shall have to strip off the whole of the old plaster or such portion of it as may be directed, and to relay it to the Executive Engineer's satisfaction without additional payment.

Where no definite mention is made of pointing, the exposed joints shall be finished as described on page 173 in paras. 1 to 4 under "pointing, general" and shall be well rubbed with a piece of bent $\frac{3}{8}''$ iron rod.

12. The walls of a structure shall be carried up regularly, in all cases when the nature of the work will admit of it, not leaving any part 3 feet lower than another but when circumstances render it necessary to carry on the same section of a building at different levels, the breaks shall be stepped, so as to give later a uniform level and an effectual bond.

13. In all cases, returns, buttresses, counterforts, etc., are to be built up course by course, well and carefully bonded with the mainwalls, and should never be joggled on afterwards.

14. For honeycomb work fine lime mortar must be used, and each brick must have a bearing of 1 inch on each side. The joints must be struck flush, so as to give an even surface on all sides.

15. Round pillars will be built with quadrant-shaped bricks, and when the pillars are of considerable height, flat circular discs of stone or cement concret of the same diameter as the pillar and about 3 inches thick, shall be introduced at every 4 to 6 feet ties and as bond the cost of such discs shall be included in the rate of brick work.

16. On all unfinished portions of the masonry water tables shall be provided and kept filled with water; and masonry shall be kept well wetted while in progress, and for at least 15 days after completion.

17. Door and window openings shall have flat or relieving arches or lintels spanning across them; A flat arch shall have a camber or rise of 3 to 4 inches. (Plate XIII.)

18. Filling for segmental portions over door and window frames, is best done with wooden planks, since brick or stone filling in such places, easily works loose. A single slab of flagstone (Yerguntla, for instance) neatly shaped to fit the segmental opening, or a shaped cement concrete slab, fitting into shallow chases in the introdos when the brickwork is not to be plastered, will also do as well.

19. Jambs may be either square or splayed; the latter are convenient in affording room for shutters, but splayed jambs should only be used when there is a good interval between windows as splayed jambs weaken the brickwork masonry more than square jambs. When splayed jambs are to have linings, they may be built with square offsets.

20. String courses, cornices, and mouldings will be set straight and true, with as fine joints as possible.

21. The ends of all girders should rest in recesses, having space for the free circulation of air round the timber.

22. Scaffolding must be double, that is, it must have two sets of upright supports. Care must be taken, in leaving out a brick to allow the end of the scaffolding pole on the inner side to rest on the wall, that such brick is always a header and that not more than one header for each pole is ever left out. By this means the bond of the wall can easily be made complete and perfect as the scaffolding is being removed. To insure the safety of the workmen, all scaffolding must be approved by the Executive Engineer.

23(*a*) All brick-work in walls, arches, square columns, beick-on-edge and flat floors, and under flagging in floors, will be measured net according to class, whether the bricks be moulded or not.

(*b*) All cornices, corbels, brackets, strings, beads, ogees, circular and polygonal columns, mouldings, etc., will be measured square, over the greatest depth and projection for the whole feature.

(*c*) No deductions will be made for flues left in the masonry for fire, ventilation, or drainage purposes.

(*d*) No deductions from the contents of the wall will be made in order to compensate for the additional trouble in forming such.

(*e*) All rates are inclusive of quoins and jambs.

(*f*) No extra price will be paid for wooden bricks built into masonry; the wood bricks themselves are to be supplied without charge.

(*g*) The rate for each description of work includes scaffolding, tools and plant of every description.

(*h*) All rates for arching shall include the cost of centering for spans up to 12′ inclusive. For spans over that the centering shall be separately paid for.

24. All brickwork shall be washed down on completion, and all stains, removed from the face.

25. On completion of a work, all rubbish to be removed, unsightly holes or pits levelled up, and the whole surroundings of the work left clean and neat, before the final bills are prepared.

TABLE XXXIV.

MINIMUM THICKNESS OF WALLS OF BURNT BRICK AND LIME MORTAR, FOR DOMESTIC BUILDINGS, AS REQUIRED BY THE BOMBAY BUILDING BYE LAWS.

Height.	Length of wall between partitions	Thickness.
(*a*) Up to 10 feet.	Whatever its length ...	9 inches.
(*b*) 10 to 15 feet.		14 inches for a height of 8 feet; 9 inches for the remaining height.
(*c*) 15 to 25 feet.	Up to 30 feet ...	14 inches for the whole height.
	Above 30 feet ...	18½ inches below the topmost storey, if of more than one storey. If of ground floor or first storey only, 18½ inches for a height of 15 feet above its base, and in either case 14 inches thick for the rest of its height.
(*d*) 25 to 30 feet.	Up to 35 feet length ...	18½ inches below the uppermost two storeys, if it comprises more than two storeys. If it does not comprise more than two storeys, 18½ inches below topmost storey, and in either case, 14 inches for the rest of its height.
	Above 35 feet length ...	18½ inches below the topmost storey and 14 inches thick for the rest of its height.
(*e*) 30 and 40 feet.	Up to 35 feet length	18½ inches below the uppermost two storeys and 14 inches for the rest of its height.
	Above 35 feet length ...	23½ inches for the height of one storey. 18½ inches for the rest of its height below the topmost storey, 14 inches thick for the rest of its height.
(*f*) 40 and 50 feet.	Up to 35 feet length ...	18½ inches below the topmost storey, 14 inches for the rest of the height.
	Above 35 feet length ...	24 inches for the height of one storey. 18½ inches for the rest of its height below the topmost storey. 14 inches thick for the rest of its height.
(*g*) 50 and 60 feet.	Up to 40 feet length ...	23½ inches thick for the height of one storey.

TABLE XXXIV—contd.

Height.	Length of wall between partitions.	Thickness.
		18½ inches for the rest of its height.
	Above 40 feet length ...	23½ inches for the height of two storeys.
		18½ inches for the rest of its height, except the top storey.
		14 inches top storey.
	Above 50 feet length ...	28½ inches for the first storey.
		24 inches next two storeys.
		18½ inches for the rest of its height.
(*h*) 60 and 70 feet ...	40 feet length ...	23½ inches for two storeys.
		18½ inches for the remaining height, except top storey.
		14 inches top storey.
	Above 40 feet length ...	28½ inches first storey.
		23½ inches next two storeys.
		18½ nches rest of its height, except the top storey.
		14 inches top storey.

TABLE XXXV.

MINIMUM THICKNESS OF WALLS FOR PUBLIC BUILDINGS OR BUILDINGS OF THE WAREHOUSE CLASS.

Height.	Length of wall between partitions.	Thickness of wall.	Remarks.
(*a*) 15′	Unlimited ...	14″.	1. In any wall over 25′ in height the uppermost 15′ to be not less than 14″ thick.
(*b*) 15′ to 25′ ...	Unlimited ...	18½″ at base.	2. The remainder of the wall below the uppermost 15′ shall not be less in thickness than the space contained between two straight lines drawn from each outer side of the wall at its base to each outer side of the wall 15′ below the top.
(*c*) 25′ to 30′ ...	Up to 45′ ...	18½″ at base.	3. Cross walls to be at least two-thirds of the external walls, subject to a minimum of 9″.
Do. ...	Above 45′ ...	24″ at base.	
(*d*) 30′ to 40′ ...	Up to 30′ ...	18½″ at base.	
Do. ...	30′ to 60′ ...	24″ at base.	
Do. ...	Above 60′ ...	28½″ at base.	
(*e*) 40′ to 50′ ...	Up to 40′ ...	24″ at base.	
Do. ...	40′ to 70′ ...	28½″ at base.	
Do. ...	Above 70′ ...	33½″ at base.	
(*f*) 50′ to 60′ ...	Up to 35′ ...	24″ at base.	
Do. ...	35′ to 50′ ...	28½″ at base.	
Do. ...	Above 50′ ...	33½″ at base.	
(*g*) 60′ to 70′ ...	Up to 30′ ...	24″ at base.	
	30′ to 45′ ...	28½″ at base.	
	Above 45′ ...	33½″ at base.	

BRICK-WORK, FIRST CLASS.

Specification No. 51.

1. **Bricks.**—The bricks to be of uniform size (9 inches × $4\frac{1}{4}$ inches × $2\frac{1}{2}$ inches, unless otherwise specified), moulded on tables with sand, *surki* or water, as may be ordered by the Executive Engineer, and thoroughly well burnt and sound, ringing clearly when struck with a trowel.

2. **Soaking.**—The bricks to be soaked in water for about 12 hours before they are put into the work.

3. **Laying.**—The bricks are to be laid flush in mortar in such bond as the Executive Engineer may direct, every course must be thoroughly grouted, and the whole work executed in a good and workmanlike manner.

4. **Facework.**—As far as practicable, bricks of a uniform colour are to be selected for the face-work when it is not to be plastered.

5. **Mortar.**—Shall be lime mortar, cement mortar, lime-cement mortar or cement-lime mortar as specified and the proportions of lime/or/and cement, and sand or other fine aggregate shall be those specified or ordered by the Executive Engineer.

6. **Joints.**—The bed-joints are not to exceed $\frac{3}{8}$ inch in thickness, *i.e.*, with bricks $2\frac{1}{2}$ inches thick, 4 courses including mortar joints, are not to exceed $11\frac{1}{2}$ inches in height.

7. **Bats.**—No bats or half bricks to be used in the work unless absolutely necessary as closer.

For Rate Abstract see p. 352.

BRICK-WORK, SECOND CLASS.

Specification No. 52.

As for 1st class, but bricks may be moulded on the ground and joints up to $\frac{1}{2}$ inch thickness are permitted.

For Rate Abstract see p. 352.

BRICK-IN-MUD WORK.

Specification No. 53.

Bricks as in brickwork 2nd class, but laid in mud, made from clay having neither too much nor too little sand in its composition, approved by the Executive Engineer, which is to be worked with water and well tempered till it is perfectly free from lumps and of the consistency of stiff paste. To be mixed with chopped grass in such proportions as may be directed.

The mud mortar joints shall not be more than half an inch thick.

For Rate Abstract see p. 353.

SUN-DRIED BRICK-IN-MUD.

Specification No. 54.

Shall be constructed under the same specification as the above with the exception that the bricks will not be burnt.

The bricks to be wel' moulded of tempered clay and well dried before using. Table-moulded bricks shall not be used for this class of work, as mud plaster does not adhere well to them.

BRICK NOGGING.

Specification No. 55.

1. **Description of work.**—This description of work, 6 inches only in thickness, will consist of a combination of teak posts and planking, the interspaces being filled in with brick-work 1st class, plastered with lime on both faces. The joints should be as thin as is consistent with good work.

2. **Network of timber.**—The uprights or posts measure 6 inches × 5 inches and are placed at central distances of 5 feet. Between these posts and notched into them there will be horizontal ribs of teak planking, 6 inches × 2 inches fixed 3 feet vertical distances apart. Between the ribs, cross-braces or diagonals, 6 inches × 1½ inches, will be inserted, halved at points of intersection and spiked to the posts. All faces of timber coming in contact with masonry to be well coated with boiling coal tar.

3. **Interspaces.**—All interspaces shall then be filled in with brick in lime masonry, built in so as to leave equal rebates on the timber pieces on both faces, so that when the brickwork is plastered on both faces, the surfaces will be flush with the timberwork

4. **Plastering.**—After the completion of the walling, the surfaces of the work to be thoroughly wetted and nails driven into the timber framework to give a hold to the lime plaster with which both faces of the work should then be finished off.

For Rate Abstract see p. 353.

REINFORCED BRICK-WORK WALLS.

Specification No. 56.

1 **Bricks.**—Shall be as for brickwork first class.

2 **Mortar.**—Shall be cement and sand mortar, and not less than one part of cement shall be used to three parts of sand by volume (cement being taken 90 lbs. = 1 cubic foot).

3 **Reinforcement.**—Shall be mild steel rods of the sizes specified or ordered by the Executive Engineer, and these shall be bedded inside the joint, one on each side at uniform distances from the face. care being taken to see that they have a good cover of at least ½" of mortar. The reinforcement shall be used in courses at such intervals as specified, and the inner and out bars shall be tied together, by ties at specified intervals. At ends of the wall the reinforcement will be carried at least 6 inches into the intersecting or limiting walls.

Joints.—Joints in which the reinforcement is placed, shall have a thickness sufficient to give a bed of at least ½" of mortar below the steel, and a similar thickness of mortar cover on top.

Note.—One brick-wide reinforced brickwork walls have now replaced brick-nogging, and are also much used for partition walls. In some cases even brick-on-edge reinforced brickwork walls are used, e.g., for partitions of small height.

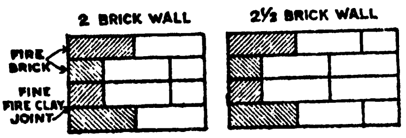
SPECIFICATION FOR BOILER BRICKWORK.

Specification No. 57.

The following special clauses should be added to the specification laid down above for ordinary brickwork in the case of boiler brickwork :—

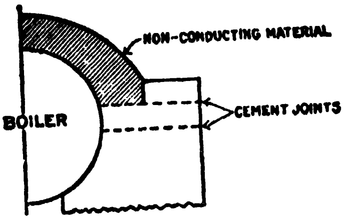
1. All brickwork setting of boilers, flues, ash pits and economisers, etc., where exposed to flame or hot gases, shall be lined with firebrick, whether shown in the drawings or not. Brick chimneys shall be lined with firebrick from the base to a height which should be fixed in accordance with the local conditions.

2. The joints of the fire-brick lining, shall be made with fireclay as fine as possible, and the ordinary bricks, though set in as fine mortar joints as possible, must necessarily be laid with somewhat coarser joints. The ordinary bricks will therefore require to be specially moulded, and selected to suit the make of firebrick used, so that the depth of one firebrick, including one fireclay joint, should correspond with the depth of one ordinary brick, including one mortar joint as shown above.



The firebricks should be merely dipped in well puddled fireclay mixed with water to the consistency of paste, so that there is no appreciable thickness of joint between the firebricks. Endeavours should be made to obtain firebricks of a suitable thickness to bond in with the local brick to avoid the necessity of specially moulding bricks. Firebricks are made in different thicknesses for this purpose.

3. The firebrick linings shall be laid one course of headers followed by two courses of stretchers, and the ordinary brickwork, laid to correspond with this setting.



(Not to Scale)

4. Where brickwork touches the boiler, fireclay only shall be used ; on no account shall mortar containing lime or cement come in contact with any part of the boiler proper.

The top two courses of brickwork shall be set in cement except where in contact with the boiler.

5. At the top of the boiler side walls an off-set or chase shall be left into which the non-conducting composition covering the boiler can be joined, as shown in the sketch.

6. The brickwork shall be allowed to dry thoroughly before a fire is lighted and any cracks appearing on subsequent firing due to expansion or contraction or faulty drying of the mortar shall at once be cared for by scraping out the joints and repointing with fireclay whilst the brickwork is hot (ordinary mortar cannot be used in such cases).

The firebrick lining shall be carried round the fire-box doors and across the top and bottom of the tube headers in water tube boilers. The space between the tube headers shall be carefully packed with asbestos packing and fireclay.

CEMENT CONCRETE BLOCK MASONRY.

Specification No. 58.

1. **Cement.**—All cement used shall be Portland cement of slow setting quality and shall be in accordance with the latest British standard specification in operation.

The brand of cement shall be approved by the Executive Engineer and shall be tested before it is used on the work.

2. **Sand.**—The sand shall be clean, gritty, and composed of hard silicious grains. It shall be free from clay or organic matter. All sand shall pass through a mesh $\frac{1}{8}$th of an inch square. If there is any trace of earthy matter the sand must be washed.

The sand used for fine surfaces of blocks, shall pass through a mesh of $\frac{1}{16}$th of an inch, and shall be washed if necessary.

3. **Aggregate.**—The aggregate shall consist of shingle or broken stone, sound, hard and durable, to pass through a mesh of $\frac{3}{4}''$ as far as possible. All aggregate must be perfectly clean, being washed if necessary, and free from any sulphur. No limestone must be used.

4. **Mixing of concrete.**—Unless otherwise specified, in particular cases, the concrete shall be mixed in the proportion of six parts of aggregate, three parts of sand and one part of cement. The concrete must be thoroughly mixed, at least three times in a dry state before water is added, and as far as possible, a fairly wet mixture must be used.

The mixture for fine surfaces, shall be in the proportion of two parts of sand (1/16" mesh), and one part cement. The mixture must be sufficiently wet to prevent crumbling and breaking away, when the block is taken out of the mould.

All concrete must be mixed on a watertight platform.

5. **Type of machine.**—The block making machine shall be of the "Winget" type or any other type approved by the Executive Engineer.

6. **Class of blocks.**—The blocks shall be solid or hollow, rock faced, or solid or hollow, plain faced, with fine faces on one or two sides, as ordered by the Executive Engineer to suit the requirements. Partition blocks shall not have fine surfaces. All blocks shall be exactly of the same shape, perfect, and uniform in every respect.

All angles shall be true and square. Blocks that are cracked or are deformed in any way shall be rejected.

7. **Making blocks.**—The concrete and fine surface mixture should be put into the mould simultaneously, the latter being separated by a steel plate or sheet iron $\frac{3}{4}''$ away from the inside edge of mould. When three inches of both mixtures are put in, the plate is to be pulled up to the top of the concrete and tamping commenced. The corners and sides should be tamped first, and then the centre portion. In this manner another 3" of concrete should be consolidated, and so on, till the block is complete.

About three or four hours later, or as soon as the surface cannot be rubbed off by the finger, watering of blocks should be commenced. The blocks must be kept wet continuously for a period of ten days.

8. **Masonry work.**—The blocks shall be saturated with water before they are used in the work. The blocks shall be set in mortar (1 part cement to three parts sand), and all joints both vertical and horizontal shall be grouted with cement mortar in each course, before another course is commenced. A systematic bond must be maintained throughout the work—foundation, plinth and superstructure. Two vertical joints must not come one above the other. All masonry work must be uniform and true in line and plumb. All pointing is to be done, as soon as possible, after the blocks are laid. The pointing mortar shall be in the proportion of one part cement to two parts sand (1/16″ mesh).

9. **Cornices, copings, lintels, etc.**—All parts of work such as cornices, copings, and lintels, which cannot be made in a machine, must be moulded in pucca teakwood, moulds, lined with zinc or steel plate, or they may be made *in situ*. In any case the work when finished must be absolutely true in line and level, and finished off smooth. Masonry work will be kept wet for a period of ten days after being laid.

10. **Doors and windows.**—The frames of doors and windows must be attached to the masonry by means of flat iron holdfasts $6'' \times 2'' \times \frac{1}{4}''$, bolted to the wood at one end, and bent at the other end to ensure a strong and perfect connection.

All work shall be done strictly according to the drawings and the instructions of the Executive Engineer.

LINTELS.

General.—Before the invention of reinforced concrete two methods were used to span over the openings in a wall. Either the openings were arched over, or they were spanned by lintels of wood, steel sections or stone. Wood lintels are liable to decay, stone lintels are costly, and it is not always possible to obtain slabs without flaws of the required length and depth. Steel sections have not been much used as they involve waste of material and when exposed to the sun are liable to work loose on account of their high rate of expansion. The usual manner of spanning a gap economically was therefore to turn an arch over it. Arches however require headway, and since reinforced concrete has come into common use, they are being discarded in favour of R. C. C. lintels.

Loads.—The loads coming on a lintel are difficult to determine precisely, as this depends on (1) the arching action in the wall above the lintel,

(2) the depth of the wall above the lintel,

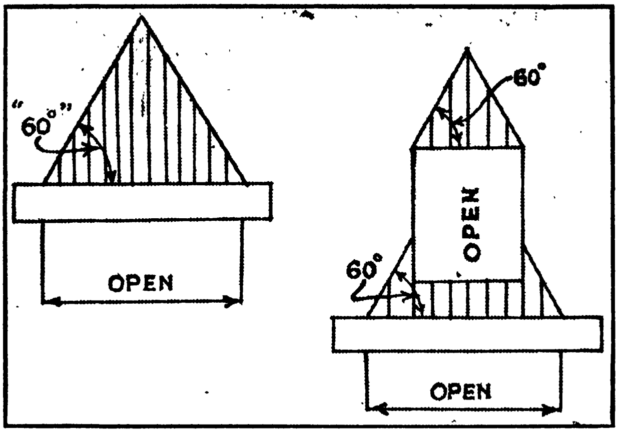
(3) the position of openings above the lintel,

(4) the concentrated loads such as those of beams etc.

In normal cases it is usually specified that beams etc. shall not be located above wall openings, and (4) above may be eliminated. If however this cannot be avoided, the lintel has to be specially designed to take such concentrated loads.

In brick walls, and walls with similar units in layers set in good mortar, if the height of the wall above the lintels is equal to, or exceeds, 0·87 x span, and if there is a sufficient length of wall on both sides of the opening to provide a proper bearing for the lintel, it is usual to assume triangular loading, the sides of the triangle being drawn at 60° from each edge of the opening. If opening occurs *within* the triangle thus formed on the lintel top with the span as the base, the load on the lower lintel will be that portion of the triangle not covered by the opening plus the triangular load on the opening.

The following two sketches explain the loading, the hatched portion being the extent of wall carried by the lintel :—



In other cases e.g. uncoarsed rubble walls, built in weak mortar or in mud ; where arch action is uncertain, it is safer to take the span as uniformly loaded. The height of wall to be taken is more uncertain but, a range from one span-height, to 1·5 the span-height, to circumstances of each case, would probably be ample.

Lintels are designed in the same way as Rough Cast Cement slabs, the bending moment being WL/6 for the equilateral triangle loading and WL/8 for the uniform loading where W is the total load L, the effective span in feet and M is obtained in foot-lbs.

The following table is based on an equilateral triangle loading, excluding all concentrated loads from beams, or spread loads from floors, and will apply for small openings in buildings. The unit stresses for concrete and steel are 600 lbs. per square inch and 16,000 lbs. per square inch in tension and compression respectively. Weight of masonry 144 lbs. per cft. cover ½″ over steel. Minimum reinforcement size ⅜″ diam :—

TABLE XXXVI.

R. C. C. Lintels.

Clear Span in feet.	Minimum bearing.	Overall depth of lintel.	Thickness of wall.	As Necessary.	Reinforcing bars.		Remarks.
				sq. in.	No.	diam.	
3′·0″	0′·4½″	0′·3¾″	0′·9″	0′124	2	⅜″	Minimum reinforcement ; ⅜″ diam. and 2 Nos.
4′·0″	0′·6″	0′·4″	0·9″	0·184	2	⅜″	
5′·0″	0′·6″	0′·4½″	0·9″	0·245	3	⅜″	
6′·0″	0′·8″	0′·7″	0·9″	0·373	4	⅜″	
7′·0″	0′·10″	0′·8½″	0·9″	0·500	{ 4 1	⅝″ ½″	
8′·0″	1′·0″	0′·10½″	0′·9″	0·581	3	½″	
9′·0″	1′·2″	1′·0″	0′·9″	0·673	{ 2 1	⅝″ ⅜″	
10′·0″	1′·5″	1.2½″	0·9″	0·829	3	⅝″	

Note.—(1) The table is calculated for equilateral triangular loading ; masonry load 144 lbs. per cft. so that it can be used both for brickwork and stores masonry. The unit stresses assumed are 600 lbs square in compression in concrete and 16,000 lbs. square in steel ; modular ration 15. The effective span has been taken according to Code of practice i.e., clear span plus effective depth or distance centre to centre bearings whichever is less. Cover ½″ over outermost metal.

(2) In all cases it is desirable to have two top bars so that a ¼″ binding 12″ centres. Can be used in forming a cage. These bars should be ¼″ diam. for spans up to 4′ and ⅜″ diam. for longer spans. When three bars are used, the Central bar should be cranked up and continued over the supports.

(3) For greater widths the reinforcement should be increased proportionately e.g., for 18″walls the reinforcement should be double that in the table.

(4) The thicknesses obtained do not make whole numbers of courses. If the lintel base should come midway between joints, cement concrete pads should be made with the top at door and window head-piece top and bottom at the *second* lower joint, thus making them of the thickness of a course + the fraction of a course to the head top, or if the masonry is brickwork, bricks on edge can be used if they can be accommodated.

If the lintal top comes midway between joints the lintel should be thickened by additional concrete so that the top is brought up to the next larger top or brick-on edge laid if passible. This concrete shall be paid at the scheduled rate for cement concretes of the type used.

Removal of forms.—Lintels *in situ*. The bottom boards should not be removed for 14 days, and care should be taken to see that heavy loads do not come on the lintel for 4 weeks.

DETAILED SPECIFICATION OF ARCHING.

ASHLAR ARCHING.

Specification No. 59.

1. The arch stones shall be in all cases of the entire thickness of the arch, and shall be carefully and accurately wrought, giving the proper radiating joints, that is, the arch stones shall be dressed full and true to their proper shapes with the necessary summering, twist, or winding, and shall be carefully set in good fine mortar.

2. **Dressing beds.**—The intrados, joints and beds to be fair-tooled and left full; the cast or keying course to be accurately fitted and driven into place with heavy wooden beaters; at all horizontal joints, the intrados to have a ¾ inch chamfer, to prevent the arises chipping.

Face stones.—The face stones may be tooled or rock-faced, with or without chamfer, as may be specified.

3. **Size of stone.**—The arch stones shall not be less than 10 inches on their least dimension, and shall break joint at least 9 inches. In arches up to 2 feet in depth, the stones shall all be of the full thickness of the ring. In arches from 2 feet in depth, the stones shall be laid header and stretcher alternately, all the headers being of full depth of the ring, and not more than two stretchers going to make up the full depth of the ring.

In arches over 3 feet in depth, the quoins and key-stones alone need be of the full thickness of the ring. The stones when laid double, as above, to form the ring, shall be laid in such bond as may be directed.

Exact uniformity will be required in the thickness of each course of arch stones, and in oblique or skew arches, great care is to be taken to dress the beds to the required winding.

4. **Centres.**—Arches to be built on proper centres approved by the Engineer, and no centre to be eased or struck without his written permission. During the progress of the work, care should be taken to distribute the load on centres, in order to obtain a true curve at the completion of the work.

5. **Joints.**—The bed joints shall be radial, and the side joints shall be at right angles to the bed joints, and the thickness of the joints shall not exceed $\frac{3}{16}$ inch.

6. **Pointing.**—The mortar of the joints on face and soffit of arch, to be the raked out as soon as the centering is removed, and the joints neatly pointed with good lime or cement mortar.

7. **Removal of bad work.**—If any arch settles unduly or becomes unsightly through carelessness, bad workmanship or bad material, it shall be removed and re-built at the contractor's expense.

8. **Measurement.**—For measurements of arch work multiply the mean of the lengths of extrados and intrados, by the full breadth of the arch and by the full depth of the stones in the archring. The rate for arch work to include the provision of proper centres, setting up, easing and removing the same.

Note.—Suitable for bridges over 60 foot span.

For Rate Abstract see p. 354.

BLOCK IN COURSE ARCHING.

Specification No. 60.

Shall be precisely similar to ashlar arching, except that, the stones shall not be less than 6 inches on their least dimensions, shall not break joint less than 6 inches, and shall only be rough-tooled on beds and joints, which shall not exceed ¼ inch in thickness.

Note.—Suitable for bridges from 30 feet to 60 feet, for verandah arches in barracks, etc., *etc.*

For Rate Abstract see p. 354.

RUBBLE ARCHING.

Specification No. 61.

1. Shall consist of flat-bedded *slabs* laid solidly and flush in mortar with their beds radial to the curve of the arch, and shall properly break joint and bond with each other. Each slab shall be hammer-dressed approximately to the proper shape with the necessary summering, so that the arch stones may bear fairly one upon another for the full thickness of the arch, and should parts of the backs of the stones be open, they shall be solidly wedged up with spauls and chips of stones set in motar. The face joints of the stones shall be dressed truly radiating and the bed joints shall be properly summered ; the ends of the face stones shall also be dressed.

2. The joints on face and soffit shall not exceed ½ an inch in thickness.

N.B.—The mortar used should be of very good quality, as the strength of rubble arches depends very much upon the strength of the mortar.

In arches of small span joints of ¾ inch need not be objected to.

3. **Quoins.**—The arch quoins to be of the same thickness as the sheeting of the course but they shall be superior selected stones, in all cases extending right through from intrados to extrados, and alternately, not less than 15 inches and 21 inches long, upon the intrados or bed face.

4. **Size of archstones and Bond.**—No arch stone in the sheeting shall be less than 3 inches on its least dimension, and the stones shall break joint with each other 6 inches. In arch rings 15 inches thick and under, all stones shall be of the full thickness of the ring.

In arch rings more than 15 inches thick, the stones will be laid in alternate courses of headers and stretchers, unless otherwise specified, but not more than two stones going to make up the thickness of the arch ring.

5. The joints on faces and soffit to be raked out as soon as the centering is removed, and neatly pointed with good mortar or cement.

Note.—Suitable for arches up to 30 feet span.

For Rate Abstract see p. 355.

TABLE XXXVII.

The following table gives the approximate cost of framed teakwood centerings, for segmental arches of culverts and bridges of the undermentioned spans, for a clear roadway of 20 feet, including cost of erecting and lowering :—

Span in feet.	Cost per running foot of span.	Total cost.	Span in feet.	Cost per running foot of span.	Total cost.
	Rs. a. p.	Rs. a. p.		Rs. a. p.	Rs. a. p.
3	19 8 0	58 8 0	15	37 8 0	562 8 0
4	21 0 0	84 0 0	20	45 0 0	900 0 0
5	24 0 0	120 0 0	25	52 8 0	1,312 8 0
6	27 0 0	162 0 0	30	60 0 0	1,800 0 0
8	30 0 0	240 0 0	36	67 8 0	2,362 8 0
10	33 0 0	330 0 0	40	75 0 0	3,000 0 0

BRICK ARCHING FOR BRIDGES.

Specification No. 62.

1. **Half-brick rings.**—The bricks to be, as in 1st class brick-work, laid in concentric half-brick rings.

2. **Joints.**—The voussoir joints are to be properly summered and not to exceed ⅜ inch in thickness.

In all arches the voussoir joints shall be truly radial to the curve at all points.

In setting the bricks in arches they are to be well pressed into their beds so as to squeeze the mortar out and leave the joint thin.

3. **Skew-backs.**—Bricks forming the skew-backs are to be moulded or cut so as to radiate truly, and defects in this particular should not be remedied by the extravagant use of mortar, or patching up by chip.

4. **Bond of rings.**—Great care to be taken that the rings are bonded together properly, whenever the joints of any of the rings come to a summering, or plane face.

5. All arches to be turned on centerings approved of by the Executive Engineer the cost of which up to 16 feet span will be included in the rates. Sand boxes invariably to be used for lowering arches over 23 feet span, such boxes being furnished by the Executive Engineer on loan to the contractor, unless otherwise specially arranged for.

6. The bricks for the spandril walls shall be cut so as to fit the curvature of the arch.

BRICK ARCHING OVER DOORS AND WINDOWS.

Specification No. 63.

The provisions shall be the same as for "brick arching for bridges" but bricks shall be as for 2nd class brick-work, and joints not to exceed ½ inch.

For Rate Abstract see pp. 355 and 356.

TABLE XXXVIII.

AREAS OF SEGMENTS, AND MEAN LENGTHS OF ARCH RINGS OF DIFFERENT THICKNESSES FOR SEGMENTAL OPENINGS OF 60° OVER DOORS, WINDOWS, ETC.

$$\text{Rise} = \frac{\text{Span}}{7 \cdot 4641}.$$

Span in feet.	Rise.	Area of segment.	Mean lengths of arch rings of different thicknesses.					
			9″	12″	13½″	15″	18″	22½″
		S. F.						
2	·27	·36	2·48	2·61	2·68	2·74	2·87	3·07
2½	·33	·57	3·00	3·13	3·20	3·26	3·39	3·59
3	·40	·82	3·53	3·66	3·73	3·79	3·92	4·12
3½	·47	1·11	4·05	4·18	4·25	4·31	4·44	4·64
4	·54	1·46	4·57	4·70	4·77	4·83	4·98	5·16
4½	·60	1·84	5·10	5·23	5·30	5·36	5·49	5·69
5	·67	2·27	5·62	5·75	5·82	5·88	6·01	6·21
5½	·74	2·75	6·14	6·27	6·34	6·40	6·53	6·73
6	·80	3·27	6·67	6·80	6·87	6·93	7·06	7·26

To find the area of a segment of 60° :—span² × ·091.
To find the mean length of arch—
length of intrados = span × 1·047.
length of extrados = (span + depth of arch) × 1·047 and mean of these is the true length of the arch.

Concrete arches for roofs, culverts, etc.

1. **Extent of use.**—Concrete arching has been frequently used for roofing police quarters, chowkies and other small buildings, for covering water tanks, and for culverts and bridges of small span.

2. **Span.**—Concrete arches are quite safe for spans up to 20 feet, and with proper precautions can be used for greater spans.

Note.—A Portland cement concrete arch, 75 feet span, 7½ feet rise, has been built over the London Metropolitan railway and proved successful. Concrete 3½ feet thick at crown, increasing towards the haunches and butting against concrete skew-backs. The concrete was composed of 1 Portland cement to 6 gravel, carefully laid in mass upon close boarding set upon the centering and enclosed at the sides.

3. **Rise and thickness of arching.**—For roofing arches, a rise of two inches to the foot is usually allowed where lime concrete is used, but the minimum thickness should not be less than 6 inches, and for greater spans, a safe rule is to increase the thickness by 1½ inches for each foot of span, over 10 feet, thus :—

Span in feet	10,	12,	14,	16,	18,	20
Thickness of arch in inches	6,	9,	12,	15,	18,	21

If Portland cement concrete be used, the thickness may be reduced.

4. For bridges and culverts the arches must be stronger.

The dimensions of some culverts actually constructed :—

Span in feet	2·5	5·0	6·25	10·0	18·0
Thickness of arch in feet... ...	1·0	1·25	1·16	1·5	2·0
Rise in feet	0·50	0·75	1·25	2·0	3·0

*5. Concrete has been largely used in the arches of culverts, etc., on the Nira canal.

The largest concrete arch has a span of 26 feet with a minimum thickness at the crown of 18 inches.

The whole of this culvert was built of concrete, with the exception of the faces of the arch and the small parapets and wing walls, in which it was found cheaper to use rubble masonry.

In building the arch the concrete was laid in radial 6-inch courses, until the inclination became too great to secure proper ramming; the courses were then laid circumferentially.

The cost of the concrete arching on the Nira canal varied from Rs. 14 to Rs. 16 per 100 cubic feet.

6. **Abutment.**—In a series of roofing arches, either the outer walls carrying the arches must be made strong enough to act as abutments, or the thrust of the two end spans must be taken by iron ties suitably arranged; it will not be necessary to add ties to the intermediate arches.

For culverts and bridges the abutments may be economically made of concrete.

**Note.*—Lime concrete arches were used for carrying irrigation canals and channels, over cross-drainages in the Central Provinces, but it was found, that the alternate wetting and drying causes deterioration of the lime concrete, with the result that chunks become detached from the soffit.

In the Bombay Presidency also, lime concrete arches carrying the canal deteriorated, the lime in the mortar becoming like putty, and had to be rebuilt. The use of lime concrete arches in carrying canals is therefore inadvisable.

It is also not advisable to use lime concrete arches, on modern roads carrying heavy motor traffic.

7. **Centres.**—The centres for concrete arches may be similar to those for masonry arches, but they must be so rigid that they will not spring under ramming.

The ordinary solid centres of mud and stone masonry are probably the most suitable, and were used on the Nira canal for all arches up to 30 feet span.

If wooden centres are used, they may be fixed, either on sand bags or wedges, to facilitate removal. The centerings should not be removed in less than 20 days and it is better to allow six weeks. Ordinary brige centerings are used and cost in Kaira about Rs. 10 to Rs. 13 per 100 superficial feet. The curve of the intrados is rendered true by means of a layer of plaster, or accurately shaped laggings may be used and covered with sheet zinc, if the number of arches is sufficient to admit of this without undue cost.

8. Cross or partition walls immediately *under* concrete arches should not be built to their full height until after the centres have been removed and the arch has had time to settle.

9. **Ventilation.**—Ventilation may be effected by glazed earthenware pipes, which should be fixed in position on the centres when laying the concrete.

These should project about one foot above the finished roof, and should be covered with a suitable cap, which may be of sheet iron or other suitable material and conical in shape.

10. The cost of concrete arching of the description referred to, excluding iron work but including centering and plastering, per 100 superficial feet (in the Kaira district), was approximately as shown in the margin.

Cost.

Lime concrete 6 inches in thickness for 100 superficial feet of roof ...	Rs. 10 to 13
Centering	„ 10 to 13
Plastering above and below ...	„ 5 to 7
Contingencies	„ 1 to 2
Total for 100 superficial feet ...	Rs. 26 to 35

In the Bijapur district, where all wood, including round teak rafters, had to be imported by rail and where tiles cost Rs. 7 per 1,000 concrete arches gave much the cheapest roofing.

For bridges and culverts, the centres will cost from Rs. 15 to Rs. 18 per 100 *square* feet, and the concrete will cost about Rs. 3 per 100 cubic feet more than similar concrete in foundations. This represents the extra labour for laying, ramming and watering.

When there are many arches to be built, and the centering materials can be used over and over again, the cost can of course be much reduced.

11 **Mode of measuring.**—Concrete roofing is measured flush from outside to outside of walling, while in tiled roofing and the extra for slopes must be added. For small buildings it will be found that 100 superficial feet of flat concrete roofing, would be equivalent to 130 to 150 superficial feet of tiled roofing.

12. **Comparison of cost.**—Double-tiled roofing with teak framing, for small spans, cost Rs. 30 to Rs. 40 per 100 superficial feet in the Kaira district, but calculating the rate per 100 square feet covered, the rate would be increased to 40 to 60 rupees. The cost for covering 100 superficial feet (similarly measured) is therefore for tiled roofing Rs. 40 to Rs. 60, and for concrete arched roofing Rs. 26 to Rs. 35, excluding iron work. The cost of iron work, or that of extra masonry in abutments if iron is dispensed with, must be added, and the amount of this additional item depends on the circumstances of each building; but for a series of police quarters or cells or similar structures, it is found in practice that the total cost of concrete roofing is generally about the same as for double tiles and teakwood, though in favourable cases it is sometimes less.

13. **Repairs.**—The main advantage of this concrete construction is, that the roofs require practically no repairs, and experience gained in constructing and maintaining more than 25,000 superficial feet in the Kaira district has established its economical character in this respect. Occasionally the plaster requires looking to, and small cracks have to be filled in as in flat roofs, but in many instances, during 18 to 20 years, nothing whatever has been necessary.

14. **Ancient concrete roofs.**—Flat roofing of concrete (without timber) is found in some of the old Mahomedan buildings in Gujarat.

15. **Leakage.**—Sometimes concrete roofs, though apparently quite sound, are found to leak after they are first made, as the lime concrete is porous. The remedy is to give the top a coat of paint; a coating or two of oxide of iron paint should render the roof quite water-tight as was found on the Mutha canal.

Tar would also do, but is objectionable for other reasons.

16. **Lime.**—For concrete arches it is most essential that the lime should be of the best quality.

The lime used at Bijapur was obtained from *kankar* nodules gathered from black-soil fields, and is of the kind usually found throughout the Deccan. An average sample gave the following analysis :—

Slica	3·58
Alumina and peroxide of iron	3·68
Carbonate of lime	91·15
Carbonate of magnesia	Trace (not determined).
	98·41

Three other samples gave percentages of 90·88, 90·68 and 91·15 of carbonates of lime. The presence of magnesia in any large quantity is very deleterious, and. there have been many failures in Baluchistan with limes made from magnesian limestone

17. **Sand.**—The sand should be clean and sharp, and should be washed if it contains any proportion of earth.

18. **Aggregate.**—The stone metal should be broken to strictly 1½ inch gauge. Instead of stone metal any of the following may be used :—

(*a*) Screened shingle, if the stones are not rounded and water-worn.

(*b*) Red laterite or ironstone nodules, often called red muram. The lumps must be hard and must be washed to remove all earth. The nodules are to be such as will pass through a 1½ inch ring and will not pass through a ½inch ring.

(*c*) Lime kankar nodules.—The hardest obtainable. The nodules must pass through a 1½ inch ring and must not pass through a ½ inch ring.

(*d*) Broken brick.—The pieces to be broken to pass through a 1½ inch ring as for road metal, and the rammers used must be light, so as not to pound up the bricks. The bricks must be thoroughly sound and well-burnt.

INSTRUCTIONS AND SPECIFICATIONS FOR LIME CONCRETE ARCHING FOR BRIDGES, CULVERTS AND AQUEDUCTS.

(Plates XVI and XVII.)

Specification No. 64.

1. **Materials and proportions.**—The mortar shall consist of :—

(*a*) 1½ parts of clean sand,

(*b*) 1 part of slaked lime.

2. The concrete shall consist of :—

(*i*) 2 parts of broken stone metal not exceeding 1½″ gauge,

(*ii*) one part of mortar.

3. The proportions of aggregate and mortar shall be carefully measured in a wooden box (' phara ') 5′ × 5′ × 1′ 1″, which must have a groove marked 4″ from its top (i. e. 9″ from its bottom), on the mixing platform.

4. Mixing platform.—Should be of wood (sleepers or planks laid with close joints) or of lime concrete, or brick or flat slab masonry. Iron sheets deteriorate rapidly. The platform must be laid perfectly level.

5. **Method of mixing materials.**—The " phara " should be placed on the mixing platform and filled to within 4″ from its top with clean well-soaked metal. The top 4″ of the " phara " should be filled with mortar well mixed so that it attains the consistency of a thick jelly.

6. The mixing of the materials shall be as follows :—

The " phara " is removed. Two men facing each other stand at the shorter end but on opposite sides of the heap. They divide the heap into two parallel heaps by drawing over the material towards themselves with the " phawra ", which is given a twist upwards so as to bring the bottom stuff uppermost each time. They proceed in this manner to the end of the heap which is thus divided equally. The two heaps are now turned over a second time, away from each other and are then about 5 feet apart. This operation is repeated a third time when the heaps are left about 7 feet apart.

CONCRETE ARCHING.

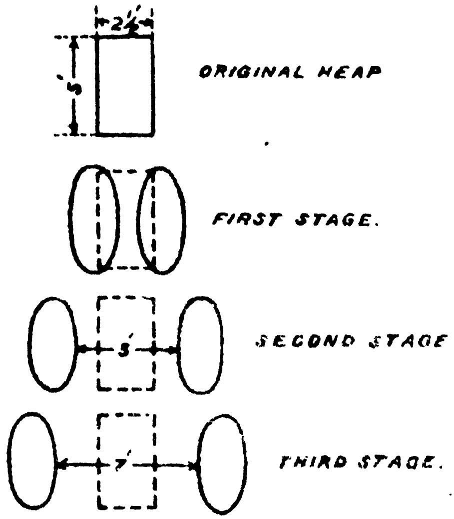


FIG I.

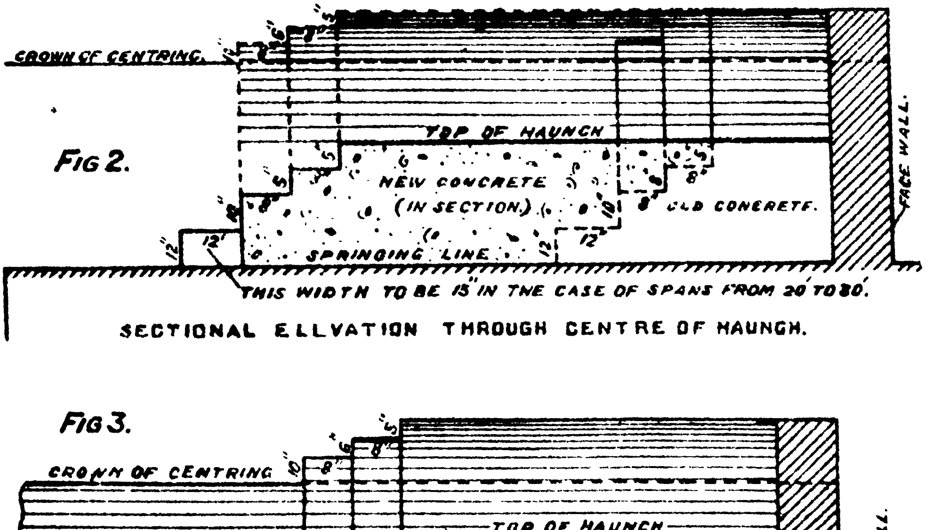
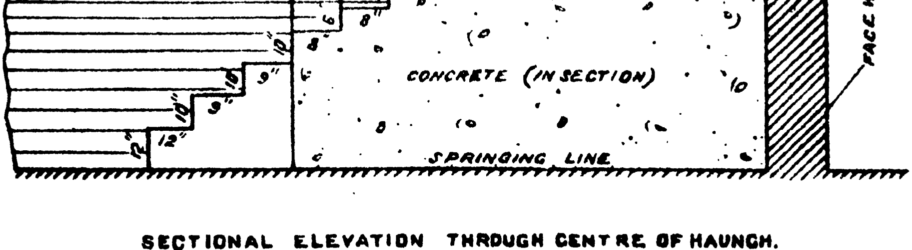


FIG 2.

SECTIONAL ELLVATION THROUGH CENTRE OF HAUNCH.

FIG 3.



SECTIONAL ELEVATION THROUGH CENTRE OF HAUNCH.

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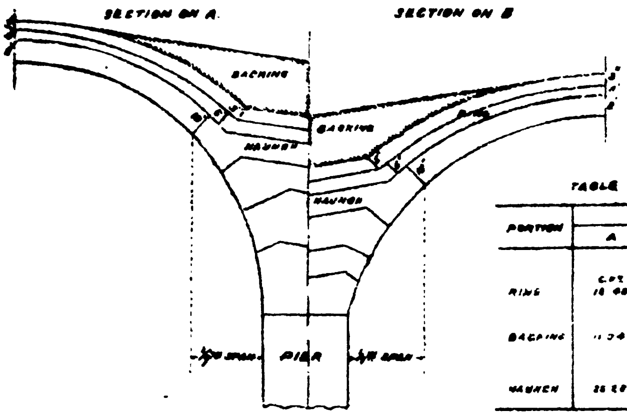
CONCRETE ARCHES

METHOD OF CONCRETING



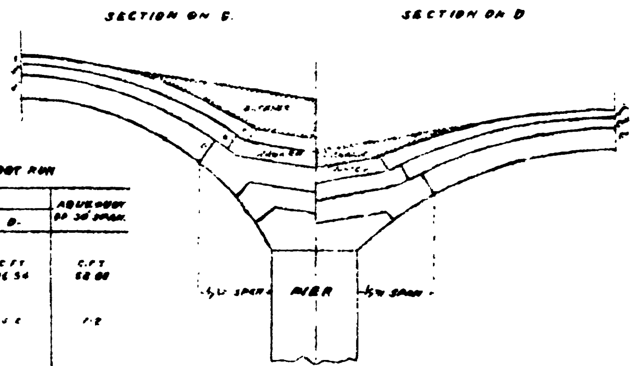
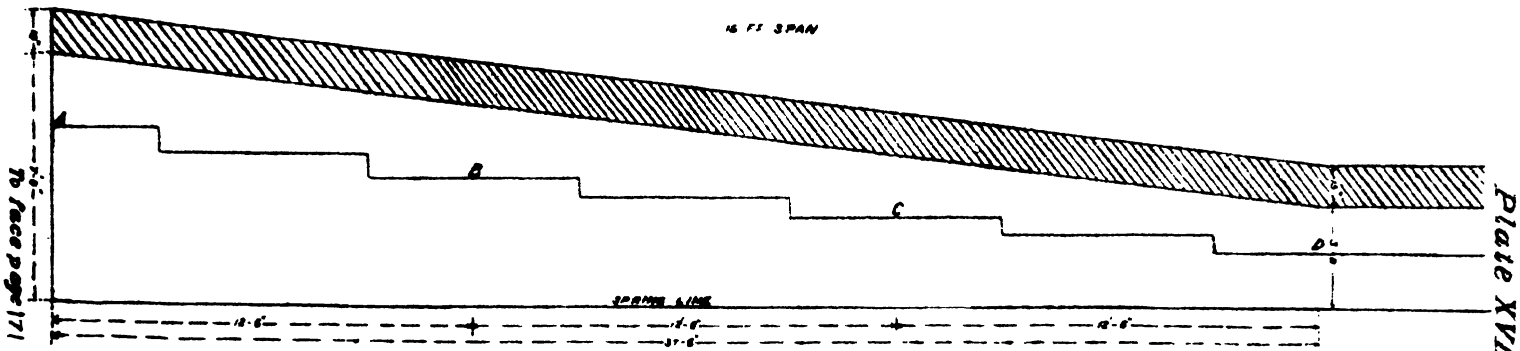


TABLE SHOWING CONTENTS PER FOOT RUN

PORTION	CULVERT OF 15 FT. SPAN				AQUEDUCT OF 30' SPAN.
	A	B	C.	D.	
RING	C.FT. 18.00	C.FT. 18.45	C.FT. 15.00	C.FT. 16.54	C.FT. 58.00
BACKING	11.24	10.00	7.65	5.2	1.2
HAUNCH	25.28	20.52	18.16	15.1	30.65

CULVERT BELL MOUTH

15 FT. SPAN



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The three stages of mixing are illustrated in Fig. 1, plate XVI. The men now stand between the two heaps which are brought together in a reverse manner to that described above. Two men working as above can mix between 500 and 600 cft. a day. The result is a well mixed concrete with no uncoated pieces of metal and is ready for use.

Adding water at the time of mixing is strictly prohibited.

7. **Laying and ramming.**—A layer of ½″ to ¾″ fresh mortar should be plastered on the centering, or any stone work before the concrete is laid. No more plastering should be done than can be covered in ten minutes by concrete. Plaster not covered in that time should be removed and redone.

8. Over the plaster the concrete is laid in a layer, a single basketful (' ghamela ') at a time. As each basketful is laid, men with iron rammers should be set to work on ramming immediately. This will give a layer of 2″ to 3″, which is easily consolidated within 15 minutes. If the mortar does not "cream" up, ramming should be continued until it does so. All loose metal should be removed before the next layer of concrete is laid. One man per 100 cft. of concrete will prove quite satisfactory. For the concrete ramming well into corners or cavities, small wooden rammers with chisel-shaped heads should be used.

9. Lime concrete arches are laid in two ways :—

(1) Laying the arch in thin complete rings till the full depth of the arch is obtained.

(2) Laying the arch voussoir-wise i.e. laying the arch of the full depth and full length from face to face, and to cover such portion of the centering as can be finished in a day, leaving a radial surface for next day's laying. Care should be taken to see that the radial joints are symmetrical on both sides of the arch.

10. **Ring method of laying.**—The haunches should first be laid, and the width of the haunch on the centering should not exceed 1/7th span of the arch measured from the face of the pier or abutment. The laying of concrete in the haunches should proceed in the manner indicated in the drawing (plate XVII), and the layers should have concave surfaces.

The joints of haunches should be at right angles to the curve of the centering that is radial.

The concrete should be left off each day in steps as shown in the drawing, and as under :—

Depth of arch ring.	1st step.	2nd step.	3rd step.	4th step.
12″	6″	3″	3″	......
15″	8″	4″	3″	......
21″	9″	5″	4″	3″
24″	9″	6″	5″	4″
30″	10″	7″	7″	6″

11. In the case of segmental arches, in the haunches on piers or abutments a step of 12″ depth for spans of 15′ to 20′, and 15″ depth for spans of 25′ to 30′ with a projection of 12″ beyond the first step should be kept so as to have a proper bond in the next length of the arch laid. This is shown in Fig. 2, plate XVI.

In the case of semi-circular arches the haunches should be stepped off with two or three steps according to the depth of the haunch as shown in Fig. 3, plate XVI.

12. The middle portion of the arch ring, that is the portion between the haunches, must be laid in one day, otherwise the arch will not be homogeneous. The arch ring should be laid in three layers, as mentioned in paragraph 10 above, and the backing should be completed with the last layer of the arch ring so as to make the arch water-tight for culverts and aqueducts.

13. **Voussoir-wise method.**—Both haunches of a span should be completed first. The method of laying concrete in the haunches, should be the same as in the case of the ring method and as per drawing. Then the length of the arch ring (middle portion) which can be completed in one day, should be taken in hand. Under no circumstances should the arch ring be laid in layers in two days. If the full thickness of the ring is not completed in one day, the piece should be removed and relaid.

14. **Finishing off.**—The concrete used in the top most layer of arches for culverts and aqueducts, should contain 55 per cent. mortar, so that it creams up easily. Twelve hours after completion of the last layer and the backing, a $\frac{3}{8}''$ layer of mortar should be laid. This mortar layer, or plaster, should be tapped with wooden beaters for two or three days continuously.

15. **Watering.**—After an arch has been completed, it should be covered with $\frac{1}{2}''$ layer of sand, kept well watered constantly for two months. The haunches should be kept full of water during this period.

16. **Centrings.**—Earth centrings are generally used for culverts and bridges, also for aqueducts of spans less than 10′, or where there is no fear of water coming up against the centrings. Over the earth filling of the centring, flat stone chips are laid, and on these chips $\frac{1}{2}''$ to $\frac{3}{4}''$ lime plaster is applied. Finally cow-dung wash should be applied to the plaster, and just an hour before concrete is laid, a fresh layer of thick cow-dung wash should be applied to the centring. The centring should not be removed until at least three weeks after completion, of arches of spans of under 10 feet and longer for larger spans. The approximate period determining the time that must elapse before a centring can be removed is given in the following farmula :—

$$N = 9{\cdot}36\sqrt{S \times T}.$$

Where N = Number of days after completing arch.
S = Span of arch in feet.
T = Thickness of arching at crown in feet.

Rate Abstract.—The following is a rate abstract for laying concrete including cost of materials and centring in the Lonand district :—

Materials.	Quantity.	Rate.	Per.	Amount.	Labour.	Quantity.	Rate.	Per	Amount.
Metal 1½″ ... Cft.	100				Grinding mortar	50			
Sand ... „	50				Laying concrete	100			
Lime ... „	33				Watering ... „				
					Total, labour		...		...
Total, materials		...	...	...	Total, magerials		...		...
					Total per 100 Cft.		...		...

For general rate abstract see page 356.

POINTING.

General.

1. Pointing should be avoided as much as possible as the raking out of joints is generally undesirable. Good mortar is removed and a mortar which is very seldom sufficiently watered is substituted. Lime pointing of coursed work should be prohibited. Instead the joints should be struck neatly 2 or 3 days after the masonry has been laid.

2. The joints should be rubbed smooth with a *nayla* as soon as they have begun to set; the lime when so rubbed works out to the surface combines slightly with the iron and when set, forms a very hard skin having a continuous union with the hearting.

3. The exact joint should be struck with a trowel on a straight-edge and all superfluous mortar removed.

4. This is all that is necessary, and, if done while the work is in progress before the mortar has set, the joints look as well and neat as any pointing, and of course save the unnecessary cost of pointing.

5. When pointing is considered necessary, the following specifications may be used:—

LIME POINTING.

Specification No. 65.

1. **Face-work.**—All face or visible work shall be pointed, unless otherwise specified.

2. **When to be done.**—Shall, if possible, be done while the mortar in the joints is " green " and fresh.

3. **Raking out joints.**—The mortar shall be raked out of the joints at least ¾ inch deep, 7 or 8 days after the courses are laid. The dust shall then be brushed out of the joints, and the work well wetted and washed with water.

4. **Mortar.**—The mortar shall consist of equal proportions of lime and fine sand shall not be ground fine, but the sand should be finer than that in ordinary mortar. A little wood apple (*bael-frujt*) pulp should be added to the mortar, but the addition of chopped hemp should be prohibited.

5. **Joints, raised or flat.**—The joints of the pointed work shall be neatly defined by the pointing, the lines shall be regular and uniform in breadth and the joints shall be raised or flat as may be directed. No false joints will be allowed. When " tuck " pointing is required, it should project from the joints so as to form a narrow white ridge, the edges of which should be cut off parallel, so as to leave a raised line about 1/8 inch wide.

6. **Wetting.**—The work pointed shall be kept wet for at least three days after the pointing is complete.

For Rate Abstract, see page 357.

CEMENT POINTING.

Specification No. 66.

1. Shall be executed as rapidly as possible, and not again touched after it has once begun to set, which it will do very soon. It must then be kept constantly wetted for ten days.

2. Mortar to consist of equal parts of Portland cement and sand.

For Rate Abstract see page 358.

"PONTING OF STONE MASONRY (COURSED RUBBLE) WITH NAYLAS ILLUSTRATED IN PLATE XVII-A.

Specification No. 67.

1. The small 4″ nayla to be used only for vertical joints while the other two naylas for horizontal ones.

2. For horizontal joints the long nayla should first be used to get a proper straight line.

3. The joints should then be pressed with the naylas as soon as the mortar has begun to set and the hollow spaces refilled with fresh hard mortar, tapped and pressed with the nayla to allow the mortar to consolidate in the joints. Joints should be rubbed straight truly vertical with small nayla, and horizontal with medium nayla, till they get $\frac{1}{4}''$ deep into the masonry and assume a fairly blackish colour.

4. After rubbing, the extra mortar found spread on the edges of joints should be carefully scraped off with the nose of the nayla (specially provided for the purpose in leaf shape) to give a neat appearance."

PLASTER.

General.

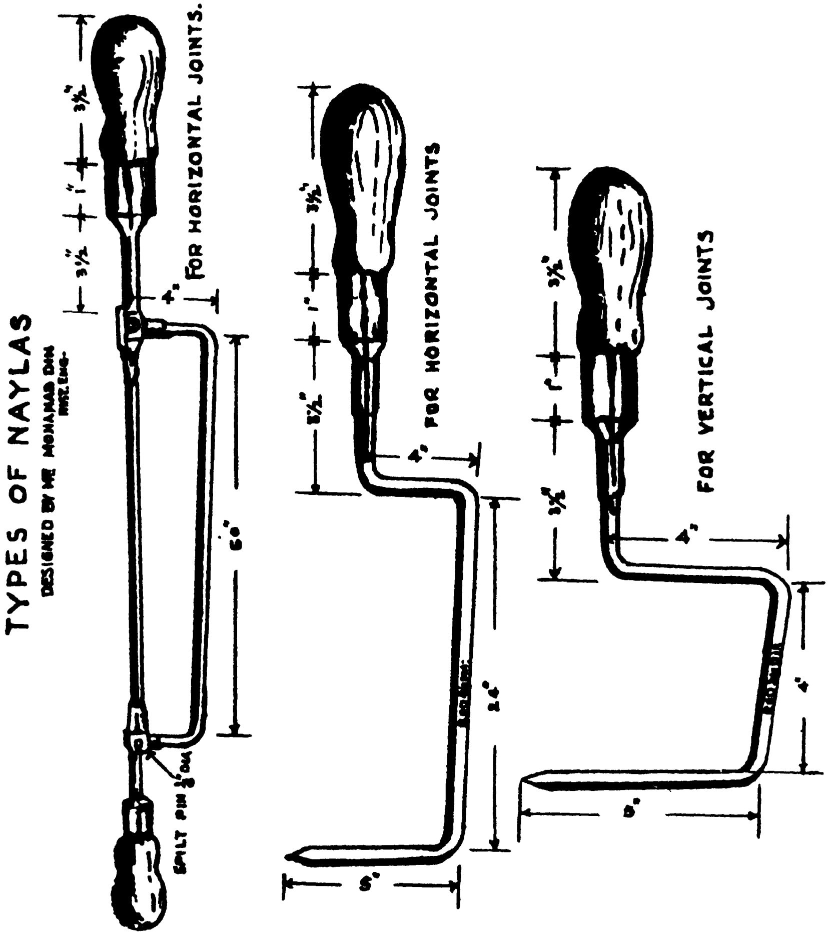
1. Joints will be raked out as for pointing and the walls throughly wetted. Walls may be plastered with lime, cement, or mud plaster, as may be ordered, and the plaster may be applied in 1, 2 or 3 coats, but no single coat shall exceed $\frac{3}{4}''$ in thickness. On very rough walls a preliminary coat must be given to fill up the hollows before the first plastering coat is laid on.

2. Patches of plaster 6″ × 6″ should be put on about 10 feet apart, as gauges to ensure even plastering in one plane. Cement plastering must be done in squares or strips as cracks appear if a large surface is done.

3. Fat or shell limes make the best plaster. In hydraulic limes there is always a danger that some particles may be unslaked which, slaking after being laid, will cause blisters to form in the plaster.

4. Mortar for lime plaster to be in the proportion of 1 lime to 1 sand well mixed in a mortar mill. To every 100 cubic feet of mortar about 10 lbs. of *gugal* (a kind of

Plate XVII A



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fragrant gum—*Amyris agallocha*) to be added. The *gugal* to be boiled with a sufficient quantity of fresh water before being mixed with the mortar. A small quantity of hemp (6 lbs. to 100 c. feet of mortar) chopped up small is often added to the mortar in addition and well mixed by beating with wooden tappers.

This mortar should not be used fresh but allowed to stand for about 48 hours before being used being turned once a day to make the mixture thorough.

LIME PLASTER, ROUGH, ¾ INCH THICK.

Specification No. 68.

1. **Wetting masonry.**—All joints in masonry and brick-work are to be raked out to a depth of at least ¾ inch and the wall to be washed with fresh water and thoroughly wetted for six hours before plastering is commenced.

2. **Thickness.**—A rendering of plaster sufficiently thick to cover by ¼ inch all projections, (¾ inch for rubble and ½ inch for brick-work will generally be sufficient) to be applied in an even and uniform coat well pressed into the joints and to be well beaten for 1½ days with hand tappers the plaster being wetted occasionally with fresh water while the beating is in progress. Over this a mixture of fine lime and white-washing lime in the proportion of two of the former to one of the latter, to be laid and made smooth with wooden rubbers, and very lightly beaten.

3. **Finishing coat.**—Finally, the finishing coat, consisting of one part of fine lime and two parts of white-washing lime, is to be applied and well polished with trowels.

4. The completed plaster should be allowed to rest for 24 hours, and then be sprinkled with water at short intervals for four or five days.

Notes.—(*a*) The plaster should also be well sprinkled during the process of beating with a mixture of 7 lbs. of *gur* (coarse sugar) dissolved in 20 to 30 gallons of fresh water to which may be added 4 lbs. of wood apple (*bael* fruit pulp). This will quicken the setting and improve the quality of the mortar.

(*b*) In all plaster work long straight edges should be freely used to ensure a perfectly even surface. All corners and angles should be plumb and true and the soffits of arches must be true arcs of circles.

5. **Powdered soap-stone.**—For very fine work the addition of a little powdered soap-stone will increase the whiteness and polish of the plaster.

6. **Rate.**—The rate of each kind of work to include all ladders, stages, scaffolding, etc., that may be required.

7. **Mouldings.**—All mouldings shall be worked true to template and drawn neat, clean and level. All exposed angles and junctions with door frames to be carefully finished. Arrises to be beaded, if ordered.

8. **Measurement.**—Plaster shall be measured on length and height of walls, no deductions being made for openings, or additions allowed for returns and soffits, the latter being considered equivalent to the former.

Cornices and mouldings to be paid for per running foot.

The following is a useful mixture for repairing plaster which is not to be covered over by paint or lime wash :—

	Lbs.
Kunkar lime, roughly ground...	50
Cement	5
Black slag from brick-kilns, roughly ground ...	15
Black colouring matter extracted from the cooked fruit of wild pomegranate (*anari*)	½
Gur (coarse sugar)	2
Bael-fruit	2

For Rate Abstract see pp. 358 and 359.

HIRDA PLASTER.

Specification No. 69.

Preparation of wall to receive plaster.—All joints in stone masonry to be raked out to a depth of ¾", and the wall washed for 6 hours with fresh water. In brick-work, the mortar to be allowed to project to form a key.

Plaster.—(1) Lime to be screened through a sieve of 12 meshes to the inch, and the proportion of mortar for plaster to be 1 of lime to 1 of sand, well mixed in a mortar mill.

(2) The mortar shall be well turned over and thoroughly ground, and after taking out shall be kept well wetted for a period of two weeks. It will then be again put in the ghani and reground.

(3) After this, the mortar to be kept for 24 hours, and immediately before using, to be brought to the right consistency, with water prepared as under :—

To eight gallons of water, one seer (2 lbs.) of gur, and 5 seers (10 lbs.) of hirda fruit the husk of which has been thoroughly bruised, are added, and allowed to soak for 48 hours. This solution will be sufficient for about 100 c. ft. of mortar, and shall be added after stirring as required, a solution prepared by dissolving 7 lbs. of gur in 25 gallons of water.

(4) A rough coat of plaster to be thrown on the walls to the thickness of about ¼" to form a key for the rendering.

(5) The hirda plaster to be then applied sufficiently thick to cover by ¼" all projections, ¾" for rubble and ½" for brickwork, any stones projecting beyond this thickness having previously been dressed down ; it is to be well beaten for 1½ days with hand tappers putting on one coolie to every 200 sq. ft. of wall surface. While the beating is in progress the surface to be wetted frequently with fresh water in which 7 lbs. of 'gur' are dissolved in 20 to 30 gallons of water. Special care to be taken to see that external angles are well tapped. This rendering to be then left and watered with fresh water for 6 days.

(6) Over the rendering a fine coat of fine lime and whitewashing lime in the proportion of 2 whitewashing lime and 1 fine lime not more than 1/16" thick and made smooth with wooden rubbers and straight edges and very lightly beaten. The use of straight edges to be insisted on and all angles to be in plumb.

(7) Lastly a finishing coat of whitewashing lime only, laid as thinly as possible and well polished with a steel trowel.

(8) The completed plaster to be watered for 4 or 5 days after being allowed to stand for 24 hours.

LIME PLASTER, ROUGH CAST, HALF INCH THICK.

Specification No. 70.

Raking out of joints, thoroughly wetting the wall surface, etc., as in Sp. No. 68.—This is a rough plaster composed of slaked lime, mixed with coarse gravel and lime screenings, in such proportions as may be ordered, applied to the exterior of buildings about ½ inch in thickness, dashed on to form a uniformly rough surface ; if it is to be coloured, mix the colour with the rough mortar.

For Rate Abstract see p. 359.

ROUGH CAST CEMENT PLASTER.

Specification No. 71.

1. **Wetting and raking masonry.**—All joints in stone and brick masonry shall be thoroughly wetted and raked out to a depth of at least ¾″, and the walls washed with fresh water and thoroughly wetted for three hours, before the plastering is done.

2. **Coats.**—The plaster shall be laid in two coats. The first coat shall consist of 1 part of cement and 1 part of clean sharp sand. The thickness of the first coat shall be just sufficient to fill up all unevennesses in the surface under treatment. The second coat shall consist of 1 part of cement, 1 part of fine sand and 1 part of coarse sand or ¼″ gravel. The thickness of this coat shall be ½″.

3. **Application.**—The first coat shall be dashed on to the prepared surface with a trowel to even up inequalities, but the surface shall not be smoothed. The second coat shall be applied while the first coat is still soft.

4. **Mixing.**—Cement and sand shall be mixed dry in the proportion specified, and water shall be added to form an easily worked paste. In no case, shall mortar which has been allowed to stand for more than half an hour after mixing, be used.

5. **Colouring.**—If it is desired to colour the surface, the best plan is to mix the colour with the second coat, in the proportion required to give the desired tinge. As the colour fades, on drying a deeper shade than is desired should be applied.

6. The cement mortar that falls to the ground in the process of application shall on no account be used.

7. **Watering.**—Care shall be taken to keep the whole surface thoroughly wetted for at least a week.

8. **Measurement.**—The measurements shall be by square feet, no deductions being made for door and window openings unless the plaster is on both sides, in which case the deduction shall be for one face only.

For Rate Abstract see p. 360.

BRICK-RUBBED ROUGH PLASTER.

Specification No. 72.

Wet wall thoroughly, and then daub on a paste formed of pure or nearly pure lime and water at every few inches of wall, and rub freely with a soft red brick dipped in strong jagri water, say 1 lb. to the gallon of water. Continue the rubbing till it sets, in a few minutes. The plaster should be just sufficient to cover all inequalities in the building courses.

This description of work can be done at about 12 to 15 annas per 100 squares feet.

CEMENT PLASTER.

Specification No. 73.

1. The walls to be prepared as for lime plaster.

2. "Render" with a mortar of equal parts of Portland cement and fine sand 1 inch thick, unless otherwise specified, and roughen but do not beat.

3. Float or "set" with a thin coat, ⅛ inch, of pure Portland cement, and polish well immediately with a trowel or flat board.

The cement to be used within twenty to thirty minutes after it leaves the mixing board or mill.

For Rate Abstract see p. 361.

CEMENT RENDERING.

General.—(1) "Rendering" is the application of a mortar surfacing on brick, stone or concrete walls. It differs from ordinary plastering in that cement is used as the binding agent in place of lime, and chopped grass, hair, etc., are not added to the mortar.

(2) **Cleaning the surface.**—The wall surface shall be prepared to receive the baiking coat of rendering by being thoroughly cleaned from dust, loose particles, grease and oil stains by washing, using a wire brush if necessary.

(3) **Preparing the surface to form a key.**—The brickwork, stone masonry or concrete shall be prepared to receive the rendering by harking, raking out joints to a small depth not more than ¼", or in the case of hardened concrete by beating a thoroughly saturated surface by a 1 : 6 solution of hydrochloric and water, washing down within six hours and wire brushing, so as to expose the aggregate. If in the opinion of the Executive Engineer, the surface provides sufficient key, and is perfectly even, a single coat ⅜" to ½" thick shall suffice.

(4) **Key Coat.**—If however a good key is not obtained, a base coat, of course sand and cement in the proportion of 1½ parts sharp sand ¼" down to 1 part portland cement, mixed in sufficient water shall be applied, being dashed on to the wall in

an uneven manner. This coat should be applied in ¾″ layers stone masonry till stone bushing is covered. (Layer projections being marked previously.)

(5) **Materials.**—(*a*) The aggregates shall be perfectly clean, hard, sharp and well-graded, cleanliness being obtained by thorough washing. If the aggregate is crushed stone very fine particles and dust shall be eliminated. The cement shall comply with the latest Br. St. specifications and shall be kept perfectly dry. The water for mixing shall be tap water where possible, and where this is not available, it should be clean and uncontaminated by acids, dissolved salts or other deletarious matter.

(*b*) The grading of the aggregate shall be ¼″ down for key and backing coat, and that for the finishing coat 1/8″ down.

(*c*) The proportions in the case of cement and aggregates are 1 : 3, for the backing and finishing coats, but 1 : 1½ for the key coat.

(6) **Backing Coat** shall be prepared with the proportions given in paragraph 5(*c*) and shall be mixed with adding water from 12 to 16 per cent. of the total volume of aggregate and cement. It shall be laid to a uniform thickness of ⅜″ and just after the material has started to set, it shall be scored in wavy lines by a wire-nail comb to form a bond for the next coat, and the work then allowed to set for at least 30 hours, the work being kept well damp.

(7) Finishing Coat shall be of the proportions given in paragraph 15(*c*), shall be mixed with the addition of water forming 14 to 18 per cent. of the total volume of aggregate and cement, and shall be approximately 1/8″ thick. The base coat shall be washed clean and the finishing coat carefully applied evenly.

(8) **Curing.**—The finishing coat shall be protected from the sun and hot winds or rain by wet screens till it has hardened sufficiently to be unaffected by the external application of water. It shall then be wetted and kept damp for a period of at least 7 days.

(9) **Precautions against cracking and crazing.**—The surface shall be divided by joints to prevent cracking, and these joints shall be placed horizontally at the sill and lintel levels of windows and vertically at openings in wall and angles and corners. The surface shall be kept damp and allowed to dry as slowly as possible.

Rough Cast.

General.—The key and backing shall be applied as for rendering and a thin coat added to take the rough cast.

Proportions.—Three parts approved aggregate ⅜″ to ¾″ in size mixed with cement and fine sand in the proportion of 1 cement to 1½ sand.

Mixing.—A slightly larger amount of water shall be added than for ordinary rendering to ensure the larger aggregate being thoroughly covered and the whole thoroughly mixed and cast on by hand or applied with a trowel or float curing and precautions against cracking as in rendering.

PLASTER OF CHUNAM AND PORTLAND CEMENT.

Specification No. 74.

To be made in a similar manner to ordinary lime or chunam plaster as described above, with the exception that Portland cement and prepared lime or chunam shall be used in equal proportions in the mortar and the plaster finished with a coating of *neeru* and cement, also mixed in equal proportions, or cement and fine sand, as may be directed by the Executive Engineer.

The mortar to be used within twenty to thirty minutes after it leaves the mixing board or mill.

MADRAS PLASTER (ON ¾″ ROUGH COAT OF LIME PLASTER).

Specification No. 75.

Plaster the walls with chunam plaster as per specification No. 68, taking care that the face of this plaster is kept ⅛″ less than the required face or finished surface. Allow this to set for 2 or 3 days and then score the surface of it thoroughly with diagonal lines crossing each other. Then keep constantly watered and allow to remain till nearly set, when the polish coat may be proceeded with.

1st coat.—One coat about ⅛ inch thick of the following mixture to be applied, and brought to an exact level surface with long wooden floats (or, where required, with curved moulds) :—

Shell lime	12 parts.
Fine white sand	9 parts.
Powdered marble	1 part.

The surface of the rough coat to be well watered before applying this coat.

The sand is ground very fine in a flour 'chakki'. The marble is also ground fine in a mortar and pestle, and sifted through muslin. The materials are mixed with water and kept in a heap well wetted for two days.

2nd coat.—The same mixture as used for the first coat is now to be ground on curry stones with stone rollers, to the consistency of fine river mud, and a layer of this about 1/32″ thick, is to be applied over the first coat which is to be wetted before hand.

. The surface of this second coat is now to be polished first with trowels and then with very hard smooth stones. While the polishing with smooth hard stones is going on, soapstone powder contained in thin muslin bags is to be dusted on the surface, and work to be continued until a high smooth polish is obtained.

Great care to be taken to avoid bad joints between two days' work.

For Rate Abstract, exclusive of ¾ inch rough coat of lime plaster, see p. 361.

PAINTING MASONRY JOINTS WITH A MIXTURE OF PITCH AND TAR.

Specification No. 76.

Two parts by weight of coal tar, and one part by weight of pitch are put in a vessel and heated and stirred,until the mixture is sufficiently liquid to enable it to be applied with a brush, to masonry joints or wall surface.

This mixture has been found to keep out damp very well in Belgaum.

MUD PLASTER.

Specification No. 77.

For mud plaster none but well tempered clay or brick earth, free from vegatable mould, gravel or roots, should be used. The clay is to be sifted fine and thrown into a pit with chopped straw and cowdung in the proportion of 1 cubic foot of fine clay to 1 cubic foot of cowdung. It is then to be well mixed and flooded with water and left for a week or two, after which it is to be floated on in thin coats, any extra thickness required being given by increasing the number of coats, and not the thickness of each.

EXPANDED METAL LATHING AND PLASTER PARTITION.

Specification No. 78.

Expanded metal and plaster partition.—The partition to consist of an expanded metal lathing ground, covered with a total thickness of 2″ of lime plaster finished smooth on both sides. The work will be measured as square feet on one side only.

2. The expanded metal ground, is to consist of expanded metal diamond mesh lathing, size No. 1, $\frac{3}{8}$″ short way of mesh and 24 gauge of metal, weight approximately $3\frac{1}{2}$ lb. per superficial yard. This lathing is to be stiffened by $\frac{3}{8}$″ diameter round iron tension rods, spaced one foot apart vertically, and these rods are to be fixed tight and firm by suitable clips, to the joists or tee irons or tie-beams of trusses in the ceiling and floor ; the lathing is to be tied (at intervals of not more than 4″) to these tension rods, by means of 18 gauge galvanized soft iron wire, and where the sheets join they are to be overlapped one mesh, and tied in a similar manner at similar intervals Where the lathing butts up against wood-work (such as door and window frames, etc.) it is to be fixed at intervals of not more than 4″, by galvanized iron slice cut staples of $1\frac{1}{4}$″ length.

3. All metal work such as clips, tension rods, etc., is to be coated with two coats of red oxide paint before being fixed in the work and only painted lathing is to be used.

4. As the sheets are stronger the long way of the meshes, they should be fixed with the long-way meshes at right angles to the tension rods, and care should be taken that the strands in the various sheets all slope in one direction.

5. Ordinary lime plaster is to be used and is to be finished to a total thickness of 2″, including a fine coat on each side. The plaster should be mixed "stiff" Excessive pressure should be avoided when laying it. The water used for the plaster should be perfectly clean.

6. **Render coat.**—To consist of $1\frac{1}{2}$ parts of clean sharp coarse river sand, 1 part of thoroughly cool slaked lime, and not less than $\frac{1}{2}$ part of Portland cement, thoroughly mixed with chopped hemp, free from grease, dirt and other impurities, in the proportion of not less than 1 lb. of hemp to 3 c. ft. of mortar.

7. **Finish.**—To be the usual fine finishing coat.

GUNITING.

Gunite is a mixture of cement and sand deposited in the form of a cement plaster ejected under a pressure of 30/40 lbs. per square inch, from a cement-gun. The sand and ement are mixed almost dry, the necessary water being added as the mixture issues from the gun.

This process has been extensively used in rehabilitating old Reinforced concrete work which has deteriorated, either due to climatic conditions or inferior work or any other reason. It is also used in providing a very impervious layer to resist water pressure on pipes, cisterns etc., or as water-proofing for exposed work.

It has manifest advantages : viz.

(1) rapidity of execution in any situation without taking down members.

(2) High impermeability and

(3) High compressive strength.

Specification for rough cast cement plaster Gunite $\frac{1}{2}''$ thick.

Material.—The material to be fed to the ' cement gun ' must not be too moist or too dry. It is therefore recommended that slightly moist sand should be used.

The grain diam. of the material used in the different types, must not exceed the following dimensions :—

Cement Gun. Type N-2	...	3/8″
„ „ N-1	...	1/4″
„ „ N-0	...	$\frac{1}{8}''$ to $\frac{1}{4}''$

Sand should be clean, sharp and well graded.

Air.—The compressed air entering the gun must be dry and free from oil.

Water.—Must be pure and potable quality.

Shooting.—The surface or area to be gunited must be carefully cleaned using compressed air or water or both. Sharp sand is fed into the gun-surfaces which absorb much water and thus prevent the Gunite from adhering or setting properly must be thoroughly wetted before the Gunite is applied.

Notes.—While shooting the nozzle should under normal conditions be held at a distance of 30″ to 35″ from the surface to be treated.

If sand trowelling is obligatory, it should be done immediately after shooting as ' Gunite' hardens in a short time.

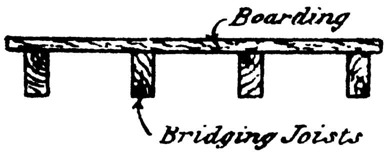
Before Guniting the casing forms and must be thoroughly wetted in order to facilitate early removal.

Plate XVIII

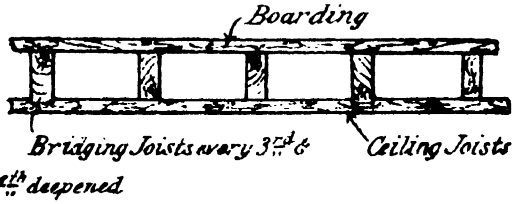
— CONSTRUCTION OF WOODEN FLOORS. —

— SINGLE JOISTED FLOORS —

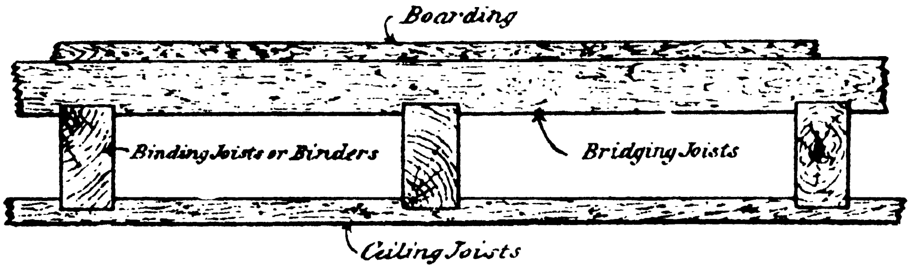
Without Ceiling Joists



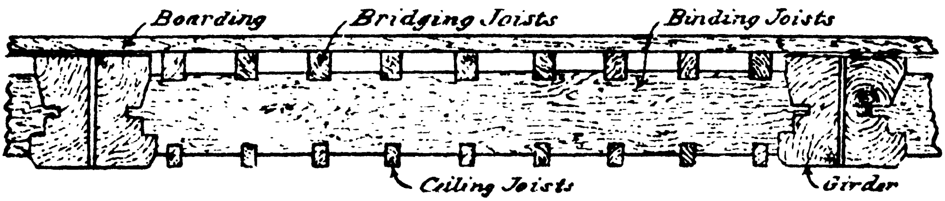
With Ceiling Joists



— DOUBLE FLOOR WITH CEILING JOISTS. —



— FRAMED FLOOR. —



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FLOORS.

WOODEN FLOORS.

Notes.

1. There are three general divisions of wooden floors:—

Single floors,

Double floors,

Framed floors.

2. In all of these the floor planking is carried by the "bridging joists," the difference consisting in the way these bridging joists are supported.

3. Floors require to be stiff and rigid under the maximum load they may be called upon to carry, and on this account the timbers are usually stronger than would be necessary if strength only were considered.

4. In order to calculate the stiffness of the floor it is usual to allow for a bending of from $\frac{1}{40}$ inch to $\frac{1}{30}$ inch for every foot of the span, and floors are generally cambered to this amount when being laid.

5. **Single floors** consist of planking and bridging joists only, the bridging joists being generally placed 12 inches apart centre to centre, spanning the whole room and resting on wall plates. The joists must be as stiff as possible, but in order that there shall be no difficulty in fixing the planking to them, they must have a sufficient breadth. The minimum is generally taken as 2 inches.

6. With spans greater than 8 feet, there is a danger of the joists bending sideways or buckling, and they are, therefore, strutted apart to prevent this.

7. Tredgold recommends that single floors should not have a greater span than 12 feet, but they are frequently used for domestic work for spans up to 18 feet, and they are the cheapest, strongest and simplest form with a given quantity of timber, but the ceilings are liable to crack.

8. **Double Floors.**—In these, the bridging joists do not span the whole room but rest on other joists placed at right angles to them, called *binding joists* or *binders.*

9. Binders are generally placed from 6 to 8 feet apart (Tredgold recommends 4 to 6 feet). If it can be avoided, they should not be placed immediately over window or door openings, but if this is unavoidable, they should rest on strong wall plates or templates, long enough to distribute the weight well over the piers.

10. Double floors are stiffer than single floors, prevent the passage of sound better, but the weight of the floor is thrown on to a few points in the walls. The depth of floor is also increased, and hence the height and cost of the building.

11. **Framed floors.**—In these, another timber in the shape of a girder is added. The binding joists are framed into the girders generally by double tusk tenons. As this weakens the girder considerably, the ends of binding joists are often supported by iron stirrups.

12. Girders and binders should be deep and as stiff as possible, so that there may be no danger of the ceiling cracking.

Tredgold recommends that girders should not be more than 10 feet apart.

13. Where there are fire-places in the room or flues in the wall, no joists should be placed in the masonry for the full width of the chimney breast. The ends of the joists should be carried by a trimming joist, placed 2 feet away from the chimney breast, and supported by the two joists which are outside the chimney breast. These two joists to be broader by $\frac{1}{8}$ inch for each joist supported by the trimmer, which may be of the same dimensions. The space between the trimmer and chimney breast, to be covered by stone flags or reinforced slabs.

WOODEN FLOORING FOR GROUND FLOORS.

Specification No. 79.

1. **Concrete.**—The foundation concrete to be prepared and laid in 2 layers each 3" deep as the Executive Engineer may direct. In ramming the concrete, care to be taken by constant tests to ensure the required level being maintained, and the floor having an even surface.

2. On this will be placed at 2 feet clear intervals, both along the length and breadth of the room, blocks of stone or brick masonry, 9 inches square.

3. **Joists.**—On these blocks will rest flooring joists, 4 inches × 4 inches, which will support the plank flooring.

4. **Air passages.**—A sufficient number of air passages to be provided through the walls to admit of a free circulation of air under the planked floor; the outer faces of these passages to be covered generally with expanded metal of narrow mesh.

For Rate Abstract see p. 362.

5. The floor planking to be as specified below :—

FLOOR PLANKING.

Specification No. 80.

1. **Timber.**—To be the best Moulmein teak boards, thoroughly seasoned, and of the greatest length procurable.

2. **Scantlings.**—Boards to be $1\frac{1}{2}$ inches thick and from 4 to 6 inches in width.

3. **Side joints.**—To be tongued and grooved, or tongued and ploughed, as may be specified in each instance.

4. **Heading joints.**—Heading joints to rest upon the joist below, to break joint with one another, and to be rebated and tongued together.

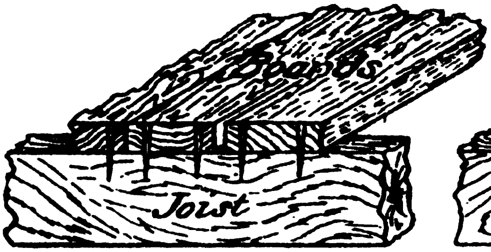
5. **Laying.**—The boards to be jammed together, as they are being laid, by flooring cramps; each board to be secured in position by two $2\frac{1}{2}$ inch screws screwed to each of the joists below.

6. **Planing.**—The heads of all screws to be countersunk and the exposed surfaces of boards then planed quite smooth.

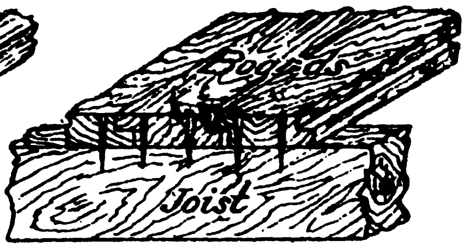
For Rate Abstracts see p. 362.

Different Methods of Laying Floor Boards

Plain Jointed

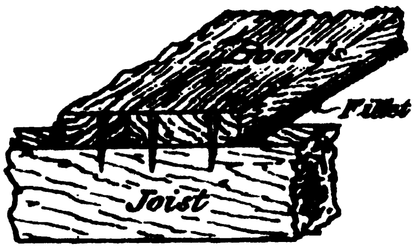


Rebated

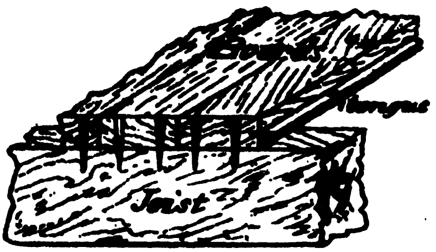


Rebated, Tongued & Grooved

Rebated & Filleted



Tongued & Ploughed



Tongued & Grooved

to face Page 184

GIRDERS AND JOISTS.

1. Shall be taken as wrought timber, put up in place.

2. For rate for floors, including girders and joists, see rates for single and double floors, pages 186 to 189.

SINGLE FLOORING.

Specification No. 81.

1. **Timber.**—To be constructed from the best Moulmein teak timber, well seasoned, free from sapwood, large or loose knots, shakes, or other imperfections.

2. **Bridging joists.**—Bridging joists to be laid in all cases at central distances of 12 inches apart, and their ends to be nailed, cogged or notched on, to the wall plates on which they rest. Their breadth may vary from 2 to 3 inches. The scantlings in each instance to be in accordance with those given in the accompanying tables. (See tables XXXIX and XL.)

3. **Strutting apart.**—When the bridging joists exceed 10 feet in length, they are to be strutted apart at intervals of about 6 feet, by simple pieces of board, one inch thick, fitted in between the joists at right angles to them, and of their full depth, or by herring-boning with strips of wood, 2 inches × 1 inch.

4. **Wall plates.**—Wall plates to be laid flush with the inner face of the wall, and to be in as long lengths as possible. When two or more pieces are required to extend along the length of the wall their ends to be carefully scarfed together. Their scantlings to be $4\frac{1}{2}$ inches × 3 inches.

5. **Floor planking.**—Floor planking to be in accordance with specification No. 80.

6. **Ventilation.**—Care to be taken that free circulation of air is allowed round the ends of the bridging joists and along the inner side of the wall plates to which they are secured.

7. **Dimensions and rates.**—The following tables show the dimensions and approximate rates for single flooring, including joists, planking, etc., complete. These rates will of course vary with the cost of teak-wood, and the rates of labour, etc., prevailing in each district.

TABLE XXXIX.

APPROXIMATE RATES FOR SINGLE FLOORING AS PER SPECIFICATION.

Weight supported—140 lbs. per square foot.

Span in feet.	Area supported.	Joists 12 inches apart. No.	L feet.	B inches	D inches	C. F.	Wall plates. No.	L feet.	B inches	D inches	C.F.	Total c. ft. joists and wall plates.	Rate.	Total cost of joists and wall plates. Rs.	a.	1¼" floor planking at Rs. 82·5 per 100 sq. ft. Rs.	a.	Total cost of area in column II. Rs.	a.	Rate per 100 sq. ft. Rs.	a.
VI ..	60	10	7	2½	4	4·86						6·73	Rs. 6-12-0 per c. ft., which includes fixing in place, cost of carriage, etc., etc.	45	7	49	8	94	15	158	4
VIII ..	80	10	9	2½	5¼	8·59						10·46		70	9	66	0	136	9	170	11
X ..	100	10	11	2½	6¾	12·89						14·76		99	10	82	8	182	2	182	2
XII ..	120	10	13	2½	8	18·05						19·92		134	2	99	0	233	2	194	13
XIV ..	140	10	15	2½	9½	24·74	2	10	4½	3	1.87	26·61		179	10	115	8	295	2	211	5
XVI ..	160	10	17	2½	11	32·46						34·33		231	12	[illegible]	0	363	12	227	5
XVIII ..	180	10	19	2½	12¼	40·40						42.27		285	6	148	8	433	[illegible]	241	1
XX ..	200	10	21	2½	13½	49·21						51·08		214	13	165	0	509	13	254	14

Note.—For scantling of joists varying from 2 to 3 inches in breadths see Table XLIII.

TABLE XL.

APPROXIMATE RATES FOR SINGLE FLOORING AS PER SPECIFICATION.

Weight supported—168 *lbs. per square foot.*

Span in feet.	Area supported.	Joists 12 inches apart. No.	L feet	B Inches.	D Inches.	C. F.	Wall plates. No.	L feet	B Inches.	D Inches.	C. F.	Total c. ft. joists and wall plates.	Rate. Rs. 6-12-0 per c.ft which includes fixing in place cost of carriage etc. etc.	Total cost of joists and wall plates. Rs.	a.	1½" floor planking at Rs. 82.5 per 100 sq. ft. Rs.	a.	Total cost of area in column II. Rs.	a.	Rate per 100 sq. ft. Rs.	a.
VI ..	60	10	7	2½	4¼	5.10						7.03		47	7	49.5		96	15	161	9
VIII ..	80	10	9	2½	5¾	8.98						10.85		73	3	66	0	139	3	174	0
X ..	100	10	11	2½	7¼	13.83						15.70		105	15	82.5		188	7	188	7
XII ..	120	10	13	2½	8½	19.18						21.05		140	8	99		239	8	199	9
XIV ..	140	10	15	2½	10	26.04	2	20	4½	3	1.87	27.91		188	7	115.5		303	15	217	2
XVI ..	160	10	17	2½	11½	33.94						35.81		141	11	132		373	10	233	8
XVIII ..	180	10	19	2½	13	42.88						44.75		302	1	148.5		450	6	250	5
XX ..	200	10	21	2½	14½	52.86						54.73		369	6	165		584	6	267	3

Note.—For scantlings of joists varying from 2 to 3 inches in breadth see Teable XLIV.

DOUBLE FLOORING.

Specification No. 82.

1. General.—Similar in all respects as regards timber, floor planking, bridging joists, etc., to specification for the various items of work.

2. Girders.—The bridging joists to be supported intermediately on girders, placed at such central distances apart as may be specified from 6 to 10 feet, and to be of the scantling requisite in each case (see tables XLI and XLII).

3. Templates or corbels.—The ends of the girders to rest in the walls, on stone or wooden templates not less than 2 to 4 feet in length, or on wall-fixed stone corbels provided for that purpose.

4. Ventilation.—When laid on templates in the wall, care to be taken to secure a free circulation of air round the ends.

5. Rise in centre.—All floors of the above description to be laid with at rise in the centre of ¾ inch in every 20 feet, to allow for the subsequent settlement which is likely to take place.

6. Dimensions and rates.—The following two tables show the dimensions of joists, and approximate rates for two classes of double flooring. These rates will of course vary with the cost of teakwood, and the rates for labour, prevailing in each district.

TABLE

DIMENSIONS AND APPROXIMATE

Weight supported—

Span in feet.	Distance apart of girders.	Area supported.	Girders, 6, 8 and 10 feet apart. No.	L Feet.	B Inches.	D Inches.	C. ft.
XII	6	72	1	13½	6¼	11¼	6·85
	8	96			7	12	7·87
	10	120			7½	12¾	8·66
XIV	6	84	1	15½	7¼	12½	9·75
	8	112			7¾	13½	11·26
	10	140			8¼	14¼	12·65
XVI	6	96	1	17½	8	14	13·61
	8	128			8½	15	15·49
	10	160			9	15¾	17·22
XVIII . ..	6	108	1	20	8¾	15¼	18·53
	8	144			9½	16¼	21·44
	10	180			10	17¼	23·95
XX	6	120	1	22	9½	16½	23·94
	8	160			10¼	17¾	27·79
	10	200			10¾	18¾	30·79
XXII	6	132	1	24	10½	17¾	30·32
	8	176			11	19	34·83
	10	220			11½	20	38·33

Note.—For scantlings of girders placed at central

TABLE

DIMENSIONS AND APPROXIMATE

Weight supported—

Span in feet.	Distance apart of girders.	Area supported.	Girders 6, 8 and 10 feet apart. No.	L feet.	B Inches.	D Inches.	c. ft.
XII	6	72	1	13½	6¾	11¾	7·43
	8	96			7¼	12¼	8·49
	10	120			7¾	13¼	9·62
XIV	6	84	1	15½	7½	13¼	10·69
	8	112			8¼	14¼	12·65
	10	140			8½	15	13·72
XVI	6	96	1	17½	8½	14½	14·97
	8	128			9	15¼	16·05
	10	160			9½	16½	19·05
XVIII	6	108	1	20	9¼	16	20·55
	8	144			9¾	17	23·02
	10	180			10½	18	26·25
XX	6	120	1	22	10	17¼	26·25
	8	160			10¾	18½	30·38
	10	200			11¼	19½	33·51
XXII	6	132	1	24	10¾	18½	33·14
	8	176			11½	19¾	37·85
	10	220			12	21	42·00

Note.—For scantlings of girders placed at central

XLI.

COST OF DOUBLE FLOORING.

140 lbs. per square foot.

Joists 12 inches apart.					Total c. ft. girders and joists.	Rate.	Total cost of girders and joists.	Floor plank at Rs. 82·5.	Total cost of area in column III.	Rate per 100 sq. ft.
No.	L	B	D	C.ft.			Rs. a.	Rs. a.	Rs. a.	Rs. a.
	Feet.	Inches.								
13	6	2½	4	5·41	12·26	Rs. 6-12-0 per c. ft., which including fixing in place, cost of carriage, etc., etc.	82 11	59 7	142 2	197 7
	8	2½	5½	9·92	17·79		120 1	79 3	199 4	207 10
	10	2½	6¾	15·23	23·39		161 4	99 0	260 4	216 13
15	6	2½	4	6·25	16·00		108 0	69 4	177 4	211 0
	8	2½	5½	11·45	22·71		153 4	92 5	245 9	219 4
	10	2½	6¾	17·57	30·22		204 0	115 8	319 8	228 3
17	6	2½	4	7·08	20·69		139 9	79 3	218 12	227 14
	8	2½	5½	12·98	28·47		192 3	105 9	297 12	232 9
	10	2½	6¾	19·92	37·14		250 11	132 0	382 11	239 2
19	6	2½	4	7·92	26·44		178 6	89 1	267 7	247 11
	8	2½	5½	14·51	35·95		242 11	118 12	360 7	251 1
	10	2½	6¾	22·26	46·21		311 14	148 8	460 6	255 12
21	6	2½	4	8·75	32·69		220 9	99 0	319 9	266 5
	8	2½	5½	16·04	43·83		295 14	132 0	427 14	267 6
	10	2½	6¾	24·61	55·40		373 14	165 0	538 14	269 7
23	6	2½	4	9·58	39·90		269 4	108 13	378 1	286 6
	8	2½	5½	17·56	52·39		353 10	145 3	498 13	283 6
	10	2½	6¾	26·95	65·28		440 8	181 8	622 0	282 12

distances apart other than the above see table XLV.

XLII.

COST OF DOUBLE FLOORING.

168 lbs. per square foot.

Joists 12 inches apart.					Total c. ft. girders and joists.	Rate.	Total cost of girders and joists.	Floor plank at Rs. 82·5.	Total cost of area in column III.	Rate per 100 sq. ft.
No.	L	B	D	C. ft.			Rs. a.	Rs. a.	Rs. a.	Rs. a.
	Feet.	Inches								
13	6	2½	4¼	5·75	13·18	Rs. 6-12-0 per c. ft., which including fixing in place, cost of carriage, etc., etc.	88 15	59 7	148 6	206 4
	8	2½	5¾	10·37	18·86		127 5	79 3	206 8	215 1
	10	2½	7¼	16·36	25·98		175 0	99 0	274 0	228 6
15	6	2½	4¼	6·64	17·33		117 0	69 4	186 4	221 11
	8	2½	5¾	11·97	24·62		166 2	92 5	258 7	230 13
	10	2½	7¼	18·88	32·60		220 0	115 8	335 8	239 10
17	6	2½	4¼	7·52	22·49		151 12	79 3	230 15	240 10
	8	2½	5¾	13·57	30·52		205 15	105 9	311 8	243 6
	10	2½	7¼	21·39	40·44		273 0	132 0	405 0	253 2
19	6	2½	4¼	8·41	28·96		195 7	89 1	284 8	266 14
	8	2½	5¾	15·17	38·19		257 13	118 12	376 9	261 9
	10	2½	7¼	23·91	50·16		338 10	148 8	487 2	270 10
21	6	2½	4¼	9·29	35·64		240 9	99 0	339 9	282 15
	8	2½	5¾	16·77	47·15		318 4	132 0	450 4	281 7
	10	2½	7¼	26·43	59·94		404 10	165 0	569 10	284 13
23	6	2½	4¼	10·18	43·32		292 6	108 13	401 3	303 15
	8	2½	5¾	18·36	56·21		379 6	145 3	524 9	298 2
	10	2½	7¼	28·94	70·94		478 14	187 8	666 6	300 3

distances apart other than the above see table XLVI.

TABLE XLIII.

SCANTLINGS OF TEAK JOISTS AT 12 INCHES APART.

ength of bearing in feet.	LOAD 1½ CWT. PER SQUARE FOOT. Scantlings in inches.									
	B	D	B	D	B	D	B	D	B	D
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
VI	2	4½	2¼	4¼	2½	4	2¾	4	3	3¾
VIII	2	6	2¼	5¾	2½	5½	2¾	5¼	3	5
X	2	7¼	2¼	7	2½	6¾	2¾	6½	3	6¼
XII	2	8¾	2¼	8½	2½	8	2¾	7¾	3	7½
XIV	2	10¼	2¼	10	2½	9½	2¾	9¼	3	9
XVI	2	11¾	2¼	11½	2½	11	2¾	10½	3	10¼
XVIII.	2	13¼	2¼	12¾	2½	12½	2¾	11¾	3	11½
XX	2	14½	2¼	14	2½	13½	2¾	13	3	12¾

TABLE XLIV.

SCANTLINGS OF TEAK JOISTS AT 12 INCHES CENTRAL DISTANCE APART.

Length of bearing in feet.	LOAD 1½ CWT. PER SQUARE FOOT. Scantlings in inches.									
	B	D	B	D	B	D	B	D	B	D
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
VI	2	4¾	2¼	4½	2½	4¼	2¾	4¼	3	4
VIII	2	6¼	2¼	6	2½	5¾	2¾	5½	3	5½
X	2	7¾	2¼	7½	2½	7¼	2¾	7	3	6¾
XII	2	9¼	9¼	9	2½	8½	2¾	8¼	3	8
XIV	2	11	2¼	10½	2½	10	2¾	9¾	3	9½
XVI	2	12½	2¼	12	2½	11½	2¾	11	3	10¾
XVIII	2	14	2¼	13½	2½	13	2¾	12½	3	12¼
XX	2	15½	2¼	15	2½	14½	2¾	14	3	13½

Note.—(*a*) Tables XLIII to XLVI have been calculated from the formula for deflection.

$$D = \frac{5}{8} \times \frac{1}{16} \times \frac{L^3 \times W}{E \times bd^3}$$

where D is deflection in inches, and should not exceed $\frac{1}{40}$ inch per foot of span, E is a constant for resistance of teak to deflection = Modulus of elasticity ÷ (4 × 1728). L = length in feet. W = distributed weight in lbs. In tables XLIII and XLIV, E is taken = 281, and in Tables XLV and XLVI, E = 250.

$$\therefore D = \frac{WL^3}{6400\ bd^3},\ \text{with } E = 250.$$

(*b*) Timber beams.—(1) For concentrated load, breaking weight in lbs. $= \frac{cbd^2}{L}$, where c = 683 for teak.

(2) 2 × c × load = distributed breaking load in lbs.

(3) $c = \frac{LW}{bd^2}$.

(4) The best dimensions for a rectangular beam are, $\frac{b}{d} = \frac{5}{7}$ o. $b = \frac{5}{7} d$; or $W = \frac{c \times \frac{5}{7} d \times d^2}{L}$

(5) Factor of safety = 10.

(6) $WL = 137bd^2$ for uniformly distributed load.

TABLE XLV.

SCANTLINGS OF TEAK GIRDERS.

Spans in feet.	LOAD 1¼ CWT. PER SQUARE FOOT. Distance from centre to centre of girders in feet.											
	5		6		7		8		9		10	
	B	D	B	D	B	D	B	D	B	D	B	D
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
X ...	5½	9¼	5¾	9¾	5¾	10¼	6	10½	6¼	10½	6½	11
XII ...	6¼	10¾	6½	11¼	6¾	11¾	7	12	7¼	12½	7¼	12¾
XIV ...	7	12	7¼	12½	7½	13	7¾	13½	8	14	8½	14¼
XVI ...	7¾	13¼	8	14	8¼	14½	8½	15	8¾	15¼	9	15¾
XVIII ...	8¼	14½	8¾	15¼	9	15¾	9½	16¼	9¾	16¾	10	17¼
XX ...	9	15¾	9½	16½	9¾	17	10¼	17¾	10½	18¼	10¼	18¾
XXII ...	9¾	17	10¼	17¾	10½	18¼	11	19	11¼	19½	11½	20
XXIV ...	10½	18	11	18¾	11¼	19½	11¾	20¼	12	20¾	12½	21½

TABLE XLVI.

SCANTLINGS OF TEAK GIRDERS.

Spans in feet.	LOAD 1½ CWT. PER SQUARE FOOT. Distance from cetre to centre of girders in feet.											
	5		6		7		8		9		10	
	B	D	B	D	B	D	B	D	B	D	B	D
	Im.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
X ...	5¾	9¾	6	10¼	6¼	10½	6¼	11	6½	11¼	6¾	11½
XII ...	6½	11¼	6¾	11¾	7	12¼	7¼	12½	7½	13	7¾	13¼
XIV ...	7¼	12½	7½	13¼	8	13¾	8¼	14¼	8½	14½	8½	15
XVI ...	8	14	8½	14½	8¾	15	9	15½	9¼	16	9½	16½
XVIII ...	8¾	15¼	9¼	16	9½	16½	9¾	17	10¼	17½	10½	18
XX ...	9½	16½	10	17¼	10¼	17¾	10¾	18½	11	19	11¼	19½
XXII ...	10¼	17¾	10¾	18½	11	19¼	11½	19¾	11¾	20½	12	21
XXIV ...	10¾	18¾	11½	19¾	11¾	20½	12¼	21¼	12½	21¾	13	22

Note.—The above tables have been calculated by the formula for deflection (1/40 inch per foot with B : D : : 1 : $\sqrt{3}$).

To extend the use of tables XLIII toXLVI, it may be noted that if the load per square foot, or the central distances apart, be increased or decreased, then the breadth should be increased or decreased in the same proportion.

For example in table XLIV, if the joists be placed at 15 inches apart in a 20 feet bearing, the breadth of the joist should be increased from 2 to 2½ inches for equal strength,

TABLE

STRENGTH

$W \times L = cbd^2 = \frac{137}{112} bd^2$, where L is in feet, W is safe distributed load in

D	1	1¼	1½	1¾	2	2¼	2½	2¾	3	3¼
1	1·22	1·47	1·83	2·08	2·45	2·69	3·06	3·30	3·67	39·1
1¼	1·96	2·45	2·81	3·30	3·79	4·28	4·77	5·26	5·75	6·24
1½	2·69	3·43	4·16	4·77	5·38	6·24	6·85	7·58	8·20	8·93
1¾	3·79	4·65	5·63	6·61	7·46	8·44	9·42	10·28	11·25	12·23
2	4·89	6·11	7·34	8·56	9·79	11·01	12·23	13·46	14·68	15·19
2¼	6·24	7·71	9·51	10·89	12·35	13·94	15·53	17·00	18·59	19·82
2½	7·58	9·54	11·50	12·97	15·29	17·25	19·08	21·04	22·88	24·83
2¾	9·19	11·62	13·83	16·15	18·47	20·79	23·12	25·44	27·77	30·00
3	11·01	13·70	16·51	19·20	22·01	24·71	27·52	30·21	33·03	35·72
3¼	12·97	16·15	19·33	22·63	25·81	29·11	32·29	35·47	38·78	41·96
3½	14·92	18·72	22·51	26·18	29·97	33·76	37·43	41·22	44·89	48·68
3¾	17·25	21·53	25·81	30·00	34·37	38·66	43·05	46·48	51·62	55·90
4	19·67	24·46	29·46	34·25	39·14	44·04	48·94	53·82	58·71	63·61
4¼	22·17	28·04	34·13	38·65	44·34	49·66	55·29	60·79	66·30	71·80
4½	24·71	30·95	37·89	43·30	49·54	55·78	61·89	68·13	74·25	80·49
4¾	27·64	34·62	41·34	48·32	55·17	62·14	68·99	75·84	82·81	89·66
5	30·58	38·16	45·87	53·45	61·16	68·74	76·45	84·03	91·74	99·32
5¼	33·76	42·20	50·51	58·96	67·40	75·84	84·28	92·72	101·4	109·6
5½	37·04	46·24	55·53	64·71	74·00	83·31	92·48	101·8	110·9	120·2
5¾	40·49	50·52	60·67	70·86	80·85	91·11	101·2	111·2	121·3	129·7
6	44·04	55·04	66·10	77·06	88·37	99·08	110·1	121·1	132·0	143·1
6¼	47·82	59·60	71·68	83·67	95·66	105·5	118·7	130·9	143·1	155·3
6½	51·02	64·59	77·55	90·50	103·4	116·3	129·7	141·9	154·9	167·5
6¾	55·78	69·72	83·55	97·61	111·4	126·0	139·1	152·0	167·5	181·0
7	59·94	74·80	89·90	104·8	119·9	134·6	149·2	165·1	179·8	191·5
7¼	64·34	80·37	96·51	112·5	128·4	144·3	159·2	178·0	193·3	209·2
7½	68·74	86·00	103·2	120·4	132·0	155·3	172·5	189·6	206·7	223·8
7¾	73·52	91·86	110·2	128·4	146·8	165·1	183·5	201·8	220·2	238·5
8	78·28	97·65	117·4	137·0	156·6	176·1	195·7	215·3	234·9	251·4
8¼	83·31	101·1	124·8	145·6	166·4	187·2	207·9	228·8	249·5	270·3
8½	88·32	110·5	132·0	154·1	176·7	199·4	221·7	243·4	265·5	287·5
8¾	93·70	114·9	140·7	163·9	187·2	210·3	234·1	258·1	281·3	304·6
9	99·08	123·5	148·0	171·3	198·2	222·9	247·1	272·5	297·2	321·7
9¼	104·7	130·9	156·6	183·5	209·2	236·1	261·8	287·6	314·4	340·1
9½	110·3	137·2	165·1	193·3	220·2	248·3	276·4	303·4	331·5	358·4
9¾	116·3	145·6	171·3	203·1	232·4	261·8	291·2	319·3	348·6	378·0
10	122·3	152·9	183·5	214·1	244·7	275·2	305·8	336·4	367·0	397.6
10¼	128·4	159·2	192·7	224·8	257·9	288·7	320·1	353·5	385·3	417·1
10½	134·6	168·5	201·8	236·1	269·7	303·4	337·1	370·6	404·5	437·9
10¾	141·3	176·8	211·6	247·1	282·6	318·0	353·5	389·0	424·5	459·9

XLVII.

OF TEAK BEAMS. (Values of WL.)

cwts. For concentrated loads take half the values. Factor of safety 10.

3½	3¾	4	4¼	4½	4¾	5	5¼	5½	5¾	6
4·28	4·53	4·80	5·14	5·38	5·75	6·12	6·36	6·72	6·98	7·24
6·73	7·22	7·58	8·07	8·56	9·26	9·54	10·03	10·52	11·01	11·50
9·66	10·26	11·01	12·02	12·35	13·09	13·70	14·43	15·17	15·79	16·51
13·09	14·07	15·05	16·12	17·06	17·86	18·72	19·69	20·55	21·53	22·50
17·13	18·35	19·57	20·79	22·02	23·24	24·46	25·69	26·91	28·23	29·36
21·65	23·24	24·71	25·70	27·88	29·46	30·95	32·53	34·01	35·60	37·19
26·79	28·62	30·58	32·54	34·37	36·33	38·16	40·14	42·08	43·91	45·87
32·42	34·74	37·04	39·27	41·59	43·91	46·24	48·56	50·90	53·21	55·53
38·53	41·22	44·04	46·73	49·54	52·23	55·05	57·64	60·55	63·24	66·05
45·26	48·32	51·52	54·92	58·10	61·41	64·59	67·89	71·07	74·25	77·55
52·48	56·15	59·94	63·73	67·40	71·19	74·86	78·65	82·45	86·11	89·91
60·18	64·46	68·75	73·15	77·43	81·71	85·87	90·37	94·55	98·96	102·24
68·50	73·39	78·29	83·19	88·07	92·96	97·86	102·75	107·6	112·5	117·4
77·31	81·96	88·32	93·94	99·45	104·61	110·5	116·0	121·5	127·2	132·1
84·47	92·84	99·08	105·3	111·4	117·7	123·6	129·7	135·8	141·9	148·0
96·63	103·5	110·3	117·3	124·8	130·9	138·2	144·3	151·7	159·0	165·1
105·0	114·6	122·3	129·7	137·0	145·6	152·9	160·2	167·6	176·7	183·4
118·0	126·0	134·6	143·1	151·8	160·2	168·8	178·0	185·9	193·2	201·8
129·7	138·2	148·0	157·9	166·4	176·7	184·7	194·5	203·1	212·8	221·7
141·9	151·7	160·4	171·5	182·2	193·1	201·8	212·8	221·9	232·4	242·2
154·1	165·1	176·7	184·2	198·2	209·2	220·2	231·2	242·2	253·2	258·2
167·5	179·2	190·8	201·1	215·3	227·6	238·5	250·8	263·0	275·2	286·2
181·0	193·3	206·7	220·2	232·4	245·9	258·1	271·6	283·8	296·8	309.5
194·5	209·2	222·9	237·3	250·8	264·2	278·9	292·3	307·0	320·7	333·7
209·2	225·1	239·8	254·4	269·1	285·0	299·7	314·4	329·0	344·9	359·6
225·1	241·0	256·9	272·5	289·9	305·8	321·7	337·6	353·5	369·4	385·3
241·0	258·1	275·2	293·3	309·5	326·6	343·7	370·9	378·0	395·1	412·2
256·9	275·2	293·6	311·9	330·3	348·6	366·9	385·3	403·6	422·0	440·4
274·0	293·6	313·1	332·7	352·6	372·1	391·7	411·3	430·9	450·4	470·0
291·1	311·9	332·7	353·5	374·3	395·1	415·9	436·7	457·5	478·3	499·1
309·5	331·5	353·5	375·5	397·6	419·6	441·6	463·6	485·6	507·6	529·7
327·8	351·1	375·5	397·6	422·0	445·3	468·5	492·7	515·0	538·2	561·5
346·2	371·9	396·3	420·8	445·3	470·9	495·4	519·0	544·8	570·0	594·5
365·7	392·7	418·3	445·8	470·9	496·2	523·5	549·2	574 9	601·8	627·5
386·5	413·5	441·6	469·7	496·2	524·8	551·7	578·8	606·7	634·9	661·8
418·3	435·5	464·8	499·1	523·5	552·9	580·0	610·4	639·7	669·0	695·3
428·1	458·7	489·3	519·9	550·5	590·0	611·6	642·2	672·8	703·3	733·9
450·1	482·2	513·8	546·2	578·2	610·4	642·2	674·6	706·8	744·9	770·6
471·9	505·2	539·4	573·1	606·7	640·5	674·0	708·0	741·3	779·2	807·3
494·2	629·7	665·1	600·6	636·1	671·4	707·0	742·5	778·0	812·2	847·7

TABLE

D	1	1¼	1½	1¾	2	2¼	2½	2¾	3	3¼
11	148·0	184·7	221·7	259·3	296·1	332·7	369·4	407·3	444·0	480·5
11¼	154·7	193·3	232·4	270·3	309·5	348·6	386·5	425·7	464·8	502·8
11½	160·4	201·8	242·2	282·6	332·9	363·3	403·7	444·0	485·0	526·0
11¾	168·8	211·6	253·2	296·0	337·6	380·4	422·0	464·8	506·4	549·2
12	176·7	220·2	264·2	308·3	352·3	396·3	440·4	484·4	528·5	672·5
12½	191·1	238·9	286·7	334·5	382·3	430·0	477·8	525·6	573·4	621·2
13	206·7	258·4	310·1	361·8	416·4	465·1	516·8	568·5	620·2	671·9
13½	223·0	278·7	334·4	390·2	445·9	501·6	557·4	613·1	668·9	724·6
14	239·8	299·7	359·6	419·5	479·5	539·4	599·4	659·3	719·3	779·2
14½	257·2	321·5	385·8	450·1	514·4	578.7	643·0	707·2	771·5	835·8
15	275·2	344·0	412·8	481·6	550·4	619·3	688·1	756·9	825·7	894·5
15½	293·9	367·3	440·8	514·3	587·8	661·2	734·7	808·2	881·6	955·1
16	313·1	391·4	469·7	548·0	626·3	704·6	782·9	861·1	939·4	1017·7
16½	333·0	416·3	499·5	582·8	666·0	749·3	832·5	915·8	999·0	1082·3
17	353·5	441·9	530·3	618·6	707·0	795·4	883·8	972·2	1060·5	1148·0
17½	374·6	468·3	561·9	655·6	749·2	842·9	936·5	1030·2	1123·8	1217·5
18	396·3	495·4	594·5	693·6	792·6	891·7	990·8	1089·9	1189·0	1288·1
18½	418·6	523·3	628·0	732·6	837·3	942·0	1046·6	1151·3	1255·9	1260·6
19	441·7	552·1	662·5	772·9	883·4	993·8	1104·2	1214·0	1325·0	1435·5
19½	465·1	581·4	697·7	814·0	930·3	1046·5	1162·8	1279·1	1395·4	1511·6
20	489·3	611·6	733·9	856·3	978·6	1100·9	1222·2	1345·5	1467·9	1590·2
20½	514·1	642·6	771·1	899·6	1028·1	1156·6	1285·1	1413·7	1542·2	1670·7
21	539·4	674·3	809·1	944·0	1078·9	1213·7	1348·0	1483·5	1618·3	1753·2
21½	566·4	708·0	849·7	991·3	1132·9	1274·5	1416·1	1557·7	1699·3	1840·9
22	592·0	740·0	888·1	1036·1	1184·1	1332·1	1480·1	1628·1	1776·1	1924·1
22½	619·3	774·1	928·9	1083·7	1238·5	1393·3	1548·1	1703·0	1857·8	2012·6
23	646·1	807·6	969·1	1130·6	1292·2	1453·7	1615·2	1776·7	1938·3	2099·8
23½	675·5	844·4	1013·3	1182·2	1351·0	1519·0	1688·8	1857·7	2026·6	2195·5
24	704·6	880·7	1056·9	1233·0	1409·2	1585·3	1761·4	1937·6	2113·7	2289·9

XLVII—*contd.*

3½	3¾	4	4¼	4½	4¾	5	5¼	5½	5¾	6
517·5	555·3	591·0	628·7	665·3	703·3	740·0	766·7	813·4	851·4	888·1
541·9	580·0	619·0	658·1	694·0	735·2	774·2	812·2	851·4	890·5	928·4
566·4	606·7	646·7	687·5	727·8	768·2	808·6	849·0	889·3	929·7	962·2
589·8	633·6	675·2	718·0	759·6	802·4	844·0	886·8	928·4	971·2	1012·8
616·5	660·1	704·6	748·6	792·6	836·8	880·7	924·8	968·8	1012·8	1056·9
668·9	716·7	764·5	812·3	860·1	907·9	955·6	1003·4	1051·2	1099·0	1146·8
723·5	775·2	826·9	878·6	930·3	981·9	1033·6	1085·3	1137·0	1188·7	1240·3
780·3	836·1	891·8	947·5	1003·5	1059·0	1114·8	1170·5	1226·2	1282·0	1337·7
839·1	889·1	959·0	1018·9	1078·9	1138·8	1198·7	1258·7	1318·6	1378·6	1438·5
900·1	964·4	1028·7	1093·0	1157·3	1221·6	1285·9	1350·2	1414·5	1478·8	1543·1
963·3	1032·1	1[illegible]0·9	1169·7	1238·5	1307·3	1376·1	1444·9	1513·7	1582·5	1651·3
1028·6	1102·0	1[illegible]75·5	1249·0	1322·4	1395·9	1469·4	1542·9	1616·3	1689·8	1763·3
1096·0	1174·3	1252·6	1330·8	1409·2	1487·4	1565·7	1644·0	1722.3	1800·6	1878·9
1165·5	1248·8	1332·0	1415·3	1498·5	1581·8	1665·0	1748·3	1831·5	1914·8	1998·1
1237·3	1325·7	1414·0	1502·4	1590·8	1679·2	1767·6	1855·0	1944·3	2032·7	2121·1
1311·1	1404·8	1498·4	1592·1	1685·8	1779·4	1873·1	1966·7	2060·4	2154·0	2247·0
1387·1	1486·2	1585·3	1684·4	1783·5	1882·5	1981·6	2080·7	2179·8	2278·9	2377·9
1465·3	1569·9	1674·6	1799·3	1883·9	1988·6	2093·2	2197·9	2302·6	2407·2	2511·9
1545·9	1656·3	1766·7	1877·1	1987·6	2098·0	2208·4	2318·8	2429·2	2539·7	2650·1
1628·0	1744·2	1860·5	1976·8	2093·1	2209·4	2325·6	2441·9	2558·2	2674·5	2790·8
1712·5	1834·8	1957.2	2079·5	2201·8	2324·1	2446·4	2568·8	2691·1	2813·4	2935·7
1790·2	1927·7	2056·2	2184·7	2313·2	2441·8	2570·3	2698·8	2827·3	2955·8	3084·3
1888·0	2022·9	2157·8	2292·6	2427·5	2562·3	2697·2	2832·1	2966·9	3101·8	3236·7
1982·5	2124·2	2265·8	2407·4	2549·0	2690·8	2831·4	2973·0	3114·6	3256·2	3398·6
2072·1	2020·1	2368·2	2516·2	2664·[illegible]	2812·2	2960·2	3108·2	3256·2	3404·2	3552·2
2167·4	2322·2	2477·0	2631·8	2786·7	2941·5	3096·3	3251·1	3405·9	3560·7	3715·5
2261·3	2422·8	2584·3	2745·9	2907·4	3068·9	3240·4	3391·9	3553·5	3715·0	3876·5
2364·3	2533·2	2702·1	2871·0	3039·9	3208·7	3377·6	3546·5	3715·4	3884·3	4053·1
2466·0	2642·2	2818·3	2994·4	3170·6	3346·7	3522·9	3699·0	3875·2	4051·3	4227·6

TABLE

D	6½	7	7½	8	8½	9	9½	10	10½
12½	1242·3	1337·9	1432·5	1529·0	1624·6	1720·2	1815·7	1911·3	2006·8
13	1343·7	1447·1	1550·4	1653·8	1757·2	1860·5	1953·9	2067·2	2170·0
13½	1449·2	1560·7	1672·1	1783·6	1895·1	2006·6	2118·0	2229·5	2341·0
14	1558·4	1678·2	1798·1	1918·0	2037·9	2157·7	2277·6	2397·5	2517·4
14½	1671·8	1800·3	1928·9	2057·4	2186·0	2314·6	2443·2	2571·8	2700·4
15	1789·0	1926·6	2064·2	2201·8	2339·4	2477·0	2614·6	2752·2	2889·9
15½	1910·2	2057·1	2204·1	2351·0	2498·0	2644·9	2791·8	2938·8	3085·7
16	2035·4	2192·0	2348·6	2505·2	2661·7	2818·3	2974·4	3131·4	3288·0
16½	2164·6	2331·1	2497·6	2664·1	2830·6	2997·1	3163·6	3330·1	3496·6
17	2297·8	2474·6	2651·3	2828·1	3004·9	3181·6	3358·4	3535·1	3711·9
17½	2434·9	2622·3	2809·6	2996·9	3184·2	3871·5	3558·8	3746·1	3933·4
18	2576·1	2774·3	2972·4	3170·6	3368·8	3566·9	3765·1	3963·2	4161·4
18½	2721·2	2930·5	3139·9	3349·2	3558·5	3767·8	3977·2	4186·5	4395·8
19	2870·9	3091·8	3312·6	3033·4	3754·3	3975·1	4196·0	4416·8	4637·7
19½	3023·3	3255·9	3488·9	3721·0	3953·6	4186·2	4418·7	4651·3	4883·8
20	3180·4	3425·0	3669·7	3914·3	4159·0	4403·6	4648·2	4892·9	5137·5
20½	3344·4	3598·4	3855·4	4112·5	4369·5	4626·5	4883·6	5140·6	5397·6
21	3506·4	3776·1	4045·8	4315·5	4585·2	4855·0	5124·7	5393·4	5664·1
21½	3681·8	3965·0	4248·4	4531·7	4814·0	5098·1	5381·5	5662·7	5945·9
22	3848·2	4144·3	4440·3	4736·3	5032·3	5328·3	5624·4	5920·4	6216·4
22½	4025·2	4334·8	4644·4	4954·0	5263·7	5573·3	5883·0	6192·6	6502·2
23	4199·5	4522·6	4845·6	5168·7	5491·7	5814·7	6137·8	6460·8	6783·9
23½	4390·9	4728·7	5066·4	5404·2	5741·8	6079·8	6417·4	6755·1	7092·9
24	4579·9	4932·1	5284·4	5636·7	5089·0	6341·3	6693·6	7045·9	7398·1

XLVII—*contd.*

11	11½	12	12½	13	13½	14	14½	15
2102·4	2198·0	2293·5	2389·1	2484·7	2580·2	2675·8	2771·4	2866·9
2274·0	2377·6	2480·7	2584·0	2687·4	2790·8	2894·1	2997·5	3100·9
2452·2	2563·9	2675·4	2786·9	2898·4	3009·9	3121·3	3232·8	3344·3
2637·2	2757·1	2877·0	2996·9	3116·7	3236·6	3356·5	3476·4	3596·2
2829·0	2957·0	3086·2	3214·8	3343·4	3471·9	3600·5	3729·1	3857·7
3027·5	3165·1	3302·7	3440·3	3577·9	3715·5	3853·1	3990·7	4128·4
3232·6	3379·6	3526·5	3673·5	3820·4	3957·3	4114·3	4261·2	4408·1
3444·6	3601·2	3757·8	3914·3	4070·9	4227·4	4384 0	4540·6	4697·2
3663·1	3829·6	3996·1	4162·6	4329·1	4495·6	4662·1	4828·7	4995·2
3888·6	4065·4	4242·1	4418·9	4595·6	4772·4	4949·1	5125·9	5302·7
4120·7	4308·0	4495·3	4682·6	4870·0	5057·2	5244·5	5431·9	5619·2
4359·6	4557·7	4755·9	4954·0	5152·2	5350·4	5548·5	5746·7	5944·9
4605·1	4814·5	5023·8	5232·1	5442·4	5651·7	5861·0	070·4	6279·7
4858·5	5079·3	5300·2	5529·0	5741·9	5962·7	6183·5	6404.4	6625·2
5116·4	5349·0	5581·5	581[illegible]·1	6046·7	6279·2	6511·8	6744·4	6976·9
5382·2	5626 8	5871·5	6116·1	6360·7	6605·4	6815·0	7094·7	7339·3
5654·6	5911·7	6168·7	6425·7	6682·7	69[illegible]9·7	7196·7	7453·7	7710·8
5933·8	6203·6	6473·3	6743·0	7012·7	7282·4	7552·2	7821·9	8091·6
6229·2	6512·4	6797·2	7080·4	7363·6	7646·8	7930·1	8213·3	8496·5
6512·4	6808·4	7104·5	7400·5	7696·5	7992·5	8288·5	8584·6	8880·6
6811·8	7121·4	7431·1	7740·7	8050·3	8359·9	8669·6	8979·2	9288·8
7106·9	7430·0	7753·0	8076·0	8399·0	8722·1	9045·2	9368·2	9691·2
7430·7	7768·4	8106·2	8443·9	8781·7	9119·5	·457·2	9794·9	10132·8
7750·4	8102·7	8455·0	8807·3	9159·6	9[illegible]11·9	9861·2	10216·5	10568·7

TABLE

D	15½	16	16½	17	17½	18	18½	19	19
12½	2962·5	3058·0	3153·6	3249·2	3344·7	3440·3	3535·9	3631·4	3727·0
13	3204·2	3307·6	3410·9	3514·3	3617·7	3721·0	3824·4	3927·8	4031·1
13½	3455·8	3567·2	3678·7	3790·2	3901·7	4013·1	4124·6	4236·1	4347·6
14	3716·1	3836·0	3955·9	4075·7	4195·6	4315·5	4435·4	4555·2	4675·1
14½	3986·3	4114·9	4243·5	4372·1	4500·7	4629·3	4757·9	4886·4	5015·0
15	4266·0	4403·6	4541·2	4678·8	4816·4	4954·0	5091·6	5229·3	5356·9
15½	4555·1	4702·0	4848·9	4995·9	5142·8	5289·8	5436·7	5583·7	5730·6
16	4853·7	5010·3	5166·9	5323·4	5480·0	5636·6	5793·2	5949·7	6106·3
16½	5161·7	5328·2	5494·7	5661·2	5827·7	5994·2	6160·7	6327·3	6493·8
17	5479·4	5656·2	5832·9	6009·6	6186·4	6363·2	6540·0	6716·7	6893·4
17½	5806·5	5993·8	6181·1	6368·4	6555·7	6743·0	6930·3	7117·6	7304·9
18	6143·0	6341·2	6539·3	6737·5	6935·7	7133·8	7332·0	7530·1	7728·3
18½	6489·0	6698·4	6907·7	7117·0	7326·3	7535·6	7746·0	7955·3	8164·6
19	6846·0	7066·9	7287·7	7508·6	7729·4	7956·2	8171·1	8392·0	8612·8
19½	7209·5	7442·0	7674·6	7907·2	8139·7	8372·3	8604·9	8837·4	9070·0
20	7584·0	7828·6	8073·3	8317·9	8562·5	8807·2	9051·8	9296·5	9541·1
20½	7967·8	8224·8	8481·8	8738·9	8995·9	9252·9	9510·0	9766·9	10024·0
21	8361·3	8661·0	8900·8	9170·5	9440·2	9709·9	9979·6	10249·3	10519·1
21½	8779·7	9062·9	9346·1	9629·3	9912·6	10195·8	10478·9	10762·2	11045·4
22	9176·6	9472·6	9738·6	10064·7	10360·7	10656·7	10952·7	11248·7	11544·7
22½	9598·4	9908·1	10217·7	10527·8	10836·9	11146·6	11456·2	11765·5	12075·5
23	10014·3	10337·3	10660·4	10983·4	11306·4	11629·5	11952·5	12277·6	12600·6
23½	10470·5	10808·3	11146·0	11483·8	11821·5	12159·3	12407·1	12834·8	13172·6
24	10921·0	11273·3	11625·6	11977·9	12330·2	12682·5	13034·8	13387·0	13739·3

XLVII—*concld.*

20	20½	21	21½	22	22½	23	23½	24
3822·6	3918·1	4013·7	4109·3	4204·8	4300·4	4395·9	4491·5	4587·1
4134·5	4237·8	4341·2	4444·6	4547·9	465[illegible]·3	4754·7	4858·0	4961·4
4459·0	4570·5	4682·0	4793·5	4905·0	501[illegible]·4	5127·9	5239·8	5350·9
4795·0	4914·9	5034·7	5154·6	5274·5	5394·4	5514·2	5634·1	5754·0
5143·6	5272·2	5400·8	5529·4	5658·0	5786·6	5915·2	6043·8	6172·4
5494·5	5632·1	5769·7	5907·3	6044·9	6182·5	6320·2	6457·8	6595·4
5877·5	6024·5	6171·4	6318·4	6465·3	6612·2	6759·2	6906·1	7053·1
6262·9	6419·5	6576·0	6732·6	6889·2	7045·7	7202·3	7358·9	7515·5
6660·3	6826·8	6993·3	7159·8	7326·3	7492·8	7659·3	7825·9	7992·4
7070·2	7246·9	7423·7	7600·5	7777·2	7954·0	8130·7	8307·5	8484·2
7492·2	7679·5	7866·8	8054·1	8241·4	8428·7	8616·0	8803·4	8990·7
7926·5	8124·6	8322·8	8520·9	8719·1	8917·3	9115·4	9313·6	9511·8
8373·9	8583·0	8792·6	9001·9	9211·2	9420·6	9629·9	9839·2	10048·5
8833·6	9054·5	9275·3	9496·1	9717·0	9937·9	10158·7	10379·5	10600·4
9302·6	9535·1	9767·7	10000·3	10232·8	10465·4	10698·0	10930·5	11163·1
9785·8	10030·4	10275·0	10519·7	10764·3	11008·9	11253·6	11498·3	11742·9
10281·0	10538·0	10795·1	11052·1	11309·2	11566·2	11823·2	12080·2	12337·3
10788·8	11058·5	11328·2	11598·0	11867·7	12137·4	12407·1	12676·8	12946·6
11328·7	11611·9	11895·1	12178·3	12461·5	12744·7	13028·0	13311·2	13594·4
11840·8	12136·8	12432·8	12728·8	13024·8	13320·9	13616·9	13912·9	14208.9
12385·1	12694·7	13204·3	13314·0	13623·6	13933·2	14242·9	14552·5	14862·1
12923·7	13246·7	13579·7	13902·8	14225·8	14548·9	14871·9	15194·9	15518·0
13510·4	13848·1	14185·9	14523·6	14861·4	15199·2	15536·9	15874·7	16212·4
14091·6	14443·9	14796·2	15148·5	15500·8	15853·0	16465·3	16557·6	16909·9

Note.—To use the tables.

1. For distributed load, multiply the weight in cwts. by the span in feet. Select a depth for the beam which is not less than 1/14th of the span. Run horizontally along that depth, till the above product is found. The figure at the top of the column gives the required breadth for the beam.

2. To find the deflection in inches, multiply W in cwts. by the cube of the span in feet, which is given in column 2 of table No. XLVIII, and divide by the breadth in inches of the beam and the figure given in column 3, against the depth.

Example.—

3. Find a section for a beam for effective span 20′ and load 12 cwts. per foot run.

W = 12 × 18·5 = 222·0 cwts.

W × L = 222 × 20 = 4440.

Select depth $\frac{20 \times 12}{14}$ = 17·14″ or say 18″.

The nearest values of W L against 18″ depth = 4359·6 and 4557·7.

∴Select breadth 11¼″.

∴18″ × 11¼″ would do.

For 18½″ depth, 10¾″ breadth would do, giving a slightly greater stiffness.

To find the deflection (see table XLVIII).

$$\text{Deflection in inches} = \frac{W \times L3}{b \times \text{constant}} = \frac{222 \times 8000}{11{\cdot}25 \times 333258} = \frac{1''}{2{\cdot}1}$$

Permissible deflection = $\frac{1}{40}$ × 20 = ½″.

4. For concentrated loads, double the value of W × L, and select depth of beam, 1/8th of span, and proceed as above to find the suitable breadth for beam.

5. The values of W × L for depths between 1″ and 12″ and breadths 6¼″ to 12″ are got by doubling the values given in the table for half of the corresponding breadths.

TABLE XLVIII

DEFLECTIONS OF TEAK RECTANGULAR BEAMS.

Values of cubes of certain numbers, and values of 57·143 d^3, where d=depth, and $\frac{1}{57 \cdot 143} = \frac{1 \times 5 \times 1}{16 \times 8 \times 250} \times 112$. (See Note (a) under Table XLIV)

For the use of this table see note, items 2 and 3, below table XLVII.

Depth in inches 1	Cubes of numbers in column 1. 2	Values of 57·143 d^3 3
1	1·0	57·1
$1\frac{1}{4}$	2·0	111·6
$1\frac{1}{2}$	3·4	192·9
$1\frac{3}{4}$	5·4	306·3
2	8·0	457·1
$2\frac{1}{4}$	11·4	650·9
$2\frac{1}{2}$	15·6	892·9
$2\frac{3}{4}$	20·8	1188·3
3	27·0	1542·9
$3\frac{1}{4}$	34·3	1961·6
$3\frac{1}{2}$	42·9	2450·0
$3\frac{3}{4}$	52·7	3013·4
4	64·0	3657·2
$4\frac{1}{4}$	76 8	4386·6
$4\frac{1}{2}$	91·1	5207·2
$4\frac{3}{4}$	107·2	6124·1
5	125·0	7142·9
$5\frac{1}{4}$	144·7	8268·8
$5\frac{1}{2}$	166·4	9505·6
$5\frac{3}{4}$	190·1	10862·9
6	216·0	12341·9
$6\frac{1}{4}$	244·1	13590·9
$6\frac{1}{2}$	274·6	15692·9
$6\frac{3}{4}$	307·5	17574·2
7	343·0	19600·1
$7\frac{1}{4}$	381·1	21775·9
$7\frac{1}{2}$	421·9	24107·2
$7\frac{3}{4}$	465·5	26599·2
8	512·0	29257·2
$8\frac{1}{4}$	561·5	32086·7
$8\frac{1}{2}$	614·1	35092·9
$8\frac{3}{4}$	669·9	38.81·4
9	729·0	42627·6
$9\frac{1}{4}$	791·5	45226·0
$9\frac{1}{2}$	857·4	48993·0
$9\frac{3}{4}$	926·9	52963·5
10	1000·0	57143·0
$10\frac{1}{4}$	1076·9	61536·8

TABLE XLVIII—*contd.*

Depth in inches. 1	Cubes of numbers in Column 1 2	Values of 57·143 d³. 3
10½	1157·6	66150·2
10¾	1242·3	70988·6
11	1331·0	76057·3
11¼	1423·8	81361·8
11½	1520·9	86906·3
11¾	1622·2	92699·4
12	1728·0	98743·1
12½	1953·1	111607·0
13	2197·0	125543·2
13½	2460·4	140593·2
14	2744·0	156800·4
14½	3048·6	174207·5
15	3375·0	192857·7
15½	3723·9	212793·4
16	4096·0	234057·7
16½	4492·1	260864·3
17	4913·0	280743·4
17½	5359·4	306250·6
18	5832·0	333257·9
18½	6331·6	361807·9
19	6859·0	391943·8
19½	7414·9	423708·1
20	8000·0	457144·0
20½	8615·1	492294·2
21	9261·0	529201·3
21½	9938·4	569708·5
22	10648·0	608458·6
22½	11390·6	560894·3
23	12167·0	695258·6
23½	12977·9	741594·7
24	13824·0	789944·5

TABLE XLIX.

BENDING MOMENTS OF CONTINUOUS BEAMS, RAFTERS OR PURLINS, OF UNIFORM SECTION LOADED UNIFORMLY WITH POINTS OF SUPPORT EQUIDISTANT FROM ONE ANOTHER AND IN THE SAME STRAIGHT LINE.

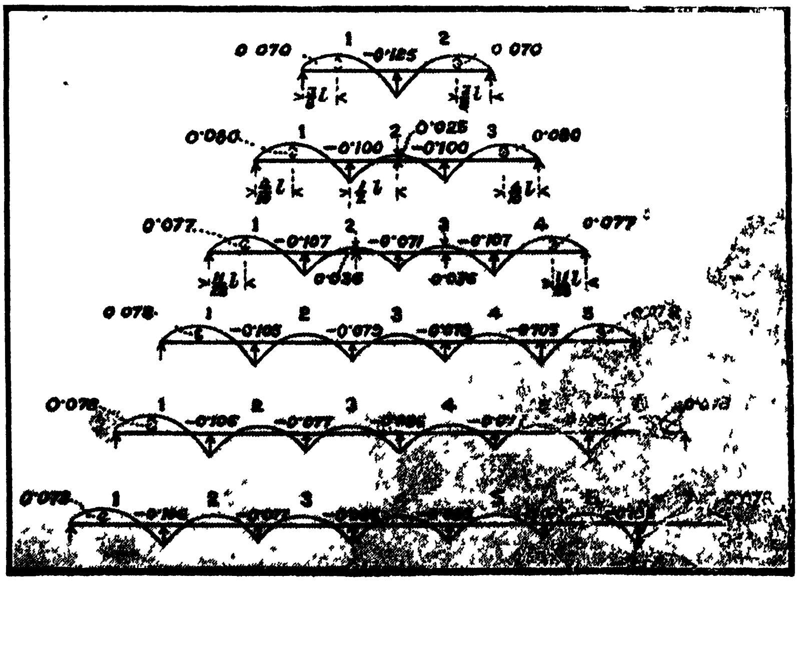
Conditions of support with w lbs per foot run, and l = length of span between supports

1 *Total load* $= wl$ A C B (one span l) $R_A = \frac{wl}{2}$ $R_B = \frac{wl}{2}$ $M_A = 0$, $M_C = \frac{wl^2}{8}$, $M_B = 0$.	3 *Total load* $= 3wl$. A C D B (three spans, each l) $R_A = \frac{4}{10}wl$, $R_C = \frac{11}{10}wl$, $R_D = \frac{11}{10}wl$, $R_B = \frac{4}{10}wl$. $M_A = 0$, $M_C = \frac{4}{5}\frac{wl^2}{8}$, $M_D = \frac{4}{5}\frac{wl^2}{8}$, $M_B = 0$.
2 *Total load* $= 2wl$ A C B (two spans, each l) $R_A = \frac{3wl}{8}$, $R_C = \frac{10wl}{8}$, $R_B = \frac{3wl}{8}$ $M_A = 0$, $M_C = \frac{wl^2}{8}$, $M_B = 0$	4 *Total load* $= 4wl$ A C E D B (four spans, each l) $R_A = \frac{11}{28}wl$, $R_C = \frac{32}{28}wl$, $R_E = \frac{26}{28}wl$, $R_D = \frac{32}{28}wl$, $R_B = \frac{11}{28}wl$. $M_A = 0$, $M_C = \frac{6}{7}\frac{wl^2}{8}$, $M_E = \frac{4}{7}\frac{wl^2}{8}$, $M_D = \frac{6}{7}\frac{wl^2}{8}$, $M_B = 0$

NOTE.—R_A = reaction at A, and M_A = Bending Movement at A

TABLE XLIX A.

Bending moments in continuous beams, ends supported, uniform load on all spans, spans all equal. Coefficients of (wl^2)



NOTES ON ROLLED STEEL BEAMS AND GIRDERS.

1. **Rolled steel beams.**—Rolled steel beams may, with great advantage, be used as a substitute for timber girders or binders when the span of the floor is great, for they are less bulky and more durable.

Rolled beams in steel may ordinarily be obtained of various sections from 3 to 24 inches in depth, and have been manufactured up to a depth of even 3 feet; but for a greater depth than 12 to 14 inches, a built-up girder is usually preferable and more economical. In order not to exceed the deflection of $\frac{1}{40}$ inch per foot of span, the proportion of length to depth of girder or joist, should not be greater than 20 to 1, for uniformly distributed load, and 13 to 1, for the same load concentrated at the centre of span.

2. **Plate girders.**—Plate girders may be constructed of sizes far exceeding those of the largest rolled beams, and may be built up by riveting plates and steel angles together in different ways.

The depth of plate girders varies from $\frac{1}{10}$ to $\frac{1}{15}$ of span; $\frac{1}{12}$ is said to be the most economical proportion.

The width of the flange under compression should not be less than $\frac{1}{30}$ to $\frac{1}{40}$ of the span, or it will be liable to buckle sideways.

Both flanges must be wide enough for the rivets, and for the ends of stiffeners where they are used.

No plates of less than $\frac{1}{4}$ inch in thickness, should be used or they will soon be destroyed by corrosion. There should be as few joints as possible, specially in the tension flange and web.

3. The ends of girders must not be rigidly *fixed*, unless they have been designed as girders to be fixed at the ends; otherwise, stresses will come upon them, which they were not designed to bear.

4. The ends of girders resting upon wall should be supported by hard stone bed plates, and may be bedded upon sheet lead or upon two thicknesses of asphalted or tarred felt, and if they are required to afford a tie to the structure, they may be secured by bolts to the walls. The stone bed plate should be chamfered at its outer face.

5. Girders of over 50 feet span should have cast-iron shoes upon the ends, so that, they may slide when the girder alters in length under changes of temperature, and large girders should have one end supported by rollers under a casting.

6. As a rule, girders should be connected by the webs, not the flanges. The latter arrangement would often be inconvenient, and would in many cases be equivalent to fixing the ends, or making the girders continuous, which would be objectionable.

7. Where possible, the holes for bolts, etc., should be made as near as possible to the neutral axis or centre line of the girder, so that they may be clear of the direct stresses upon it.

8. Care should be taken to use market sizes of plates and steel angles as far as possible.

For example, the web in small girders should, where possible, be made an even multiple of two inches, in order that market widths of plates may be used to avoid the extra cost of shearing.

Steel angles should not be specified of peculiar size and thickness exactly to suit the calculated dimensions, or the difficulty in fitting them will cause not only expense but delay.

Expense is incurred by using extra sizes. It may, howev beer, cheaper in some cases to use extra lengths, in order to reduce the number of joints.

9. All parts should be so arranged as to be got at easily, for riveting and for periodical painting.

10. Plate girders should be constructed with a camber of about $\frac{1}{480}$ of the clear span, so that when loaded they may not sag or appear to do so.

11. Provision for a live load (see table XXIX) must be made in addition to the dead load of the floor itself. The following may be taken as safe combined loads in ordinary cases :—

Dwellings, etc.	150 lbs. per square foot.
Public halls	180 ,,
Warehouses	300—400 ,,
Heavy machinery	400—500 ,,

12. **Boaring.**—For rolled steel joints over small spans, say up to 8 feet, a bearing of 6 inches over the walls at either ends should be allowed ; for spans from 9 feet to 12 feet, a bearing of 9 inches ; and for R. S. beams or girders, over spans 12 to 30 feet, a bearing of 12 inches at least should be provided.

In case if heavy loads and larger spans, the bearing is to be determined by the safe bearing capacity of the bed-stone, used under the ends of the girder, and the safe strength of the masonry below the bed-stone.

GENERAL SPECIFICATION FOR ROLLED STEEL GIRDERS.

Specification No. 83.

1. Extent of contract.

(Here enter description of steel work required with general over-all dimensions.)

2. **Quality of steel.**—The steel of which the girders are to be made is to be " open hearth process (acid or basic) or Acid Bressemer process ", well and cleanly rolled to the full section shown on the drawings or named in the specification, and to be free from scales, blisters, surface flaws, laminations, craked edges and defects of every sort ; and should comply with the latest Br. St. Spec. for structural steel in all respects.

3. **Joints.**—Joints in plates, angles, etc., are to be made only in such positions as may be shown on plans or ordered, and all covers are to be cut and are to fit in their positions accurately. All joints are to be cut truly square and to butt properly together.

4. **Riveting.**—The riveting throughout the whole of the work, must be executed in the neatest and most workmanlike manner. All holes are to accurately punched, both as regards size and pitch, by efficient punching machinery, and where so marked to be drilled, so that the riveting may bring each plate or bar into its proper position and into direct and immediate contact

with the adjoining pieces. All rivets must fit the holes fully and perfectly, and have cup-heads or such other shape as may be ordered or approved, and must be finished off neatly. Where rivets are marked to be countersunk, the countersinking in the plates or bars must be done with a suitable drill, and the rivets finished smooth and flush. If any rivets in position, when tested with a hammer, are found to be in the least degree loose, they shall be cut out and replaced, at the contractors' cost, by others which shall fill the holes perfectly.

5. **Welds.**—All welds, where considered necessary by the Executive Engineer, shall be thoroughly sound and of full section without flaws or other defects.

6. **Dimensions.**—In case of differences, figure dimensions on plans to be taken in preference to scaled dimensions, and dimensions mentioned in the specification in preference to both.

7. **Bearings.**—The rivets over the whole area of the bearings of girders to be countersunk.

8. **Camber.**—The girders shall each be so formed that, when resting on their bearings and supporting their own weight, they shall have a camber upwards of $\frac{1}{40}$ inch per every running foot of the clear span.

9. **Painting.**—Each girder, immediately it is completed and passed by the Executive Engineer, shall be painted with a coat of oxide of iron paint in the contractors' yard, and two more coats of paint in such colour as the Executive Engineer may direct, after the girders are placed in position.

10. **Testing.**—When the girders are finished, they shall each or a certain number of them, as the Executive Engineer may direct, be tested with evenly distributed loads given below without deflecting at the centre more than $\frac{1}{40}$ of an inch per running foot of their clear spans, and without suffering a permanent set or injury :—

Description of girder.	Evenly distributed test loads.	Remarks.

The testing shall be carried out in the presence of the Executive Engineer, or his authorized deputy, either by directly loading the girders or in any other way approved by the Executive Engineer, and the girders shall stand the above tests to his entire satisfaction. All expenses of testing the girders, painting and conveying them to the work, as well as of hoisting and fixing them in position, to be borne by the contractors and to be included in their tendered rates.

11. **General execution.**—The entire steel work to be executed in the most approved and workmanlike manner, according to the directions and to the entire satisfaction of the Executive Engineer, who shall have power to control and inspect, to test and to reject the whole or any portion of the work, which he may consider unsatisfactory, and the contractors shall be bound to accept his decision as final.

TABLE L.

STRENGTH T AND L IRON (MOLESWORTH'S POCKET BOOK) AND OF T AND L STEEL.

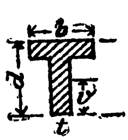
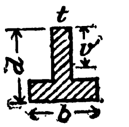
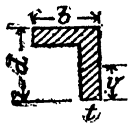
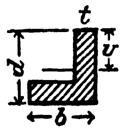
L = Span in feet.
I = Moment of Inertia.
v = Distance of neutral axis from extreme edge.
K = Coefficient for each section (see table below)=WL.
W = Total safe load in lbs. distributed over span, including weight of iron, or steel.

F = Safe stress, in tons per square inch in extreme fibres of beam=5 tons per square inch for iron, and 7½ tons per square inch for steel.

Bending moment $= \frac{12WL}{8} =$ moment of resistance to bending $= \frac{IF}{v}$.

$$\therefore WL = \frac{8}{12} \cdot \frac{IF}{v} = K$$

$$\therefore W = \frac{K}{L}.$$

Dimensions of section in inches.				Values of		Value of K for different sections and positions.							
Breadth b.	Depth d.	Thickness t.	Weight in lbs. per running foot.	I.	v or $u-v$								
						Iron.	Steel.	Iron.	Steel.	Iron.	Steel.	Iron.	Steel.
4	4	½	12·75	5·5641	2·8160	14750	22125	11800	17700	11062	16593	8850	13275
3	4	½	11·05	5·0485	2·6731	14102	21153	11282	16923	10576	15864	8461	12691
4	3	½	11·05	2·4234	2·1731	8327	12490	6662	9993	6245	9367	4996	7494
3½	3½	½	11·05	3·6350	2·4423	11113	16669	8890	13335	8335	12502	6668	10002
3½	3½	⅜	8·45	2·8650	2·4870	8602	12903	6882	10323	6451	9676	5161	7741
3	3	½	9·36	2·1640	2·0682	7813	11719	6250	9375	5860	8790	4688	7032
3	3	⅜	7·18	1·7597	2·1125	6220	9330	4976	7464	4665	6997	3732	5598
2½	2½	½	7·65	1·2274	1·6945	5408	8112	4326	6489	4056	6084	3245	4867
2½	2½	⅜	5·89	·9838	1·7382	4226	6339	3381	5071	3170	4755	2536	3804
2½	2½	5/16	4·98	·8486	1·7604	3600	5400	2881	4321	2701	4051	2160	3240
2½	2½	¼	4·04	·7031	1·7829	2945	4417	2356	3534	2209	3313	1767	2650
2	2	½	5·83	·5900	1·3214	3334	5001	2667	4000	2500	3750	2000	3000
2	2	⅜	4·62	·4791	1·3642	2622	3933	2098	3147	1966	2949	1573	2359
2	2	5/16	3·92	·4162	1·3861	2242	3363	1794	2691	1682	2523	1345	2017
2	2	¼	3·19	·3476	1·4083	1843	2764	1474	2211	1382	2073	1106	1659
1½	1½	⅜	3·28	·1867	0·9911	1407	2110	1126	1689	1055	1582	814	1266
1½	1½	5/16	2·85	·1639	1·0123	1209	1813	967	1450	908	1362	725	1087
1½	1½	¼	2·33	·1385	1·0341	1000	1500	800	1200	750	1125	600	900
1½	1½	3/16	1·79	·1099	1·0562	777	1165	622	933	583	874	466	699
1¼	1¼	⅛	1·16	·0778	1·0788	538	807	430	645	403	604	323	483

For values of I and K, in sections similar to those given above, if I_1, K_1 and d_1 be the values for the requred section, then $I_1 = I\frac{d_1^4}{d^4}$ and $K_1 = K\frac{d_1^3}{d^3}$

Example:—Find I_1 and K_1 for 4 × 4 × ⅝T. I and K for 2 × 2 × $\frac{5}{16}$ inches=4162 and·2242 respectively. Therefore, $I_1 = \cdot 4162 \times \frac{256}{16} = 6\cdot 66$; and $K_1 = 2242 \times \frac{64}{8} = 17936$.

TABLE LI

STANDARD SIZES OF EQUAL ANGLES AND THEIR PROPERTIES

TABLE

STANDARD SIZES OF EQUAL ANGLES

Equal

Reference No.	Size A × B.	Thickness. t	Sectional area.	Calculated weight per foot.	Centre of Gravity.
	Inches.	Inches.	Inches.²	Lb.	Inches.
BSEA 101	1 × 1 ..	·125	·23	·80	·29
		·1875	·34	1·15	·31
BSEA 102	1¼ × 1¼ ..	·125	·30	1·01	·34
		·1875	·43	1·47	·37
BSEA 103	1½ × 1½ ..	·1875	·53	1·79	·43
		·25	·69	2·34	·46
BSEA 104	1¾ × 1¾ ..	·1875	·62	2·11	·49
		·25	·81	2·76	·52
BSEA 105	2 × 2 ..	·1875	·71	2·43	·56
		·25	·94	3·19	·58
		·3125	1·15	3·92	·61
BSEA 106	2¼ × 2¼ ..	·1875	·81	2·75	·62
		·25	1·06	3·61	·64
		·3125	1·31	4·45	·67
BSEA 107	2½ × 2½ ..	·25	1·19	4·04	·70
		·3125	1·46	4·98	·73
		·375	1·73	5·90	·75
BSEA 108	3 × 3 ..	·25	1·44	4·89	·83
		·375	2·11	7·17	·88
		·5	2·75	9·35	·92

LI

AND THEIR PROPERTIES.

Angles.

Moments of Inertia.			Radii of Gyration.			Moduli of Section,		Reference No.
about xx or yy	about UU	VV	about xx or yy	about UU	VV	Z_x	Z_y	
Inches.	Inches.		Inches.	Inches.		Inches.		
·02	·03	·01	·29	·37	·19	·03	·03	
·03	·04	·01	·29	·36	·19	·04	·04	BSEA 101.
·04	·06	·02	·37	·47	·24	·05	·05	
·06	·09	·02	·37	·46	·24	·07	·07	BSEA 102.
·10	·17	·04	·45	·56	·29	·10	·10	
·13	·21	·06	·44	·55	·29	·13	·13	BSEA 103.
·17	·27	·07	·52	·66	·34	·14	·14	
·22	·35	·09	·52	·65	·34	·18	·18	BSEA 104.
·26	·41	·11	·60	·76	·39	·18	·18	
·34	·53	·14	·60	·75	·39	·24	·24	
·40	·64	·17	·59	·75	·38	·29	·29	BSEA 105.
·38	·60	·16	·68	·86	·44	·23	·23	
·49	·77	·20	·68	·85	·44	·30	·30	
·59	·94	·25	·67	·85	·43	·37	·37	BSEA 106.
·68	1·08	·28	·76	·95	·49	·38	·38	
·83	1·31	·34	·75	·95	·48	·47	·47	
·96	1·52	·40	·74	·94	·48	·55	·55	BSEA 107.
1·20	1·91	·49	·91	1·15	·59	·55	·55	
1·72	2·73	·71	·90	1·14	·58	·81	·81	
2·18	3·44	·92	·89	1·12	·58	1·05	1·05	BSEA 108.

TABLE

Reference No.	Size A × B.	Thickness. t.	Sectional area.	Calculated weight per foot.	Centre of Gravity.
	Inches.	Inches.	Inches.	Lb.	Inches.
BSEA 109	3½ × 3½ ..	·25	1·69	5·74	·95
		·375	2·49	8·45	1·00
		·5	3·25	11·05	1·05
BSEA 110	4 × 4 ..	·375	2·86	9·73	1·12
		·5	3·75	12·75	1·17
		·625	4·61	15·68	1·22
BSEA 111	4½ × 4½ ..	·375	3·24	11·00	1·24
		·5	4·25	14·45	1·20
		·625	5·24	17·80	1·34
BSEA 112	5 × 5 ..	·375	3·61	12·28	1·37
		·5	4·75	16·16	1·42
		·625	5·86	19·93	1·47
BSEA 113	6 × 6 ..	·375	4·36	14·82	1·61
		·5	5·75	19·55	1·66
		·625	7·11	24·17	1·71
		·75	8·44	28·69	1·76
BSEA 114	7 × 7 ..	·5	6·75	22·95	1·91
		·625	8·36	28·42	1·96
		·75	9·94	33·79	2·01
BSEA 115	8 × 8 ..	·625	9·61	32·68	2·20
		·75	11·44	38·89	2·25
		·875	13·24	45·00	2·30

Remarks :—

1. The thickness printed in heavy type are the Standards. For the information of designer of structural steelwork thicknesses can be obtained.
2. The dimensions, thickness and profile of Standard Equal Angles shall be in accordance with the accompanying list accepted as conforming to the standard.
3. Angles ordered to the standard thickness shall be practically accurate in profile; but if the thickness is above when above the Standard instead of square; but the radii at the roof and toe will remain unchanged. In Equal
4. Angles may be ordered by width of flanges and thickness, or by width of flanges and weight per foot, but not by

LI (*contd.*)

Moments of Inertia.			Radii of Gyration.			Moduli of Section.		Reference No.
about xx yy	about UU	VV	about xx yy	UU	VV	X	Z	
Inches.^{4}	Inches.^{4}		Inches.	Inches.		Inches.^{3}		
1·94	3·09	·80	1·07	1·35	·69	·76	·76	
2·80	4·45	1·15	1·06	1·34	·68	1·12	1·12	
3·57	5·65	1·49	1·05	1·32	·68	1·46	1·46	BSEA 109.
4·26	6·77	1·75	1·22	1·54	·78	1·48	1·48	
5·46	8·66	2·26	1·21	1·52	·78	1·93	1·93	
6·56	10·37	2·76	1·19	1·50	·77	2·36	2·36	BSEA 110.
6·15	9·78	2·52	1·38	1·74	·88	1·89	1·89	
7·92	12·59	3·26	1·37	1·72	·88	2·47	2·47	
9·56	15·15	3·98	1·35	1·70	·87	3·03	3·03	BSEA 111.
8·53	13·57	3·49	1·54	1·94	·98	2·35	2·35	
11·04	17·55	4·53	1·52	1·92	·98	3·08	3·08	
13·37	21·21	5·53	1·51	1·90	·97	3·78	3·78	BSEA 112.
14·95	23·79	6·11	1·85	2·34	1·18	3·40	3·40	
19·48	30·99	7·96	1·84	2·32	1·18	4·49	4·49	
23·73	37·73	9·74	1·83	2·30	1·17	5·54	5·54	
27·74	44·01	11·47	1·81	2·28	1·17	6·54	6·54	BSEA 113.
31·42	50·02	12·82	2·16	2·72	1·38	6·17	6·17	
38·45	61·19	15·72	2·14	2·71	1·37	7·63	7·63	
45·12	71·72	18·53	2·13	2·69	1·37	9·04	9·04	BSEA 114.
58·26	92·75	23·78	2·46	3·11	1·57	10·05	10·05	
68·58	109·11	28·06	2·45	3·09	1·57	11·94	11·94	
78·44	124·65	32·23	2·43	3·07	1·56	13·77	13·77	BSEA 115.

the properties are given of sections differing from the standard thicknesses in steps of 0·0625 inch, but other intermediate

and sketch, but finished sections in which the angle between the flanges is not less than 89° nor more than 91° shall be

the Standards, the flanges will be longer than the Standards. The profile at the back of the toe will be slightly rounded
Sides Angles the thickness of the flanges will be the same.
both thickness and weight per foot.

TABLE

STANDARD SIZES OF UNEQUAL ANGLES

Unequal

Reference No.	Size A. × B.	Thickness. t	Sectional area. a	Calculated weight per foot. w	Centre of Gravity. xx	yy
	Inches.	Inches.	Inches.²	Lb.	Inches.	
BSUA 101	2 × 1½ ..	·1875	·62	2·11	·63	·38
		·25	·81	2·76	·63	·41
BSUA 102	2½ × 2½ ..	·1875	·71	2·43	·83	·34
		·25	·94	3·19	·86	·37
BSUA 103	2½ × 2 ..	·1875	·81	2·75	·75	·50
		·25	1·06	3·61	·77	·53
		·3125	1·31	4·45	·80	·55
BSUA 104	3 × 2 ..	·25	1·19	4·04	·98	·48
		·3125	1·46	4·98	1·00	·51
		·375	1·73	5·90	1·03	·53
BSUA 105	3 × 2½ ..	·25	1·31	4·47	·89	·65
		·3125	1·62	5·51	·92	·67
		·375	1·92	6·54	·94	·70
BSUA 106	3½ × 2½ ..	·25	1·44	4·89	1·09	·60
		·3125	1·78	6·04	1·12	·63
		·375	2·11	7·17	1·15	·65
BSUA 107	3½ × 3 ..	·3125	1·93	6·58	1·04	·79
		·375	2·30	7·81	1·07	·82
		·5	3·00	10·20	1·12	·87
BSUA 108	4 × 2½ ..	·25	1·56	5·32	1·30	·56
		·3125	1·93	6·58	1·33	·59
		·375	2·30	7·81	1·36	·61
BSUA 109	4 × 3 ..	·3125	2·09	7·11	1·24	·75
		·375	2·49	8·45	1·27	·77
		·5	3·25	11·05	1·32	·82

Remarks :—

1. The thicknesses printed in heavy type are the Standards. For the information of designers of structural steelwork thicknesses can be obtained.
2. The dimensions, thickness and profile of Standard Unequal Angles shall be in accordance with the accompanying accepted as conforming to the Standard.
3. Angles ordered to the standard thickness shall be practically accurate in profile; but if the thickness is above the above the Standards, instead of square, but the radii at the root and toe will remain unchanged. In Unequal Sided
4. Angles may be ordered by width of flanges and thicknesses, or by width of flanges and weight per foot, but not by

LII—(*contd.*)

AND THEIR PROPERTIES.

Angles.

Moments of Inertia about xx	yy	about UU	VV	Radii of Gyration about xx	yy	about UU	VV	Moduli of Section Zx	Zy	Reference No.
Inches.⁴		Inches.⁴		Inches.		Inches.		Inches.³		
·24	·11	·29	·06	·62	·43	·68	·32	·17	·10	
·31	·15	·37	·08	·61	·42	·68	·31	·23	·13	BSUA 101.
·45	·12	·49	·07	·79	·41	·83	·32	·27	·10	
·58	·15	·64	·09	·78	·40	·82	·32	·35	·14	BSUA 102.
·49	·28	·62	·14	·78	·58	·88	·42	·28	·18	
·63	·36	·81	·19	·77	·58	·87	·42	·37	·24	
·77	·43	·98	·23	·77	·57	·86	·42	·45	·30	BSUA 103.
1·06	·38	1·22	·22	·94	·56	1·01	·43	·52	·25	
1·29	·45	1·48	·26	·94	·56	1·00	·43	·65	·30	
1·50	·53	1·72	·31	·93	·55	1·00	·42	·76	·36	BSUA 104.
1·14	·72	1·50	·36	·93	·74	1·07	·52	·54	·39	
1·39	·87	1·82	·44	·93	·73	1·06	·52	·6[illegible]	·48	
1·62	1·02	2·13	·51	·92	·73	1·05	·52	·79	·56	BSUA 105.
1·75	·74	2·08	·41	1·10	·72	1·20	·54	·73	·39	
2·14	·91	2·55	·51	1·10	·71	1·20	·53	·90	·48	
2·51	1·06	2·98	·59	1·09	·71	1·19	·53	·07	·57	BSUA 106.
2·27	1·54	3·06	·75	1·08	·89	1·26	·62	·92	·70	
2·67	1·80	3·59	·88	1·08	·88	1·25	·62	1·10	·83	
3·40	2·28	4·55	1·13	1·06	·87	1·23	·61	1·43	1·07	BSUA 107.
2·54	·77	2·85	·46	1·27	·70	1·35	·54	·94	·40	
3·11	·94	3·49	·56	1·27	·70	1·34	·54	1·17	·49	
3·66	1·10	4·10	·66	1·26	·69	1·34	·53	1·38	·58	BSUA 108.
3·30	1·59	4·04	·86	1·26	·87	1·39	·64	1·20	·71	
3·80	1·87	4·75	1·01	1·25	·87	1·38	·64	·42	·84	
4·97	2·37	6·04	1·30	1·24	·85	1·36	·63	1·85	1·09	BSUA 109.

the properties are given of sections differing from the standard thicknesses in steps of 0·0625 inch, but other intermediate list and sketch, but finished sections in which the angle between the flanges is not less than 89° nor more than 91° shall be Standard, the flanges will be longer than the Standards. he profile at the back of the toe will be slightly rounded when Angles the flanges may differ in thickness, but the difference shall not exceed ·05 inch. both thickness and weight per foot.

TABLE

STANDARD SIZES UNEQUAL ANELES

Unequal

Reference No.	Size A × B.	Thickness. t	Sectional area. a	Calculated weight per foot. w	Centre of Gravity. xx	yy
	Inches.	Inches.	Inches.²	Lbs.	Inches.	
BSUA 110 ..	.. 4 × 3½ ..	·3125	2·25	7·64	1·16	·92
		·375	2·67	9·09	1·19	·94
		·5	3·50	1·91	1·24	·99
BSUA 111 ..	.. 4½ × 3 ..	·3125	2·25	7·64	1·44	·70
		·375	2·67	9·09	1·47	·73
		·5	3·50	1·91	1·52	·78
BSUA 112 ..	.. 5 × 3 ..	·3125	2·40	8·17	1·66	·67
		·375	2·86	9·73	1·68	·69
		·5	3·75	12·75	1·73	·74
BSUA 113 ..	.. 5 × 3½ ..	·375	3·05	10·37	1·59	·85
		·5	4·00	13·61	1·64	·90
BSUA 114 ..	.. 5 × 4 ..	·375	3·24	11·00	1·51	1·01
		·5	4·25	14·45	1·56	1·06
BSUA 115 ..	.. 6 × 3 ..	·375	3·24	11·00	2·12	·63
		·5	4·25	14·45	2·17	·68
BSUA 116 ..	.. 6 × 3½ ..	·375	3·42	11·63	2·01	·77
		·5	4·50	15·30	2·06	·82
BSUA 117 ..	.. 6 × 4 ..	·375	3·61	12·28	1·91	·92
		·5	4·75	16·16	1·97	·97
		·625	5·86	19·93	2·02	1·02
BSUA 118 ..	.. 7 × 3½ ..	·4375	4·40	14·97	2·47	·74
		·5	5·00	17·00	2·50	·76
BSUA 119 ..	.. 7 × 4 ..	·5	5·25	17·85	2·39	·90
		·625	6·48	22·05	2·44	·95
BSUA 120 ..	.. 8 × 3½ ..	·4375	4·84	16·46	2·92	·69
		·5	5·50	18·70	2·95	·72
BSUA 121 ..	.. 8 × 4 ..	·5	5·75	19·55	2·83	·85
		·625	7·11	24·17	2·88	·90
BSUA 122 ..	.. 8 × 6 ..	·5	6·75	22·95	2·44	1·45
		·75	9·94	33·79	2·54	1·55
BSUA 123 ..	.. 9 × 4 ..	·5	6·25	21·25	3·27	·80
		·75	9·19	31·24	3·38	·90

LII—(*contd.*)

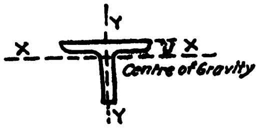
AND THEIR PROPERTIES

Angles

Moments of	Inertia			Radii of	Gyration.			Moduli of Section.		Reference No.
about xx	yy	about UU	VV	about xx	yy	about UU	VV	Zx	Zy	
Inches.[1]		Inches.[1]		Inches.		Inches.		Inches.[3]		
3·47	2·47	4·77	1·18	1·24	1·05	1·46	·72	1·22	·96	
4·09	2·91	5·61	1·39	1·24	1·04	1·45	·72	1·45	1·37	
5·24	3·72	7·16	1·79	1·22	1·03	1·43	·72	1·90	1·48	BSUA 110.
4·59	1·64	5·28	·94	1·43	·85	1·53	·65	1·50	·71	
5·41	1·92	6·22	1·11	1·42	·85	1·53	·64	1.79	·85	
6·94	2·45	7·96	1·43	1·41	·84	1·51	·64	2·33	1·10	BSUA 111.
6·14	1·68	6·80	1·01	1·60	·84	1·68	·65	1·84	·72	
7·25	1·97	8·03	1·19	1·59	·83	1·68	·65	2·18	·85	
9·33	2·51	10·31	1·54	1·58	·82	1·66	·64	2·86	1·11	BSUA 112.
7.63	3·09	8·99	1·73	1·58	1·01	1·72	·75	2·24	1·16	
9·84	3·96	11·56	2·24	1·57	·99	1·70	·75	2·93	1·52	BSUA 113.
7·97	·453	10·18	2·32	1·57	1·18	1·77	·85	2·28	1·52	
10·29	5·83	13·11	3·01	1·56	1·17	1·76	·84	2·99	1·98	BSUA 114.
11·99	2·05	12·72	1·32	1·93	·80	1·98	·64	3·09	·87	
15·51	2·62	16·43	1·70	1·91	·78	1·97	·63	4·05	1·13	BSUA 115.
12·62	3·21	13·87	1·96	1·92	·97	2·01	·76	3·16	1·18	
16·36	4·13	17·95	2·53	1·91	·96	2·00	·75	4·15	1·65	BSUA 116.
13·21	4·74	15·24	2·72	1·91	1·15	2·05	·87	3·23	1·54	
17·14	6·11	19·73	3·52	1·90	1·13	2·04	·86	4·25	2·02	
20·82	7·37	23·90	4·29	1·88	1·12	2·02	·86	5·23	2·48	BSUA 117.
22·22	3·80	23·58	2·44	2·25	·93	2·31	·74	4·91	1·38	
25·07	4·27	26·59	2·75	2·24	·92	2·31	·74	5·57	1·56	BSUA 118.
26·26	6·33	28·69	3·89	2·24	1·10	2·34	·86	5·70	2·04	
32·00	7·64	34·90	4·74	2·22	1·09	2·32	·86	7·02	2·51	BSUA 119.
32·08	3·80	33·38	2·59	2·57	·90	2·63	·73	6·31	1·39	
36·24	4·38	37·69	2·93	2·57	·89	2·62	·73	7·17	1·57	BSUA 120.
37·95	6·50	40·28	4·18	2·57	1·06	2·65	·85	7·34	2·06	
46·37	7·87	49·15	5·10	2·55	1·05	2·63	·85	9·06	2·54	BSUA 121.
43·47	21·08	53·28	11·26	2·54	1·77	2·81	1·29	7·82	4·63	
62·60	30·14	76·49	16·24	2·51	1·74	2·77	1·28	11·47	6·77	BSUA 122.
52·46	6·65	54·70	4·41	2·90	1·03	2·96	·84	9·16	2·08	
75·45	9·87	78·49	6·33	2·87	1·01	2·92	·83	13·43	3.02	BSUA 123.

TABLE LIII.

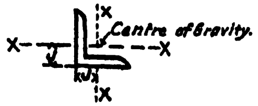
PROPERTIES OF STEEL TEES AND SAFE LOADS AS STRUTS WHEN USED AS PRINCIPALS OF TRUSSES.



Size and thickness.	Area, square inches	Weight per foot, lbs.	Dimension. J.	Moments of inertia.		Radii of gyration.		Safe load as a strut in tons; over a length of									
				About XX.	About YY.	About XX.	About YY.	2′	3′	4′	5′	6′	7′	8′	9′	10′	12′
6×4×3/8 ..	3·634	12·36	·91[illegible]	4·700	6·344	1·137	1·137	21·5	21·1	20·5	19·9	19·1	18·2	17·2	16·2	15·0	12·5
6×4×1/2 ..	4·771	16·22	·96[illegible]	6·070	8·621	1·128	1·344	28·2	27·7	26·9	26·1	25·1	23·8	22·6	21·1	19·5	16·3
6×4×5/8 ..	5·878	19·99	1·0[illegible]	7·350	10·912	1·118	1·362	34·7	34·0	33·2	32·1	38·0	29·3	27·7	25·9	23·9	19·9
6×3×1/2 ..	4·272	14·53	·684	2·635	8·649	·785	1·423	24·8	23·9	22·7	21·1	10·4	17·4	15·3	13·4	11·8	..
6×3×5/8 ..	5·256	17·87	·732	3·144	10·938	·773	1·443	30·5	29·4	27·8	25·9	23·7	21·1	18·5	16·2	14·2	..
5×4×3/8 ..	3·257	11·07	·998	4·471	3·691	1·172	1·065	19·2	18·8	18·3	17·6	16·8	15·9	14·9	13·8	12·6	10·4
5×4×1/2 ..	4·268	14·51	1·05	5·772	5·017	1·163	1·084	25·2	24·7	24·0	23·2	22·2	21·0	19·8	18·4	16·8	14·0
5×3×3/8 ..	2·875	9·78	·691	1·973	3·716	·828	1·137	16·8	16·2	15·5	14·5	13·4	12·2	10·9	9·[illegible]	8·5	..
5×3×1/2 ..	3·762	12·79	·741	2·516	5·031	·818	1·156	21·9	21·2	20·2	18·9	17·5	15·8	14·0	12·4	10·9	..
4×4×3/8 ..	2·872	9·77	1·11	4·189	1·901	1·208	·814	16·7	16·2	15·4	14·4	13·3	12·0	10·7	9·4	8·3	..
4×4×1/2 ..	3·758	12·78	1·16	5·402	2·590	1·199	·830	21·9	21·2	20·2	19·0	17·6	16·0	14·2	12·6	11·1	..
4×3×3/8 ..	2·498	8·49	·767	1·860	1·914	·863	·875	14·6	14·1	13·6	12·8	11·9	10·9	9·8	8·7	7·8	..
4×3×1/2 ..	3·262	11·08	·816	2·365	2·599	·851	·893	19·0	18·4	17·6	16·6	15·5	14·2	12·7	11·2	9·9	..
3½×3½×3/8 ..	2·496	8·49	·988	2·768	1·284	1·053	·717	14·4	13·8	12·9	11·9	10·7	9·3	8·1	7·[illegible]	..	..
3½×3½×1/2 ..	3·259	11·08	1·04	3·543	1·752	1·043	·733	18·9	18·1	17·0	15·7	14·2	12·5	10·8	9·4	..	..
3×3×3/8 ..	2·121	7·21	·868	1·708	·816	·897	·620	12·1	11·4	10·4	9·3	8·0	6·8	5·7	..	..	..
3×3×1/2 ..	2·76	9·38	·918	2·165	1·115	·886	·636	15·8	14·9	13·7	12·3	10·7	9·1	7·7	..	..	..
3×2½×3/8 ..	1·929	6·56	·695	1·015	·814	·725	·650	11·0	10·5	9·7	8·7	7·6	6·5	5·6	..	..	..
3×2½×1/2 ..	2·506	8·52	·742	1·275	1·109	·713	·665	14·4	13·7	12·7	11·5	10·1	8·7	7·4	..	..	..
2½×2½×1/4 ..	1·197	4·07	·697	·677	·302	·752	·502	6·7	6·1	5·3	4·4	3·6	..	..	..	..	..
2½×2½×5/16 ..	1·474	5·01	·724	·823	·387	·747	·512	8·2	7·5	6·6	5·5	4·5	..	..	..	..	..
2½×2½×3/8 ..	1·742	5·92	·750	·959	·473	·742	·521	9·7	8·9	7·9	6·6	5·4	..	..	..	..	..
2¼×2¼×1/4 ..	1·071	3·64	·638	·488	·224	·675	·457	5·9	5·2	4·4	3·6	2·8	..	..	..	..	..
2¼×2¼×3/8 ..	1·554	5·28	·689	·685	·349	·664	·474	8·6	7·7	6·6	5·4	4·3	..	..	..	..	..
2×2×1/4 ..	·947	3·22	·579	·337	·157	·597	·407	5·1	4·4	3·5	2·7	..	..	..	..	..	..
2×2×3/8 ..	1·367	4·64	·628	·469	·246	·586	·424	7·4	6·5	5·3	4·1	..	..	..	..	..	..
2×1½×1/4 ..	·820	2·79	·408	·148	·15[illegible]	·425	·441	4·4	3·9	3·2	2·5	..	..	..	..	..	..
2×1½×3/8 ..	1·180	4·01	·455	·202	·246	·414	·457	6·3	5·5	4·5	3·5	..	..	..	..	..	..
1½×2×1/4 ..	·820	2·70	·648	·307	·068	·612	·288	3·9	2·0	..	..	..	..	..	..	..	..
1½×2×5/16 ..	1·003	3·41	·674	·369	·088	·607	·296	4·8	3·6	..	..	..	..	..	..	..	..
1¾×1¾×1/4 ..	·820	2·79	·519	·221	·107	·520	·361	4·2	3·5	2·7	..	..	..	..	..	..	..
1¾×1¾×5/16 ..	·999	3·40	·544	·265	·137	·515	·370	5·2	4·4	3·4	..	..	..	..	..	..	..
1½×1½×1/4 ..	·692	2·35	·460	·135	·067	·442	·312	3·4	2·6	1·9	..	..	..	..	..	..	..

TABLE LIV.

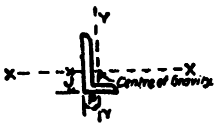
PROPERTIES OF STEEL EQUAL ANGLES AND SAFE LOADS AS STRUTS.



Size and thickness.	Area square inches.	Weight per foot, lbs.	Dimension. J.	Moments of inertia. XX.	Lest radius of gyration.	Safe load as a strut in tons; over a length of													
						2′	3′	4′	5′	6′	7′	8′	9′	10′	12′	14′	16′	18′	20′
8×8×⅝ ..	9 ·609	32 ·67	2 ·20	58 ·2	1 ·57	57 ·2	56 ·6	55 ·9	54 ·9	53 ·8	52 ·5	51 ·0	49 ·4	47 ·6	43 ·7	39 ·1	34 ·4	30 ·2	26 ·4
8×8×¾ ..	11 ·437	38 ·89	2 ·25	68 ·5	1 ·56	68 ·0	67 ·4	66 ·5	65 ·3	64 ·0	62 ·5	60 ·7	58 ·7	56 ·5	51 ·8	46 ·3	40 ·7	35 ·6	31 ·2
6×6×⅝ ..	7 ·112	24 ·18	1 ·71	23 ·8	1 ·18	42 ·0	41 ·3	40 ·4	39 ·2	37 ·8	36 ·1	34 ·3	32 ·4	30 ·2	25 ·5	21 ·4	18 ·0	..	..
6×6×¾ ..	8 ·441	28 ·70	1 ·76	27 ·8	1 ·17	49 ·0	49 ·0	47 ·9	46 ·5	44 ·8	42 ·8	40 ·6	38 ·2	35 ·6	30 ·0	25 ·2	21 ·1	..	..
5×5×½ ..	4 ·750	16 ·15	1 ·42	11 ·0	·98	27 ·9	27 ·2	26 ·3	25 ·2	23 ·9	22 ·4	20 ·7	18 ·8	17 ·0	13 ·8	..	..	..	..
5×5×⅝ ..	5 ·860	19 ·92	1 ·47	13 ·4	·98	34 ·4	33 ·6	32 ·5	31 ·1	29 ·4	27 ·6	25 ·5	23 ·2	21 ·0	17 ·0	..	..	..	..
4½×4½×½ ..	4 ·252	14 ·46	1 ·29	7 ·92	·87	24 ·9	24 ·1	23 ·1	21 ·8	20 ·4	18 ·7	16 ·8	15 ·0	13 ·3	..	..	..	..	..
4½×4½×⅝ ..	5 ·236	17 ·80	1 ·34	9 ·56	·87	30 ·6	29 ·7	28 ·4	26 ·9	25 ·1	23 ·0	20 ·7	18 ·4	16 ·4	..	..	..	..	..
4×4×½ ..	3 ·749	12 ·75	1 ·17	5 ·46	·77	21 ·8	20 ·9	19 ·8	18 ·4	16 ·8	15 ·0	13 ·2	11 ·5	10 ·1	..	..	..	..	..
4×4×⅝ ..	4 ·609	15 ·67	1 ·22	6 ·56	·77	26 ·7	25 ·7	24 ·3	22 ·6	20 ·7	18 ·4	16 ·2	14 ·1	12 ·4	..	..	..	..	..
3½×3½×⅜ ..	2 ·485	8 ·45	1 ·00	2 ·80	·68	14 ·3	13 ·6	12 ·7	11 ·5	10 ·2	8 ·8	7 ·6	6 ·5	..	..	..	..	..	..
3½×3½×½ .	3 ·251	11 ·05	1 ·05	3 ·57	·68	18 ·7	17 ·8	16 ·6	15 ·1	13 ·3	11 ·5	9 ·9	8 ·5	..	..	..	..	..	..
3½×3½×⅝ ..	3 ·985	13 ·55	1 ·09	4 ·27	·68	22 ·9	21 ·8	20 ·3	18 ·5	16 ·3	14 ·1	12 ·1	10 ·4	..	..	..	..	..	..
3×3×5/16..	1 ·779	6 ·05	·853	1 ·47	·58	10 ·1	9 ·4	8 ·6	7 ·5	6 ·4	5 ·4	..	..	..	..	..	..	..	..
3×3×⅜ ..	2 ·111	7 ·18	·877	1 ·72	·58	12 ·0	11 ·2	10 ·1	8 ·8	7 ·4	6 ·2	..	..	..	..	..	..	..	..
3×3×½ ..	2 ·752	9 ·36	·924	2 ·19	·58	15 ·6	14 ·6	13 ·2	11 ·5	9 ·7	8 ·1	..	..	..	..	..	..	..	..
3×3×⅝ ..	3 ·362	11 ·43	·970	2 ·59	·58	19 ·1	17 ·8	16 ·1	14 ·1	11 ·8	9 ·9	..	..	..	..	..	..	..	..
2½×2½×¼ ..	1 ·187	4 ·04	·703	·677	·48	6 ·6	5 ·9	5 ·1	4 ·2	3 ·3	..	..	..	..	..	..	..	..	..
2½×2½×5/16	1 ·464	4 ·98	·728	·822	·48	8 ·1	7 ·3	6 ·3	5 ·1	4 ·1	..	..	..	..	..	..	..	..	..
2½×2½×⅜ ..	1 ·733	5 ·89	·752	·962	·48	9 ·6	8 ·6	7 ·4	6 ·1	4 ·9	..	..	..	..	..	..	..	..	..
2½×2½×½ ..	2 ·249	7 ·65	·799	1 ·21	·48	12 ·4	11 ·2	9 ·7	7 ·9	6 ·3	..	..	..	..	..	..	..	..	..
2¼×2¼×¼ ..	1 ·063	3 ·61	·643	·489	·44	5 ·8	5 ·1	4 ·3	3 ·4	..	..	..	..	..	..	..	..	..	..
2¼×2¼×5/16	1 ·309	4 ·45	·668	·592	·43	7 ·1	6 ·2	5 ·1	4 ·0	..	..	..	..	..	..	..	..	..	..
2¼×2¼×⅜ ..	1 ·547	5 ·26	·692	·686	·43	8 ·4	7 ·4	6 ·1	4 ·8	..	..	..	..	..	..	..	..	..	..
2×2×3/16..	·715	2 ·43	·554	·260	·39	3 ·8	3 ·2	2 ·5	1 ·9	..	..	..	..	..	..	..	..	..	..
2×2×¼ ..	·938	3 ·19	·581	·336	·39	5 ·0	4 ·2	3 ·3	2 ·6	..	..	..	..	..	..	..	..	..	..
2×2×5/16..	1 ·153	3 ·92	·605	·401	·38	6 ·1	5 ·1	4 ·0	3 ·0	..	..	..	..	..	..	..	..	..	..
2×2×⅜ ..	1 ·36	4 ·62	·629	·467	·38	7 ·2	6 ·1	4 ·7	3 ·6	..	..	..	..	..	..	..	..	..	..
1¾×1¾×3/16	·622	2 ·11	·495	·172	·34	3 ·2	2 ·6	1 ·9	..	..	..	..	..	..	..	..	..	..	..
1¾×1¾×¼ ..	·814	2 ·77	·520	·220	·34	4 ·1	3 ·3	2 ·5	..	..	..	..	..	..	..	..	..	..	..
1¾×1¾×3/16	·997	3 ·39	·544	·264	·34	5 ·1	4 ·1	3 ·0	..	..	..	..	..	..	..	..	..	..	..
1½×1½×3/16	·526	1 ·79	·434	·105	·29	2 ·5	1 ·8	..	..	..	..	..	..	..	..	..	..	..	..
1½×1½×¼ ..	·686	2 ·33	·458	·134	·29	3 ·3	2 ·4	..	..	..	..	..	..	..	..	..	..	..	..
1½×1½×3/16	·839	2 ·85	·482	·159	·29	4 ·0	2 ·9	..	..	..	..	..	..	..	..	..	..	..	..
1¼×1¼×3/16	·436	1 ·47	·371	·058	·24	1 ·9	1 ·2	..	..	..	..	..	..	..	..	..	..	..	..
1¼×1¼×¼ ..	·561	1 ·91	·396	·973	·23	2 ·3	1 ·5	..	..	..	..	..	..	..	..	..	..	..	..

TABLE LV.

PROPERTIES OF STEEL UNEQUAL ANGLES AND SAFE LOADS AS STRUTS



Size and thickness.	Area, square inches	Weight per foot, lbs.	Dimensions.		Moments of inertia.		Least radius of gyration	Safe load as a strut in tons ; over a length of									
			J.	P.	About XX.	About YY.		2′	3′	4′	5′	6′	7′	8′	9′	10′	12′
7×3½×⅝ ..	6·172	20·98	2·55	·814	30·55	5·15	·74	35·7	34·3	32·3	29·8	27·0	23·8	20·7	18·1	..	..
7×3½×¾ ..	7·313	24·86	2·60	·862	35·68	5·95	·73	42·3	40·5	38·1	35·1	31·7	27·8	24·2	21·0	..	..
6½×4½×⅝ ..	6·482	22·04	2·13	1·14	27·09	10·60	·96	38·0	37·1	35·8	34·2	32·3	30·2	27·8	25·2	22·7	18·3
6½×4½×¾ ..	7·680	26·13	2·18	1·19	31·66	12·32	·96	45·1	44·0	42·5	40·6	38·3	35·8	33·0	29·9	26·9	21·7
6×4×½ ..	4·750	16·15	1·96	·974	17·1	6·10	·86	27·7	26·9	25·8	24·3	22·6	20·7	18·6	16·5	14·7	..
6×4×⅝ ..	5·860	19·92	2·02	1·02	20·8	7·36	·86	34·2	33·2	31·8	30·0	27·9	25·6	22·9	20·4	18·1	..
6×3½×½ ..	4·502	15·31	2·06	·823	16·4	4·14	·75	26·1	25·1	23·6	21·9	19·9	17·6	15·3	13·4	11·7	..
6×3½×⅝ ..	5·549	18·87	2·11	·872	19·88	4·97	·75	32·2	30·9	29·1	27·0	24·5	21·7	18·9	16·5	14·4	..
6×3×½ ..	4·252	14·46	2·17	·683	15·5	2·62	·63	24·3	22·9	21·1	18·9	16·3	13·9	11·7	..	..	..
6×3×⅝ ..	5·236	17·80	2·22	·731	18·79	3·13	·63	29·9	28·3	25·9	23·3	20·1	17·1	14·5	..	..	..
5½×3½×½ ..	4·252	14·46	1·85	·857	12·80	4·05	·75	24·6	23·7	22·3	20·7	18·8	16·6	14·5	12·6	11·0	..
5½×3½×⅝ ..	5·236	17·80	1·90	·905	15·6	4·86	·75	30·3	29·1	27·5	25·4	23·1	20·4	17·8	15·6	13·6	..
5½×3×½ ..	4·003	13·61	1·95	·711	12·2	2·58	·64	22·9	21·7	20·0	18·0	15·6	13·3	11·3	..	..	..
5½×3×⅝ ..	4·925	16·74	2·00	·759	14·7	3·08	·63	28·2	26·6	24·4	21·9	18·9	16·1	13·6	..	..	..
5×4×½ ..	4·252	14·46	1·56	1·06	10·3	5·82	·84	24·8	24·0	22·9	21·6	20·0	18·3	16·3	14·4	12·8	..
5×4×⅝ ..	5·236	17·80	1·60	1·11	12·4	7·01	·83	30·5	29·5	28·2	26·5	24·5	22·3	19·8	17·5	15·5	..
5×3½×½ ..	4·003	13·61	1·64	·897	9·86	3·96	·75	23·2	22·3	21·0	19·5	17·7	15·6	13·6	11·9	10·4	..
5×3½×⅝ ..	4·925	16·74	1·69	·944	11·9	4·75	·74	28·5	27·2	25·7	23·8	21·6	19·0	16·5	14·4	12·5	..
5×3×½ ..	3·749	12·75	1·73	·742	9·33	2·51	·64	21·5	20·[illegible]	18·7	16·8	14·6	12·4	10·6	..	..	..
5×3×⅝ ..	4·609	15·67	1·78	·789	11·25	3·00	·64	26·4	24·9	23·0	20·7	17·9	15·3	13·0	..	..	..
4½×3½×½ ..	3·749	12·75	1·44	·940	7·31	3·84	·74	21·7	20·8	19·6	18·1	16·4	14·4	12·6	11·0	..	..
4½×3½×⅝ ..	4·609	15·67	1·48	·987	8·81	4·61	·74	26·7	25·6	24·1	22·3	20·2	17·8	15·5	13·5	..	..
4×3×⅜ ..	2·485	8·45	1·27	·771	3·89	1·87	·64	14·2	13·5	12·4	11·1	9·7	8·2	7·0	..	..	..
4×3×½ ..	3·251	11·05	1·31	·819	4·98	2·37	·63	18·6	17·5	16·1	14·4	12·5	10·6	9·0	..	..	..
4×3×⅝ ..	3·985	13·55	1·36	·865	5·96	2·83	·63	22·8	21·5	19·7	17·7	15·3	13·0	11·0	..	..	..
3½×3× 5/16 ..	1·934	6·58	1·04	·792	2·27	1·53	·62	11·0	10·4	9·5	8·5	7·3	6·2	5·2	..	..	..
3½×3×⅜ ..	2·298	7·81	1·07	·819	2·67	1·80	·62	13·1	12·4	11·3	10·1	8·7	7·4	6·2	..	..	..
3½×3×½ ..	3·001	10·20	1·11	·867	3·40	2·28	·61	17·1	16·1	14·7	13·0	11·1	9·4	8·0	..	..	..
3½×3×⅝ ..	3·673	12·49	1·16	·912	4·05	2·71	·61	20·9	19·7	18·0	16·0	13·6	11·5	9·7	..	..	..
3½×2½×¼ ..	1·44	4·90	1·10	·602	1·76	·748	·54	8·1	7·5	6·7	5·7	4·7	3·9	..	..	..	..
3½×3½× 5/16 ..	1·779	6·05	1·12	·627	2·15	·910	·54	10·0	9·2	8·2	7·0	5·8	4·8	..	..	..	..
3½×2½×⅜ ..	2·111	7·18	1·15	·652	2·52	1·06	·53	11·8	10·9	9·7	8·2	6·7	5·5	..	..	..	..
3½×2½×½ ..	2·752	9·36	1·20	·699	3·20	1·34	·53	15·4	14·2	12·6	10·6	8·8	7·2	..	..	..	..
3×2½×¼ ..	1·312	4·46	·895	·643	1·14	·716	·52	7·3	6·7	5·9	5·0	4·1	..	..	..	..	..
3×2½× 5/16 ..	1·62	5·51	·921	·673	1·39	·871	·52	9·1	8·3	7·3	6·1	5·0	..	..	..	..	..

TABLE LV—(*contd.*)

Size and thickness.	Area, square inches.	Weight per foot, lbs.	Dimensions.		Moments of inertia.		Least radius of gy-ration.	Safe load as a strut in tons; over a length of									
			J.	P.	About XX.	About YY.		2′	3′	4′	5′	6′	7′	8′	9′	10′	12′
3×2½×⅜ ..	1·921	6·53	·945	·697	1·62	1·02	·52	10·7	9·9	8·7	7·3	6·0	..	..	..	..	..
3×2½×½ ..	2·499	8·50	·992	·744	2·05	1·28	·52	14·0	12·8	11·3	9·5	7·8	..	..	..	..	..
3×2×¼ ..	1·187	4·04	·976	·482	1·06	·373	·43	6·4	5·7	4·7	3·7	..	..	..	..	..	..
3×2× 5/16 ..	1·464	4·98	1·00	·508	1·29	·452	·42	7·9	6·9	5·6	4·4	..	..	..	..	..	..
3×2×⅜ ..	1·733	5·89	1·03	·532	1·50	·525	·42	9·4	8·2	6·6	5·2	..	..	..	..	..	..
3×2×½ ..	2·249	7·65	1·07	·578	1·89	·656	·42	12·1	10·6	8·6	6·7	..	..	..	..	..	..
2½×2×¼ ..	1·063	3·61	·774	·527	·636	·359	·42	5·7	5·0	4·1	3·2	..	..	..	..	..	..
2½×2× 5/16 ..	1·309	4·45	·799	·552	·770	·433	·42	7·1	6·2	5·0	3·9	..	..	..	..	..	..
2½×2×⅜ ..	1·547	5·26	·823	·575	·895	·502	·42	8·3	7·3	5·9	4·6	..	..	..	..	..	..
2×1½× 3/16 ..	·622	2·11	·627	·381	·240	·115	·32	3·1	2·4	1·8	..	..	..	..	..	..	..
2×1½×¼ ..	·814	2·77	·653	·407	·308	·146	·31	4·0	3·1	2·2	..	..	..	..	..	..	..
2×1½× 5/16 ..	·997	3·39	·678	·431	·369	·174	·31	4·9	3·8	2·7	..	..	..	..	..	..	..

Note.—The safe loads in table Nos. LIII, LIV and LV are for struts with both ends fixed.

In the case of strut with one end fixed, and the other rounded, the allowable load is found by referring in the table to a length of 1⅓rd times the actual length; whilst with both ends rounded the reference length should be 1⅔rd times the actual length.

Example.—For a stanchion or strut 9 feet long, with one end fixed and the other rounded, reference should be made in the table to a length of 12 feet; or, if both ends are rounded, to a length of 15, feet, where the respective safe loads will be found.

TABLE

SIZES OF BEAMS FOR

Weight supported per square foot.		1 cwt. = 112 lbs.							1¼ cwts. = 140 lbs.					
R. S. joists required spaced 1" apart		T 2"×2"×¼" @3·22 lbs.	3"×1½" @ 4 lbs.				4"×1¾" @ 5 lbs.		3"×1½" @ 4 lbs.				4"×1¾" @ 5 lbs	
R. S beams spaced apart in feet.		4	5	6	7	8	9	10	4	5	6	7	8	9
Clear span in feet.	Length of beam in feet.													
8	9·5	..	..	..	..	..	..	..	..	..	..	..	..	..
9	10·5	..	..	..	..	..	..	..	..	..	..	..	..	..
10	11·5	..	..	..	..	..	..	..	6×3	7×4	7×4	7×4	7×4	8×4
11	12·5	6×3	7×4	7×4	7×4	8×4	8×4	8×4	7×4	7×4	7×4	8×4	8×4	9×4
12	13·5	7×4	7×4	7×4	8×4	8×4	9×4	9×4	7×4	8×4	8×4	9×4	9×4	9×4
13	14·5	7×4	8×4	8×4	9×4	9×4	9×4	8×5	8×4	8×4	9×4	9×4	8×5	10×5
14	15·5	8×4	8×4	9×4	9×4	8×5	10×5	10×5	8×4	9×4	9×4	10×5	10×5	10×5
15	16·5	8×4	9×4	9×4	8×5	10×5	10×5	10×5	9×4	9×4	10×5	10×5	10×5	10×5
16	18	9×4	9×4	10×5	10×5	10×5	10×5	12×5	9×4	10×5	10×5	10×5	12×5	12×5
17	19	9×4	10×5	10×5	10×5	12×5	12×5	12×5	10×5	10×5	10×5	12×5	12×5	12×5
18	20	10×5	10×5	10×5	12×5	12×5	12×5	15×5	10×5	10×5	12×5	12×5	15×5	15×5
19	21	10×5	10×5	12×5	12×5	12×5	15×5	15×5	10×5	12×5	12×5	15×5	15×5	15×5
20	22	10×5	12×5	12×5	12×5	15×5	15×5	15×5	12×5	12×5	15×5	15×5	15×5	15×5
21	23	12×5	12×5	12×5	15×5	15×5	15×5	15×5	12×5	15×5	15×5	15×5	15×5	15×5
22	24	12×5	12×5	15×5	15×5	15×5	15×5	15×5	12×5	15×5	15×5	15×5	15×5	14×6 @57
23	25	12×5	15×5	15×5	15×5	15×5	15×5	14×6 @57	15×5	15×5	15×5	15×5	14×6 @57	14×6 @57
24	26	15×5	15×5	15×5	15×5	14×6 @46	14×6 @57	15×6	15×5	15×5	15×5	14×6 @57	15×6	15×6
25	27	15×5	15×5	15×5	15×5	14×6 @57	15×6	15×6	15×5	15×5	14×6 @57	15×6	15×6	16×6

Note.—The dimensions of

LVI.

DIFFERENT WEIGHTS AND SPANS.

1¼ cwts. = 168 lbs.						1¾ cwts. = 196 lbs.					2 cwts. = 224 lbs.					Clear span in feet.
3″×1¾″ @ 4 lbs.				4″×1¾″ @ 5 lbs.		3″×1¾″ @ 4 lbs.			4″×1¾″ @ 5 lbs.		3″×1¾″ @ 4 lbs.			4″×1¾″ @ 5 lbs.		
4	5	6	7	8	9	4	5	6	7	8	4	5	6	7	8	
..	..	..	..	..	..	..	..	..	..	..	6×3	7×4	7×4	7×4	8×4	8
6×3	7×4	7×4	7×4	7×4	8×4	6×3	7×4	7×4	7×4	8×4	7×4	7×4	7×4	8×4	9×4	9
7×4	7×4	7×4	8×4	8×4	9×4	7×4	7×4	8×4	8×4	9×4	7×4	7×4	8×4	9×4	9×4	10
7×4	7×4	8×4	8×4	9×5	9×4	7×4	8×4	8×4	9×4	8×5	8×4	8×4	9×4	8×5	8×5	11
8×4	8×4	9×4	9×4	8×5	8×5	8×4	9×4	9×4	8×5	10×5	8×4	9×4	8×5	10×5	10×5	12
8×4	9×4	9×4	8×5	10×5	10×5	9×4	9×4	8×5	10×5	10×5	9×4	8×5	10×5	10×5	10×5	13
9×4	9×4	10×5	10×5	10×5	10×5	9×4	10×5	10×5	10×5	12×5	8×5	10×5	10×5	12×5	12×5	14
9×4	10×5	10×5	10×5	12×5	12×5	10×5	10×5	10×5	12×5	12×5	10×5	10×5	12×5	12×5	15×5	15
10×5	10×5	10×5	12×5	12×5	15×5	10×5	10×5	12×5	12×5	15×5	10×5	12×5	12×5	15×5	15×5	16
10×5	10×5	12×5	12×5	15×5	15×5	10×5	12×5	12×5	15×5	15×5	12×5	12×5	15×5	15×5	15×5	17
10×5	12×5	12×5	15×5	15×5	15×5	12×5	12×5	15×5	15×5	15×5	12×5	15×5	15×5	15×5	15×5	18
12×5	12×5	15×5	15×5	15×5	15×5	12×5	15×5	15×5	15×5	15×5	12×5	15×5	15×5	15×5	14×6 @46	19
12×5	15×5	15×5	15×5	15×5	14×6 @46	12×5	15×5	15×5	15×5	14×6 @41	15×5	15×5	15×5	14×6 @46	14×6 @57	20
12×5	15×5	15×5	15×5	15×5	14×6 @57	15×5	15×5	15×5	14×6 @46	14×6 57	15×5	15×5	15×5	14×6 @57	15×6	21
15×5	15×5	15×5	14×6 @46	14×6 @57	15×6	15×5	15×5	14×6 @46	14×6 @57	15×6	15×5	15×5	14×6 @57	15×6	16×6	22
15×5	15×5	15×5	14×6 @57	15×6	16×6	15×5	15×5	14×6 @57	15×6	16×6	15×5	14×6 @57	15×6	16×6	18×7	23
15×5	15×5	14×6 @57	15×6	16×6	16×6	15×5	14×6 @57	15×6	16×6	18×7	14×6 @46	15×6	16×6	18×7	18×7	24
15×5	14×6 @57	15×6	16×6	18×7	18×7	15×5	15×6	16×6	18×7	18×7	14×6 @57	15×6	18×7	18×7	18×7	25

beams are given in inches.

TABLE LVII.

SIZES OF JOISTS FOR DIFFERENT WEIGHTS AND SPANS

Weight supported per sq. foot.		1 cwt. = 112 lbs.	1¼ cwt. = 140 lbs.	1½ cwt. = 168 lbs.	1¾ cwt. = 196 lbs.	2 cwts. = 224 lbs.
R. S. joists spaced apart in feet.		1	1	1	1	1
Clear span in feet.	Length of joists in feet.					
		(T. steel.)				
4	5	2″ × 2″ × ¼″	3″ × 1½″	3″ × 1½″	3″ × 1½″	3″ × 1½″
5	6	3″ × 1½″	3″ × 1½″	3″ × 1½″	3″ × 1½″	3″ × 1½″
6	7	3″ × 1½″	3″ × 1½″	3″ × 1½″	3″ × 1½″	3″ × 1½″
7	8	3″ × 1½″	3″ × 1½″	4″ × 1¾″	4″ × 1¾″	4″ × 1¾″
8	9	4″ × 1¾″	4″ × 1¾″	4″ × 1¾″	4″ × 1¾″	4″ × 1¾″
9	10	4″ × 1¾″	4″ × 1¾″			
10	11	4″ × 1¾″				

TABLE LVIII.

STRENGTH OF MILD STEEL ROLLED BEAMS.

Joists supported at both ends ; load dead, uniformly distributed ; weight of joist included.

Section.	Weights in lbs. per ft.	Thickness of web.	Moment of inertia.	Constants.	
				For load.	For deflection.
Inches.	Lbs.	Inches.	Quartic inch.		
24 × 7½	100	0·6	2,654	1,105·83	·078
20 × 7½	89	0·6	1,670	835·00	·0937
18 × 7	75	0·55	1,149	638·35	·104
16 × 6	62	0·55	725·7	453·55	·117
15 × 6	59	0·50	628·9	419·25	·125
15 × 5	42	0·42	428·0	285·30	·125
14 × 6	57	0·50	532·9	380·60	·133
14 × 6	46	0·40	440·5	314·60	·133
12 × 6	54	0·50	375·5	312·90	·156
12 × 6	44	0·40	315·3	262·75	·156
12 × 5	32	0·35	220·0	183·30	·156
10 × 8	70	0·60	344·9	344·9	·1875
10 × 6	42	0·40	211·5	211·5	·1875
10 × 5	30	0·36	145·6	145·6	·1875
9 × 7	58	0·55	229·5	255·0	·208
9 × 4	21	0·30	81·1	90·10	·208
8 × 6	35	0·44	110·5	138·12	·234
8 × 5	28	0·35	89·32	111·65	·234
8 × 4	18	0·28	55·69	69·60	·234
7 × 4	16	0·25	39·21	56·0	·268
6 × 5	25	0·41	43·61	72·65	·3125
6 × 4½	20	0·37	34·62	57·70	·3125
6 × 3	12	0·26	20·21	33·68	·3125
5 × 4½	18	0·29	22·69	45·38	·375
5 × 3	11	0·22	13·61	27·22	·375
4¾ × 1¾	6½	0·18	6·73	14·165	·395
4 × 3	9½	0·22	7·52	18·80	·469
4 × 1¾	5	0·17	3·668	9·17	·469
3 × 3	8½	0·20	3·787	12·62	·625
3 × 1½	4	0·16	1·659	5·53	·625

Note.—1. This table is calculated allowing for limit of stress of 7½ tons per square inch. If it is desired to change this limit of stress the constant for load and deflection must be altered proportionately.

2. Joists are tested with central loads and must show no permanent set after test. The loads are arranged so as to produce a limiting stress of 7½ tons per square inch. Samples cut from the joists are required to bear an ultimate stress of 27 to 32 tons per square inch with an elongation of 20 per cent. in a length of 8 inches.

3. Steel joists are now invariably supplied (by the Director General of Stores, India Store Department, London) because "open hearth" mild steel has practically supplanted wrought-iron for structural work.

4. In estimates of weight 2 per cent. should be added to allow for variations in rolling. The sections given are all stock sections.

To use the table.

(*i*) To find the load and corresponding deflection for a given section of joist with a given span—

(*a*) Divide the constant for load by the distance *in feet* from centre to centre of bearings ; the qoutient is the total safe distributed load in tons, including the weight of the joist.

(*b*) Multiply the constant for deflection by the square of the distance *in feet* from centre to centre of bearings and divide the result by 100; the quotient is the deflection in inches.

(*c*) If the actual load is less than the tabular load, as calculated above in (*a*), then the deflection will also be less in the same proportion.

(*ii*) To select a joist for a given external load (*i.e.*, load exclusive of the weight of joist) and a given span—

Multiply the load *in tons* by the distance *in feet* from centre to centre of bearings and take a section against which the constant for load is slightly higher. The weight of the joist should then be added to the external load and the section tried as in (*i*) for load and deflection.

TABLE LIX

I-BEAMS—THEIR STANDARD SIZES AMD PROPERTIES.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Reference No.	Size A × B.	Sectional area. *a*	Approximate Weight per foot.	Standard Thickness.		Radii.		Moments of Inertia.		Radii of Gyration.		Moduli of Section.	
				Web t_1	Flange t_2	Root r_1	Toe r_2	J_x	J_y	i_x	i_y	Z_x	Z_y
	Ins.	Ins.	Lb.	Inches		Inches		Inches		Inches		Inches	
BSB 101 ..	3 × 1½	1·18	4	·16	·249	·25	·12	1·66	·13	1·19	·33	1·11	·17
BSB 102 ..	3 × 3	2·52	8·5	·20	·332	·37	·18	3·81	1·25	1·23	·70	2·54	·83
BSB 103 ..	4 × 1¾	1·47	5	·17	·239	·27	·13	3·66	·19	1·58	·36	1·83	·21
BSB 104 ..	4 × 3	2·94	10	·24	·347	·37	·18	7·79	1·33	1·63	·67	3·89	·88
BSB 105 ..	4¾ × 1¾	1·91	6·5	·18	·325	·27	·13	6·73	·26	1·88	·37	2·83	·30
BSB 106 ..	5 × 3	3·26	11	·22	·376	·37	·18	13·68	1·45	2·05	·67	5·47	·97
BSB 107	5 × 4½	5·88	20	·29	·513	·49	·24	25·03	6·59	2·06	1·06	10·01	2·93
BSB 108	6 × 3	3·53	12	·23	·377	·37	·18	20·99	1·46	2·44	·64	7·00	·97
BSB 109	6 × 4½	5·89	20	·37	·431	·49	·24	34·71	5·40	2·43	·96	11·57	2·40
BSB 110	6 × 5	7·37	25	·41	·520	·53	·26	43·69	9·10	2·44	1·11	14·56	3·64
BSB 111	7 × 4	4·75	16	·25	·387	·45	·22	39·51	3·37	2·89	·84	11·29	1·69
BSB 112	8 × 4	5·30	18	·28	·398	·45	·22	55·63	3·51	3·24	·81	13·91	1·75
BSB 113	8 × 5	8·28	28	·35	·575	·53	·26	89·69	10·19	3·29	1·11	22·42	4·08
BSB 114 ..	8 × 6	10·30	35	·35	·648	·61	·30	115·06	19·54	3·34	1·38	28·76	6·51
BSB 115	9 × 4	6·18	21	·30	·457	·45	·22	81·13	4·15	3·62	·82	18·03	2·07
BSB 116 ..	9 × 7	14·71	50	·40	·825	·69	·34	208·13	40·17	·376	1·65	46·25	11·48

TABLE LIX—*contd.*

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Reference No.	Size A × B.	Sectional area.	Approximate Weight per foot.	Standard Thickness.		Radii.		Moments of Inertia.		Radii of Gyration.		Moduli of Section.	
				Web t	Flange t_2	Root r_1	Toe r_2	J_x	J_y	i_x	i_y	Z_x	Z_y
	Inches	Inches	Lb.	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches
BSB 117	10×4½	7·35	25	·30	·505	·49	·24	122·34	6·49	4·08	·94	24·47	2·88
BSB 118	10×5	8·85	30	·36	·552	·53	·26	146·23	9·73	4·06	·105	29·25	3·89
BSB 119	10×6	11·77	40	·36	·709	·61	·30	204·80	21·76	4·17	1·36	40·96	7·25
BSB 120	10×8	16·18	55	·40	·783	·77	·38	288·69	54·74	4·22	1·84	57·74	13·69
BSB 121	12×5	9·45	32	·35	·550	·53	·26	221·07	9·69	4·84	1·01	36·84	3·88
BSB 122	12×6	13·00	44	·40	·717	·61	·30	316·76	22·12	4·94	1·30	52·79	7·37
BSB 123	12×6	15·89	54	·50	·883	·61	·30	375·77	28·28	4·86	1·33	62·63	3·49
BSB 124	12×8	19·12	65	·43	·904	·77	·38	487·77	65·18	5·05	1·85	81·30	16·30
BSB 125	1×53	10·30	35	·35	·604	·53	·26	283·51	10·82	5·25	1·03	43·62	4·33
BSB 126	14×6	13·59	46	·40	·698	·61	·30	442·57	21·45	5·71	1·26	63·22	7·15
BSB 127	14×6	16·78	57	·50	·873	·61	·30	533·34	27·94	5·64	1·29	76·19	9·31
BSB 128	14×8	20·59	70	·46	·920	·77	·38	705·58	66·67	5·85	1·80	100·80	16·67
BSB 129	15×5	12·36	42	·42	·647	·53	·26	428·49	11·81	5·89	·98	57·13	4·72
BSB 130	15×6	13·24	45	·38	·655	·61	·30	491·91	19·87	6·10	1·23	65·59	6·62
BSB 131	16×6	14·71	50	·40	·726	·61	·30	618·09	22·47	6·48	1·24	77·26	7·49
BSB 132	16×6	18·21	62	·55	·847	·61	·30	725·05	27·14	6·31	1·22	90·63	9·05
BSB 133	16×8	22·06	75	·48	·938	·77	·38	973·91	68·30	6·64	1·76	121·74	17·08
BSB 134	18×6	16·18	55	·42	·757	·61	·30	841·76	23·64	7·21	1·21	93·53	7·88
BSB 135	18×7	22·09	75	·55	·928	·69	·34	151·18	46·56	7·22	1·45	127·91	13·30

TABLE LIX—*contd.*

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Reference No.	Size A × B	Sec-tional area.	Appro-ximate Weight per foot.	Standard Thickness.		Radii.		Moments of Inertia		Radii of Gyration.		Moduli of Section.	
				Web t_1	Flange t_2	Root t_1	Toe t_2	J_x	J_y	I_x	I_y	Z_x	Z_y
	Inches	Inches	Lb.	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches
BSB 136	18×8	23·53	80	·50	·950	·77	·38	1292·07	69·43	7·41	1·72	143·56	17·36
BSB 137	20×6½	19·12	65	·45	·820	·65	·32	1226·17	32·56	8·01	1·31	122·62	10·02
BSB 138	20×7½	26·19	89	·60	1·010	·73	·36	1672·85	62·54	7·99	1·55	167·29	16·68
BSB 139	22×7	22·06	75	·50	·834	·69	·34	1676·80	41·07	8·72	1·36	152·44	11·73
BSB 140	24×7½	27·94	95	·57	1·011	·73	·26	2533·04	62·54	9·52	1·50	211·09	16·68

Remarks.

1. The dimensions, thickness and profile of Standard Beams shall be in accordance with the accompanying list and sketch. The standard thickness of flanges shall be measured at distances half-way between the extreme edges of the flanges and the nearer side of the web.

2. Beams ordered to the standard thickness shall be practically accurate in profile; but if the thickness of the web is less or greater than these Standards, the width of the section will be decreased or increased by the same amount; otherwise the profile will remain constant.

3. Beams may be ordered by depth of section, width of flanges and thickness, or by depth of section, width of flanges and weight per foot, but not by both thickness and weight per foot. Where thickness is employed in ordering, decimals of an inch shall be used. The Institution suggests that all Beams be ordered by depth of section, width of flanges and weight per foot.

TAB

BRITISH STAN

Safe uniformly distributed exterior load

Section Reference Number.	Size Inches.	Weight lbs. per Foot.	3′	4′	5′	6′	7′	8′	9′
BSB 140	24″×7½″	95	351·70	263·69	211·48	175·66	150·49	131·60	116·89
BSB 139	22″×7″	75	253·97	190·42	152·28	126·84	108·64	94·91	84·39
BSB 138*	20″×7½″	89	278·18	209·04	166·80	138·76	119·02	104·08	92·41
BSB 137	20″×6½″	65	204·28	153·16	122·48	102·01	87·38	76·41	69·86
BSB 136	18″×8″	80	239·16	179·31	143·38	119·42	102·19	88·20	79·42
BSB 135*	18″×7″	75	212·56	159·37	127·43	106·13	90·94	79·48	70·62
BSB 134	18″×6″	55	155·81	116·81	93·41	77·80	66·64	58·26	51·74
BSB 133	16″×8″	75	202·80	152·04	121·57	101·25	86·73	75·82	67·56
BSB 132	16″×6″	62	150·97	113·18	90·49	75·36	64·54	56·42	50·10
BSB 131	16″×6″	50	128·70	96·48	77·15	64·24	55·31	48·11	42·72
BSB 130	15″×6″	45	109·26	81·84	65·99	54·54	46·71	40·84	36·26
BSB 129*	15″×5″	42	95·05	71·26	56·94	47·44	40·62	35·50	31·52
BSB 128	14″×8″	70	167·91	125·88	100·64	93·81	71·78	62·75	55·72
BSB 127*	14″×6″	57	126·90	95·14	76·06	63·34	54·20	47·38	42·07
BSB 126	14″×6″	46	104·79	78·57	62·82	52·32	43·81	39·18	34·79
BSB 125	13″×5″	35	72·65	54·46	43·55	36·25	31·05	27·14	24·10
BSB 124	12″×8″	65	135·41	101·50	81·15	67·40	57·87	50·48	44·91
BSB 123*	12″×6″	54	104·23	78·15	62·46	52·00	44·53	38·92	34·55
BSB 122*	12″×6″	44	86·54	65·62	52·45	43·68	37·41	32·68	29·01
BSB 121*	12″×5″	32	61·06	45·77	36·59	30·47	26·09	22·80	20·24
BSB 120	10″×8″	55	96·15	72·08	57·62	47·97	41·07	36·19	31·86
BSB 119	10″×6″	40	68·22	51·17	40·87	34·02	29·54	25·46	22·69
BSB 118	10″×5″	30	48·71	36·51	29·28	24·29	20·80	18·17	16·13
BSB 117	10″×4½″	25	40·75	30·54	24·41	20·32	17·40	15·20	13·49
BSB 116	9″×7″	50	77·01	57·72	46·24	38·41	32·88	28·78	25·49
BSB 115*	9″×4″	21	30·00	22·49	17·97	14·96	12·81	11·20	9·93
BSB 114	8″×6″	35	47·88	34·99	28·68	23·89	20·42	17·84	15·82
BSB 113*	8″×5″	28	37·33	27·98	22·36	18·61	15·92	13·91	12·35
BSB 112*	8″×4″	18	23·17	17·37	13·88	11·55	9·88	8·64	7·68
BSB 111*	7″×4″	16	18·80	14·08	11·25	9·37	8·01	7·00	6·21
BSB 110*	6″×5″	25	24·24	18·16	14·50	12·06	10·32	9·01	7·10
BSB 109*	6″×4½″	20	19·25	14·42	11·52	9·59	8·20	7·16	5·63
BSB 108	6″×3″	12	11·65	8·73	6·97	5·80	4·96	4·34	3·41
BSB 107	5″×4½″	20	16·65	12·47	9·96	8·29	6·75	5·14	4·08
BSB 106*	5″×3″	11	9·11	6·82	5·45	4·53	3·67	2·81	2·21
BSB 105*	4¾″×1¾″	6·5	4·71	3·57	2·82	2·34	1·81	1·38	1·09
BSB 104	4″×3″	10	6·46	4·84	3·87	2·58	2·05	1·58	1·24
BSB 103*	4″×1¾″	5	3·05	2·28	1·82	1·35	0·98	0·74	0·58
BSB 102	3″×3″	8·5	4·22	3·15	2·02	1·39	1·06	0·77	0·60
BSB 101	3″×1½″	4	1·85	1·38	0·89	0·60	0·44	0·33	0·25

LE LX.

DARD BEAMS.

in tons on beams with varying spans.

Spans in Feet (Effective).

10′	11′	12′	13′	14′	15′	16′	17′	18′	19′	20′
105·13	95·51	87·46	80·64	74·80	69·75	65·30	61·37	57·88	54·72	51·95
75·89	68·92	63·12	58·20	53·96	50·31	47·11	44·27	41·75	39·49	37·45
83·10	75·47	69·11	63·72	59·09	55·07	51·55	48·44	45·68	43·19	40·96
61·02	54·61	50·75	46·78	43·40	40·44	37·88	35·57	33·53	31·72	30·02
71·43	65·85	59·49	54·78	50·77	47·33	44·30	41·60	39·26	37·12	35·18
63·50	57·66	52·79	48·67	45·12	42·05	39·36	36·97	34·86	32·96	31·24
46·52	42·24	38·71	36·65	33·06	30·82	28·84	27·10	25·56	24·15	22·90
60·54	54·97	50·33	46·39	43·01	40·08	37·50	35·29	33·22	31·40	29·77
45·04	40·89	37·43	34·50	31·98	29·80	27·88	26·19	24·67	23·33	22·11
38·10	34·87	31·92	29·43	27·28	25·42	23·78	22·34	21·06	19·93	18·88
32·60	29·59	27·09	24·97	23·15	21·56	20·16	18·94	17·84	16·87	15·97
28·34	25·73	23·55	21·70	20·12	18·74	17·53	16·47	15·52	15·66	13·89
50·9	45·47	41·62	38·45	35·58	33·34	31·40	29·12	27·44	25·48	22·89
37·81	34·32	31·42	28·95	26·83	24·99	23·39	21·97	20·69	19·20	17·26
31·27	28·33	25·98	23·94	22·19	20·67	19·34	18·16	17·11	15·88	14·27
21·65	19·67	17·99	16·58	15·36	14·31	13·38	12·57	11·29	10·18	9·14
40·35	36·63	33·53	30·88	28·61	26·67	24·95	22·01	20·20	17·45	15·67
31·05	28·18	25·78	23·76	22·01	20·50	19·17	16·92	15·02	13·41	12·04
26·07	23·67	21·65	19·96	18·49	17·22	16·11	14·22	12·62	11·27	10·12
18·19	16·51	15·10	13·92	12·90	12·01	11·25	9·90	8·80	7·85	7·04
28·62	25·98	23·76	21·89	20·28	16·74	14·63	12·90	11·43	10·18	9·12
20·30	18·42	16·86	15·52	13·68	11·87	10·39	9·14	8·10	7·21	6·47
14·50	13·15	12·03	11·08	9·76	8·46	7·41	6·49	5·77	5·15	4·60
12·13	11·00	10·07	9·26	8·16	7·08	6·19	5·49	4·84	4·31	3·86
22·91	20·77	19·00	16·13	13·85	12·00	10·49	9·22	8·17	7·27	6·49
8·92	8·00	7·40	6·28	5·38	4·66	4·07	3·58	3·17	2·81	2·51
14·22	12·61	10·46	7·88	7·62	6·64	5·75	5·06	4·46	3·26	3·53
11·08	9·76	8·15	6·91	5·91	5·12	4·17	3·93	3·47	3·07	2·74
6·88	6·04	5·06	4·29	3·68	3·18	2·77	2·44	2·15	1·90	1·70
5·20	4·27	3·56	3·02	2·58	2·23	1·91	1·70	1·49	1·32	1·17
5·72	4·70	3·90	3·31	2·81	2·43	2·06	1·83	1·60	1·40	1·24
4·53	3·73	3·10	2·63	2·24	1·93	1·67	1·46	1·27	1·12	0·98
2·75	2·25	1·88	1·59	1·35	1·16	1·01	0·89	0·78	0·68	0·59
3·25	2·66	2·21	1·86	1·58	1·36	1·17	1·01	0·87	0·76	0·66
1·75	1·46	1·21	1·02	0·86	0·73	0·63	0·55	0·48	0·41	0·36
0·87	0·71	0·59	0·50	0·41	0·36	0·31	0·26	0·22	0·19	0·17
1·00	0·81	0·67	0·55	0·46	0·39	0·33	0·28	0·24	0·21	0·17
0·47	0·38	0·31	0·26	0·21	0·18	0·15	0·13	0·11	0·09	0·07
0·47	0·38	0·30	0·25	0·20	0·16	0·14	0·11	0·09	0·07	0·04
0·20	0·16	0·13	0·11	0·09	0·07	0·06	0·05	0·04	0·03	0·02

TAB

BRITISH STAN

Safe uniformly distributed exterior load

Section Reference Number.	Size Inches.	Weight lbs. per Foot.	Spans in feet (effective).						
			21′	22′	23′	24′	25′	26′	27′
BSB 140	24″ × 7½″	95	49·35	47·07	44·89	42·96	41·11	39·40	37·95
BSB 139	22″ × 7″	75	35·89	33·96	32·37	30·92	29·65	28·44	27·33
BSB 138*	20″ × 7½″	89	38·03	37·08	35·39	33·84	32·41	31·08	29·48
BSB 137	20″ × 6½″	65	28·51	27·25	26·00	24·84	23·81	22·79	21·62
BSB 136	18″ × 8″	80	33·41	31·86	30·38	28·66	25·66	24·47	22·67
BSB 135*	18″ × 7″	75	29·69	28·28	26·98	25·79	23·68	21·79	20·12
BSB 134	18″ × 6″	55	21·76	20·73	19·78	18·90	17·35	15·97	14·73
BSB 133	16″ × 8″	75	28·29	26·10	23·78	21·74	19·91	18·34	16·91
BSB 132	16″ × 6″	62	21·00	19·39	17·69	16·32	14·84	13·63	12·56
BSB 131	16″ × 6″	50	17·92	16·51	15·06	13·77	12·63	11·61	10·70
BSB 130	15″ × 6″	45	14·45	13·13	11·96	10·91	9·99	9·18	8·46
BSB 129*	15″ × 5″	42	12·55	11·38	10·36	9·45	8·67	7·96	7·33
BSB 128	14″ × 8″	70	20·65	18·76	17·07	15·56	14·28	13·53	12·07
BSB 127*	14″ × 6″	57	15·58	14·12	12·85	11·73	10·73	9·86	9·06
BSB 126·	14″ × 6″	46	12·89	11·68	10·33	9·70	8·88	8·15	7·50
BSB 125	13″ × 5″	35	8·24	7·46	6·79	6·19	5·67	5·17	4·77
BSB 124	12″ × 8″	65	14·13	12·82	11·63	10·58	9·70	8·87	8·14
BSB 123*	12″ × 6″	54	10·84	9·81	8·90	8·11	7·41	6·79	6·21
BSB 122*	12″ × 6″	44	9·12	8·25	7·49	6·83	6·23	5·71	5·24
BSB 121*	12″ × 5″	32	6·35	5·74	5·21	4·74	4·33	3·95	3·65
BSB 120	10″ × 8″	55	8·20	7·40	6·72	6·10	5·57	5·05	4·61
BSB 119	10″ × 6″	40	5·82	5·24	4·74	4·32	3·93	3·58	3·26
BSB 118	10″ × 5″	30	4·14	3·74	3·38	3·07	2·79	2·53	2·32
BSB 117	10″ × 4½″	25	3·46	3·12	2·82	2·56	2·33	2·12	1·93
BSB 116	9″ × 7″	50	5·81	5·24	4·72	4·27	3·89	3·53	3·21
BSB 115*	9″ × 4″	21	2·25	2·02	1·82	1·65	1·49	1·34	1·22
BSB 114	8″ × 6″	35	3·15	2·82	2·54	2·29	2·08	1·86	1·68
BSB 113*	8″ × 5″	28	2·45	2·20	1·98	1·78	1·59	1·44	1·30
BSB 112*	8″ × 4″	18	1·51	1·35	1·22	1·09	0·98	0·89	0·80
BSB 111*	7″ × 4″	16	1·04	0·93	0·83	0·74	0·66	0·60	0·53
BSB 110*	6″ × 5″	25	1·08	0·95	0·84	0·74	0·65	0·57	0·50
BSB 109*	6″ × 4½″	20	0·86	0·76	0·67	0·59	0·52	0·45	0·39
BSB 108	6″ × 3″	12	0·53	0·46	0·41	0·37	0·32	0·27	0·23
BSB 107	5″ × 4½″	20	0·57	0·49	0·43	0·37	0·31	0·26	0·22
BSB 106*	5″ × 3″	11	0·31	0·27	0·24	0·21	0·18	0·14	0·12
BSB 105*	4¾″ × 1¾″	6·5	0·14	0·12	0·10	0·08	0·07	0·06	0·05
BSB 104	4″ × 3″	10	0·15	0·12	0·10	0·07	0·06	0·03	..
BSB 103*	4″ × 1¾″	5	0·06	0·05	0·04	0·03	0·02	..	..
BSB 102	3″ × 3″	8·5	0·03	0·02	..	..	..	..	..
BSB 101	3″ × 1½″	4	..	..	..	..	..	..	..

Note.—(1) *Safe loads.*—(*i*) The safe loads given in the table are exclusive of the weights of the girders.
(*ii*) The figures to the left of the zig-zag line represent the safe loads according to the strength formula for a beam supported at both ends and uniformly loaded, *viz.*—

W (in tons) = 8 × Resistance about xx × Working stress (7½ tons per square inch) ÷ Span (in inches).

$$= \frac{5 \times \text{Resistance about xx.}}{\text{Span in feet.}}$$

LE LX—*contd.*

DARD BEAMS.

in tons on beams with varying spans.

Spans in Feet (Effective).

28′	29′	30′	32′	34′	36′	38′	40′	42′	44′	46′
36·50	35·17	33·91	31·62	27·77	24·53	21·78	19·41	17·37	15·58	14·01
26·28	25·33	24·84	20·76	18·24	16·04	14·21	12·63	11·27	9·08	9·03
27·29	25·33	23·55	20·47	17·95	15·75	13·94	12·32	10·93	9·85	8·77
20·04	18·60	17·30	15·07	13·15	11·66	10·22	9·06	8·05	7·16	6·39
21·00	19·46	18·07	15·68	13·69	12·01	10·47	9·34	8·26	7·33	6·50
18·61	17·25	16·63	13·92	12·16	10·74	9·43	8·22	7·29	6·48	5·71
13·63	12·64	11·73	101·9	8·88	7·78	6·74	6·03	5·33	4·72	4·17
15·62	14·46	13·43	11·61	10·09	8·81	7·73	6·78	5·95	5·24	4·60
11·60	10·73	9·94	8·58	7·45	6·49	5·67	4·95	4·33	3·78	3·31
9·88	9·15	8·49	7·34	6·37	5·56	4·87	4·26	3·74	3·27	2·87
7·81	7·22	6·68	5·77	4·99	4·34	3·78	3·30	2·88	2·51	2·18
6·76	6·24	5·78	4·97	4·31	3·76	3·24	2·88	2·45	2·12	1·84
11·12	10·29	9·51	8·18	7·08	6·12	5·33	4·63	4·02	3·49	3·01
8·36	7·72	7·15	6·13	5·28	4·62	3·06	3·53	2·98	2·56	2·18
6·92	6·40	5·92	5·08	4·38	3·86	3·28	2·85	2·48	2·14	1·83
4·38	4·04	3·73	3·19	2·74	2·36	2·02	1·73	1·48	1·26	1·07
7·49	6·89	6·36	5·42	4·63	3·97	3·38	2·90	2·47	2·08	1·69
5·72	5·25	4·84	4·11	3·50	3·60	2·56	2·17	1·83	1·54	1·26
4·80	4·43	4·08	3·47	2·97	2·54	2·16	1·85	1·55	1·32	1·09
3·23	3·07	2·82	2·40	2·05	1·74	1·49	1·26	1·07	0·90	0·73
4·22	3·86	3·54	2·97	2·56	2·09	1·74	1·41	1·15	0·91	0·69
2·98	2·73	2·46	2·09	1·75	1·47	1·21	1·00	0·80	0·62	0·47
2·11	1·97	1·76	1·47	1·23	1·02	0·84	0·68	0·55	0·42	0·31
1·77	1·62	1·47	1·25	1·03	0·86	0·71	0·57	0·45	0·35	0·26
2·91	2·65	2·41	2·00	1·64	1·34	1·07	0·84	0·63	0·45	0·38
1·11	1·00	0·91	0·74	0·60	0·48	0·38	0·29	0·22	0·16	0·10
1·52	1·37	1·23	1·00	0·80	0·62	0·46	0·33	0·21	0·10	..
1·17	1·06	0·95	0·77	0·61	0·47	0·36	0·25	0·16	0·07	..
0·73	0·[illegible]	0·59	0·46	0·37	0·28	0·26	0·13	0·07	..	..
0·47	0·42	0·37	0·28	0·21	0·15	0·10	0·04	..	..	.
0·43	0·38	0·32	0·21	0·12	0·05	..	..	..	..	..
0·34	0·29	0·24	0·16	0·10	0·04	..	..	..	.	..
0·20	0·17	0·15	0·10	0·06	0·03	..	..	..	..	..
0·18	0·14	0·10	0·04	..	..	..	..	..	..	..
0·10	0·08	0·05	0·0[illegible]	..	..	..	..	..	..	..
0·03	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..
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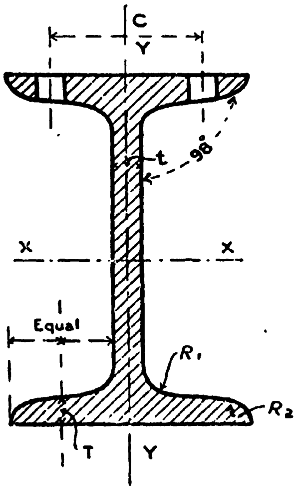


(*iii*) The figures to the right of the zig-zag line represent the safe loads with deflection limited to $\frac{1}{480}$ × Span, for which the formula is :—

$$\text{Deflection} = \frac{1}{480} \times \text{Span (in inches)} = \frac{5}{384} \times \frac{\text{W (in tons)} \times \text{Span (in inches)}}{\text{Modulus of elasticity (12,000 tons)} \times \text{Moment of inertia about xx}}$$

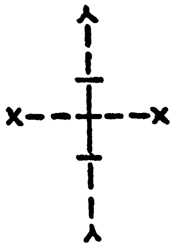
$$\text{or W (in tons)} = \frac{40}{3} \times \frac{\text{Moment of inertia about xx}}{\text{Span in feet}^2}.$$

Note (2) :—The sections marked with an asterisk are almost identical with old sections.

TABLE LXI.

I-BEAMS AS STANCHIONS.

Safe loads in tons. Ends fixed. (Factor of safety 4).



Size inches.	Area square inches.	Weight per foot lbs.	Radii of gyration in inches.		Safe load in tons for									
					Lengths in feet.									
			About XX.	About YY.	6	8	10	12	14	16	18	20	22	24
24×17½	29·40	100	9·5	1·5	164	154	143	130	115	100	87	76	...	...
20×17½	26·17	89	7·99	1·54	146	138	129	118	105	92	80	70	...	...
10×8	20·6	70	4·09	1·86	118	113	108	101	94	86	78	70	62	56
18×7	22·06	75	7·21	1·46	122	115	106	96	84	73	63	...	...	...
9×7	17·06	58	3·66	1·64	96	92	86	79	72	64	56	50	...	...
16×6	18·23	62	6·31	1·21	98	89	79	67	57	48	...	...	...	...
15×6	17·35	59	6·02	1·27	94	8[illegible]	77	67	57	48	...	...	...	...
14×6	16·76	57	5·63	1·29	91	84	76	66	56	48	...	...	...	...
12×6	15·88	54	4·86	1·33	87	8[illegible]	73	64	55	47	...	...	...	...
14×6	13·53	46	5·70	1·26	73	6[illegible]	60	52	44	37	...	...	...	...
12×6	12·94	44	4·93	1·31	70	65	59	51	44	38	...	...	...	...
10×6	12·35	42	4·13	1·36	68	63	57	51	44	38	32	...	...	...
8×6	10·29	35	3·27	1·32	56	52	47	41	35	30	...	...	...	...
15×5	12·35	42	5·88	0·978	62	54	44	36	...	...	...	...	...	...
12×5	11·47	39	4·77	1·03	59	52	43	35	...	...	...	...	...	...
10×5	10·29	35	4·03	1·07	53	47	40	33	27	...	...	...	...	...
12×5	9·41	32	4·83	1·01	48	42	35	28	...	...	...	...	...	...
10×5	8·82	30	4·06	1·05	45	40	34	28	23	...	...	...	...	...
8×5	8·24	28	3 29	1·11	43	39	33	28	23	...	...	...	...	...
6×5	7·35	25	2·43	1·11	38	34	30	25	20	...	...	...	...	...
6×4½	5·88	20	2·42	0·959	29	25	21	17	...	...	...	...	...	...
5×4½	5·29	18	2·0[illegible]	1·03	27	24	20	16	...	...	...	...	...	...
9×4	6·176	21	3·6[illegible]	0·824	29	23	18	...	...	...	...	...	...	...
8×4	5·294	18	3·24	0·822	25	20	15	...	...	...	...	...	...	...
7×4	4·706	16	2·88	0·851	22	18	14	...	...	...	...	...	...	...

Note.—In the case of one end fixed, and the other rounded, the allowable load is found by referring in the table to a length of 1⅓ times the actual length; whilst with both ends rounded the reference length should be 1⅔ times the actual length.

Example.—For a stanchion or strut 9 feet long, with one end fixed and the other rounded, reference should be made in the table of safe loads to a length of 12 feet; or if both ends are rounded, to a length of 15 feet, when the respective safe loads will be found.

TABLE LXII.

SAFE LOADS ON NEW BRITISH STANDARD HEAVY BEAMS AS STANCHIONS.

Reference number.	Size.	Approximate weight per foot.	Sectional area.	Least radius of gyration.	Safe load in tons. Length. 6′	7′	8′	9′
	Inches.	Lb.	Sq. in.	Inches.				
N. B. S. H. B. 11	18×8	80	23·526	1·718	137·2	132·0	126·9	121·8
,, 10	16×8	75	22·063	1·759	129·3	124·6	119·9	115·2
,, 9	14×8	70	20·589	1·800	121·3	117·0	112·7	108·4
,, 8	12×8	65	19·122	1·846	113·2	109·3	105·5	101·6
,, 7	10×8	55	16·177	1·840	95·7	92·4	89·1	85·8
,, 6	10×6	40	11·771	1·360	64·6	61·3	58·1	54·8
,, 5	9×7	50	14·712	1·652	85·0	81·7	78·3	75·0
,, 4	8×6	35	10·296	1·378	56·7	53·9	51·1	48·3
,, 3	6×5	25	7·351	1·159	38·2	35·8	33·4	31·1
,, 2	5×4½	20	5·882	1·058	29·5	27·4	25·3	23·2
,, 1	4×3	10	2·940	·672	11·1	9·5	7·8	..

Reference number.	Safe load in tons. Length. 10′	11′	12′	13′	14′	15′	16′	18′	20′
N. B. S. H. B. 11	116·6	111·5	106·4	101·2	96·1	91·0	85·8	75·6	65·3
,, 10	110·5	105·8	101·1	96·4	91·7	87·0	82·3	72·9	63·5
,, 9	104·1	99·8	95·5	91·3	87·0	82·7	78·4	69·8	61·2
,, 8	97·7	93·8	89·9	86·0	82·2	78·3	74·4	66·6	58·8
,, 7	82·5	79·2	75·9	72·6	69·3	66·0	62·7	56·2	49·6
,, 6	51·6	48·3	45·1	41·8	38·6	35·3	32·1	..	..
,, 5	71·6	68·3	65·0	61·6	58·3	54·9	51·6	44·9	38·2
,, 4	45·5	42·7	39·0	37·1	34·3	31·5	28·7	..	..
,, 3	28·7	26·3	23·9	21·6	19·2	..	..	..	..
,, 2	21·1	19·0	16·9	14·9	..	..	..	..	..
,, 1									

Note.—1. Formula.—$p = 16{,}000 - 70\frac{l}{r}$ with a maximum of 14,000 lb.

Where.—p = Safe permissible stress per square inch.
l = Length of member in inches, and
r = Least radius of gyration in inches.

2.—No compression member shall have a length exceeding 120 times its least radius of gyration.

To the right of zigzag line the values of $\frac{l}{r}$ exceed 120.

TABLE

BROAD FLANGE BEAMS,

SAFE LOADS AS STANCHIONS. Safe loads in tons on stanchions for heights of 8 to 32 feet. (L. C. C. formula. Ends fixed.)										SECTION.	
8′	10′	12′	14′	16′	18′	20′	24′	28′	32′	Approximate size. Ins.	Weight per foot. Lbs.
33	30	27	24	21	18	13	..	..	..	5½ × 5½	24
36	33	30	27	24	21	18	..	..	..	6 × 6	25
45	42	38	35	32	28	25	14	..	..	6¼ × 6¼	31
49	45	42	39	35	32	28	19	..	..	6¾ × 6¾	33
53	49	46	42	39	35	32	25	11	..	7 × 7	35
56	53	49	46	43	39	36	29	17	..	7½ × 7½	37
68	64	60	56	53	49	45	37	27	12	8 × 8	44
72	68	64	61	57	53	49	41	34	18	8¼ × 8¼	46
76	73	69	65	61	57	53	46	38	25	8½ × 8½	48
81	77	73	69	65	61	58	50	42	32	9 × 9	51
95	91	86	82	78	73	69	60	52	43	9½ × 9½	59
100	95	91	87	82	78	74	65	56	48	10 × 10	61
104	100	96	91	87	83	78	70	61	53	10¼ × 10¼	64
109	105	100	96	92	87	83	75	66	57	10½ × 10½	66
126	121	116	111	107	102	97	88	78	69	11 × 11	76
131	126	121	117	112	107	102	93	83	74	11½ × 11½	79
136	131	127	122	117	112	108	98	89	79	12 × 12	82
151	146	141	135	130	125	119	109	98	87	12½ × 12½	91
153	148	143	137	132	126	121	110	99	88	13½ × 12	92
169	163	157	151	145	139	133	121	109	97	14 × 12	101
171	165	159	153	147	140	134	122	110	97	15 × 12	103
184	177	171	164	157	151	144	131	118	105	16 × 12	110
187	180	173	166	160	153	146	133	119	106	17 × 12	112
204	196	189	182	174	167	159	145	130	115	18 × 12	122
207	199	192	184	176	169	161	146	131	116	19 × 12	124
224	216	208	199	191	183	175	158	141	125	20 × 12	135
231	222	213	205	196	187	178	161	144	126	22 × 12	139
252	243	233	223	214	204	194	175	156	136	24 × 12	153
259	249	239	229	219	209	199	179	158	138	26 × 12	157
282	271	260	249	237	226	215	193	171	149	28 × 12	171
289	278	266	254	243	231	220	196	173	150	30 × 12	176
296	284	272	260	248	236	224	200	176	152	32 × 12	181
321	308	295	282	268	255	242	215	189	163	34 × 12	196
329	315	301	287	274	260	246	218	191	163	36 × 12	201
336	322	308	293	279	265	250	222	193	165	38 × 12	206
344	329	314	299	284	270	255	225	196	166	40 × 12	211

Note.—Broad flange beams are rolled steel sections with wide flanges, and are specially designed in the smaller employed, and are cheaper and more reliable in every respect. The larger section take the place of riveted girders,

LXIII

(GREY PROCESS.) AS GIRDERS AND STANCHIONS.

SAFE LOADS AS GIRDERS

Safe distributed loads in tons for spans of 8 to 64 feet.

8′	10′	12′	14′	16′	18′	20′	24′	28′	32′	36′	40′	44′	48′	56′	64′
8	7	5	5	4	..	..	..	..	..	..	..	..	..	..	..
10	8	6	5	5	..	..	..	..	..	..	..	..	..	..	..
12	10	8	7	6	6	..	..	..	..	..	..	..	..	..	..
14	11	9	8	7	6	..	..	..	..	..					
16	13	11	9	8	7	6	..	..	..	..					
18	14	12	10	9	8	7	..	..	..	..					
22	18	15	13	11	10	9	..	..	..	..	..	..	..	..	..
25	20	17	14	12	11	10	8	..	..	..	..	..	..	..	..
..	22	18	16	14	12	11	9	..	..	..	..	..	..	..	..
..	24	20	17	15	13	12	10	..	..	..	..	..	..	..	..
..	29	25	21	18	16	15	12	..	..	..	..	..	..	..	..
..	32	27	23	20	18	16	13	11	..	..	..	..	..	..	..
..	35	29	25	22	19	17	14	12	..	..	..	..	..	..	..
	..	32	27	24	21	19	16	13	12	..	..	..	..	..	..
	..	37	32	28	25	22	19	16	14	..	..	..	..	..	..
..	..	40	35	30	27	24	20	17	15	13	..	..	..	..	..
..	..	43	37	32	29	26	22	18	16	14	..	..	..	..	..
..	..	51	44	38	34	31	25	22	19	17	15	..	..	..	..
..	..	..	47	41	37	33	27	23	20	18	16	15	..	..	..
..	..	..	54	48	42	38	32	27	24	21	19	17	..	..	..
..	..	..	58	51	45	41	35	29	24	22	20	18	17	..	..
..	..	..	66	58	51	46	38	33	29	25	23	21	19	..	..
..	..	..	71	62	55	50	41	35	31	27	25	22	21	18	..
..	..	..	81	71	63	57	47	41	35	31	28	26	24	20	..
..	..	..	87	76	68	61	51	43	38	34	30	28	25	22	19
..	..	..	98	86	76	69	57	49	43	38	34	31	29	24	21
..	..	..	..	97	86	78	65	55	48	43	39	35	32	28	24
..	..	..	..	115	102	92	76	65	57	51	46	42	38	33	28
..	..	..	..	127	113	102	85	72	63	56	51	46	42	36	32
..	..	..	..	147	131	118	98	84	73	65	59	53	49	42	37
..	..	..	..	161	143	129	107	92	80	71	64	58	53	46	40
..	..	..	..	175	155	140	116	100	87	77	70	63	58	50	43
..	..	..	..	199	177	159	133	114	99	88	79	72	66	57	50
..	..	..	..	..	191	172	143	123	107	95	86	78	71	61	53
..	..	..	..	..	204	184	153	131	115	102	92	83	76	65	57
..	..	..	..	..	219	197	164	141	123	109	98	89	82	70	61

Figures on the right hand side of the zigzag line produce a deflection greater than span ÷ 360.

section up to 12″ × 12″, to be used as columns. They can be substituted wherever cast iron columns are usually with a big saving in the weight of steel involved, and the avoidance of expensive labour charges.

MURAM FLOOR.

Specification No. 84.

1. All filling upto one foot below the proposed floor level shall be dug out, and the foot deep hollow thus created shall be treated in the following manner.

2. Six inches of good hard muram shall be laid to a template evenly and watered thoroughly for two days. When the whole thing has become slushy, chopped dry grass must be spread on the surface, and trampled on by coolies, so as to thoroughly incorporate it in the body of the muram. Then the surface should be farily levelled, and beaten with hand rammers, to one uniform level. It should then be allowed to dry for 2 or 3 days.

3. Then another layer of good hard muram, 3-inch thick, should be added, and treated exactly like the first layer. After this has also dried, the uppermost layer of 3 inches in thickness should be added and similarly treated. After this layer has dried, a thin layer of very good muram and chopped dry grass shall be sprinkle and watered thoroughly, and beaten with hand rammers. The surface should be allowed to dry. Cracking will now be seen to have much diminished.

Finally sprinkle a very fine layer of muram dust, mixed with some finely chopped straw, water, and thoroughly beat with hand rammers. The surface will not now crack on drying and the floor is complete.

PAVED FLOOR.

Specification No. 85.

1. **Filling.**—The *muram* filling to be levelled, watered and well rammed until it is completely consolidated. For inner floors the excavations will be perfectly level, but in all verandahs it will be executed so as to ensure an outward slope of 1 in 40 to the surface of the flooring when completed. For inner floors, the filling shall have a slope of 1 in 40 either towards outer walls, or towards a door or a sink, to facilitate washing of the pavement. For a verandah the same slope shall be given from the wall to the outside edges of the verandah.

2. **Concrete.**—A concrete substratum to be laid 4½ to 6 inches thick as specified and thoroughly ramed. Concrete to be as in specification No. 25.

3. **Slabs.**—All stone slabs to be of approved quality—hard, even, sound, durable and of uniform thickness.

They shall be as far as possible of specified sizes, 3 to 4 inches in thickness for blue basalt, 2½ inches for Porbandar stone, and 1 inch to 1½ inches for Shahabad or Tandur stone.

4. **Dressing.**—The stones to be very finely flat, chisel-dressed on the surface, without windings, and the courses to be of uniform width, the joints running true and parallel from side to side.

5. **Joints and laying.**——The stones to be laid with joints not exceeding ¼ inch thick and to be evenly and firmly bedded flush in mortar on the concrete, and no hollows left. Courses to be parallel and at right angles to the wall, and the stone to break joint at least 6 inches.

Sides to be dressed true and square for at least half the depth from the face, and on no account shall the edges be wedge-shaped. The joints shall be set in Portland cement for 1 inch in from face.

6. **Diamond-cut pavement.**—For diamond-cut pavement all stones to be of regular and equal size laid in courses at an angle of 45° with the wall. The length of the side of the diamond-cut stones, shall not be less than 12 inches, unless specially ordered by the Executive Engineer.

7. Unless otherwise mentioned, the rate for all paving shall include the cost of laying of a 4½″ to 6″ thick base of concrete, as may be specified.

8. All paving when handed over is to be perfectly clean and free from all mortar stains, etc.

9. In all pavements in bridge floors or causeways or other situations where water will flow over the pavement, the joints in the pavement shall run diagonally to the direction of flow of water.

10. All trap stone used for pavements, shall, unless otherwise ordered, be of the kind known as "khar" or boulder stone.

For Rate Abstract see p. 363.

PAVING, SECOND SORT.

Specification No. 86.

As above, but not quite so finely dressed; joints to be upto 5/16 inch thick and dressed true for the top 1 inch.

For Rate Abstract see p. 363.

Note.—Suitable for barracks.

PAVING, THIRD SORT.

Specification No. 87.

As above, but only rough point chisel-dressed, with ⅜ inch joints and true for ½ inch from top. Size of stones to be not less than 12″ × 6″. Concrete 3 inches thick consolidated to form the bed.

For Rate Abstract see p. 364.

PAVING, FOURTH SORT.

Specification No. 88.

As above, but irregular shaped and sized stones roughly dressed with point chisel, joints upto ⅜ inch, true for top ½ inch, concrete 3 inches thick consolidated for bedding.

Note.—The last two sorts are only suited for minor buildings, such as cook-houses, *dharmashalas*, etc.

For Rate Abstract see p. 364.

TANDUR, SHAHBAD FLAGSTONE PAVING.

(1) **Filling.**—The sand, muram, chárá or earth filling as specified, shall be laid in 6″ layers, which shall be well watered and consolidated by ramming. The top-most layer which will be next to the concrete, shall be laid to a slope of 1 in 40. This slope being towards outer walls, or doors, or sinks, so as to facilate washing of room floors. In a verandah the slopes hall be from the building wall to the plinth edge.

(2) **Concrete bed.**—A lime or cement concrete bed of approved proportions of ingredients, shall be laid to the slope of 1 in 40, over the consolidated filling. The thickness of this bed shall be as specified, and the concrete shall be thoroughly consolidated. It shall be kept wet, and allowed to harden for seven days, before laying the pavement.

(3) **Pavement flags.**—Shall be normally 1″ to 1½″ in thickness, of approved quality, and size not less than 12″ in either length or breadth. The top shall be smooth.

(4) **Dressing.**—For side joints, the flags will be dressed square for at least half the thickness of the stone, and the thickness of the joint shall not exceed ⅜″.

(5) **Laying.**—The slabs will be evenly and firmly bedded to the required slope in lime or cement mortar of the specified proportions. The side joints shall be filled with 1 : 2 or 1 : 3 cement mortar as specified and finished smooth or slightly sunk pattern.

(6) **Joints.**—The slabs (except in diamond pattern paving) shall be laid so as to give continuous parallel long joints, with cross joints at right angles to them. The slabs in adjoining lines shall break joint at least 6″.

(7) **Maturing.**—The pavement shall be kept well covered with damp sand or water, for a week.

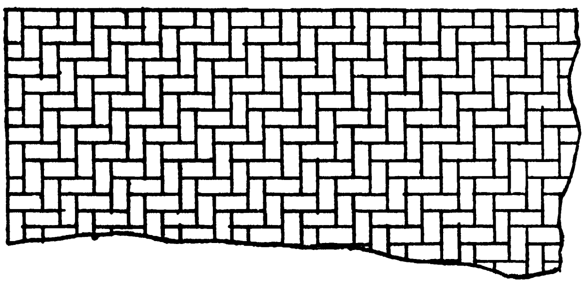
BRICK OR TILED FLOOR.

Specification No. 89.

1. **Brick-on-edge flooring.**—The filling to be excavated to the depth necessary, carefully levelled and well rammed. On the bed thus prepared spread a layer of 3 inches of sand on which a course of brick-in-mortar to be laid flat. The brick-on-edge to be then laid very carefully, either in parallel rows breaking bond, or in herring bone bond. Alternatively 6 inches of brick concrete, of proportions to be specified by the Executive Engineer, to be laid over the earthen bed and well rammed. Over this, the brick-on-edge floor shall be laid as before.

BOND OF BRICK-ON EDGE MASONRY IN PAVEMENT.

BOND OF BRICK-ON-EDGE MASONRY IN PAVEMENT.



(2) The bricks for the top on floor course shall be selected well-burnt bricks, of good colour and shape with rubbed joints. They shall be thoroughly wetted before being laid.

(3) The mortar shall be of the specified proportions of cementing material, surkhi and sand, and the paving joints shall not be more than ⅜″ in thickness.

(4) After the bricks have been laid, mortar should be scraped out from the joints to a depth of ¾ inch, cement grouted and then cement pointed. After pointing, the whole surface should be kept watered for three weeks.

For Rate Abstract see p. 365.

TILE OR SQUARE BRICK FLOORING.

Specification No. 90.

1. The bed to be excavated and prepared as above and a 6″ layer of lime or cement brick concrete to be laid and well rammed. Over this, paving tiles or bricks sound, well shaped and thoroughly burnt, to be laid in mortar, so as to break joint. Care to be taken in all cases that a perfectly even smooth floor is obtained.

2. The joints to be rubbed and the hardest and best bricks to be selected to be thoroughly wetted, and set flat in lime or cement mortar.

As regards other points the work shall be carried out as in the specification above.

For Rate Abstract see p. 365.

CHUNAM OR TERRACED FLOOR.

Specification No. 91.

1. **Filling.**—The *muram* filling to be levelled, watered and well rammed before the concrete is put in.

2. **Concrete.**—A layer of lime concrete, of the proportions to be specified by the Executive Engineer to be laid and well rammed with wooden or iron beaters: three coolies at least per day to be employed per square of 100 square feet.

3. When the consolidation of the concrete has been satisfactorily completed a layer of plaster, of proportions specified by the Executive Engineer, to be laid evenly over the surface, and well beaten down with flat beaters for three days, three coolies per day per square being employed.

4. A thin coat of every fine plaster to be floated over the surface, well rubbed in, and polished with soap-stone till perfectly smooth and hard. Care to be taken to keep the surface moist by covering it with damp straw, until the whole is completed and fit for exposure.

For Rate Abstract see p. 366.

CEMENT CONCRETE FLOORING.

Specification No. 92.

1. To be laid as specified under chunam or terraced floors above, the proportions of ingredients being eight parts of broken stone, three parts of river sand, and one part of Portland cement.

2. The fine aggregate and the coarse aggregate shall be perfectly clean, and of the type specified. The fine aggregate, and the coarse aggregate shall be thoroughly wetted and the surplus water allowed to drain out. The fine aggregate and cement in the specified proportion shall be worked together with just sufficient water to make stiff mortar. The coarse aggregate shall then be added, and the mixture turned over till a thoroughly mix is obtained.

3. The mixed concrete shall be laid immediately after preparation, and no concrete which has been allowed to stand till the cement has begun setting shall be used, without the special premissicr of the Executive Engineer, and then only if, not more than an hour has elapsed since the mixing, the concrete has been kept shaded and damp, and is turned over thoroughly again before laying.

4. The surface to be rendered with a thin coat of 1 : 1 cement mortar uniformly floated on, and kept watered for 10 days.

Note.—In rendering the cement concrete with cement mortar, the rendering should be carried out, after the concrete has been thoroughly rammed and has dried *sufficiently* to allow the rendering to be worked up. The surface should be sprinkled with dry cement mortar and this should be added to gradually during the process of rendering, which cannot be completed properly until the concrete has dried *somewhat*. If the rendering is carried out until the concrete has set and thoroughly dried, there can be no intimate union between the concrete and the rendering, and the latter will remain brittle and liable to damage. When the rendering has set sufficiently, the whole surface should be kept flooded with water for 10 days.

Cement rendering on lime mortar concrete requires to be made thicker than one on cement concrete.

(2) Except where concrete is required in very small quantities, machine-mixing should always be specified, as this method besides being economical, gives a more thorough incorporation of material and the output being much faster, work is speeded up.

CONCRETE FLOORS OF MADRAS TYPE.

TYPE, A.

Specification No. 93.

The wearing surface consists of ¾ inch to 1½ inches of cement concrete laid on 4″ or 5″ lime concrete, the surface being rubbed smooth.

1. Special care must be taken that the filling under the lime concrete is wetted and thoroughly consolidated, or the whole floor will be liable to crack.

2. The cement concrete must be laid before the lime concrete has set, and the surface of the lime concrete must be thoroughly clean and be moistened before laying the cement concrete.

3. The cement concrete should consist of hard stone aggregate graded from ⅛″ to ½″, and mixed with cement in the proportion of 2½ or 3 to 1.

4. As large unbroken areas of cement concrete are liable to crack, it is advisable to divide the floor, either into strips or into squares or rectangles; the width of each strip and the sides of squares and rectangles should be not longer than 8 feet.

5. The edge of each section into which the floor is divided should be defined by flat bars of steel or wood, with depths the same as that proposed for the finished floor; they should be whitewashed, in order to prevent adherence of concrete. Adjoining sections of the floor should be completed on different days.

6. The cement concrete, which should not be too dry, must be used immediately it has been mixed, and spread evenly, using a straight edge, and be at once well beaten with 5 lb. wooden " thapies ".

7. Different gangs must be employed for each of the operations of mixing, spreading, and beating, to keep the work going continuously. As many men should be employed for beating as there is room for as it is very important that the consolidation should be carried out quickly.

8. The concrete must be beaten till the mortar creams to the surface, which should be in less than 15 minutes from the time of commencing the beating. It must be remembered that cement sets quickly, and the work is spoiled either if the beating is continued too long, or is not sufficiently thorough.

9. After the mortar has creamed to the surface, the floor should be polished with trowels; the men engaged on this should be made to sit on small boards on the new floor, if necessary.

10. After the slabs have set, the joint bars should be removed and the joints filled with a mixture of 1 of cement to 2 of sand, finished in the same way as the rest of the surface.

11. If it is desired to have a fine polish, after the concrete has set, the surface should be rubbed over with small hard polishing stones; neat cement may be sprinkled on sparingly through a pepper pot if found necessary.

12. To make a coloured floor, the following materials must be mixed, in the quantities stated, with every cubic foot of mortar used for the top layer of the cement concrete.

Red.— One-twelfth cubic foot red oxide of iron powder: or in certain cases red earth may be used.

Terracotta colour.—Can be obtained by mixing burnt yellow ochre.

Black.—One-sixth cubic foot manganese dioxide.

Buff.—One-sixteenth cubic foot yellow ochre.

Note.—(1) Coloured cements are now obtainable in many tints. White cement is also obtainable, and the required tints can be more easily obtained by mixing red oxide, yellow ochre, or manganese dioxide with it, than is the case with ordinary Portland cement.

(2) *Use of oils.*—Linseed oil, boiled or raw, with or without other additions has been tried on dusting concrete floors, but is not very successful. Its resistance depends on an oxidised film of oil, which wears off soon.

China-wood or Tung oil, either alone or in combination with linseed or other oils or resins is more effective, and is the base for various paints for concrete floors, walls etc.

Floor paints in various colours are available give a hard, wear-resisting surface, and withstand the action of water. The floor paint penetrates into the body of the concrete, leaving a hard resistant film at the top.

Note.—The addition of a small amount say a lb. of China-wood or Tung oil to the ingredients, improves the wearing qualities and gives a better finish.

TYPE B.

Specification No 94.

This type has a bed of 4 inches or 5 inches of lime concrete, the surface being hardened with a small quantity of cement.

(1) Sift evenly 20 lbs. of dry cement over every 100 square feet of lime concrete, before the latter has set, and smooth off the surface. Regarding the preparation of the surface over which the concrete has to be laid, watering and using the floor after completion, the same directions as stated for the type, A, should be followed. It is not advisable to attempt to colour this kind of floor.

(2) In cases where a floor cheaper and less durable than the first sort is required, such as for the upper stories of residences, or for Indian quarters in which shoes are not worn : in short, in all cases, where lime or cement plastered floors have hitherto been adopted type, B may very well be used, the cost being about Rs. 10 per 100 square feet at Madras.

(3) This kind of floor can be prevented from becoming dusty by thoroughly rubbing in a mixture in equal parts of unboiled linseed oil and beeswax, after the cement has thoroughly set, but before the floor has been taken into use.

(4) The test for a properly finished floor, is that a fracture made in any portion of it, should disclose the colour of the cement in the top layer shading off into that of the line in the lower layer, the line of demarcation of the two layers being hardly distinguishable.

GRANOLITHIC FLOORS.

General.—" Granolithic " is a term, applied alike to concrete floors having a cement and sand finish, and to those having a surface layer of crushed granite or other hard tough rock bonded with cement.

This type of floors is laid on reinforced concrete slabs in either of two ways, viz.—

(1) the granolithic topping is laid immediately after the base,

(2) the base is allowed to harden and the topping then bonded to it.

The first method makes the topping practically a part of the structural slab, but a newly laid granolithic surface can not be used for at least five days, and even after that, the surface is liable to damage if construction is started soon, as the surface takes time to attain a sufficient degree of hardness. To prevent delay in working, the second method is usually employed in buildings, for all floors excepting the terrace floor.

Specification 95.

(1) **Preparation of base.**—The base surface shall be thoroughly scrabed to remove laitance, sand etc., washed clean, and soaked with water until no more water is absorbe.

(2) **Grouting.**—The free water from the base being removed, a coat of a mixture of cement and water, of the consistency of thick cream, brushed on to the surface, just prior to placing the topping.

(3) **Topping proportions.**—The proportions usually adopted are :—

1 part Portland cement,

½ to ¾ parts fine aggregate of selected graded sand, or clean hard crushings passing through ¼" mesh.

1½ to 2 parts of ⅜" size crushed granite.

quarter pea-gravel etc.

Mixing.—The ingredients above are mixed with just sufficient water to obtain the plasticity required. Mix for a larger period in preference to adding more water to obtain this plasticity.

Laying.—The concrete as prepared above, must be laid immediately after the mixing is complete, on the fresh-grouted base. It should be spread evenly and straight-edged carefully, any low places being filled, humps removed, and the whole surface again straight-edged.

Compacting.—As soon as the layer is even, the surface should be rapidly compacted by ramming or beating, screeded to a uniform line and level, and floated. Finally, it should be trowelled smooth (the trowel being used as sparingly as possible), before the initial set has commenced.

Protection.—The floor must be protected from sunlight and wind, and from rain for twelve hours, while setting.

Curing.—The finish should be covered immediately after it has got its final set, and should be kept continuously wet for at least 10 days.

Surface-grinding.—When the concrete is 4 to 7 days old, it should be surfaced by a surface-grinding machine. This grinding removes laitonce or loose material, produces a smooth finish, and minimizes " dusting " under use.

Surface-dressing.—Finally after the floor has dried, the surface should be given three coats of sodium silicate, each after the previous one has dried. The surface should be washed clean and dried before the silicate is applied.

Note.—Similar toppings can be laid over a concrete base for the ground floor. In this case the concrete base is laid over a thoroughly consolidated murum or other fill, and the topping laid as above.

TERRAZZO FINISH.

General Definition.—Ordinary terrazzo is a concrete with a marble chippings aggregate, with a surface ground to a smooth finish.

Materials.—The marble chippings should be of any colour required and are obtainable in the following gradings, 3/32″, $\frac{1}{8}$″, $\frac{1}{4}$″, $\frac{3}{8}$ and $\frac{1}{2}$″.

The cement should be ordinary grey Portland cement, or white or coloured cement.

Proportions.—The proportions of mix depend on the size of chippings used, and on the mixing of the different gradings. The usual proportions are :—

		Cement.	Chippings.
3/22″ grading	... ...	1 part	$2\frac{1}{2}$ parts.
$\frac{1}{8}$″ and $\frac{1}{4}$″ grading	... ...	1 ,,	3 ,,
$\frac{3}{8}$″ and $\frac{1}{2}$″ grading	... ...	1 ,,	$2\frac{1}{2}$,,
mixed $\frac{1}{8}$″ to $\frac{1}{2}$″ grading	... ...	1 ,,	3 ,,

On no account should the mix be richer than 1 : $2\frac{1}{2}$.

Mixing Materials.—This is of extreme importance as the uniform appearance of the resultant surface depends on a thorough mixture. The chippings if not different gradings should first be thoroughly mixed dry, and then the cement (grey, white or coloured) added, and the chippings and cement thoroughly mixed, the materials being evenly spread on the platform (not heaped). Water is then added from a can with a fine rose until the proper consistency is obtained giving a plastic mix which will just stay if heaped without flouring. Machine-mixing is preferable, but the usual type of concrete mixers are unsuitable, and special machines are required.

Laying.—The concrete base on which the topping is to be placed, must be sound and with a clean rough surface. After the base is laid, the terrazzo topping should follow the next day. A layer of 1 : 3 cement mortar $\frac{5}{8}$″ thick, is spread over the base and levelling strips arranged to obtain the required depth of topping. The terrazzo mix is then placed and screeded level by running a straight-edge across the screeds. After this the surface is rammed to consolidate the terrazzo, and to obtain a level surface which is finally trowelled lightly. Untarred roofing felt strips are placed along the walls to prevent terrazzo from coming in contact with walls.

Thickness of Topping.—This is usually $\frac{3}{4}$″ and one square yard of terrazzo required 63 chippings and 22 lbs. cement.

Curing.—The floor should be kept damp between the times of laying the topping and starting the grinding which can normally be started three days after laying.

Polishing.—(*a*) The first grinding to be done with a coarse Carborandum brick or disk, using water freely. The whole area is then scrubbed using plenty of water, till trace of the grinding mud is removed.

(*b*) All pores and holes are then filled with a fine, identically tinted mix well pressed in by a trowel. This fill a little above the rest of the floor, and keep these spots damp.

(*c*) The second grinding should be done after a further five days using a finer grained Carborundum brick or disk, and this completes the grinding unless there are still faulty patches, which must be filled and a third grinding carried out.

(*d*) After each grinding in the floor should be washed throughly, but after the final grinding, this washing should be done with hot water and a pure soft soap.

Waxing.—After the washed floor has dried, it should be slightly waxed, as this prevents the marble chippings from absorbing dust.

Maintenance.—New terrazzo floors should be washed and waxed as above every week, for several months after finishing.

Note.—(1) The terrazzo topping can be made in various colours or combination colours. Trial mixture shall be made, laid and ground, to obtain required tints. The following remarks will serve as a guide :—

Tint required.	Aggregates chippings.	Cementing material.
Red	... 2 parts ¼″ grade, dark red 1 part ⅛″ grade, dark red.	... Portland cement, 1 part with red oxide, 1/12th (by weight).
	1 part ¼″ grade, dark red 1 part ⅛″ grade, pink.	Do. do.
Pink in Red	... 1 part ⅜″ grade, pink 1 part ¼″ grade, pink 1 part ⅛″ grade, pink	... Portland cement, 1 part with dark red oxide 1/12th (by weight).
White in red	... 1 part each of ⅛″, ¼″ and ⅜″ grade, white chippings.	Portland cement, 1 part mixed with 1/10th part by weight of dark red oxide, and very small proportion of ultra-marine blue by weight.
White in black	... 1 part each of ¼″, ⅜″ and ½″ grade white chippings.	Portland cement, 1 part mixed with ⅛″ part black manganese.
White and Black (speckled)	... ½ part each of ⅛″, ¼″ and ⅜″ grade, white chippings. ½″ part each of ⅛″, ¼″ and ⅜″ grade, black chippings.	Portland cement, ½ part white.
Black in green	... 1 part each of ⅜″, ¼″, ⅜″ and ½″ grade green chippings.	1½ parts Portland cement, mixed with ⅛th part chrominium oxide by weight.

Note.—(2) When the terrazzo topping is to be laid over an old concrete base, it is important that this should be sound and have a clean rough surface to facilitate keeping. Joints in the toppings should always come over the floor slab joints and in any case the topping should not have panels bigger than 12 square feet in area. The topping should be cured for as long a period as possible.

Terrazzo precast slabs tiles are obtainable in Bombay.

FLOOR OF PORTLAND CEMENT BRICKS.

To be formed from ground clinkers, vitrified bricks or such hard materials mixed with Portland cement, clinkers being roughly ground, mixed with cement, moulded and left to set. These form a heavy, hard and exceedingly durable floor.

LAYING MOSAIC FLOORS.

Mix one part powdered brick with slaked lime and water, and spread it to a depth of 2 to 2½ inches over the masonry bedding; bringing the surface to a fine level. This should be done in small pieces at a time, to prevent drying. On this lay a thin layer of cement, prepared with two parts of sifted slaked lime, one of powdered marble and one of puzzolana, mixed to a consistency of paste ; not thicker than $\frac{1}{8}$th of an inch. After a lapse of 4 hours, this may be considered ready to receive marble pieces. If it is desired to form a pattern with designs, define the outlines into their respective colours by hammering in the marble pieces taking their best sides to form the outlines ; the size of pieces to be $1\frac{1}{2}$ inch cube or less, according to the size of the diagram ; after which fill in the spaces with pieces of colours according to the design. When this is done, a stone roller, about 12 inches diameter and $1\frac{1}{2}$ to 2 feet long, is passed over the surface gently, water being sprinkled every now and then ; this carefully done for about 4 hours, will bring all the pieces of marble an even surface, and will work up the cement below between the interstices. Allow the surface so prepared to dry for 24 hours, after which rule the same with the piece of pumice stone, 9″ × 10″ × 3″ fixed to a wooden handle six feet long ; this polishes the surface as well as works up the conical pieces of marble to an even and smooth plane. This will have to be done for at least two weeks. Allow the floor to dry for some weeks before use. If extra polish is required, rub the surface with Tripoli powder and powdered blue vitriol or sulphate of copper, with a few drops of vinegar or dilute acetic acid.

BROKEN TILES PATTERN FLOOR.

Lay the concrete bed to a level $\frac{3}{4}$ inch lower than the finished level of the floor. When dry, lay a thin layer of Portland cement or *neeru* chunam, say 1/10 inch deep, taking a small portion at a time, in order to prevent too rapid drying, and arrange the pieces of tiles of such design, that different colours may form a pattern either ; mixed or of different coloured strips. When aid, sprinkle dry cement or *neeru* over the surface, passing the roller as described for mosaic floors. An hour or two's manipulation will set all the pieces compactly and form a nice surface. Greater care has to be bestowed in arranging or laying the pieces of tiles, than in laying the pieces of marble. When the floor is quite dry, which will take about three weeks, wash it with water, rubbing the surface with pumice stone ; a slight rubbing with oil will bring out all the rich colour of tiling.

MINTON TILE FLOOR.

Specification No. 96.

1. **Pattern of tiles.**—The pattern of the tiles to be selected and approved by the Executive Engineer.

2. **Bedding.**—The concrete bedding, 6 inches thick, to be prepared as specified to be evenly covered with a coat of mortar truly level after two or three days.

3. **Setting in cement.**—The tiles to be carefully set perfectly true in Portland cement, on the surface thus prepared. For every 100 square feet of tiles not less than three cubic feet of cement should be used.

4. **Cleaning.**—The floors should be thoroughly washed within ten days of completion of each portion, and handed over clean.

For Rate Abstract see p. 366.

ASPHALT MASTIC FLOORS.

1. **General.**—Asphalt are combinations of bitumen and calcareous matter sometimes found in nature sometimes artificially formed.

Natural asphalts are superior to artificial imitations, probably because in them the bitumen is more thoroughly incorporated with the limestone or other calcareous matter.

The natural asphalt is generally ground, mixed with sand and a further proportion of bitumen and run into moulds, and when thus mixed is known as *mastic.*

In the preparation of mastic, mineral pitch (bitumen) must be used, not coal tar pitch; the latter is brittle, easily softened and weak.

Patent asphalt (as mastic) is water-proof, fire-proof, easily applied and to some extent elastic; it can, therefore, be used with advantage for many purposes.

It is an admirable material for the damp-proof courses of walls; also as a water-proof layer over arches or flat roofs, or for lining tanks.

It is useful for floors that require a very smooth surface, as in racquet courts; also for those that have to resist water, as in wash-houses and for skirtings of such places.

When spread and brought to a smooth surface, it wears well in footpaths, makes substantial and almost noiseless carriage ways, but is very slippery in damp weather.

It is also used for the joints of pavements of stone and other materials and prevents the penetration of wet.

2. **How to fuse and prepare.**—A large cauldron or iron pot having been provided and a fire lighted under it, put into it from 100 to 250 lbs. (according to the size of pot) of asphalt broken into pieces of not more than ½ lb. each; mix the asphalt with a stirrer in such a way that the pieces at the bottom are constantly brought from the bottom to the surface.

When the whole quantity is thoroughly fused, sand or grit is to be added in the proportion of 2 parts of sand to 1 part of asphalt; the sand should be added gently and constantly stirred for the purpose of keeping the contents of the boiler properly mixed, and to prevent their becoming burnt and clinkered to the sides and bottom of the boiler. When fit for use, the compost will emit jets of light smoke and freely drop from the stirrer; it should then be used as rapidly as possible to prevent its becoming over-burnt.

The contents of each cauldron should be sufficient to cover one layer,and it should be poured all along the space to be covered. If a considerable quantity remain, the gauge may be widened; but if only a small quantity, it should be put back into the cauldron and boiled over again with the next supply.

3. **Drection for applying the compost.**—Having provided gauges of the required thickness, place one with weights bearing on its outer edge parellel to one of the sides of the floor to be covered, and at a distance of about 3 feet; this will form the width of the several layers of payment or flooring to be covered. In this space the spreader kneels, and as soon as the compost is poured it is to spread with an ordinary floating rule or piece of hard, straight wood, about 3½ feet in length, to the thickness of the gauge, any unevenness in the surface being corrected by the trowel or handfloat.

4. Sanding .—Before compost becomes hard, a small quantity of very fine sand should be sifted over it, and well rubbed into it with the handfloat.

5. When the first space is finished the adjoining space should be left over, to a later period. (The object of leaving alternate vacant spaces is that the workmen employed in rubbing may not have occasion to kneel on any part of the asphalt until cool, nor should the gauge be removed till the asphalt has become set.)

Adjoining this vacant space, two gauges are then laid down at the same distance apart and weighted as before mentioned. The space between the gauges must then be covered with the compost and rubbed in the manner before described. In about half an hour the compost will have become quite firm, when the gauges should be carefully removed. The sides of gauges should be oiled to prevent their sticking.

6. For the flooring of rooms or tops of arches a layer, an inch thick, will be sufficient, or for a damp-proof course about ¾ inch, but for pavements where there is much foot traffic, the thickness should be increased from an inch to an inch and a half.

ASPHALT FLOORING.

Specification No. 97.

1. **Bed.**—To be laid on a concrete floor, as per paragraphs 1 and 2 of specification No. 91, for chunam and terraced floors, which must be perfectly dry before the asphalt is laid.

2. **Proportions.**—All dust and sand should first be swept off, and the asphalt having been mixed and melted in the following proportions (unless otherwise specified):—

Asphalt	...	...	... 1 part
Bitumen	...	...	... $\frac{1}{32}$ „
Clean sharp sand		...	... ½ „

shall be laid on smoothly and evenly ½ inch or ¾ inch thick as specified, and carefully and steadily rubbed with a handfloat until the surface is perfectly even and true.

3. **Finishing off.**—The junctions of the sections of the asphalting are to be carefully made, and before the surface becomes hard, it is to be worked perfectly level and smooth with fine clean sand, and left of a uniformly dark colour.

For Rate Abstract see p. 367.

BASTARD ASPHALT FLOORING.

Specification No. 98.

1. **Bed.**—This description of flooring will consist of a layer of road metal boiled in coal tar, the upper surface of which spread and rolled, is finished off with a coat of coarse gravel and slaked lime boiled in a mixture of pitch and coal tar, sanded and finally rolled.

2. **First layer of materials.**—The formation having been properly levelled and thoroughly rolled, upon its surfaces be spread whilst hot, a six-inch layer of materials consisting of *one-inch cube* road metal well boiled in coal tar. The materials, to be thoroughly consolidated with an iron or stone roller, kept well wetted whilst in use.

Note.—The coal tar used should be of moderate consistency and well boiled; if too liquid, it will prevent the proper adhesion of the materials when rolled.

3. **Second layer of materials.**—On the first layer a half-inch coat of materials consisting of—

Small stone chips or coarse gravel		...	...	2 parts,
Slaked lime	...	...	...	... 1 part,

boiled in a mixture of pitch and coal tar in the proportion of one part of pitch to two parts of coal tar will be applied hot, and then carefully and evenly spread out.

Note.—Pounded hard burnt brick, or *kankar* slags, may be substituted for the small stone chips or coarse gravel.

4. **Finishing.**—The surface thus formed, to be then covered with a ¼ inch layer of very fine sharp sand, and finally rolled.

5. **Method of carrying out the work.**—The work to be carried out in successive widths corresponding with the length of the roller to be used in its consolidation, so that the whole width may be evenly rolled as the roller passes over it each time. Scantlings, say 3″ × 6″ and about 9 feet in length, are set on edge and secured in position along the outer or exposed edges of each width of flooring, to confine the materials therein, whilst the process of spreading and rolling is going on. On the completion of the first width they will be removed and again fixed in new positions to admit of a second width being laid, and so on. Care to be taken to paint the last joint before adding a fresh width in order to secure proper adhesion of the materials throughout.

Note.—This description of flooring has been used on the G. I. P. railway in goods shed platforms, etc., and found to be durable, and answers well in all cases when not exposed to the action of the sun. In the floors of ordinary buildings its depth need not exceed 3 inches. Its cost per 100 superficial feet (even when 6 inches in thickness) is less than half that of the commonest description of stone paving Specification for paving, 4th sort, page 237.)

For Rate Abstract see p. 367.

NOTE ON FIRE RESISTING FLOORS.

1. In public buildings, warehouses, etc., the prevention of the spread of fire, should such a thing occur, is of the greatest importance. Fire-resisting floors will largely effect this. Floors, to be satisfactory, must have the following characteristics :—

The materials composing the floor—

(*a*) Must be fire-resisting or if liable to damage as in case of wrought or cast-iron must be protected so as to prevent failure.

(*b*) Must not be too costly either in themselves or in the effect on the cost of building itself.

(*c*) Must be strong enough.

(*d*) Must not be liable to decay.

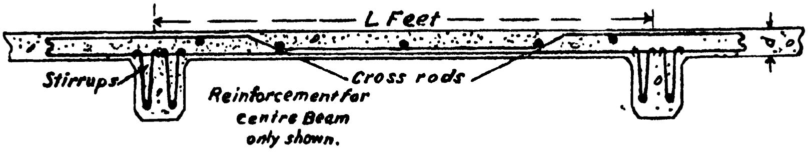
Of the materials used in construction—

Wrought iron is liable to warp and twist under the action of great heat, and must, therefore be protected. This is done by terracotta blocks or by plaster, sometimes by both.

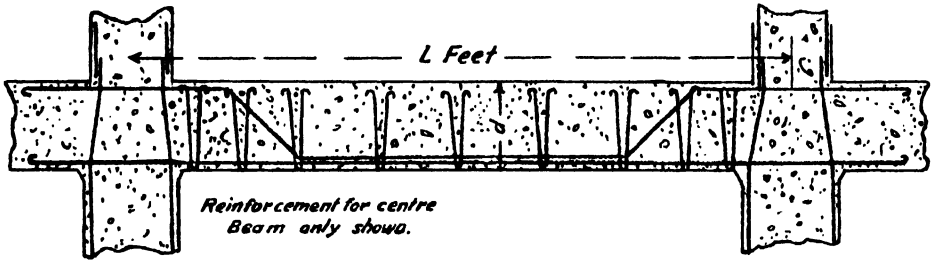
Cast-iron if greatly heated and subjected to a stream of cold water, will crack and split, or may even sometimes be melted.

FIRE RESISTING FLOORS.

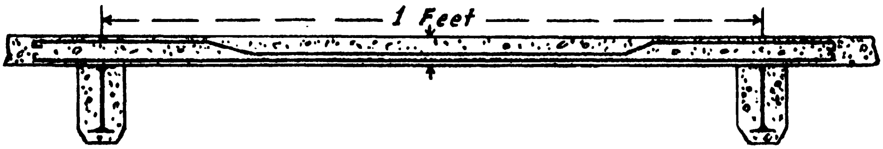
Typical Reinforced Concrete Slab & Beams.



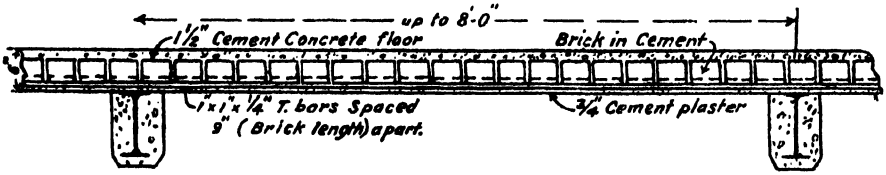
Typical Reinforced Concrete Beam.



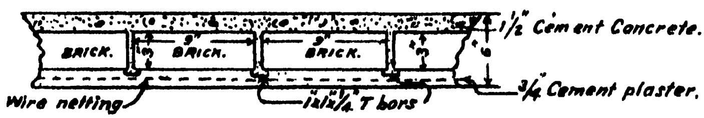
Typical Reinforced Concrete Slab on R.S. Joists encased.



Typical Reinforced brick work Slab on R.S. Joists encased.



Detail of Cross Section.



Wood, if in large scantlings and protected from the air, will stand fire well. It is sometimes protected by asbestos paints, cyantic, etc.

Brick and terracotta afford good resistance.

Concretes and plasters generally resist well, especially if largely formed of gypsum. This is, however, considerably weaker than Portland cement.

Silicate cotton, slag wool, etc., are largely used for pugging floors.

2. **Floors of reinforced concrete.** –The most satisfactory type of fire resisting floor is that of reinforced concrete, with either reinforced concrete beams or rolled steel joists. See plate XX.

Rolled steel joists are more easily laid, and are safer to use, where the contractor and the supervising staff are not experienced in reinforced concrete work.

The reinforcement should be in the form of steel rods, preferably not less than ¼ inch in diameter.

The rods should be clean and free from scales or rust, as far as possible.

The protection of the steel reinforcement depends upon the presence of a cement coat which must envelop it completely; where the cement is reduced, the steel is not protected and is certain to corrode. There is every inducement for a contractor to cut down the quantity of cement, which, apart from the reinforcing steel, constitutes two-thirds of the cost of the finished concrete. The contractor has, therefore, to be watched.

In slabs of small span it is usual to lay the rods one way across the lesser span with cross rods of small section not calculated to take any load, at about 18″ apart, across the longer span.

The cross sectional area of the steel rods in the reinforcement proper per foot run of the slab, and expressed as a percentage of the cross sectional area of the concrete slab, from the surface of the slab to the centre of the reinforcing rods, does not usually exceed ·675 per cent. at which point failure under breaking loads is likely to occur by the crushing of the concrete before the steel fails by drawing, where concrete has an ultimate strength in crushing of 2400 lbs. per square inch, and steel has an ultimate tensile strength of 30 tons per square inch.

Further reinforcement is also required in beams to meet the horizontal shear stresses in the concrete. These stresses are met by bending up at an angle less than 45°, a proportion, from one-half to two-thirds, of the main reinforcing rods at from ⅛ to ¼ span from each end, and also by providing vertical stirrups giving a cross sectional area per foot of, say, 0·1 per cent. at the ends and diminishing to 0·01 per cent. at the centre.

Shear reinforcement is not required for slabs, but where they are continuous over several supports, it is necessary to bend up half the rods at the end of the slabs so as to provide an equal number of rods at the top of the slab over each beam, as in the centre of the slab, and to avoid cracks appearing in the slab over each beam due to the reverse bending stresses.

It is not recommended that any reinforced concrete work, other than simple slabs and lintels, should be undertaken without a comprehensive study of the existing handbooks on reinforced concrete. More details will be found in the chapter on reinforced concrete.

Materials.—The cement concrete shall be of such proportions, as will give a crushing strength of 2400 lbs. per square inch at three months. The steel, unless otherwise specified shall be mild steel complying fully with the latest Br. St. specifications.

The concrete must be liquid enough to flow round the reinforcement and leave no voids, but should not be sloppy.

It is advantageous to tap the centering during concreting, to shake concrete into position and to jerk away the larger stones from the centering into the mass of the concrete.

The concrete must be well rammed as it is laid, and in the case of deep beams the use of iron rods to prod into and consolidate the concrete is recommended. The ramming should not be prolonged after the concrete has begun to set.

3. **Arched systems.**—The objection to these is that the arches exert a thrust on the walls of the building, which must be strengthened or provided with suitable tie rods. They also occupy a good deal of height. If arches are used they must not abut against stone corbels which may crack off. The jack arches are turned on the lower flanges of rolled steel beams. They are formed of either hydraulic lime concrete or of a half brick ring (*i.e.*, 4½ inches thick). The brick arches have spans, from 4 to 6 feet; rise about one-twelfth to one-sixteenth of the span. Tie rods, r, ¾ inch to 1 inch diameter, from 4 to 6 or 8 feet apart, and anchored into each wall with a stout washer W. At each wall an angle iron, a, is generally used instead of a beam. The spandrels are levelled up with concrete, enclosing wooden strips, m, m, about 1 inch × 2 inches, two over each arch. To these strips the flooring is nailed. Or the floor may be finished with stone or tile flooring laid over the concrete.

For turning the arch, each centre, C, has fastened to it at each end a bent iron strap, h, forming a hook by which the centre is suspended from the lower flanges of the beams. See plate XXI.

FLOOR OF CONCRETE JACK ARCHES AND ROLLED STEEL JOISTS.

Specification No. 99.

1. **Joists.**—The rolled steel joists to be placed at suitable distances apart, varying from 2′ 6″ to 4′, according to circumstances, and to be of the section specified.

2. **Proportions.**—The arches to be of chunam concrete mixed in the proportion of two of stone metal or brick bats to one of lime mortar. The mortar to be made of good hydraulic lime or fat lime mixed with *surki* and clean coarse river sand in equal proportions.

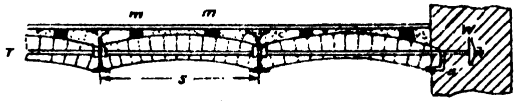
3. **Rise.**—The rise of the arches to be from 4 to 8 inches according to span, the thickness at the crown being 6 inches.

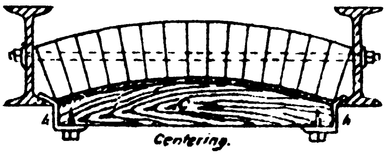
4. **Laying.**—The concrete is to be laid over centrings in a 6 inch layer and rammed for half a day. The haunches to be then filled up to the top of the arch and thoroughly rammed for two days. A final 3-inch layer of concrete should then be laid after five days and well rammed. The centring may be removed a week after laying the final layer.

Note.—A floor of lime concrete or brick jack arches, abutting on rolled steel joists, is bound to give trouble after a certain number of years, if laid in a damp locality or where moisture can get access to the steel. The lime in the lime mortar or brick-work, in the presence of moisture, corrodes steel, and in corroding, the steel swells and exerts a thrust, which may either cause cracks in the floor over joists, or compress the arch causing tension in the top surface. In dry localities with light rainfall, however, the floor is quite suitable.

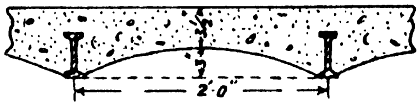
FIRE RESISTING FLOORS.

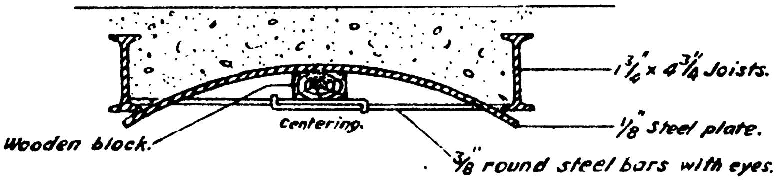
BRICK JACK ARCHES.



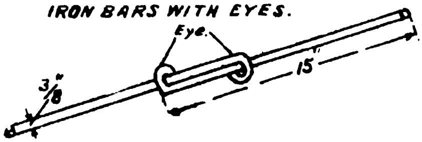


CONCRETE JACK ARCHES.

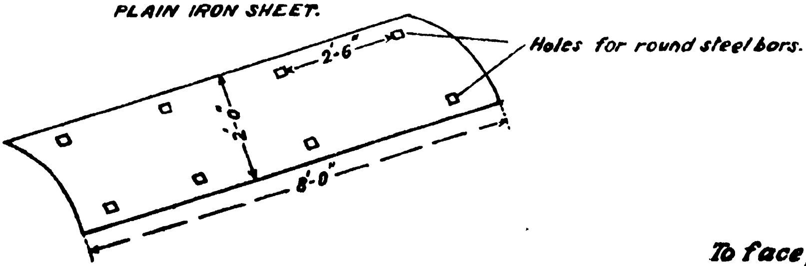




IRON BARS WITH EYES.



PLAIN IRON SHEET.



To face page 230

5. The under surface of the arches should be plastered, and the top surface shall either be finished off with chunam or cement plaster, or stone-paved, as may be desired.
6. The work must be kept damp while in progress and for a forthnight after completion.

For Rate Abstract see page 368.

CEILINGS.

General.

1. Ceilings are of various kinds—plank, asbestos, cement sheet, cloth, lath and plaster, and plaster on expanded metal lathing. The first three are the kinds most generally used.
2. Plank ceilings are fixed in two ways. In the first, the planks are fixed on the purlin-rafters, leaving the main roof timbers exposed to view. In the second, the ceiling is fastened to the underside of ceiling joists screwed to the underside of the tie beams of trusses.
3. Asbestos cement sheets are used in the same way as planks, being screwed on to the roof timbers. They have the advantage of being worm-proof and fire-proof, and require practically no maintenance.
4. Cloth ceilings are formed of stout country cloth, tied or screwed on to teak-wood or bamboo frames, the frame-work if of teak being either exposed to view from below, or covered with the cloth.
5. Lath and plaster ceilings are formed by attaching ceiling joists to the underside of the tie beams, and placing split bamboos across these, and covering the bamboos with plaster.
6. Plaster ceiling on expanded metal lathing is of similar construction. Ceiling bars or iron, called hangers, are fastened with clips to the bottom flanges of the rolled steel joists or trees forming the floor from which is suspended the ceiling on expanded metal lathing.

PLANK CEILINGS.

Specification No. 100.

1. **Planks.**—The planks to be of best Moulmein teak or of good well seasoned pine, as may be specified, to be $\frac{1}{2}$ to $\frac{3}{4}$ inch thick, of a width not exceeding 6 inches (3 inches is preferable), of a uniform colour tongued and grooved, planed on the underside and beaded or bevelled at the edges as may be ordered.
2. **Fixing.**—The planks to be attached to the top of purlin-rafters so as to leave the main roof timbers exposed to view or to be screwed to ceiling joists, $2'' \times 2\frac{1}{2}''$, placed 2 feet apart and fastened to the underside of the tie beams of trusses.
3. **Joints.**—The planks to be laid truly parallel to the walls, and to be fixed with brass screws of the proper length, or iron rails, driven countersunk, as may be ordered, the heading joints breaking joint. All joints to be neat and close. The planks shall, however, not be forced up against one another before being fixed, as they would otherwise bulge in damp weather.
4. **Moulding.**—The ceiling to be finished with a wooden moulding, running all round the walls.
5. **Varnishing.**—All planking to receive a coat of linseed oil and to be painted or varnished two coats, as specified.

For Rate Abstract see page 369.

CLOTH CEILINGS.

Specification No. 101.

1. **Cloth.**—The cloth shall consist of stout native (*dungry*) cloth and shall be supported by a light teakwood frame fixed to wooden blocks let into the walls and firmly screwed to the underside of tie beams or to ceiling joists where ceiling joists are used.

2 **Fixing.**—The cloth will be nailed to the upper side of the frame-work which will. be planed and varnished or in inferior work will be tied up to the underside by string, in which case the frame-work will be left rough. In all cases the cloth to be whitewashed.

Where ceiling joists are used, the cloth is fixed to them, and to prevent the cloth from flapping, moulded battens $1\frac{1}{2}'' \times \frac{3}{4}''$ are used to form square or oblong panels, not more than 5′ long on any side. The moulded battens are screwed through the cloth, to the ceiling joists.

3. **Moulding.**—The ceiling will be finished by a moulding running all round the walls.

For Rate Abstract see page 370.

ROOFS.

General notes.

1. The following are the various types of roof in use in this Presidency :—

Couple roof.—Formed of two inclined rafters meeting upon a ridge board to which they are nailed, the feet being nailed or notched to the wall plate. This roof is suitable for small spans up to 11 feet. If the rafters are supported in the centre by purlins resting on division walls as in police lines, servants' quarters, etc., the roof is much improved and may be used for somewhat greater spans.

Couple close roof is an improvement on the couple roof and is formed by connecting the feet of the rafters by a tie beam, which prevents them from spreading and thrusting the walls out. Can be economically used in spans up to 14 feet. If the tie beam has to support a ceiling, it should be held up by an iron king rod from the ridge.

Collar beam roof is a variation of the couple close roof, where greater head way is required, the tie beam being raised half way up the rafters. It is not such a good form, as the rafters tend to bend and thrust the walls out. May be much improved by adding a tie beam or tie rod at the foot of the rafters, when the collar beam becomes a strut and forms a good roof up to 16 feet span.

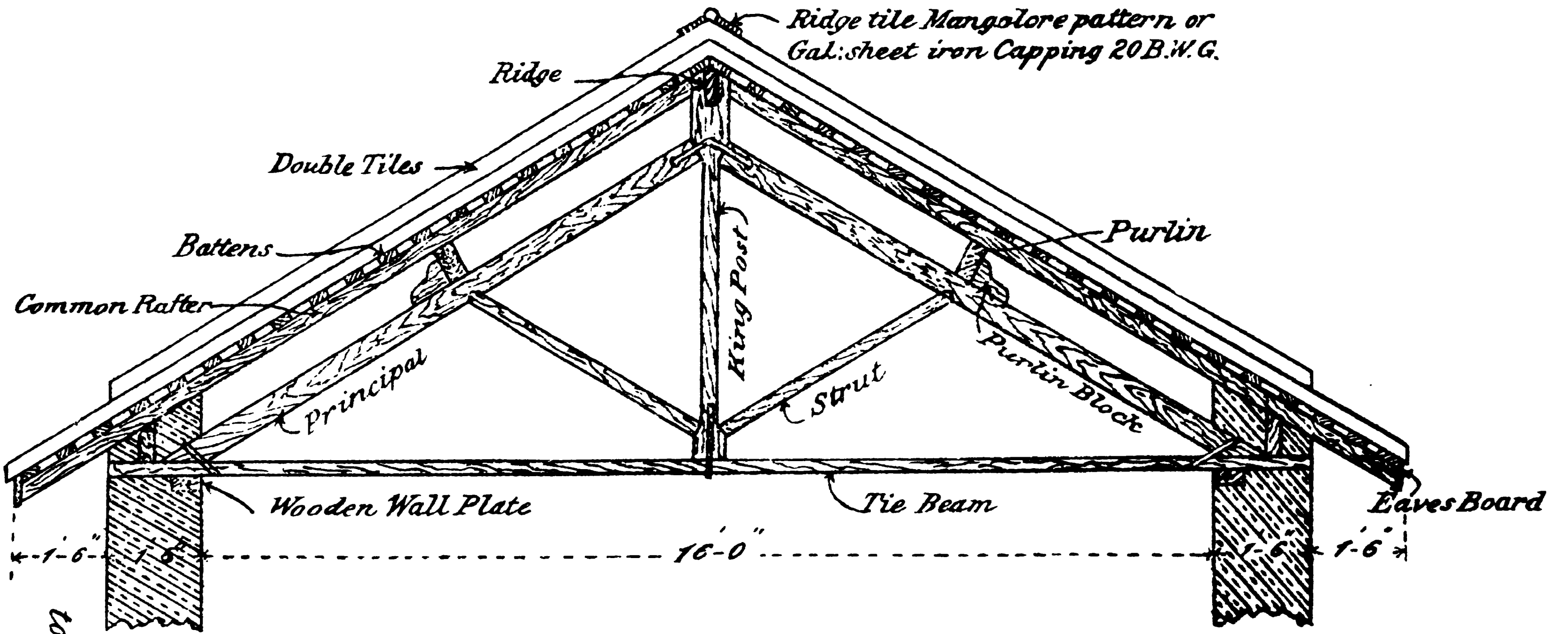
King post roof.—For spans from 16 to 26 feet. The king post forms a support for the tie beam, and the struts prevent the principal rafters from bending in the middle. For details of the truss, see plate XXII. Scantlings of timbers in trusses of various spans and different roof coverings are given in tables LXIV, LXV, LXVII and LXVIII.

Queen post roof.—If the span is greater than 26 feet, the tie beam will require more than one support. This is given by means of queen posts.

These trusses may be used for spans from 26 to 40 feet. See plate XXIII.

For scantlings see tables LXIV, LXV, LXVII and LXVIII.

— KING POST TRUSS. —



— NOTE: —

Wooden Wall Plates under Tie Beams may be used but Cut stone Bed Plates 1'×9"×6" are preferable

Plate XXII

to face Page 252.

QUEEN POST TRUSS.

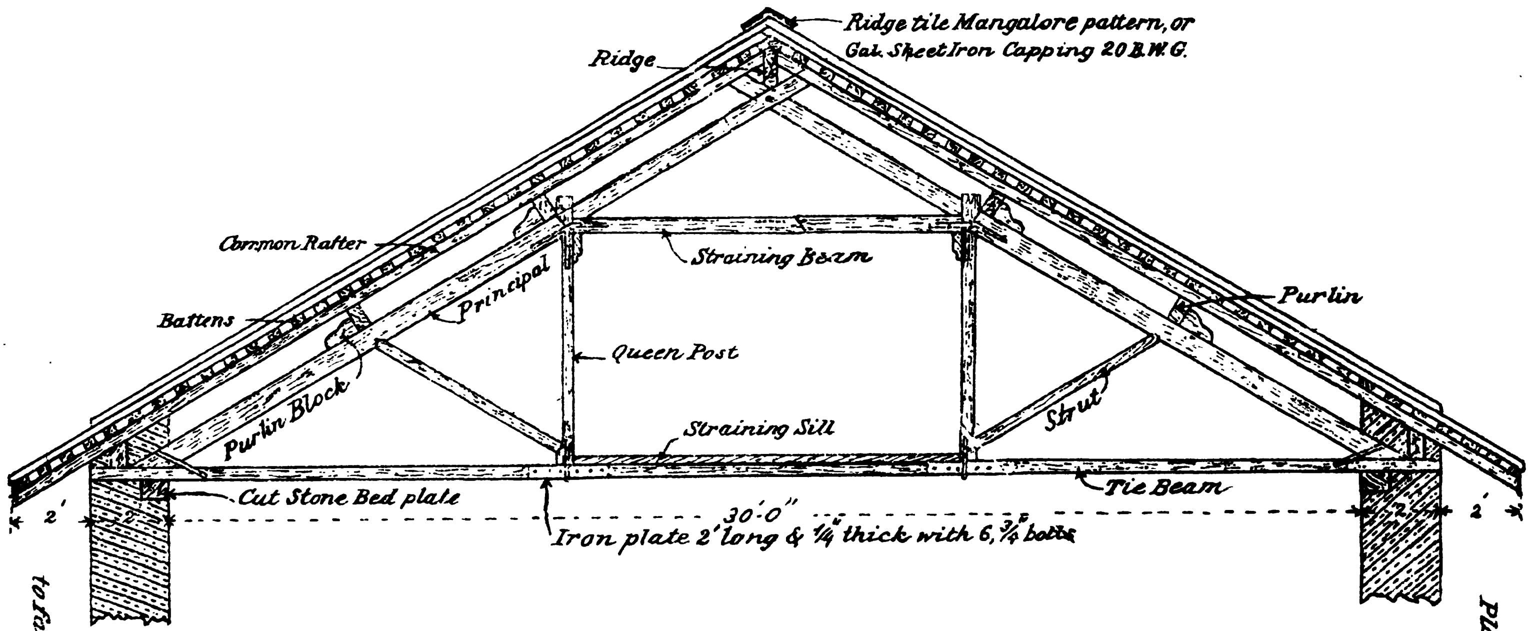


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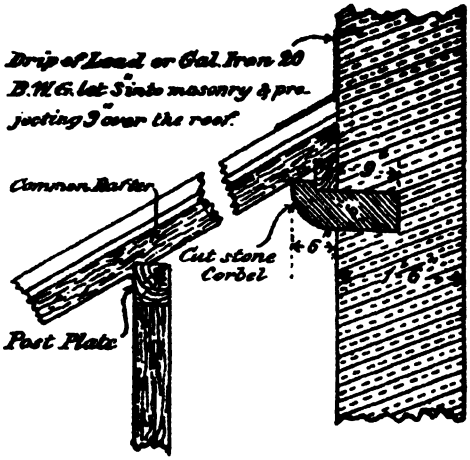
Plate XXIII

to face Page 252

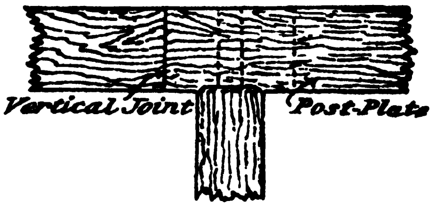
— Detached Verandah Roof —



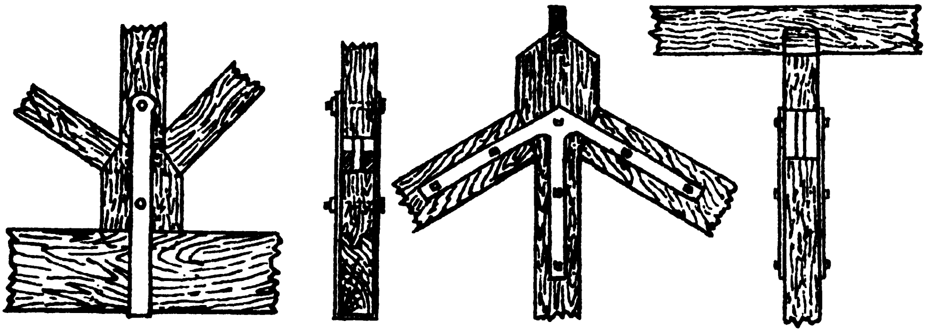
- Post and Post-Plate Joint -

Plan

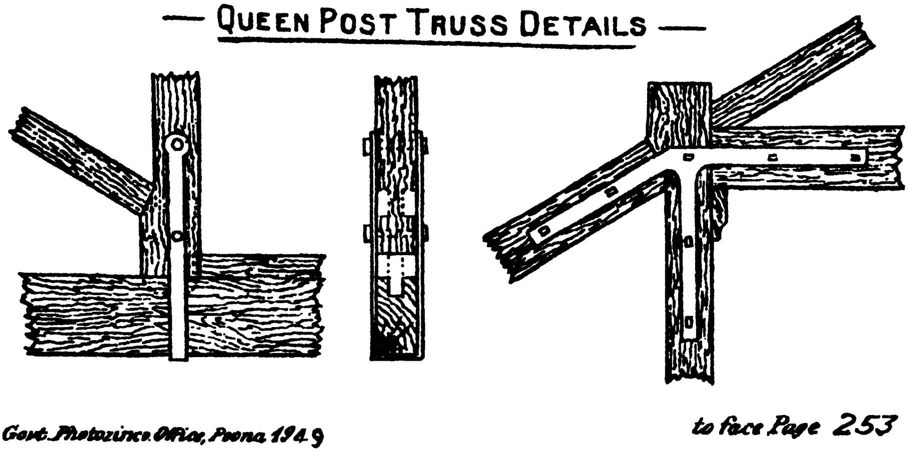
Elevation



— King Post Truss Details —



— Queen Post Truss Details —



Govt. Photozinco Office, Poona 1949

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2. In roofs of spans, 40 feet and upward, it is economical to use steel trusses. For scantlings see table LXXX.

3. Specify whether timber is to be wrought, planed, framed, beaded, chamfered, etc.

4. The wood-work of roofs should invariably be estimated separately from the covering, as otherwise the rate per square will vary with the length and breadth of every building. The wood-work should include trusses, purlins, ridges, wall-plates, rafters, etc.

5. A fair rate to take for labour on framed work is Rs. 1–14–0 per cubic foot including fixing in place. For wrought work, such as purlins, wall-plates, etc., 15 annas per cubic foot will suffice.

DOUBLE-TILED ROOF COVERING.

(Ordinary construction.)

Specification No. 102.

1. **Wood-work.** —All wood-work used in trusses, purlins, rafters, etc., to be of well-seasoned Moulmein teak, neatly planed, varnished or painted, and in other respects as specified for wood-work in general.

2. **Trusses.**—The trusses to be constructed in accordance with the drawings furnished ; all mortise and tenon joints, scarfs, etc., to be fitted together accurately in a workmanlike manner. The scantlings of the different parts, unless otherwise specified, to be in accordance with those given in tables LXIV and LXV ; to be placed at 10 feet central distances apart, their ends well tarred, bearing on stone bedplates or wooden wall plates.

3. In the case of hipped roofs, to prevent a portion of the weight of the roof coming on the nails, the hip rafters should be fixed a little lower and the purlins should rest on them, as they do in the case of the jack rafters. The space left between the top of the hip rafters and the ceiling or the bottom of the common rafters should be filled up with packing pieces.

4. **Purlins, common rafters, etc.**—Purlins, common rafters, etc., to be of the scantlings given in table LXV. Purlins to be in the greatest lengths procurable, and to be scarfed together, wherever necessary, immediately above the principal rafter of the truss on which the ends rest, and to be secured in position by purlin blocks. Common rafters to be fixed at central distances apart not exceeding 18 inches, and to be in continuous lengths from ridge to eaves (wherever possible), slightly notched to fit the purlin and with thier lower ends notched and nailed to the wall-plates.

5. **Battens.**—The battens to be of sawn teak $2'' \times \frac{1}{2}''$, placed 2 inches clear distances apart.

6. **Eaves and barge boards.**—Barge boards shou'd be from 2 inches to $2\frac{1}{2}$ inches higher than the eaves boards for a single layer and from 5 to 6 inches higher for a double layer of tiles, so as to cover the end row of the tiling. Mortar should not be laid over or alongside this boarding.

7. **Iron-work.**—All iron straps, bolts, etc., used in the work to be of good workmanship and to be blue heated and brushed over with linseed oil or coal tar.

8. **Tiles.**—The roof covering to consist of a double layer of sound well-burnt tiles of uniform colour and size, 10″×3½″ or bigger, free from flaws and defects; the tiles to ring clearly when struck together. They should be so turned as to allow of an overlap of at least 3 inches and should be carefully and truly laid at right angles to the eaves. No broken or chipped tiles to be used. The tiles must abut closely at the ridge.

9. **Soaking.**—All tiles to be soaked for 12 hours in water mixed with cowdung before being used on the work.

10. **Eaves, ridges and hips.**—The eaves to be set in mortar sparingly applied and neatly finished off. The ridges and hips to be of Mangalore pattern specials, set dry with joints pointed with Portland cement mortar, sometimes coloured to tile tint.

The under layer of tiles at the eaves shall be secured by a teakwood batten, 1 ×1½ inch, properly levelled, and fixed by ½ inch bolts and nuts to the rafters.

The tiles should fit tight under the batten and project about an inch beyond it.

Whatever style of construction is specified, the eaves shall be properly levelled and an eaves plate, 2½×¾ inch, provided.

For Rate Abstracts see p. 370 and 371.

DOUBLE-TILED ROOF COVERING.

(Purlin-rafter construction.)

Specification No. 103.

1. **Description.**—This description of roofing will correspond generally to that described in the specification for double-tiled roof covering (ordinary construction) differing from it, however, in the following respects :—

2. **Lengthening piece.**—The principal rafter to be prolonged to the eaves by the addition of a piece of timber of the same scantling bolted to its side and to the tie beam as shown in the drawing, to carry the purlin-rafter at the eaves (*vide* plate XXVI).

3. **Purlin-rafters.**—A series of purlin-rafters, 3″×4½″, placed at central distances apart of about 3 feet, to be laid on the principal rafters of the trusses (similar to ordinary purlins), secured to them in the usual way, and to be in length not less than double the distance at which the trusses are set apart. The dimensions of the trusses to be as in ordinary construction.

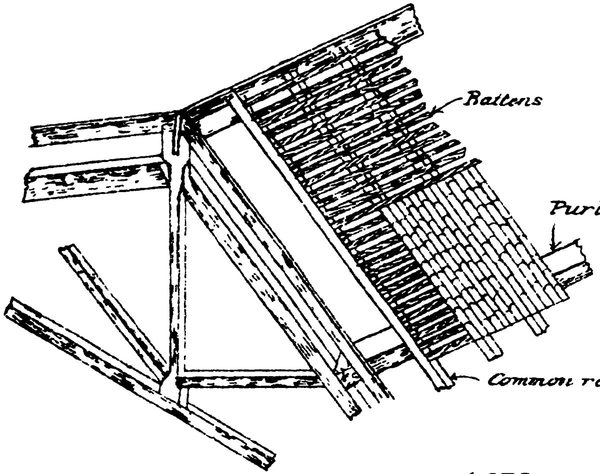
4. **Teak planking.**—Teak planking, ¾ inch thick, tongued and grooved, to be laid on these purlin-rafters continuously from ridge to eaves. In districts, however, where the rainfall is heavy, battens over teak planking may be used, for with tiles laid directly on planking, it gets soaked and wet rot sets in, and the life is considerably reduced.

5. **Tiling.**—The tiles to be laid in the ordinary way on the planking after applying two coats of hot coal tar to the latter.

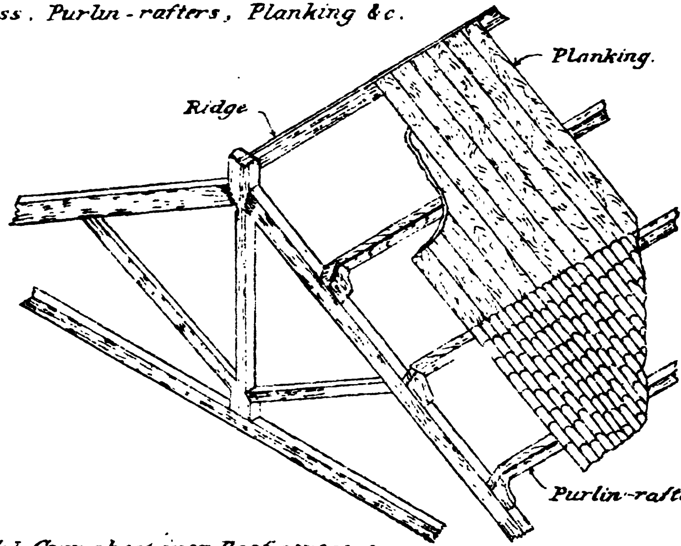
Note.—The purlin-rafters may be set, if desired, at central distances of 2 feet apart. In that case their scantling should be 3″×4″. The cost of the roof would, however, be more than if placed 3 feet apart, and of the scantling specified in paragraph 3 above.

— Double-Tiled Roof Covering —

— Ordinary Construction —
Showing
Truss, Purlins, Rafters, Battens &c.



— Purlin-rafter Construction —
Showing
Truss. Purlin-rafters, Planking &c.



NOTE

In case of Gal. Corr. sheet iron Roof covering, the Planking is to be fixed to the underside of Purlins.

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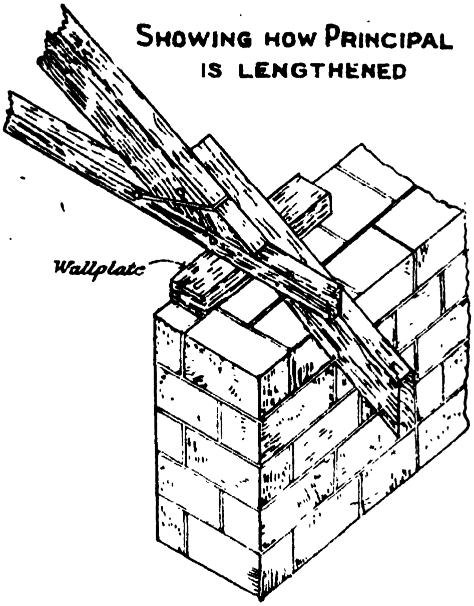
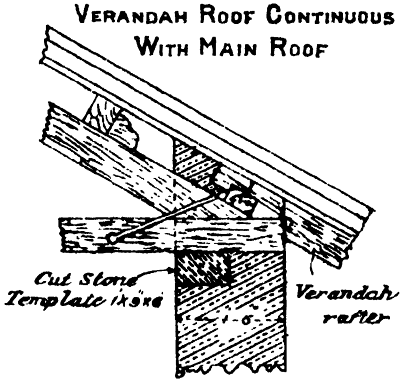
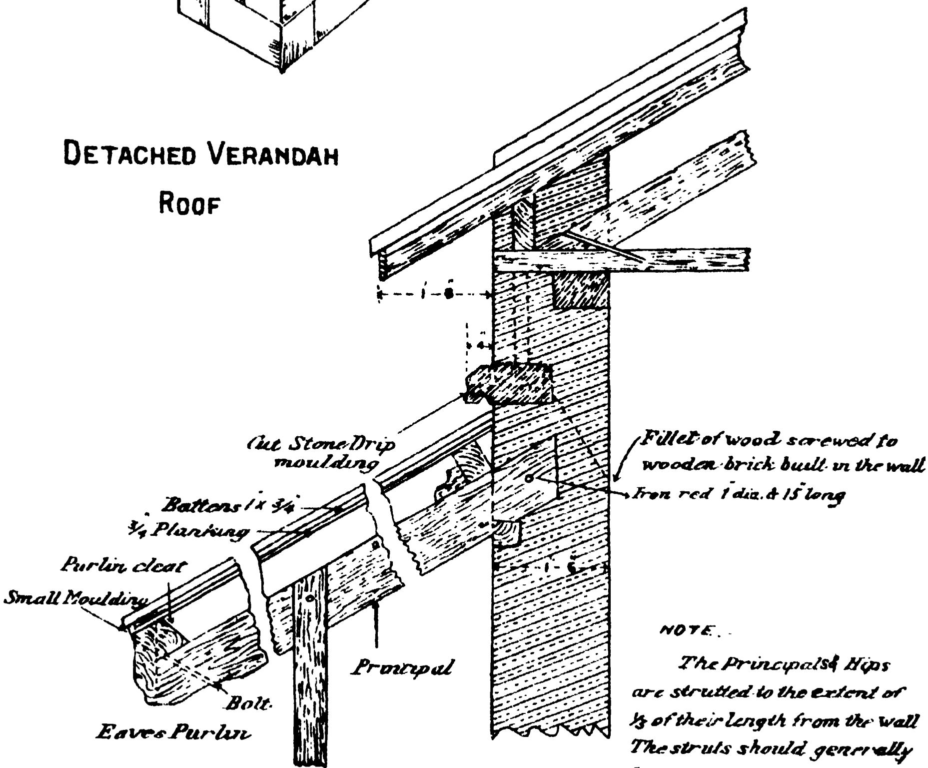
Showing how Principal is lengthened



Verandah Roof Continuous With Main Roof



Detached Verandah Roof



NOTE.

The Principals & Hips are strutted to the extent of 1/3 of their length from the wall. The struts should generally be at about 6½ feet from the floor level.

To face Page 254.

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DOUBLE-TILED VERANDAH ROOF COVERING.

Specification No. 104.

1. **Roof covering.**—Roof covering to be as specified in double-tiled roof covering (ordinary construction).

2. **Principals and purlins.**—Principal rafters, carrying a purlin, to be placed at central distances apart of 8 to 10 feet in all cases when the clear width of the verandah exceeds 8 feet.

3. **Common rafters.**—The tops of the common rafters to be secured to wall-plates laid in the wall, and on no account to be merely built into it (*vide* plates XXIV and XXVI).

4. **Drip moulding.**—A drip moulding of stone, or brick plastered, properly throated, is to be provided wherever a roof finishes against a wall as shown in plate XXVI.

The tiles must finish tight under the moulding; no filling of chunam plaster will be allowed, but a flashing of lead or zinc sheeting may be provided.

Note.—The dimensions of purlin-rafters given above are suitable when trusses are 8 feet apart. With trusses 10 feet apart use 4″ × 5″ purlins.

TABLE No. LXIV.—SCANTLINGS OF TEAKWOOD TRUSSES 10 FEET APART. DOUBLE-TILED ROOFS.
WEIGHT OF ROOF, 27 LBS. PER SQ. FOOT. WINDPRESSURE 20 LBS. NORMAL PER SQ. FOOT. SLOPE 30°.

SPANS.	TIE BEAMS.				PRINCIPALS.				KING POSTS.				STRUTS.				STRAINING BEAMS.				STRAINING SILLS.				Contents of truss.
	Length.	Breadth	Depth.	Contents.	Length.	Breadth.	Depth.	Contents.	Length.	Breadth.	Depth.	Contents.	Length.	Breadth.	Depth.	Contents.	Length.	Breadth.	Depth.	Contents.	Length.	Breadth.	Depth.	Conrents.	
	Feet.	In.	In.	C.F.	Feet.	In.	In.	C.F.	Feet.	In.	In.	C.F.	Feet.	In.	In.	C.F.	Feet.	In.	In.	C.F.	Feet	In.	In.	C.F.	C.F.
XII ...	15	3	3	0·93	7¾	3	5	1·61	4½	3	5	·47	3½	3	2	·29	...	...	...	...	...	...	...	...	3·30
XIV ...	17	3	3	1·06	9	3	5	1·87	5¼	3	5	·54	4¼	3	2½	·44	...	...	...	...	...	...	...	...	3·91
XVI ...	19	3	4	1·58	10	3	6	2·50	5¾	3	5	·60	4¾	3	3	·59	...	...	...	...	...	...	...	...	5·27
XVIII ...	21	3	4	1·75	11½	3	6	2·87	6½	3	5	·67	5¼	3	3	·66	...	...	...	...	...	...	...	...	5·95
XX ...	23	3	4	1·92	12½	3	7	3·64	7	3	5	·73	6	3	3	·75	...	...	...	...	...	...	...	...	7·04
XXII ...	25	4	4	2·78	14	4	7	5·45	7½	4	6	1·25	6½	4	3	1·08	...	...	...	...	...	...	...	...	10·56
XXIV ...	27	4	4	3·00	15¼	4	7	5·92	8¼	4	6	1·38	7	4	3	1·16	...	...	...	...	...	...	...	...	11·46
XXVI ...	29	4	5	4·03	16¼	4	7	6·32	8¾	4	6	1·46	7¾	4	3	1·29	...	...	...	...	...	...	...	...	13·10
													Queen post trusses.												
XXVIII ...	Nos. 3 11	4	5	4·58	11½ 6¾*	4 4	7 5	4·37 2·22	6	4	6	2·00	5¾	3	3	·71	10	4	6	1·67	10	4	2	·56	16·11
XXX ...	11¾	4	5	4·90	12 7½*	4 4	8 7	5·34 2·90	6½	4	6	2·16	6	3	3	·75	10¾	4	6	1·79	10	4	2	·56	18·40
XXXV ...	13½	5	5	7·03	14½ 8¼*	5 5	7 6	7·05 3·46	7½	5	6	3·12	7¼	4	3	1·20	12½	5	6	2·60	10	5	3	1·04	25·50
XL ...	15	5	6	9·37	16 [illegible]¼*	5 5	8	8·89 4·35	8¼	5	6	3·45	8	4	3	1·34	14¼	5	6	2·97	10	5	3	1·04	31·41

*For principle above straining beams.

TABLE No. LXV.—SCANTLINGS OF PRINCIAPLS, PURLINS, ETC., FOR DOUBLE TILED ROOGS.

SPANS.	PRINCIPALS. Trusses 8 feet apart. B	PRINCIPALS. Trusses 8 feet apart. D	PRINCIPALS. Trusses 10 feet apart. B	PRINCIPALS. Trusses 10 feet apart. D	PURLINS.* Trusses 8 feet apart. B	PURLINS.* Trusses 8 feet apart. D	PURLINS.* Trusses 10 feet apart. B	PURLINS.* Trusses 10 feet apart. D	COMMON RAFTERS At 18″ centre to centre. B	COMMON RAFTERS At 18″ centre to centre. D	COMMON RAFTERS At 15″ centre to centre. B	COMMON RAFTERS At 15″ centre to centre. D	RIDGES. Trusses 8 feet apart. B	RIDGES. Trusses 8 feet apart. D	RIDGES. Trusses 10 feet apart. B	RIDGES. Trusses 10 feet apart. D	HIP RAFTERS. Length.	HIP RAFTERS. Breadth.	HIP RAFTERS. Depth.	HIP RAFTERS. Contents.	JACK RAFTERS. Length.	JACK RAFTERS. Breadth.	JACK RAFTERS. Depth.	JACK RAFTERS. Contents.
	Inches.		Inches.		Inches.		Inches.		Inches.		Inches.		Inchse.		Inches.		Feet	Inches.		C.F.	Feet	Inches.		C.F.
													King post trusses.											
XII ...	3	4	3	5	4	5	4	6	2	3	2	3	2½	5	2½	7	11	3	5	1·14	...	...	...	...
XIV ...	3	4	3	5	4	5	4	6	2	3	2	3	2½	6	2½	7	12½	3	6	1·56	...	...	...	...
XVI ...	3	5	3	6	4	5	5	6	2	3	2	3	2½	6	2½	7	14¼	3	7	2·07	...	...	...	...
XVIII ...	3	5	3	6	4	5	5	6	2	3	2	3	2½	6	2½	7	15¾	3	7	2·29	11½	3	7	1·67
XX ...	4	5	3	7	4	5	5	6	2	3	2	3	2½	6	2½	8	17½	3	7½	2·73	12½	3½	7	2·12
XXII ...	4	5	4	7	4	6	5	6	3	4	3	4	2½	6	2½	8	19¼	4	8	4·27	14	4	7½	2·91
XXIV ...	4	5	4	7	4	6	5	6	3	4	3	4	2½	7	2½	8	20¾	4	8	4·61	15	5	8	4·16
XXVI ...	4	5	4	7	4	6	5	7	3	4	3	4	2½	7	2½	8	22¼	4	9	5·56	16	5	9	5·00
													Queen post trusses.											
XXVIII ...	4	5	4	7	4	5	4	6	2	3	2	3	2½	6	2½	7	The hip and jack rafters should be trussed. Size of rafters will depend on trussing employed. The jack rafters should be increased in number for spans of 35 and 40 feet.							
XXX ...	4	6	4	8	4	5	5	6	2	3	2	3	2½	6	2½	8								
XXXV ...	4	7	5	7	4	6	5	6	3	4	3	4	2½	6	2½	8								
XL ...	4	7	5	8	4	6	5	7	3	4	3	4	2½	7	2½	8								

Item	Scantling
Cut teak battens.	2 × ½ inch, 4 inches central distance = 2·08 c. ft. per square +5 per cent. for wastage = 2·18 c. ft. per 100 square ft.
WALL PLATES. Under truss.	2 pieces feet × 6 × 4 inches = 0·67 c. ft. per truss.
WALL PLATES. Under purlins or ridge.	1 piece 15 × 8 × 3 inches = ·21 c. ft.
WALL PLATES. Under hip.	1 piece 3 feet × 8 × 4 inches = ·67 c. ft.
Eaves plate.	2½ × ¾ inch = ·013 c. ft. per running ft.
Eaves board.	6 × ¾ inch = ·021 c. ft. per running ft.
Barge board.	9 × 1 inch = ·062 c. ft. per running ft.

*One prulin is intended on each side of the truss.

TABLE LXVI.

SCANTLINGS OF DOUBLE-TILED VERANDAH ROOFS. SLOPE 30°.

Span in feet.	Verandah post.	POST PLATES.			PRINCIPALS.			PRINCIPALS STRUTTED, ALTERNATIVE ARRANGEMENT.				PURLINS.			Hip rafters.	HIP RAFTERS STRUTTED, ALTERNATIVE ARRANGEMENT		Common rafters.
		Posts 8 feet central distance.	Posts 9 feet central distance.	Posts 10 feet central distance.	8 feet central distance.	9 feet central distance.	10 feet central distance.	PRINCIPAL. 8 feet central distance.	PRINCIPAL. 9 feet central distance.	PRINCIPAL. 10 feet central distance.	Struts.	Principals 8 feet central distance.	Principals 9 feet central distance.	Principals 10 feet central distance.		Hip rafters.	Struts.	
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
V	4 ×4	4 ×4½	4 ×5	4 ×6	...	...	...	...	...	...	...	...	...	...	2½×4	...	...	2×3
VI	4½×4	4 ×5	4 ×6	4 ×6	...	...	...	...	...	...	...	...	...	...	3 ×5	...	...	2×3½
VII	4½×4½	4½×5	4½×6	4½×6	...	...	...	...	...	...	...	...	...	...	3 ×6	...	...	2×4
VIII	4½×4½	4½×5	4½×6	4½×6	4 ×6½	4 ×6½	4 ×7	...	...	...	...	4×5	4×5	4×6	3 ×7	...	...	2×3
IX	4½×4½	4½×5	4½×6	4½×7	4 ×7	4 ×7	4 ×8	...	...	...	...	4×5	4×6	4×6	4 ×8	3×6	3 ×3	2×3
X	4½×4½	4½×5	4½×6	4½×7	4 ×7½	4 ×8	4 ×8½	4×5	4×6	4×7	3 ×3½	4×5	4×6	4×6	4 ×8	3×7	3 ×3½	2×3
XI	5 ×5	5 ×5	5 ×6	5 ×7	4 ×8½	4 ×8½	4½×9	4×6	4×6½	4×7	3 ×4	4×5	4×6	5×6	4 ×9	3×8	3 ×4	2×3½
XII	5 ×5	5 ×6	5 ×6	5 ×7	4½×9	4½×9½	4½ 9½	4×7	4×8	4×8½	3½×4	4×6	5×6	5×6	5 ×10	3×9	3½×4	2×4

Note.—1. The principal and hip rafters are strutted to the extent of ⅓rd of their length from the wall. For spans of 11 and 12 feet it will be found more convenient and economical to adopt the strut arrangement. The struts to spring from the wall at 6½ feet from floor level.

2. The span is the distance between the inner face of the verandah post and the wall.

3. In the case of verandahs of spans 5, 6 and 7 feet, where no principals are used, it is necessary to firmly secure the tops of the posts against leaning inwards by the weight of the verandah roof, a defect seen in most of the old roofs, by using one common rafter over each post deeper by 1″ to 1½″ and notching the post plate into it, or by any other suitable way, as, for example, by fixing iron knee straps between the posts and the common rafters over them. See page, 332 item 15.

MANGLALORE-TILED ROOFS.

(Ordinary construction.)

Specification No. 105.

1. **Wood-work.**—The description and specification of wood-work including trusses, etc., shall correspond with the details given in specification No. 102, for double-tiled roof covering (ordinary construction).

2. **Tiles.**—The tiles to be of double chanelled Basel Mission Mangalore pattern, sound, thoroughly well burnt throughout, of regular shape and uniform size, free from twist or other imperfections, and must ring clearly when struck. They must be of uniform colour throughout, and should not absorb more than1/6th of their own weight, when soaked in water for full 24 hours.

N.B.—The Executive Engineer should obtain specimens with the contractor's tenders, and should specify, as follows :—

"The tiles to be in every way equal to a specimen to be approved by the Executive Engineer, before completing the contract."

3. **Laying.**—The tiles shall be laid fair and square and breaking joint, that is, the left channel of the upper tile shall lie in the right of that below, and shall fit properly one to another, the "catches" resting fully against battens, 2″ × 1″ or 1¾″ × 1″ as specified, fixed 12½ inches centre to centre to the upper surface of the rafters, or when planking is used, battens 1″ × 1″ or 1″ × ¾″ as specified, and shall be exactly parallel to the eaves.

The lowest batten, that nearest to the eaves, should be fixed about 10 inches from the one immediately above, and should have double the ordinary thickness.

4. **Ridge tiles.**—All requisite hip and ridge tiles to be of Mangalore pattern, set dry, with joints pointed with Portland cement mortar, the whole being rendered perfectly secure and water-tight.

The tiles at gable-ends to be carefully fixed full in cement mortar.

6. **Drip moulding.**—As per paragraph 4, specification No. 104.

7. The contractor shall maintain and keep the whole roof water-tight throughout one whole monsoon.

For Rate Abstract see page 372.

Note.—For Mangalore tiled roof, purlin rafter construction, specification No. 103, page 254, for double tiled roofing, purlin rafter construction, together with the note at the end may be adopted. The ceiling should be ½ inch teak boarding; the purlins should be 3″ × 4″, placed 2 feet to 2½ feet apart centre to centre slopwise. Scantlings of teakwood trusses to be as in table LXVII. Battens 1″ × 1″ should be used over the boards, fixed 12½″ c. to c. to serve as catches. In districts of heavy rainfall slopewise battens 1″ × ½″ shall be fixed 2′ 6″ apart, and over them transverse battens as above shall be fixed, to prevent any leakage water lodging on the boards.

TABLE No. LXVII.—SCANTLINGS OF TEAKWOOD TRUSSES, 10 FEET APART. MANGALORE-TILED ROOFS.

WEIGHT OF ROOF 14 LBS. PER SQUARE FOOT. WIND PRESSURE 20 LBS. NORMAL PER SQUARE FOOT. SLOPE 30°.

Spans.	TIE BEAM.				PRINCIPALS.				KING POST.				STRUTS.				STRAINING BEAMS.				STRAINING SILLS.				Contents of truss.
	Length.	Breadth.	Depth.	Contents.	Length.	Breadth.	Depth.	Contents.	Length.	Breadth.	Depth.	Contents.	Length.	Breadth.	Depth.	Contents.	Length.	Breadth.	Depth.	Contents.	Length.	Breadth.	Depth.	Contents.	
	Ft.	Inches.		C.F.	Ft.	Inches.		C.F.	Ft.	Inches.		C.F.	Ft.	Inches.		C.F.	Ft.	Inches.		C.F.	Ft.	Inches.		C.F.	C.F.
XII	15	3	3	0·93	7¼	3	4	1·21	4½	3	5	0·46	3½	3	2	0·29									2·89
XIV	17	3	3	1·06	9	3	4	1·50	5¼	3	5	0·54	4¼	3	2	0·35									3·45
XVI	19	3	3	1·18	10	3	4	1·67	5¾	3	5	0·60	4¾	3	2	0·39									3·84
XVIII	21	3	4	1·75	11½	3	5	2·39	6½	3	5	0·67	5¼	3	2	0·44									5·25
XX	23	3	4	1·92	12½	3	5	2·60	7	3	5	0·73	6	3	2	0·50									5·75
XXII	25	3	4	2·08	14	3	5	2·91	7½	3	5	0·78	6½	3	2½	0·67									6·44
XXIV	27	3	4	2·25	15¼	3	5	3·17	8¼	3	5	0·85	7	3	2½	0·73									7·00
XXVI	29	4	4	3·22	16¼	4	6	5·41	8¾	4	6	1·46	7¾	4	3	1·29									11·3
	Nos. 3								Queen post trusses.																
XXVIII	11	4	4	3·67	11¼	4	6	3·75	6	4	5	1·66	5¾	3	3	0·71	10	4	5	1·39	10	4	2	0·56	13·66
					* 6¾	4	5	1·92																	
XXX	11¾	4	4	3·91	12	4	6	4·00	6½	4	5	1·80	6	3	3	0·75	10¾	4	5	1·49	10¾	4	2	0·59	14·62
					* ½	4	5	2·[illegible]8																	
XXXV	13½	4	5	5·62	14½	4	7	5·64	7½	4	5	2·08	7¼	4	3	1·21	12½	4	5	1·73	12½	4	2	0·69	19·77
					* 8¼	4	6	2·80																	
XL	15	5	5	7·81	16	5	7	7·78	3¼	5	6	3·44	8	4	3	1·33	14¼	5	6	2·9	14¼	5	2	0·98	28·19
					* 9	5	6	2·[illegible]																	

* For Principals above Straining beams.

TABLE No. LXVIII.—SCANTLINGS OF PRINCIPALS, PURLINS, ETC., FOR MANGALORE-TILED ROOFS.

Spans.	Principals. Trusses 8 feet apart.		Principals. Trusses 10 feet apart.		*Purlins. Trusses 8 feet apart.		*Purlins. Trusses 10 feet apart.		Common Rafters. At 18" centre to centre.		Common Rafters. At 15" centre to centre.		Ridges. Trusses 8 feet apart.		Ridges. Trusses 10 feet apart.		Hip Rafters. Length.	Hip Rafters. Breadth.	Hip Rafters. Depth.	Hip Rafters. Contents.	Jack Rafters. Length.	Jack Rafters. Breadth.	Jack Rafters. Depth.	Jack Rafters. Contents.
	B	D	B	D	B	D	B	D	B	D	B	D	B	D	B	D								
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	Ft.	In.	In.	C.F.	Ft.	In.	In.	C.F.
XII	3	4	3	4	3	4½	4	5	2	3	2	3	2	5	2	6	11	3	4	0·92	...	...	...	...
XIV	3	4	3	4	4	4½	4	5	2	3	2	3	2	5	2	7	12½	3	5	1·30	...	...	...	...
XVI	3	4	3	4	4	4½	4½	5	2	3	2	3	2	6	2	7	14½	3	5½	1·63	...	...	...	...
XVIII	3	4½	3	5	4	4½	5	5½	2	3	2	3	2	6	2	7	15¾	3	5½	1·80	11½	3	6	1·44
XX	3	5	3	5	4	4½	5	5½	2	3	2	3	2½	6	2½	7	17½	3	7	2·55	12½	3	7	1·82
XXII	3	5	3	5	4	5	5	6	2	3	2	3	2½	6	2½	7	19¼	3	8	3·21	14	3½	7	2·38
XXIV	3	5	3	5	4	5½	5	6	2	3½	2	3	2½	6	2½	7	20¾	3	8	3·45	15	4	8	3·34
XXVI	3½	6	4	6	4	5½	5	6	2	3½	2	3½	2½	6	2½	7	22¼	4	8	4·94	16	4	9	4·0
													Queen post trusses.											
XXVIII	4	5	4	6	4	5	4½	5	2	3	2	3	2½	6	2½	7	The hip rafters and jack rafters should be trussed; size of rafters will depend on trussing employed. The jack rafters should be increased in number for spans of 35 and 40 feet.							
XXX	4	6	4	6	4	5	5	5½	2	3	2	3	2½	6	2½	7								
XXXV	4	6	4	7	4	5	5	5½	2	3½	2	3	2½	6	2½	7								
XL	4	7	5	7	4	5	5	6	3	4	2	3½	2½	6	2½	7								

Item	Scantling (all spans)
Cut teak battens.	1¼×1 inch; 12¼ inches central distance = 1·17 cubic feet per square + 5 per cent. for wastage = 1·23 cubic feet per 100 square feet.
Wall plates. Under truss.	2 pieces 2 feet × 6 × 4 inches = ·67 cubic foot per truss.
Wall plates. Under purlins or ridge on partition wall.	1 piece 15 × 8 × 3 inches = ·21 cubic foot.
Wall plates. Under hip.	1 piece 3 feet × 8 × 3 inches = ·50 cubic foot.
Eaves plate.	2¼ × ¾ inch = ·013 cubic foot per running foot.
Eaves board.	6 × ½ inch = ·021 cubic foot per running foot.
Barge board.	9 × 1 inch = ·062 cubic foot per running foot.

* One purlin is intended on each side of the truss.

TABLE LXIX.

SCANTLINGS OF SINGLE OR MANGALORE-TILED VERANDAH ROOF. SLOPE OF ROOF 30°.

Span in feet.		POST PLATES.			PRINCIPALS.			PRINCIPALS STRUTTED, ALTERNATIVE ARRANGEMENT.				PURLINS.				HIP RAFTERS STRUTTED, ALTERNATIVE ARRANGEMENT.		
								Principals.										
	Verandah post.	Posts 8 feet central distance.	Posts 9 feet central distance.	Posts 10 feet central distance.	8 feet central distance.	9 feet central distance.	10 feet central distance.	8 feet central distance.	9 feet central distance.	10 feet central distance.	Struts.	Principals 8 feet central distance.	Principals 9 feet central distance.	Principals 10 feet central distance.	Hip rafters.	Hip rafters.	Struts.	Common rafters.
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
V	4 ×4	4 ×5	4 ×5	4 ×5	...	...	...	...	...	...	...	...		...	2½×4	...	...	2×3
VI	4½×4	4 ×5	4 ×5	4 ×6	...	...	...	...	...	...	...	...	...	...	2½×5	...	...	2×3
VII	4½×4½	4½×5	4½×5	4½×6	...	...	...	...	...	...	...	...	...	...	3 ×5	...	...	2×4
VIII	4½×4½	4½×5	4½×5	4½×6	4×6	4×6½	4×6½	...	...	...	...	4×4½	4×4½	4×5	3 ×6	...	...	2×3
IX	4½×4½	4½×5	4½×5	4½×6	4×6½	4×7½	4×7½	...	...	...	...	4×4½	4×5	4×5½	3 ×7	3×6	3×3	2×3
X	4½×4½	4½×5	4½×6	4½×6	4×7½	4×7½	4×8	3×6	3×6	3×6½	3×3½	4×4½	4×5	4×5½	4 ×8	3×6½	3×3	2×3
XI	4½×4½	4½×5	4½×6	4½×6½	4×8	4×8½	4×9	3×6½	3×6½	3×7	3×4	4×5	4½×5	4½×5½	4 ×8	3×7	3×4	2×3
XII	4½×4½	4½×5	4½×6	4½×7	4×9	4×9½	4×9½	3×7	4×7	4×7½	3×4	4×5	4½×5	4½×5½	4 ×9	3×8	3×4	23×3

Note.—1. The principal and hip rafters are strutted to the extent of ⅓rd of their length from the wall. For spans of 11′ and 12′ it will be found more convenient and economical to adopt the strut arrangement. The struts to spring from wall at 6½ feet from floor level.

2. The span is the distance between the inner face of the verandah post and the wall.

3. See note 3 under table LXVI.

GALVANIZED CORRUGATED-IRON ROOF COVERING.

Specification No. 106.

1. **Gauge.**—Sound, galvanized corrugated-iron of 18, 22 or 24 B.W.G. as may be specified, uninjured in carriage by the rubbing of the zinc covering or otherwise, shall be used.

2. **Laps.**—The sheets to be laid with laps of 6 inches at the ends and of two corrugations at the sides, starting the laying from the side opposite that of the prevalent winds in the monsoon.

3. **Drillings.**—The holes for the galvanised-iron screws or bolts are to be drilled (not punched) from the inside towards the outside, about 9 inches apart on the sides, and at every second corrugation on the ends, care being taken that all holes shall occur in the ridge of the sheet as laid.

4. **Fastening down.**—The sheets, when so fastened with the best galvanized-iron, bolts and lead washers, are to be set carefully on the purlins and fastened to them by Allen's or other approved fastenings, galvanized-iron-screws and washers, or by bolts, as may be shown in the drawings.

These bolts to be placed 5 feet apart horizontally and in the same line in the direction of the slope over each purlin, care being taken in the case of screws and bolts that the holes to receive them are drilled in the *ridge* of the corrugation.

5. **Ridges.**—Ridges and hips to be of neat zinc sheets, 20 B. W. G., with a 12 inch lap on each side securely fastened down, so as to prevent the rain driving under it.

Note.—In open sheds or verandahs where wind can get under the roof, it is absolutely necessary po fasten down the plates by continuous lengths of wrought-iron about 2″ × ¼″ bolted through the turlins, and also to secure the purlins by bolting them down to the masonry or other parts.

To find out a rate, for, say, 2,100 square feet of roofing, find out the number and weight of sheets of the different sizes required. Say they are as follows:—

100 sheets, 6′ × 2′ 2″, 20 gauge, weight	2,500 lbs.
100 do. 7′ × 2′ 2″ do. do.	3,000 lbs.
Total weight of galvanized sheet for 2,100 sq. ft.	=5,500 lbs.
	or 49·10 cwts.

For Rate Abstract see page 373.

CORRUGATED-IRON ROOF COVERING 20 B. W. G. WITH TEAK CEILING.

Specification No. 107.

1. Roof covering to be as specified above.

2. **Timber frame-work.**—The sheeting to be supported on teak purlins and trusses (which will accord generally with the conditions laid down in specification above) in the manner described below.

3. **Purlins.**—A series of longitudinal purlins shall be placed at central distance apart of above 3 feet, or half the length of each riveted sheet. On these the corrugated-iron sheeting shall be laid, the overlapping and bolted ends of the sheet being secured to each *alternate* purlin, by 3-inch galvanized-iron screws and washer about 6 inches apart.

4. **Teak-planking.**—Teak-planking, ½inch thick, tongued and gooved, shall then be screwed to the *under-side* of the purlins, extending from under the ridge to the walls, forming thus an air chamber of the full depth of the purlins between the planking and the roof covering above.

5. **Galvanized-wire netting.**—When Howard's or any other ridge ventilator is used as is very desirable with an iron roof, the planking shall finish at each side of the double ridge and the open spaces left shall be filled in with galvanized-wire netting; when no separate ridge ventilator is used, holes 1-inch diameter should be cut in the planking along the ridge at each side, whereby some ventilation is ensured through the spaces between the corrugated-iron sheets and the plain ridge capping; also, in any case, holes 1-inch diameter should be cut in the planking along the walls, so as to set up a current of air between the plankings and the iron sheeting.

6. Eaves gutters to be provided.

For Rate Abstract see page 374.

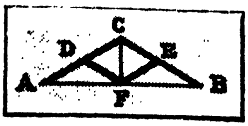
TABLE LXX.

SCANTLINGS OF TEAKWOOD TRUSSES, 10 FEET APART, FOR CORRUGATED-IRON ROOFS.

Spans.	Tie Beam.				Principals.				King Post.				Struts.				Contents of truss.
	Length.	Breadth.	Depth.	Contents.	Length.	Breadth.	Depth.	Contents.	Length.	Breadth.	Depth.	Contents.	Length.	Breadth.	Depth.	Contents.	
	Ft.	In.	In.	C. F.	Ft.	In.	In.	C. F.	Ft.	In.	In.	C.F.	Ft.	In.	In.	C.F.	
XII	15	3	3	0·93	7¾	3	4	1·28	4½	3	4½	0·42	3½	2½	2	·24	2·87
XIV	17	3	3	1·06	9	3	4	1·50	5¼	3	4½	0·49	4¼	2½	2½	·37	3·42
XVI	19	3	3	1·19	10	3	4	1·67	5¾	3	4½	0·54	4¾	2½	2½	·42	3·82
XVIII	21	3	4	1·75	11½	3	5	2·39	6½	3	5	0·68	5¼	3	2	·42	5·24
XX	23	[illegible]	[illegible]	1·92	12½	3	5	2·60	7	3	5	0·73	6	3	2	·50	5·75
XXII	25	3	4	2·08	14	3	5	2·91	7½	3	5	0·78	6½	3	2½	·67	6·44

TABLE LXXI.

KING POST TRUSS.

Member of truss.	Stress coefficient. Dead load.	Stress coefficient. Normal wind pressure on one side, and both ends fixed.	Length coefficient.	Figure. (Pitch 30°)
A D ...	·75	·73	·2888	Diagram. 
E B ...	·75	·58	·2888	
D C ...	·5	·43	·2888	
C E ...	·5	·58	·2888	
D F ...	·25	·58	·2888	
E F ...	·25	·0	·2888	
C F ...	·25	·29	·2888	
A F ...	·65	·84	·50	
B F ...	·65	·33	·50	

Example.—To find the stress in AD @ 27 lbs. per square foot dead load and 20 lbs. per square foot wind load on one side, for a 20-foot span truss spaced 10 feet apart—

Stress due to dead load $= 20 \times 1\cdot154 \times 10 \times 27 \times \cdot75 = 4{,}674$ lbs.

Stress due to wind $= \frac{20}{2} \times 1\cdot154 \times 10 \times 20 \times \cdot73 = 1{,}684$ lbs.

Total ... $= 6{,}369$ lbs.

The working stresses for compression members are as for long struts, as given in table LXXVIII.

Length of each member is got by multiplying the span by the corresponding co. fficient in the last column.

In this case length of member AD $= 20 \times \cdot29 = 5\cdot8 = 6$ feet, say.

Width of principal assumed $= 3''$.

$\frac{l}{b} = \frac{6 \times 12}{3} = 24$, working stress for which is 420 lbs. per square inch, taking the means of A and B in table LXXVIII.

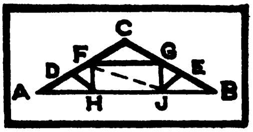
$\therefore$ Section required for AD $= \frac{6{,}359}{420} = 15$ square inches.

$\therefore$ Depth $= \frac{15}{3} = 5''$

Allowing for joints $3'' \times 7''$ may be used.

TABLE LXXII.

QUEEN POST TRUSS.

Member of truss.	Stress coefficient. Dead load.	Stress coefficient. Normal wind pressure on one side, and both ends fixed.	Length coefficient.	Figure. (Pitch 30°).
A D ...	·83	·87	·1923	
E B ...	·83	·58	·1923	
D F ...	·67	·67	·1923	Diagram.
G E ...	·67	·58	·1923	
F C ...	·17	·28	·1923	
C G ...	·17	·58	·1923	
D H ...	·17	·38	·1923	
E J ...	·17	0	·1923	
F H ...	·08	·19	·1923	
G J ...	·08	0	·1923	
A H ...	·72	1·00	·333	
J B ...	·72	·33	·333	
H J ...	·58	·67	·333	
F G ...	·43	0	·333	
F J ...	0	·58	·385	

Note.—For the method of usingt he table see example under table LXXI for king post truss.

TABLE LXXIII.

CORRUGATED-IRON ROOF COVERING FOR VARIOUS SPANS, THE SHEETS HAVING A VERTICAL AND HORIZONTAL OVERLAP OF 6 INCHES AND THEIR WIDTH BEING 2 FEET 2 INCHES.

Span.	Thickness of wall.	Horizontal projection of eaves.	Length of side.	No. and size of sheets in one side.	Total percentage of sheet area over area of roof.	REMARKS.
12	1·5	1·25	10·0	No. 1 of 7 feet and ½ of 7 feet.	35 per cent.	The projection of eaves is reduced to suit the sheets.
14	1·5	1·50	11·5	No. 1 of 8 feet and ½ of 8 feet.	34	
16	1·5	1·37	12·5	1 of 7 feet and 1 of 6 feet.	33·71	Do. do.
18	1·5	1·25	13·5	2 of 7 feet ...	33	Do. do.
20	1·5	1·11	14·5	1 of 8 feet and 1 of 7 feet.	33	Do. do.
		1·97	15·5	2 of 8 feet ...	32·71	Do. increased do.
22	1·5	1·87	16·5	2 of 7 feet and ½ of 7 feet.	36	Do. do.
24	1·5	1·67	17·5	1 of 8 feet, 1 of 7 feet and ½ of 7 feet.	36	Do. do.
26	2·0	1·50	19·0	2 of 8 feet and ½ of 8 feet.	36·34	
28	2·0	1·33	20·0	1 of 8 feet, 1 of 7 feet, 1 of 6, or 3 of 7 feet.	35	Do. reduced do.
30	2·0	1·20	21·0	1 of 8 feet and 2 of 7 feet.	34·69	Do. do.
32	2·0	1·56	22·5	2 of 7 feet, 1 of 6 feet and ½ of 8 feet.	37·15	Do. increased do.
34	2·0	1·43	23·5	3 of 7 feet and ½ of 8 feet.	36·78	Do. reduced do.
36	2·0	1·23	24·5	1 of 8 feet, 2 of 7 feet and ½ of 8 feet.	36·47	Do. do.
38	2·0	1·60	26·0	3 of 8 feet and ½ of 7 feet.	36	Do. increased do.
40	2·0	1·96	27·5	1 of 8 feet and 3 of 7 feet.	35·58	Do. do.

TABLE LXXIV

SIZES AND APPROXIMATE WEIGHTS OF GALVANIZED CORRUGATED-IRON SHEETS.

Length.	Sheets 26″ wide, with 8 corrugations of 3″ pitch.				Sheets 32″ wide, 10 corrugations of 3″ pitch.			
	B. W. G. 18	20	22	24	B. W. G. 18	20	22	24
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
6 feet ...	31	24	19½	16	36	28½	23	19
7 ,, ...	36½	28	23	19	42½	33	27	22½
8 ,, ...	41½	32	26	22½	49	38	31	25½
9 ,, ...	46½	36	29	24	55	42½	34½	29
10 ,, ...	52½	39	32½	27	61	48	39	32

Note.—Corrugated iron sheets are sold by weight in bundles. The weights of individual sheets may vary as much as 2 lbs. above or below the average weights given. The above weights are taken from bundles and, therefore, no allowance is required to be made for the weight of the packing strips. The number of corrugated iron sheets in a bundle varies. The number of sheets is arranged so that the weight of a bundle is in the region of 2 cwts., for convenience in handling.

TABLE LXXV.

APPROXIMATE NUMBER OF GALVANIZED CORRUGATED-IRON SHEETS PER TON.

Length.	Sheets 26″ wide, with 8 corrugations of 3″ pitch.				Sheets 32″ wide, with 10 corrugations of 3″ pitch.			
	B. W. G. 18	20	22	24	B. W. G. 18	20	22	24
	No.	No.	No.	No.	No.	No.	No.	No.
6 feet ...	72	95	116	140	62	79	97	117
7 ,, ...	62	81	99	120	53	68	83	100
8 ,, ...	54	71	87	100	46	59	73	88
9 ,, ...	48	63	77	93	41	53	65	78
10 ,, ...	43	57	69	84	37	47	58	70

SIZES AND APPROXIMATE WEIGHTS OF FLAT GALVANIZED STEEL SHEETS.

Length.	Width.	⅛ inch thick.	1/16 inch thick.	B. W. G. 18	20	22	24
	Inches.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
6 feet ...	36	94	47	37½	30	24½	20
6 ,, ...	48	130	65	50	40	32½	27
8 ,, ...	36	126	63	50	40½	32½	26½
8 ,, ...	48	173	87	67	54	43½	35½

Note.—The weights of these sheets vary to the extent of a pound or two, over or under.

APPROXIMATE WEIGHTS OF ZINC SHEETS.

(*Vieille Montagne.*)

B. W. G.	Approximate weight per sq. foot. Lbs.	oz.	drs.	Approximate weight per sheet (8′ × 3′) Lbs.	oz.	drs.
20	1	5	12	32	10	0
19	1	8	12	37	2	0
18	1	11	11	41	8	8

Roof of Asbestos Cement corrugated sheets and tiles.

In addition to slates and plain sheets, asbestos cement Sheets are now manufactured as corrugated sheets, and as corrugated tiles in large sheets called 'Trafford Tiles'. Both these varities are much used for roofing purposes, as they are easily laid, are good insulators against temperature, and are non-perishable. These sheets are laid exactly in the same way as Galvanized, corrugated Iron sheets, and since the weight of laid roofing per 100 sft., varies from 325 to 350 lbs., while Galvanized corrugated Iron roofing (20-B. W. G.) weighs about 265 lbs. per 100 sft., the scantlings for purtime etc. are the same as in the latter case.

The following tables give particulars of standard asbestos-cement goods—

TABLE LXXVI.

Asbestos Cement Corrugated Sheets.

Pitch of corrugations	Width of Sheets ins.	Length of Sheets.	Thickness ins.	End Lap. ins.	Side Lap.	Weight of square of finished Roofing in. lbs.	Spacing of Purlins C. to C.
5¾	41½	By 6 in. increments to 10 ft.	¼	6	half a corrugation.	350	4 ft . 6 ir.
2⅞	30	By 6 in. increments to 10 ft.	¼	6	1½ corrugation.	324	3 ft.

Corrugated Tiles in Large Sheets: "Trafford Tiles".

Corrugations per Tile.	Width of Sheets.	Length of Sheets.	Thickness ins.	End Lap. ins.	Side Lap. ins.	Weight of Square of Finished Roofing in lbs.	Spacing of Purlins C. to C.
4	3 ft. 8 in.	4 ft. 5 ft. and 6 ft.	¼	6	4	326	3 ft. 6 in. and 5 ft. 8 in. for siding.

RECOMMENDATIONS FOR USE OF UNREINFORCED CORRUGATED SHEETS FOR ROOFING.

1. **Fixing of Sheets.**—It is important when using unreinforced corrugated sheets on large roofs, in which there is likely to be some movement of the structure due to variations in climatic conditions, that expansion joints should be used in association with the sheets to permit any such movement being taken up. It is therefore, desirable that the recommendations of the Manufacturers on this point should be carefully followed. In cases where sheets have to be bolted through the lap, and on long stretches of roof, an expansion joint should be provided at the definite intervals recommended for each particular class of roof.

Holes for fixing should always be drilled and not punched. The latter method not only splays out the aperture, thus weakening the material at vulnerable points, but is also likely to commence a fracture of the sheet which will ultimately open out in weathering.

2. **Spacing of Purlins.**—In designing roofs to be covered with unreinforced corrugated sheets special consideration should be given to purlin spacing, otherwise sheets may be subjected to excessive stresses.

The following maxima spacings of purlins is recommended :—

	Centre to centre of purlins	
Small section sheets	3 ft.	0 in.
Large section and alternate flat and corrugated section sheets	4 ft.	6 in.

It cannot be too strongly emphasised that these spacings should be regarded as maxima under all conditions.

It is further recommended that additional trimmers or bridging should be used between purlins at all points where considerable roof traffic is likely to occur *e.g.*, adjoining valley or box gutters below glazing and around chimneys, ventilators or other up takes. This should be done both on new roofs and when recovering or repairing existing roofs.

Similarly, when a course of short sheets necessitating closer purlin spacing is required to make up a roof slope, it is desirable to arrange the closer purlin spacing at the eaves rather than at the ridge, as this will bring additional support where it is most required.

3. **General Recommendations.**—As large section corrugated sheets are considerably stronger than small section sheets their use is recommended, especially for large span roofs, and roofs on high buildings.

Cat ladders or roof boards should invariably be used by men working on roofs covered with corrugated sheets. The observance of this rule, which is advocated primarily on the grounds of safety will also avoid damage to the roofing material.

ROOF OF SINGLE (COUNTRY ROUND) OR MANGALORE TILES OVER GALVANIZED CORRUGATED-IRON SHEETING.

Specification No. 108

1. **Description**—The roof shall consist of teakwood trusses with purlin-rafter construction, and galvanized corrugated-iron sheets, teak battens, and single, country or Mangalore tiles.

2. **Pitch.**—The pitch of the roof to be 25° or $\frac{\text{rise}}{\text{span}} = 2/9$.

3. **Scantlings.**—The scantlings given for Mangalore-tiled roofs in tables LXVII to LXIX will answer for these roofs also. The principals are prolonged at the eaves by pieces of wood bolted to them on one side, as in the double-tiled roof of purlin-rafter construction. Verandah principals are also similarly attached.

4. **Roof covering.**—

(*a*) Galvanized corrugated-iron sheets, 22 B. W. G., shall be laid over the purlins with laps of 6 inches at the ends and two corrugations at the sides.

(*b*) Sloping teak battens $1\frac{1}{2}'' \times 1\frac{1}{2}''$, to be laid over the ridges of the corrugations 18 to 21 inches centre to centre and securely screwed through the sheets into the purlins below. Between battens the corrugated sheet shall be fastened down to the purlins by two 3 inch screws. The battens to be in the greatest lengths procurable, no single piece being screwed to less than three purlins.

(*c*) The horizontal battens $2'' \times \frac{1}{2}''$ for country tiles and $1'' \times 1'' \times \frac{3}{4}''$ for Mangalore tiles, shall be fixed to the sloping battens on which tiles shall be laid in the usual manner. When country tiles are laid, they shall be protected at the eaves by wind ties of $1\frac{1}{4} \times \frac{1}{8}''$ inch bar iron, secured by $\frac{3}{8}$-inch bolts to the corrugated sheets below.

5. **Ridges and hips.**—The ridges and hips should be of the Mangalore pattern, with joints pointed with Portland cement mortar, or of galvanized-iron or sheet zinc, 20 B. W. G., laid in suitable lengths with 9-inch laps on each side. The capping at the ridge to be fixed to the two purlins immediately below it.

N.B.—(*b*) This class of roof covering has been used successfully at hill stations, such as Purandhar, Khandala, etc., in the Poona district, where the rainfall is heavy.

(*h*) Battens may not be used in the case of country round tiles if so specified.

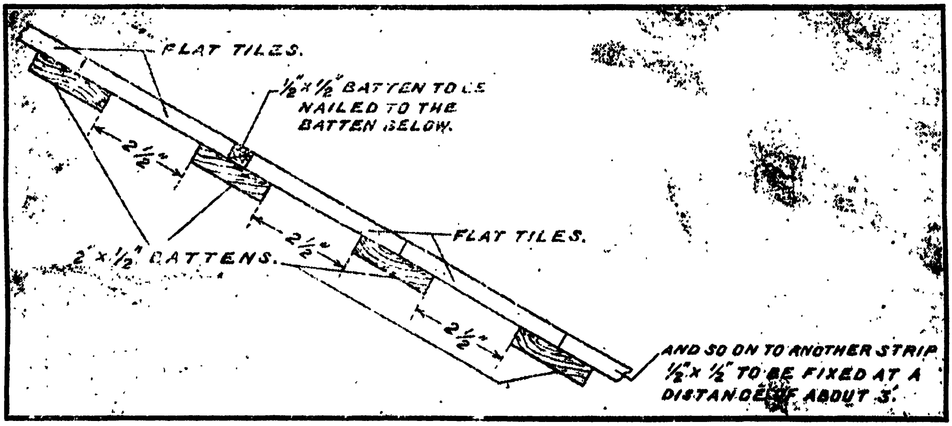
For Rates Abstract see p. 374.

BELGAUM-TILED ROOF COVERING.

Specification No. 109.

1. A layer of small flat tiles, $4\frac{1}{2}'' \times 6'' \times \frac{1}{2}''$, with edges rubbed to make close joints, soaked in pure white lime of about the consistency of cream, and allowed to dry. is laid dry on cut teak battens $2'' \times \frac{1}{2}''$ placed $2\frac{1}{2}$ inches apart in the clear ; on this is laid a layer of $\frac{1}{2}$ inch of ordinary mortar, and above this a single layer of semi-cylindrical tiles about $13\frac{1}{2}'' \times 4\frac{1}{4}''$ in size. Eaves and ridges are set in mortar.

2. It is necessary to have a $\frac{1}{2}'' \times \frac{1}{2}''$ batten running along the centre of and nailed to a $2'' \times \frac{1}{2}''$ batten, at every 3 feet down the roof slope from the ridge (see sketch). The flat tiles will abut against the narrow batten, and wholesale slipping of the roof, observed in most old roofs of this nature, will be stopped.



3. Belgaum tiled roofing is a most expensive roofing to maintain and keep watertight ; where ordinary $10'' \times 3\frac{1}{4}''$ tiles are used the roof should have double tiling. This kind of roofing should be used, only when no better roofing material is obtainable.

For Rate Abstract see p. 375.

ETERNIT SLATE ROOF COVERING.

Specification No. 110.

1. **Description.**—The roof shall consist of teakwood or steel trusses, the usual teak purlins, rafters, battens, etc., and Eternit slates as a roof covering.

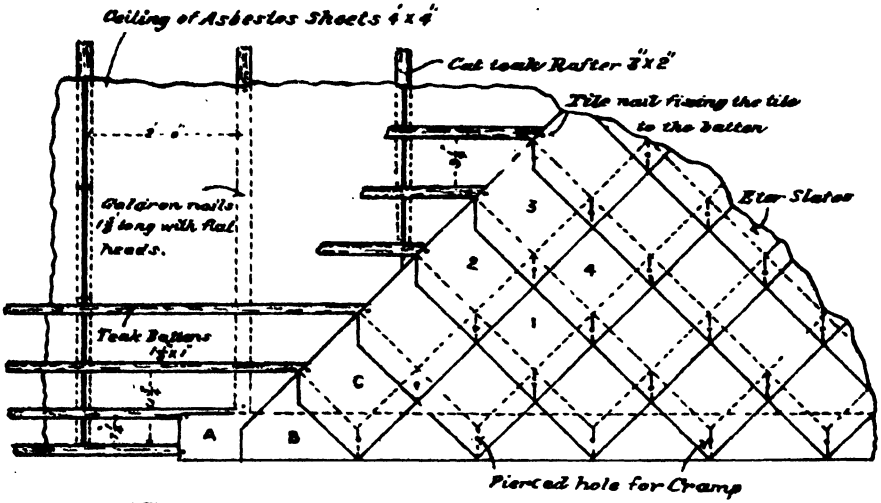
2. **Scantlings.**—The scantlings given for corrugated-iron roofs answer for this roof also.

3. **Battens.**—Eternit slates shall be fixed over teak battens, $1\frac{1}{2}'' \times 1''$, nailed $9\frac{1}{4}''$ apart centre to centre, the rafters being spaced 2 feet apart centre to centre.

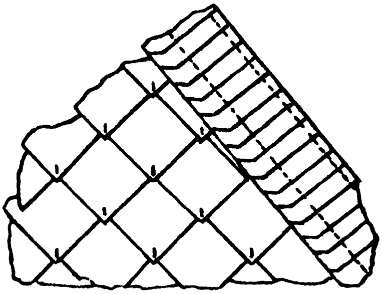
4. **Ceiling.**—When a ceiling is required asbestos sheets can be used in lieu of teak planking fixed directly over-rafters.

ETERNIT SLATE ROOF COVERING

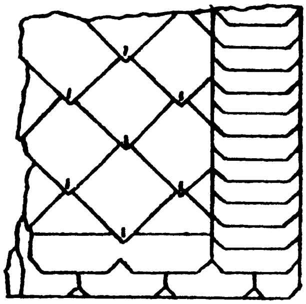
Plate XXVII



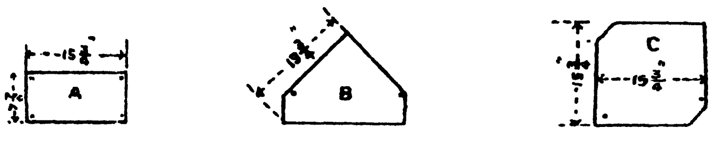
Hip Slating



Gable Slating



Eternit Slate Tiles



Cramp

These Cramps are copper discs with copper pin. The disc is slipped under the edges of the Slates 2 & 4 at point of contact & the pin passed through & turned down over 3 binding all together

Govt Photozinco: Office Poona 1949.

5. **Laying.**—In laying the slates the first row near the eaves consists of slates marked A, next is of slates B, and thence onward of slates C with an overlap of about 2¾ inches as shown in plate XXVII. Slates, A and B, are fastened by galvanized-iron wire or copper nails and slates, C, by nails and copper cramps. The chief slate is C, out of which any size can be cut.

6. **Ridge tiles.**—All requisite hip and ridge tiles to be of Mangalore pattern specials.

7. **Area covered.**—About 82 slates cover 100 sq. ft. of roof area. The standard size of slate C is 15¾″×15¾″, and they are generally made in three colours, grey, black and red.

Eternit slate roof covering is not affected by weather, is fire-resisting, light and cool. It requires very little maintenance.

Note.—This description of roof covering has been used for the Central Lunatic Asylum building at Yeravda, in the Poona district.

RUBEROID ROOF COVERING.

1. **Description.**—This is a light, flexible, non-absorbent roofing material, not attacked by white ants unaffected by extremes of heat or cold and thoroughly water-proof. Being a non-conductor of heat, it does not expand or contract and consequently the joints always remain water-tight and rooms covered with it are cool in the hot weather. It is available in two colours, *viz.*, slate and red.

2. **Weight.**—The weight of the material varies from one quarter to half a pound per square foot and, therefore, it requires very much lighter frame-work than is required with tiles.

3. **Laying.**—Ruberoid should be laid over ½″ or ¾″ teak planking, tongued and grooved, fixed to cut teak rafters spaced 2′ - 10″ centre to centre, so that the joints of the ruberoid fall over the rafters. It should be laid from the ridge to the eaves or parrallel to the eaves ; in the latter case, each higher course should overlap the lower by 2 inches. Ruberoid is secured to the planking with special nails (supplied by the makers), in the centre of every 2-inch joint. The joint is made water-tight by painting with ruberoid cement between the laps.

4. The approximate weight and prices of ruberoid per roll according to thickness are :—

TABLE LXXVII.

Roll 72′ × 3′ = 216 square feet.

Area of roof covered = 200 square feet, nett.

Description.	Weight per roll in lbs.	Approximate price per roll, delivered in Bombay with fixing materials.		Approximate area of roof covered with one ton of ruberoid.
		Rs. a.		
½ ply, grey ..	44	25 0	Inclusive of one packet of galvanized clout headed nails and one quart can of cold liquid cement for fixing on wooden roofs.	9,400 s. ft.
1 ply „	60	30 0		7,100 „
2 ply „	80 .	37 0		5,300 „
3 ply „	100	43 0		4,280 „
Red ruberoid ..	90	37 0		5,000 „
Red slate surfaced ruberoid.	36′ × 3′ wide roll.	25 0	With nails and cement for fixing on wooden roofs.	....

Ruberoid compound for fixing the above on concrete roofs supplied in ½ cwt. cases at Rs. 30 per cwt.

Note.—Ruberoid tears fairly easily and also burns.

TABLE LXXVIII.

SAFE STRESS FOR SQUARE OR RECTANGULAR WOODEN STRUTS IN LBS. PER SQUARE INCH.

l/b	Safe stress. Teak or Sal. A	B	Kail (blue pine) or Deodar. A	B	l/b	Safe stress. Teak or Sal A	B	Kail (blue pine) or Deodar. A	B
9 ..	1,070	983	650	596	35	280	164	200	123
10 ..	1,042	925	630	570	36	266	155	192	116
11 ..	1,012	865	609	537	37	252	147	184	110
12 ..	980	806	588	506	38	238	140	176	104
13 ..	936	749	567	476	39	224	132	168	99
14 ..	892	695	546	448	40	210	125	160	94
15 ..	848	642	525	422	41	204	119	154	90
16 ..	805	592	504	398	42	198	113	148	86
17 ..	768	546	483	375	43	192	107	142	83
18 ..	731	504	462	352	44	186	102	136	80
19 ..	694	465	441	329	45	180	97	130	77
20 ..	657	429	420	307	46	174	93	126	74
21 ..	620	399	404	286	47	168	89	122	71
22 ..	583	371	388	267	48	162	85	118	68
23 ..	546	345	372	250	49	156	82	114	64
24 ..	510	321	356	234	50	150	79	110	61
25 ..	475	300	340	219	51	144	76	108	59
26 ..	440	280	324	205	52	138	73	102	58
27 ..	420	261	308	191	53	132	70	98	56
28 ..	401	243	292	180	54	126	68	94	54
29 ..	382	226	276	169	55	120	66	90	52
30 ..	363	212	260	160	56	115	64	87	51
31 ..	344	202	248	152	57	110	62	84	49
32 ..	325	192	236	144	58	107	60	81	47
33 ..	309	182	224	137	59	103	58	79	46
34 ..	294	173	212	130	60	100	56	77	45

Note.—l is the length in inches and b is the least breadth in inches.

A = one end rounded, one end fixed ; B = both ends rounded.

For round posts take l/b = 1·15 × l/d, where d is the diameter in inches.

For both ends fixed take 6/10 × l/b, and use the figure given under B.

STEEL ROOF TRUSSES.

FIG 1.

Span — 25 ft.
Weight — 5½ cwts.

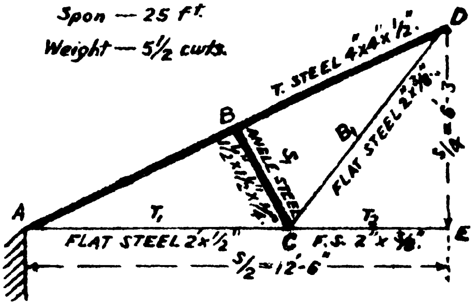


FIG 2.

Span — 30 ft.
Weight — 5½ cwts

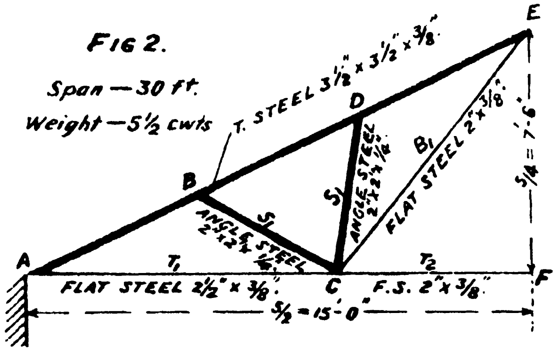
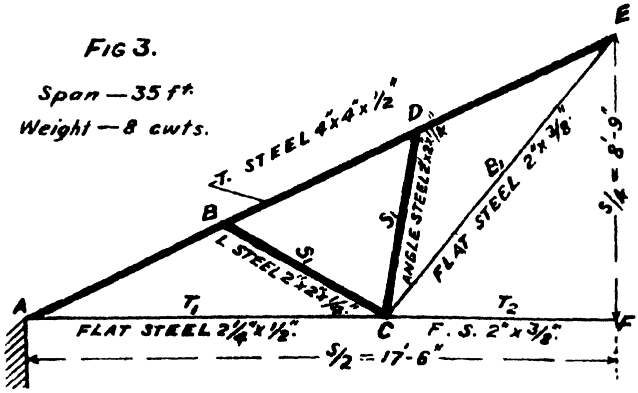


FIG 3.

Span — 35 ft.
Weight — 8 cwts.



NOTES:—(1) Trusses 10 feet apart.
(2) Heavy lines indicate Compression and light lines Tension Members.

To face page 273

G. P Z. P. POONA, 1949

TABLE LXXIX.

IRON STRAPS AND BOLTS FOR TEAKWOOD TRUSSES OF VARIOUS SPANS.

Span of roof.	Connecting principal and tie beam, and principal and posts.			Connecting tie beam and king or queen post.				Distance between end of strap and bolt.		Fish plates and bolts when required.	
	Diameter of bolt.	Strap.		Diameter of bolt.	Strap.			Principal and tie beam.	King post and tie beam.	Bolts.	Plates.
		Thick.	Wide.		Thick.	Wide.					
	In.	In.	In.	In.	In.	In.		In.	In.		
XII	$\frac{3}{4}$	$\frac{3}{8}$	$1\frac{1}{4}$	$\frac{5}{8}$	$\frac{3}{8}$	$\frac{3}{4}$	King post.	1	$\frac{3}{4}$		
XIV	$\frac{3}{4}$	$\frac{3}{8}$	$1\frac{1}{4}$	$\frac{5}{8}$	$\frac{3}{8}$	$\frac{3}{4}$		1	$\frac{3}{4}$		
XVI	$\frac{3}{4}$	$\frac{3}{8}$	$1\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{8}$	1		1	$\frac{3}{4}$		
XVIII	$\frac{3}{4}$	$\frac{3}{8}$	$1\frac{3}{4}$	$\frac{5}{8}$	$\frac{3}{8}$	1		$1\frac{1}{4}$	$\frac{3}{4}$		
XX	1	$\frac{3}{8}$	$1\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{8}$	1		$1\frac{1}{4}$	$\frac{3}{4}$		
XXII	1	$\frac{3}{8}$	$1\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{8}$	1		$1\frac{1}{2}$	$\frac{3}{4}$		
XXIV	1	$\frac{3}{8}$	$2\frac{1}{4}$	$\frac{3}{4}$	$\frac{3}{8}$	1		$1\frac{3}{4}$	$\frac{3}{4}$		
XXVI	1	$\frac{1}{2}$	$2\frac{1}{4}$	$\frac{3}{4}$	$\frac{3}{8}$	1		$1\frac{3}{4}$	$\frac{3}{4}$		
XXVIII	1	$\frac{1}{2}$	$2\frac{1}{4}$	$\frac{3}{4}$	$\frac{3}{8}$	1	Queen post.	$1\frac{3}{4}$	$\frac{3}{4}$	Bolts to be 1 inch square, 6 in number at 6 inch intervals counting from joints.	3/16" plate 10 times depth of beam in length, one in each side (not above and below) with bends clawed into timber.
XXX	1	$\frac{1}{2}$	$2\frac{1}{4}$	$\frac{3}{4}$	$\frac{3}{8}$	1		$1\frac{3}{4}$	$\frac{3}{4}$		
XXXV	$1\frac{1}{8}$	$\frac{5}{8}$	$2\frac{1}{2}$	$\frac{7}{8}$	$\frac{1}{2}$	$1\frac{1}{4}$		2	1		
XL	$1\frac{1}{4}$	$\frac{3}{4}$	$2\frac{3}{4}$	1	$\frac{5}{8}$	$1\frac{1}{2}$		$2\frac{1}{4}$	1		

STEEL TRUSSES.

General.

1. The variety of sections rolled in mild steel now obtainable, together with the practical advantage in design afforded by it, have caused the use of wood or iron for trusses, to be superseded to a great extent, especially for large spans.

2. The dimensions of the different members of steel trusses of different forms for spans of 25, 30, 35, 40, 45 and 50 are shown in detail on plates XXVIII and XXIX with their type connections.

3. When the principal rafters are long, they require support at intermediate points, which, with roofs of ordinary construction, should not be more than 7 to 8 feet apart. The trusses in this book are so designed, that the principal rafters are supported at intervals not greater than $7\frac{1}{2}$ feet, with as many of the braces, as is possible in tension and the struts as short as possible. Only such sections and scantlings as can be easily obtained in the market, have been adopted in these designs.

4. For small spans, from 25 to 35 feet, the principal rafters are of T section, united at the apex by a pair of covering plates riveted to both. Truss, Fig. No. 1, the bracing being nearly all in tension, is more economical than any other form, and is adopted for spans of from 25 to 30 feet.

5. As the span of the roof increases, the length of the rafters becomes such that they require support at more points than one, and, therefore, for spans of from 30 to 40 feet, truss, Fig No. 2, should be used. The tension members are all of flat olled steel bars on edge, which prevents them from sagging ; they, however, expose a large surface and cause a heavy appearance in small roofs.

6. All joints are shown in plates XXX and XXXI.

7. The roofs are designed to have a pitch of 1 in 2, that is, an angle of 26° 35′ with the horizon. The proportion 1 : 2, of rise to half the span, has been adopted as meeting general requirements.

8. The strength of the various parts is calculated for a horizontal wind pressure of 40 lbs. per square foot, or 40-sin 26° 35′ = 40 × ·447 = 17·88 lbs. per square foot pressure normal to the surface of roof, and for a roof covering not exceeding 13½ cwts. to a 100 square feet, (excluding the weight of the truss), with trusses 10 feet apart.

9. The tension members are designed to a working stress of 7½ tons per square inch, short struts to a compressive stress of 7½ tons, and long struts 7 tons per square inch.

10. The sizes of members of trusses for spans of 25 to 35 feet, have been calculated with both ends of the trusses fixed, and for spans of 40 feet and upwards, they are calculated with one end free to allow for the expansion and contraction caused by changes of temperature. The aggregate weight of the roof covering, consisting of Mangalore tiles, teak battens, ¾ inch thick teak planking and wooden purlins, is taken at 15 lbs. per square foot.

11. The outlines of the trusses with their dimensions are shown in Figs. 1 to 6 plates XXVIII and XXIX. Members by thick lines are in shown compression and by thin lines in tension.

Specification No. 111.

1. The steel tees, angles and flat bars to be used in trusses, should be well and cleanly rolled to the full sections shown on the contract drawings of steel trusses, or named in the specification.

2. All members should be free from scale, blisters, laminations, cracked edges and defects of any sort.

3. The steel must be of such strength and quality as to withstand safe tension and compression stresses of 7½ tons per square inch with a tensile breaking strength between the limits of 28 to 33 Tons per square inch of section and with an elongation of not less than 20 per cent. for steel 0·375″ or more in thickness, and not less than 16 per cent. thinner sections. The tensile breaking strength of rivet bars shall be between the limits of 25 to 30 tons per square inch of section with an elongation of not less than 26 per cent. measured on a standard gauge length of not less than eight diameters.

4. All rivets are to be of steel, and they must stand bending double, both hot and cold, and also flattening the head, until its diameter is 2½ times the diameter of the shank, without showing crackers or other defects.

STEEL ROOF TRUSSES.

FIG 4.

Span — 40 ft.

Weight — $8\frac{3}{4}$ cwts.

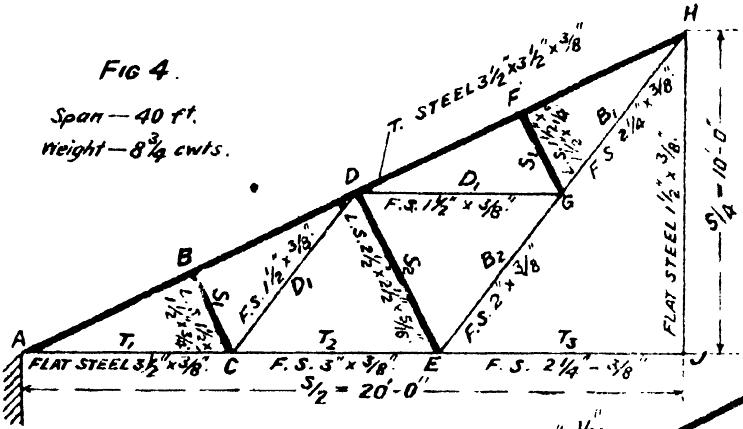


FIG 5.

Span — 45 ft.

Weight — $11\frac{1}{2}$ cwts.

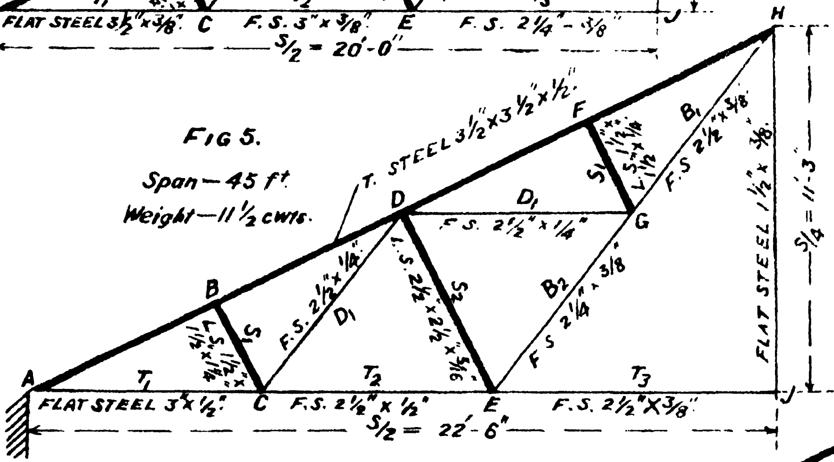
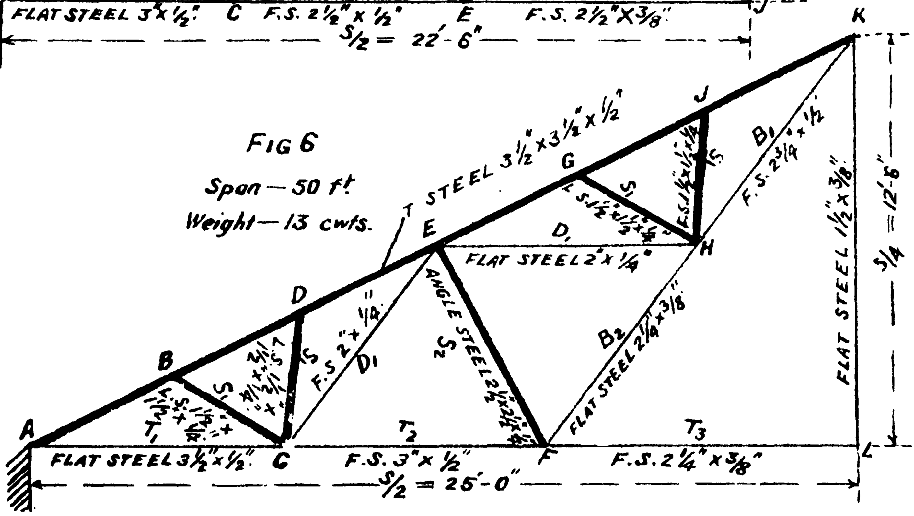


FIG 6

Span — 50 ft

Weight — 13 cwts.



Notes:— (1) Trusses 10 feet apart.

(2) Heavy lines indicate Compression and light lines Tension Members.

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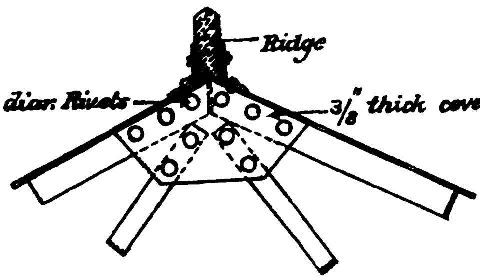
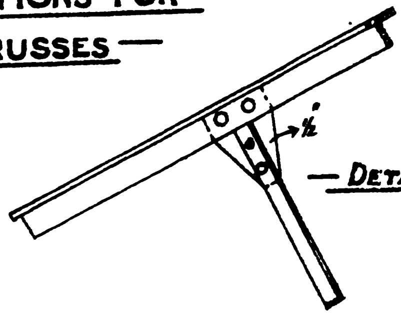
G. P. Z. P. POONA, 1949

Plate XXX

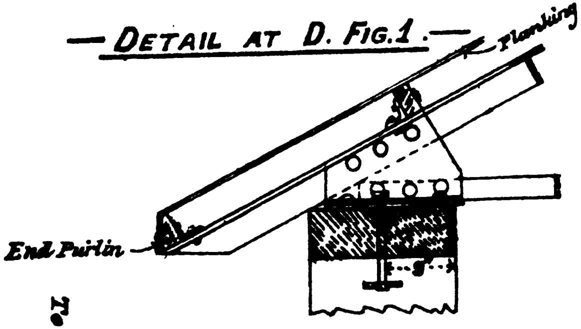
TYPE CONNECTIONS FOR ROOF TRUSSES



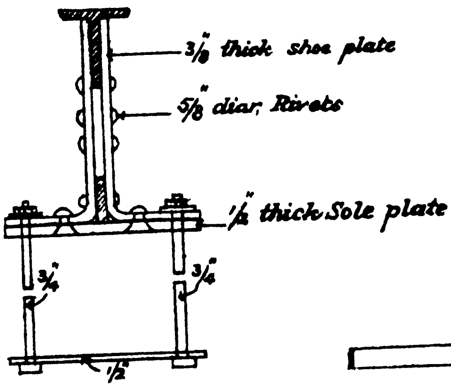
DETAIL AT D. FIG. 1.

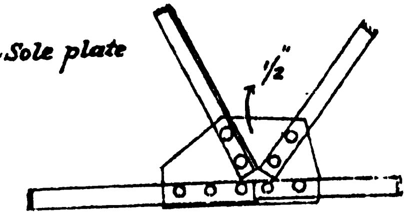


DETAIL AT B. FIG. 1



DETAIL AT A. FIGS. 1 & 2



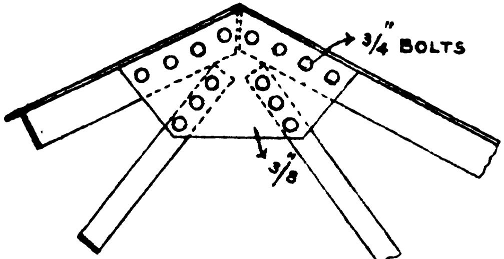


DETAIL AT C. FIG. 1

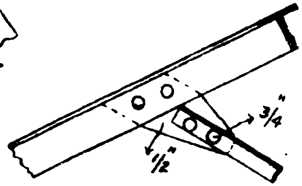
To face Page 274

Govt. Photozinco: Office Poona 1949.

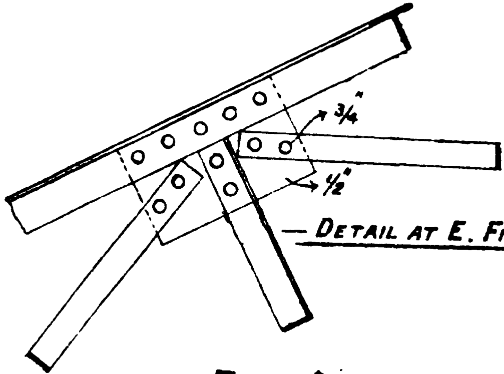
—Type connections for—
—Roof Trusses—



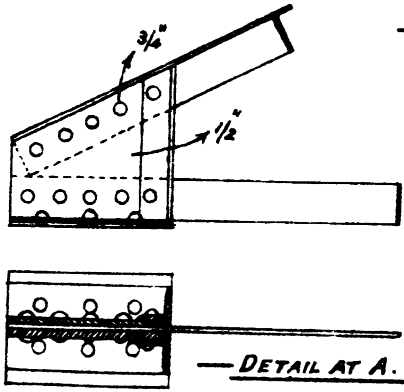
— Detail at K. Fig. 6 —



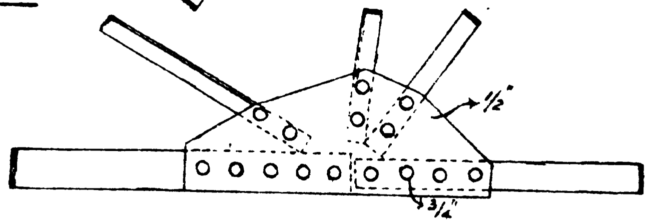
— Detail at B. Fig. 6 —



— Detail at E. Fig 6 —



— Detail at A. Fig. 6 —



— Detail at C. Fig. 6 —

Plate XXXI

To face Page 274.

Govt. Photozinco: Office, Poona 1949.

5. Tendering firms should submit with their tender the names of makers from whom they propose to obtain the steel. The quality of the steel to be employed should be " open hearth acid. "

6. All plates and bars should be carefully levelled and straightened (by pressure and not by hammering) before and after they are removed.

7. All holes should be drilled and all burrs left after drilling are to be completely removed.

8. For roofs of small spans the ends of trusses should be laid on lead sheets, and the holes for bolts which secure them should be slots, of an oblong form, so that the end can move slightly backward and forward on the lead.

9. The end from which the prevailing winds blow should invariably be fixed

10. In roofs of great span, the chair or saddle at the free end of the truss should be supported on steel rollers, so that it can move outwards and inwards with ease, when changes of dimensions are caused by temperature changes.

11. In sheds open at the sides, the trusses should be strongly braced together by wind ties, to secure them against the effect of gales.

12. The wind ties should pass from the foot of a principal rafter diagonally across three or four trusses (to which they should be secured) until they reach the ridge.

13. The wind ties should be arranged to converge in pairs and should be furnished, with adjustable joints.

14. The wooden purlins should be fixed to the principal rafters with angle irons, 5 inches long, as shown in Fig. 1, plate XXX.

15. All iron work should be painted with three coats of oil paint.

16. Stone or cement concrete templates, 6″ to 9″ thick, and of the full width of the walls, should be used to carry the trusses.

TABLE LXXX.

SCANTLINGS OF STEEL TRUSSES, 10 FEET APART.

Rise, H, $= \frac{S}{4}$ or angle 26° 35′; tie-bar, horizontal; style, triangular.

Mangalore-tiled roofs with $\frac{3}{4}''$ thick planking and wooden purlins.

Weight of roof, 15 lbs. per square foot; wind pressure, 18 lbs. normal per square foot.

Clear span in feet.	Principal rafter, T steel.	Struts, L steel.		Horizontal tie-bar of flat rolled steel.			Braces of flat rolled steel.		Diogonal braces. rolled steel	Suspending bar, rolled steel.	Weight of truss in cwts.
		S_1	S_2	T_1	T_2	T_3	B_1	B_2	D_1—D_2		
	in. in. in.	in. in. in.	in. in. in.	in. in.	in. in.	in. in.	in. in.	in. in.	in. in.	in. in.	
XXV ..	$4 \times 4 \times \frac{1}{2}$	$1\frac{1}{2} \times 1\frac{1}{2} \times \frac{1}{4}$	....	$2 \times \frac{1}{2}$	$2 \times \frac{3}{8}$	..	$2 \times \frac{3}{8}$	..	..	..	$5\frac{1}{2}$
XXX ..	$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{3}{8}$	$2 \times 2 \times \frac{1}{4}$	....	$2\frac{1}{2} \times \frac{3}{8}$	$2 \times \frac{3}{8}$	..	$2 \times \frac{3}{8}$	..	..	..	$5\frac{1}{2}$
XXXV ..	$4 \times 4 \times \frac{1}{2}$	$2 \times 2 \times \frac{1}{4}$	....	$2\frac{1}{4} \times \frac{1}{2}$	$2 \times \frac{3}{8}$	..	$2 \times \frac{3}{8}$	..	..	..	8
XL ..	$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{3}{8}$	$1\frac{1}{2} \times 1\frac{1}{2} \times \frac{1}{4}$	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$	$3\frac{1}{2} \times \frac{3}{8}$	$3 \times \frac{3}{8}$	$2\frac{1}{4} \times \frac{3}{8}$	$2\frac{1}{4} \times \frac{3}{8}$	$2 \times \frac{3}{8}$	$1\frac{1}{2} \times \frac{3}{8}$	$1\frac{1}{2} \times \frac{3}{8}$	$8\frac{3}{4}$
XLV ..	$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{1}{2}$	$1\frac{1}{2} \times 1\frac{1}{2} \times \frac{1}{4}$	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$	$3 \times \frac{1}{2}$	$2\frac{1}{2} \times \frac{1}{2}$	$2\frac{1}{2} \times \frac{3}{8}$	$2\frac{1}{2} \times \frac{3}{8}$	$2\frac{1}{4} \times \frac{3}{8}$	$2\frac{1}{2} \times \frac{1}{4}$	$1\frac{1}{2} \times \frac{3}{8}$	$11\frac{1}{2}$
L ..	$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{1}{2}$	$1\frac{1}{2} \times 1\frac{1}{2} \times \frac{1}{4}$	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$	$3\frac{1}{2} \times \frac{1}{2}$	$3 \times \frac{1}{2}$	$2\frac{1}{4} \times \frac{3}{8}$	$2\frac{3}{4} \times \frac{1}{2}$	$2\frac{1}{4} \times \frac{3}{8}$	$2 \times \frac{1}{4}$	$1\frac{1}{2} \times \frac{3}{8}$	13

Calculations of roof trusses.

Table of cœfficients for the determination of stresses, and lengths of members, in roof trusses for any span, the proportion of height to half the span being 1 : 2.

To find the stress in any member :—

Let S = span between the points of intersection of the rafters and tie.

L = total dead load carried by the truss, including its own weight.

W = total wind pressure resisted by the truss, acting on one side of the roof and normal to its surface.

F = total stress required.

Then F = (L, multiplied by the cœfficient for dead load) + (W, multiplied by the cœfficient for wind pressure).

Note.—In trusses of larger spans it is sometimes advisable to provide for expansion, in which case the cœfficient for wind pressure corresponding to "one end free" should be used.

To find the length of any member between points of intersection :—

Multiply S by the length cœfficient for that member.

Note.—The following stress cœfficients have been calculated, on the assumption that the roof purlins occur over the points of intersection of the various members with the common rafter; when such is not the case, bending is produced in the rafter, which necessitates further calculation, or allowance being made when deciding its section.

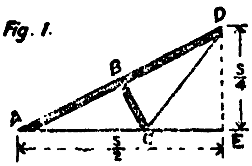
TABLE LXXXI.

STRESS AND LENGTH COEFFICIENTS FOR STELL TRUSSES

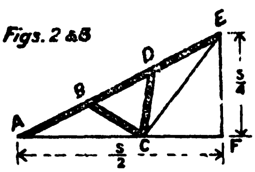
Figure No.	Member of truss.	Stress cœfficients. Dead load.	Normal wind pressure. Both ends fixed.	Normal wind pressure. One end free.	Length cœfficients.
1	A B	·838	·875	..	·27950
	B D	·727	·875	..	·27950
	B C	·223	·500	..	·13975
	A C	·750	·978	..	·31250
	C E	·500	·419	..	·18750
	C D	·250	·559	..	·31250
2 & 3	A B	·932	1·042	..	·18634
	B D	·758	·820	..	·18634
	D E	·783	1·042	..	·18634
	B C	·179	·401	..	·16797
	D C	·179	·401	..	·16797
	A C	·833	1·165	..	·31250
	C F	·500	·419	..	·18750
	C E	·333	·746	..	·31250
4 & 5	A B	·978	1·125	1·125	·13975
	B D	·922	1·125	1·125	·13975
	D F	·866	1·125	1·125	·13975
	F H	·811	1·125	1·125	·13975
	B C	·112	·250	·250	·06987
	F G	·112	·250	·250	·06987
	D E	·224	·500	·500	·13975
	A C	·875	1·258	1·397	·15625
	C E	·750	·978	1·118	·15625
	E J	·500	·419	·559	·18750
	C D	·125	·279	·279	·15625
	D G	·125	·279	·279	·15625
	G H	·375	·838	·838	·15625
	E G	·250	·559	·559	·15625

Figure

Fig. 1.



Figs. 2 & 3



Figs. 4 & 5

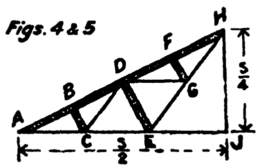
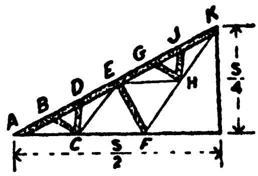


TABLE LXXXI—*contd.*

Figure No.	Member of truss.	Stress coefficients.			Length coefficients.
		Dead load.	Normal wind pressure.		
			Both ends fixed.	One end fixed.	
	A B	1·025	1·208	1·208	·09317
	B D	·938	1·097	1·097	·09317
	D E	·950	1·208	1·208	·09317
	E G	·913	1·208	1·208	·09317
	G J	·826	1·097	1·097	·09317
	J K	·838	1·208	1·208	·09317
	B C	·090	·200	·200	·08398
	D C	·090	·200	·200	·08398
6	G H	·090	·200	·200	·08398
	J H	·090	·200	·200	·08398
	E F	·224	·500	·500	·13975
	A C	·917	1·351	1·491	·15625
	C F	·750	·978	1·118	·15625
	F L	·500	·419	·559	·18750
	C E	·167	·373	·373	·15625
	E H	·167	·373	·373	·15625
	H K	·417	·932	·932	·15625
	F H	·250	·559	·559	·15625

Figure.

Fig. 6



Note.—The method of using this table is explained in the example worked out under table LXXI.

TERRACED ROOFING

Specification No. 112.

1. **Description.**—Consists of a layer of flat tiles, soaked in thick whitewash, and set in lime mortar, over 3 inches of fine concrete, which is placed on two layers of flat tiles, also set in mortar, and supported on teak scantlings placed one foot apart.

2. **Flat tiles.**—The lower layers of flat tiles 12″ × 6″ × 1″ to be laid in two courses one above the other, breaking joint with one another. Both layers to be laid with edges of tiles well rubbed, and drawn up with mortar. The upper layer to be embedded in mortar on the lower.

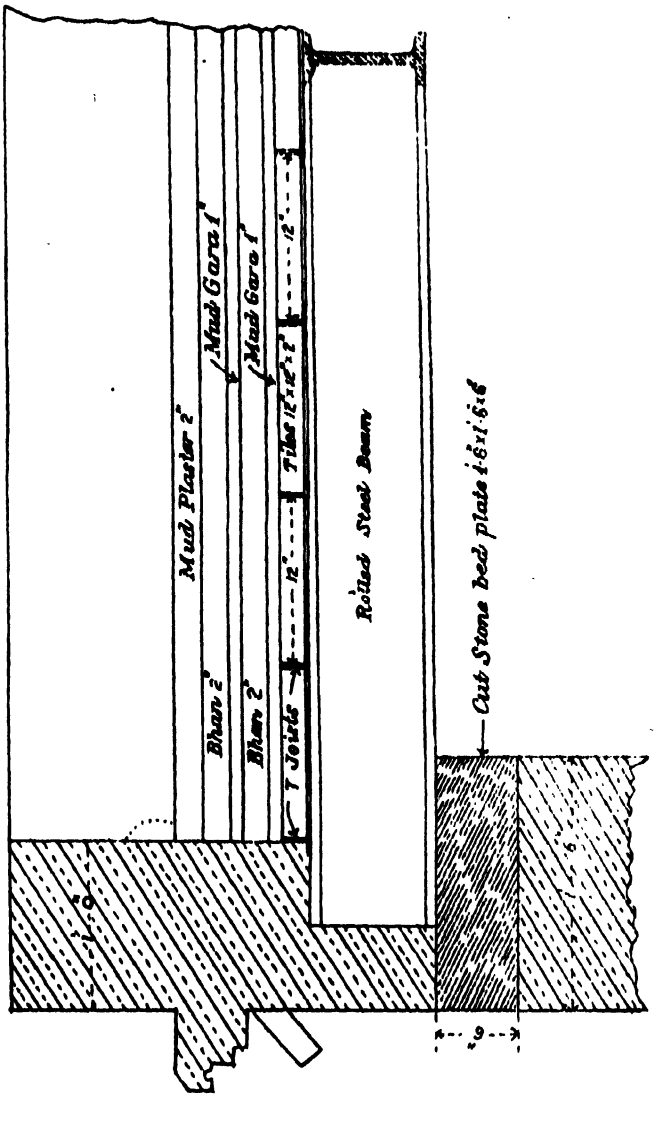
3. **Concrete.**—The concrete to be prepared as specified with slaked lime, clean sharp sand, and screened, shingle, in the proportions laid down. After the concrete has been spread, it will be wetted and beaten with light quick strokes with a hand flail, till the mortar is drawn up to the surface and the mass is well set.

4. **Upper layer of tiles.**—Over the concrete, a layer of tiles s milar to those described in paragraph 2, shall then be set. The tiles to be well soaked in thick whitewash, their edges rubbed, and drawn up with mortar as above described.

5. **Joists and wall plates.**—The whole to be supported on teak joists placed at central distances of 12 inches apart and of the scantlings given in the foot-notes, unless otherwise specified. The joists rest on wall plates 4″ × 3″ built in the wall, or on corbels outside it.

Plate XXXII

— TYPE —
- of -
— FLAT TERRACED SIND ROOF —
— Scale 1 foot to 1 inch —



To face Page 279.

6. **Slope.**—The roof to be laid with a slope of about ½ inch to a foot to drain away rain-water.

7. **String course.**—At the junction of the roof covering with any wall, a string course, projecting inside not less than 4 inches, to be built into the wall leaving 2 inches clear space above the upper surface of the roof, and this space to be carefully filled in with concrete, to prevent leakage down the wall.

Note.—The weight of terraced roofing is assumed to be 75 lbs. per square foot, including wood-work.

8. Scantlings of joists for the following spans :—

VI	feet span	3×3½	inches.	XIV	feet span	3×7½	inches.
VIII	do.	3×4½	do.	XVI	do.	3×8½	do.
X	do.	3×5½	do.	XVIII	do.	3×9½	do.
XII	do.	3×6½	do.	XX	do.	3×10½	do.

For Rate Abstracts see pp. 375 and 376.

FLAT TERRACED SIND ROOFING

Specification No. 113.

1. **Description.**—To consists of well-burnt tiles measuring 12″×12″×2″, set in lime mortar over light T steel joists 2″×2″×¼″, (as per section shown in plat XXXII) laid (flange downwards) on rolled steel beams, at central distances of 12½ inches, over which the following materials will be laid.

2. **Layers.**—Over the tiles there will be layers, of mud *gára* 1 inch thick, of *bhán* 2 inches thick, mud *gára* 1 inch thick, and *bhán* 2 inches thick ; and lastly, a plastering of mud *gára* 2-inches thick.

3. **Painting.**—All iron work to be properly cleaned and painted with one coat of red lead, which shall be included in the rate. The underside of the tiles to be either painted two coats of white zinc paint after a priming coat of raw linseed oil, or white washed, after the underside is brought to a smooth surface and pointed.

4. **Slope.**—The top surface of the roof to be laid with a slope of about ½ inch to a foot to drain away rain water.

BRICK-ON-EDGE ROOFING

Specification No. 114.

1. **Description.**—To consist of bricks laid on edge over teak joists which are to be from 1¼ to 2 feet apart from centre to centre. The bricks to be thoroughly wetted, and to be laid on edge in lime mortar over the joists diagonally.

2. **Joints.**—The mortar joints not to exceed half an inch.

3. Over the bricks-on-edge one layer of bricks to be laid flat in mortar, and the roof should then be left flooded with water about 3 inches in depth until uniform staunching is exhibited.

4. Over the flat bricks a layer of concrete 3 inches thick to be added, and neatly finished off with half an inch of lime plaster.

5. The lower surface of the roof to be neatly plastered with ½ inch of lime plaster, and white or colour-washed.

FIRE-RESISTING TERRACED ROOFING

Specification No. 115.

1. **Description.**—The roofing to consist of 3 inches of ordinary concrete, resting on a layer of bricks 2½ inches thick, supported on tee steel joists and rolled steel beams, as described below.

2. **Rolled steel beams.**—The rolled steel beams to be of the appropriate dimensions, laid down in table LXXXII, and to be laid at central distances of 4 feet. The ends of these beams to be built into the walls, and to rest on bed-plates of ¼ inch iron boiler plate, 18 inches long and 9 inches broad.

3. **Tee steel joists.**—The tee steel joists to measure 2″ × 2″ × ¼″ in all cases, and to be laid (flange downwards) on the rolled steel beams above alluded to, at central distances of 12½ inches. The continuous lengths of these joists to be secured together by means of U-shaped clips of boiler plate iron, 1½ inches broad and ¼ inch thick, hammered over them to keep them in position.

4. **Paving bricks.**—The spaces between the tee steel joists to be filled in with a single layer of sound, well-burnt bricks, 2½ inches thick, set in Portland cement mortar, with two courses of flat tiles, measuring 12″ × 6″ × 1″ one above the other, breaking joint with one another. In either case to be laid with the smooth face downwards, pointed from below, and with sides well rubbed and drawn up with mortar as above.

5. **Concrete.**—Concrete to consist of 1 part slaked lime, 2 parts sand, and 5 part screened shingle, and to be prepared as specified separately. The upper surface to be finished off with a half-inch coat of Portland cement plaster, or preferably paved with red flooring tiles. After the concrete has been spread it will be beaten with light rammers or hand flails, till the mortar is drawn up to the surface and the mass is well set.

6. **Slope.**—The roof to be laid with a slope of about ½ inch to a foot to drain away rain-water.

7. **String course.**—At the junction of the roof covering with any wall, a string course projecting not less than 4 inches, to be built into the wall 2 inches above the upper surface of the roof, and this space to be carefully filled in with concrete, to prevent leakage down the wall.

8. **Painting.**—All steel work to be properly cleaned and painted with one coat of red lead, which is to be included in the rate. The under-surface of the roof to be painted with two coats of the colour and description ordered.

9. **Camber.**—The beams to be combered to a rise of about 1 inch in 15 feet, and to be shored up from below while the concrete is being laid and rammed.

TABLE LXXXII.

FIRE-RESISTING TERRACE ROOFING.

Giving section of girders and approximate cost per 100 square feet.

Span in feet.	Area supported.	Rolled steel beams 4 feet apart at Rs. 14·4 per cwt. including cost of carriage, painting and fixing.							Cost of T steel, concrete and bricks laid complet. at Rs. 76·14 per 100 S. F.	Contingencies including bed plates, etc., at 5 per cent.	Total cost of area in column 2.	Rate per 100 S. F. roofing complete.
		Length.	Height of web.	Breadth of flange.	Thickness of web.	Weight per R. F.	Total weight.	Cost.				
	S. F.	Feet.	In.	In.	In.	Lqs.	Lbs.	Rs. a.	Rs. a.	Rs. a.	Rs. a.	Rs. a.
VI ..	24	8	4	4	17	5	40	5 1	18 7	1 3	24 11	103 2
VIII ..	32	10	4¾	1¾	·18	6½	65	8 4	24 9	1 11	34 8	107 13
X ..	40	12	4	3	·22	9½	114	14 8	30 12	2 4	47 8	118 12
XII ..	48	14	5	3	·22	11	154	19 9	36 15	2 13	59 5	123 9
XIV ..	56	16½	6	3	·26	12	198	25 3	43 0	3 6	71 9	127 14
XVI ..	64	18½	7	4	·25	16	296	37 11	49 3	4 5	91 3	142 8
XVIII ..	72	20½	8	4	·28	18	369	46 15	55 5	5 2	107 6	149 4
XX ..	80	22½	9	4	·30	21	472·5	60 1	61 8	6 1	127 10	159 9

Note.—Calculated to support a load of 100 lbs. per square foot.

GUTTERS, VALLEYS AND FLASHINGS.

Specification No. 116.

1. **Fall.**—Gutters should have a fall of at least 1 inch in 10 feet, more being always given if possible.

2. **Valleys.**—To consist of 1-inch teak planking supported on bearers properly fastened to the rafters, not less than 6 inches wide at the bottom, and turned up under the tiles 12 inches on each side, covered with (*a*) good milled lead not less than 6 lbs. to the square foot, copper nails being used in fastening lead to wood-work; (*b*) or sheet zinc, 18 or 19 B. W. G.; (*c*) or sheet iron not less than 1/16 inch thick bent to the shape required properly secured to the boarding. The boarding to be well dammered before sheeting is fixed to it.

3. **Flashings**—To be of 5 lbs. milled lead or 18 B. W. G. zinc, if possible built into the wall, or otherwise to be fastened into a groove ¾ inch deep, with wall hooks and Portland cement.

4. **Joints.**—All junctions and joints to be sound and thoroughly water-tight. Longitudinal joints to be formed on 2-inch wooden rolls, and joints at right angles to the flow by a drip with a proper lap, if levels permit, or by 3-inch joints of folded lead.

In iron gutters, joints to be made by riveting on externally a piece of iron of the shape of the gutter, the ends being first made to butt clean and sharp.

For Rate Abstract see p. 377.

DOWN PIPES.

Specification No. 117.

1. **Sheet iron.**—Down or rain-water pipes of cast-iron are costly and heavy. As a rule, they will be made of sheet iron bent on a cylindrical core and carefully riveted together. the sides having a lap of ⅝ inch beyond the rivet heads. The ends of the various lengths will butt firmly upon each other, and will be joined together by a collar of the same material, a least 6 inches long, which will first be riveted together and then shrunk on. They shall be firmly secured to the wall by semi-circular collars with flanges and flat nails 6 inches long at intervals of not more than 6 feet; joints to be made perfectly water-tight.

2. **Painting.**—If sheet iron is not galvanized, it shall receive at least three coats of paint internally and externally.

Note :—Asbestos cement down pipes are now available in the market.

RAINWATER SPOUTS FOR FLAT SIND ROOF.

Specification No. 118.

To be of iron sheet 1/16 inch thick, trough shaped, and 3 feet long × 4″ × 2″ in section, or earthenware pipes 3′ long, 4″ diameter at the upper end and tapering to 3″ at the outer end, and laid an inch below the finished surface of the roof with a slope of not less than 1 in 5 and projecting 1½ to 2 feet from the face of the wall. Iron spouts to be well coal-tarred before being laid.

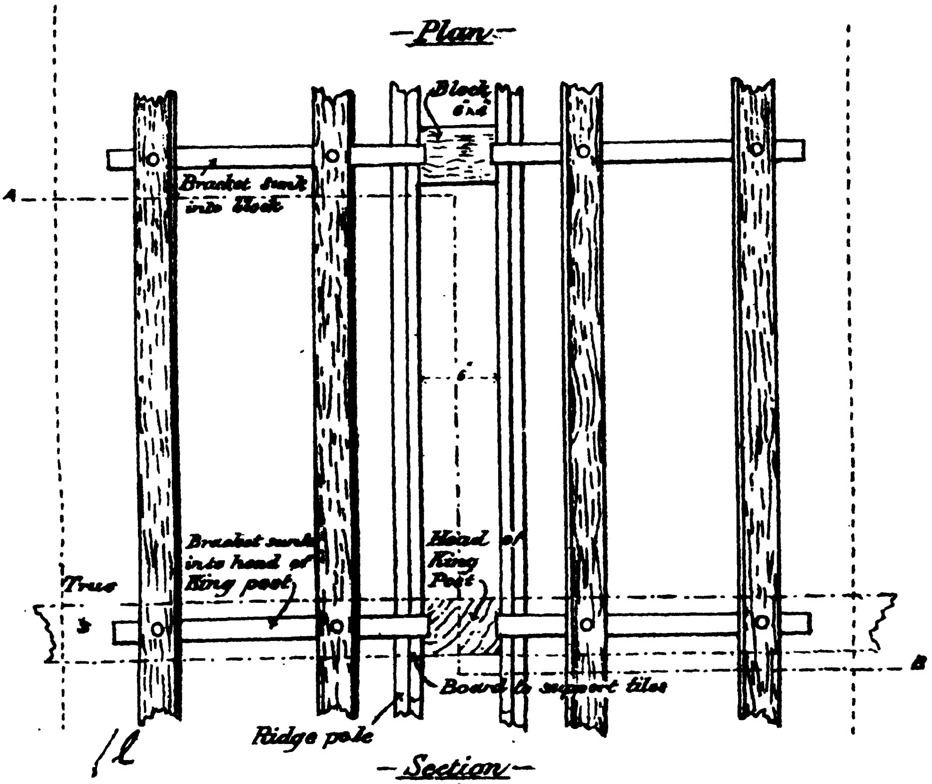
Plate XXXIII.

—Ridge Ventilator—

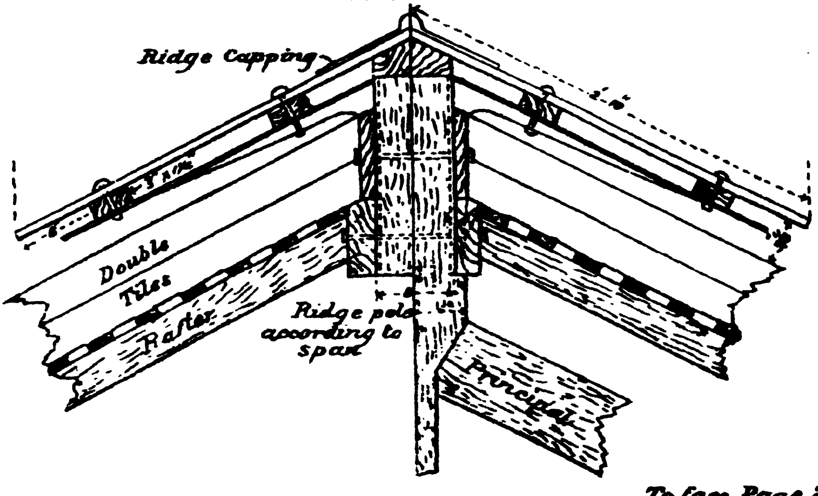
—Howard's Pattern—

Scale 1 Foot to an Inch

—Plan—



—Section—



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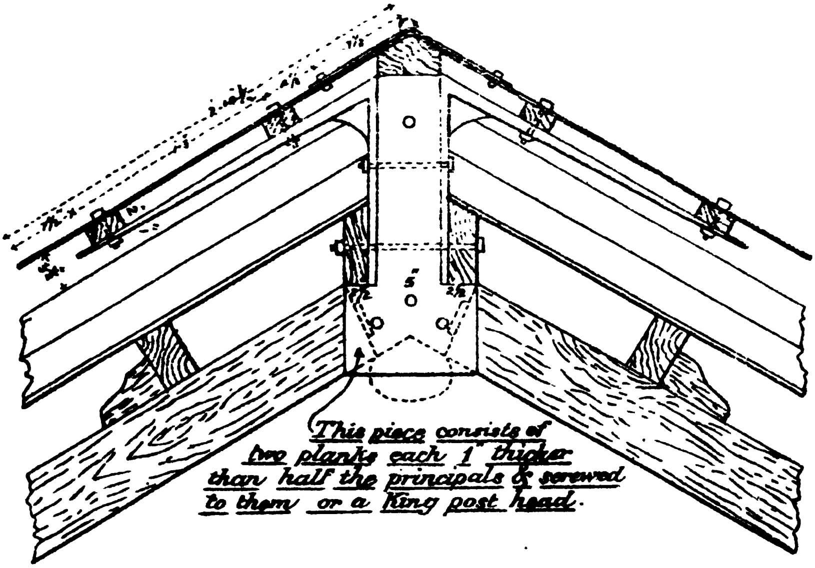
Govt. Photozinco: Office. Poona. 1849

Plate XXXIV.

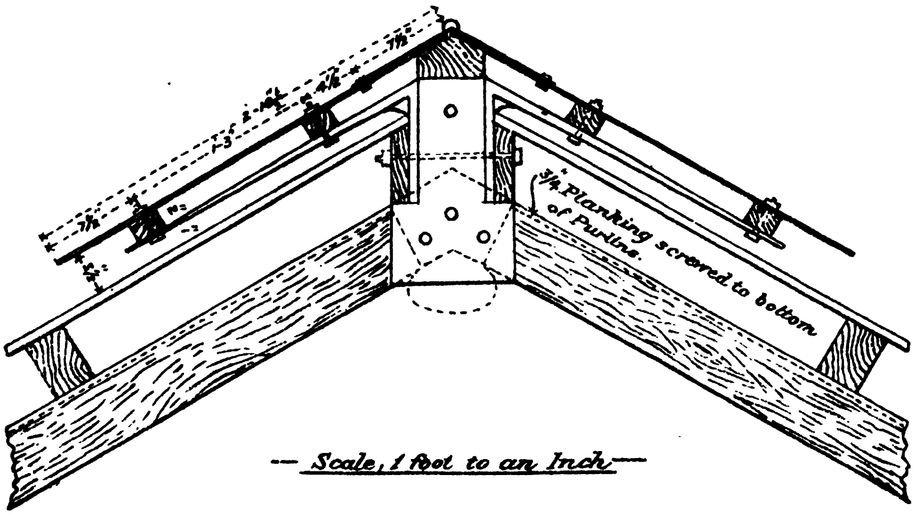
—HOWARDS VENTILATOR—

—*Adapted for purlin roof queen post truss.*—

—DOUBLE TILES—



—CORRUGATED IRON.—



— *Scale, 1 foot to an Inch* —

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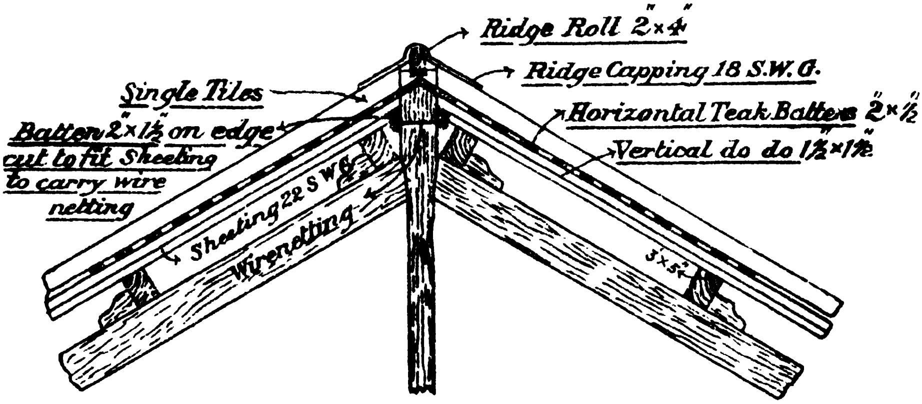
Govt Photozinco Office Poona 1949

— RIDGE ROLL VENTILATOR —

— Scale 2 Feet to 1 Inch. —

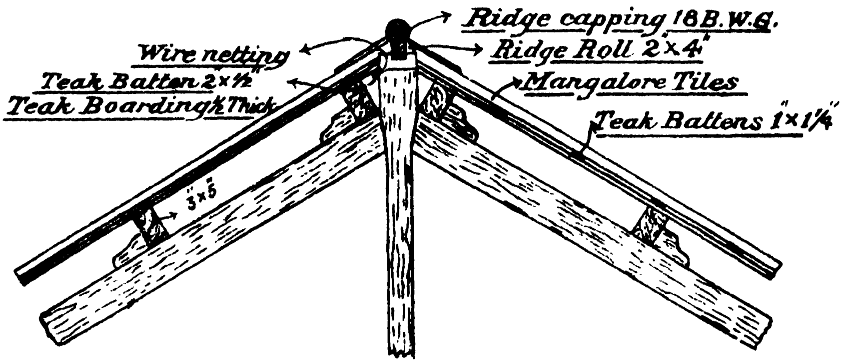
— FOR SINGLE TILES —

— FIG. 1 —



— FOR MANGALORE TILES —

— FIG. 2 —



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Govt. Photozinco Office Poona 1949.

RIDGE VENTILATOR.

(Howard's pattern.)

Specification No. 119.

1. **Ridge poles.**—Two ridge poles of suitable dimensions to be provided, one on either side of the head of the king post with a clear space of 6 inches between them.

2. **Ventilating space.**—This space will be preserved by means of cleats placed at intervals of 3 or 4 feet along the length of the ridge. The space between the two ridge poles forms an exit for foul air.

3. **Cast-iron brackets.**—To form a covering to protect the space, and at the same time to allow of the escape of foul air, the vertical limbs of the two light cast-iron brackets are secured to the inner face of either ridge pole, at the points where the cleats above mentioned occur. Two bolts are passed through the ridge poles' brackets and cleats, thus securing them in their proper places.

4. **Slope.**—The sloping limb of the cast-iron bracket, which has the same angle as the roof, depends over the main roof, so forming a line of supports for the ridge covering.

5. **Ventilator covering.**—The most durable and economical material for the ridge covering is corrugated-iron. Two battens, 3 × 1¼ inch on either bracket together with a ridge piece, is all the wood-work that is necessary. The corrugated-iron is bolted to the bracket, the bolt passing through the batens. (See plates XXXIII and XXXIV.)

6. When the roofing is of tiles, a pair of boards must be provided and secured on either side of the head of the king posts against which the ends of the tiles abut.

Note.—This ventilator is especially adopted for tiled roofs, will and has been largely used on the barracks at Poona, Kirkee, Ahmedabad, Ahmednàgar, Belgaum and Deolali. It can be adopted for either king or queen post trusses. Its cost in Bombay is about Rs. 6-3-0 per lineal foot, including cast-iron brackets, corrugated sheets, ridge capping, and all bolts and nuts.

RIDGE ROLL VENTILATOR.

1. In cases in which the ventilating area with a Howard's ventilator is greater than is necessary, ridge roll ventilators may be used.

2. The general arrangement is shown in plate XXXV, Figs. 1 and 2.

Note.—The arrangement has been largely used in the Poona district and found satisfactory and sufficient.

LIGHTNING CONDUCTORS.

Specification No. 120.

1. **Materials.**—To be copper rod (or rope) ½″ diameter or copper tape. If copper tape is used it should be 1″ × ⅛″, but a tape ¾″ × ⅛″ is sufficient for conductors less than 80 feet in length. Galvanized-iron telepraph wire weighing 600 lbs per mile (No. 5 S. W. G.) is quite big enough for iron conductors.

2. **Upper terminals or points.**—The upper end of the conductor under all circumstances to be a solid copper rod, ¾″ in diameter, terminating in a cone of which the height is equal to the radius of its base. To project at least 5 feet into the air, above the highest points of the building to which it is applied.

3. **Conductor.**—The conductors to be attached to the building by proper hold-fasts, not more than 4 feet apart, to be perfectly continuous from the top to the bottom, and preferentially to be taken down the side of the building most exposed to rain. For a height of 10 feet above the ground surface, the conductor should be protected from injury or theft, by being enclosed in a 2 or 2½ inch cast-iron pipe secured to the wall. All metal surinacesfridges, roofs, gutters, etc., to be connected by plates of copper with the conducting system.

4. **Joints.**—All joints in copper rods, besides being well cleaned, screwed, scraped or riveted, to be soldered in addition.

When iron wire used, it is to be jointed by binding the ends together, for about 4 inches, with a thin iron wire No. 14 S. W. G. and then soldering. (When possible the services of a telegraph lineman should be requisitioned for this work, as he is accustomed to it, and having tools available, will do it quickly and well.)

5. **Earth connection.**—The lower extremity of the conductor to be carried about 3 feet into the ground. A copper tape, 1″ × ⅛″ to be then soldered to it carried along a trench 30 to 40 feet in length, and connected with a copper plate not less than 9 square feet in area and 1/16 inch thick, buried in permanently wet earth and surrounded with charcoal. The copper tape to be laid in charcoal, and the trench filled up with sand. The plate should be buried from 15 to 20 feet from the building, and if practicable, two or three feet below the water level in the driest season of the year. Where the permanent water level is deep, it is necessary to provide shallow earths in trenches laid away from the building, the depths varying from 1 foot in clay soils, to 2 feet in sand or shingle through which the rain percolates more freely. The length of these trenches should be from 10 to 30 yards in dry soil. The "earth" connection must be joined to the conductor by a well-soldered joint mechanically and electrically perfect. The result of the test should not be considered satisfactory, until the resistance of the lightning conductor earth is found to be less than 10 ohms. or still less for magazines.

In Bombay, the earth connection is frequently made by fastening the end of the copper wire to a copper plug, riveted and soldered, and inserting the latter by a coupling or T joint into the nearest water main or service pipe.

The cost of the plates and all connections and joints, charcoal, etc., to be included in the rate for the conductor. Nothing extra will be allowed.

6. The measurement will be taken from the highest point of the conductor to the bottom of the earth plate.

7. **Surface drainage.**—The surface drainage in the vicinity to be regulated, if possible, to flow over the site of the trench.

8. **Painting.**—Iron rods should in all cases be painted. If rods are of copper, they may be painted or not according to architectural requirements.

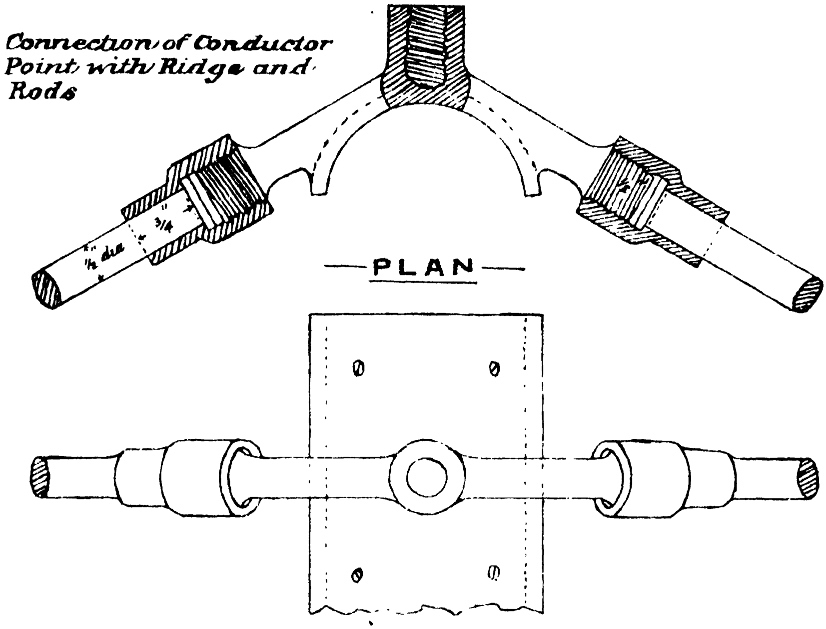
9. **Curvature.**—The rod should not be bent abruptly round sharp corners, and should, if possible, be passed straight through cornices, string courses, etc. If bending is necessary, the length of rod between the ends of curve should in no case be more than half as long again as the straight line joining them.

Plate XXXVI.

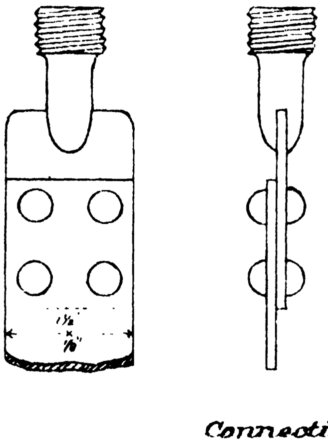
— LIGHTNING CONDUCTORS —

Scale – Half Size.

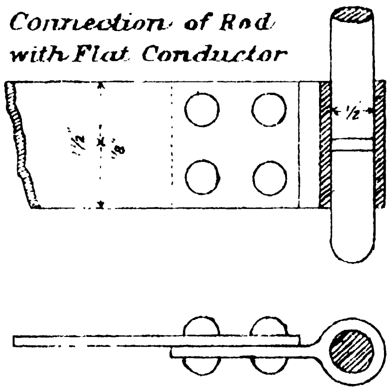
— Ridge connections for Copper Conductors. —



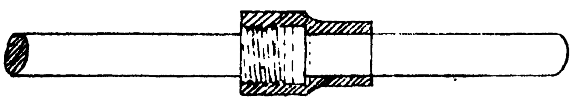
Connection of Plat with Rod Conductor



Connection of Rod with Flat Conductor



Connections for Rod.



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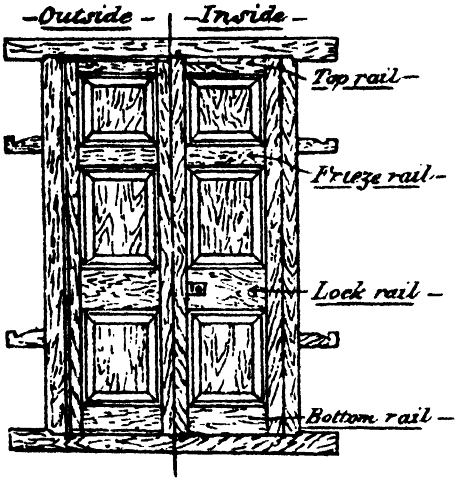
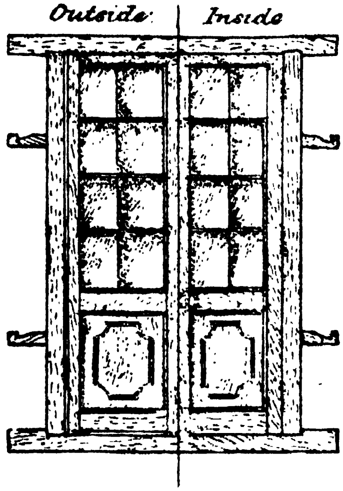
— DOORS —

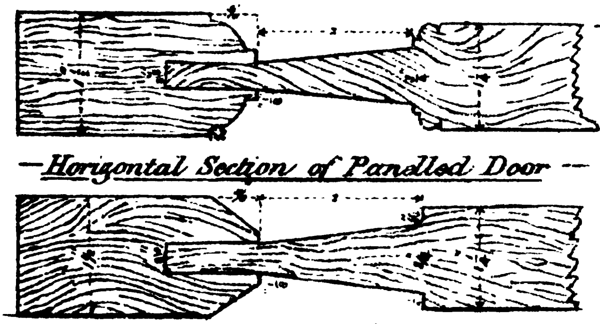
Plate XXXVII

— DOOR PANELLED —



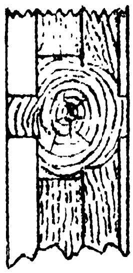
— DOOR PANELLED & GLAZED —



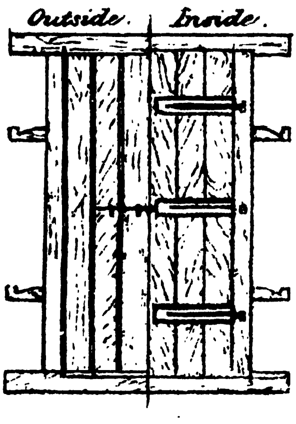


—Horizontal Section of Panelled Door —

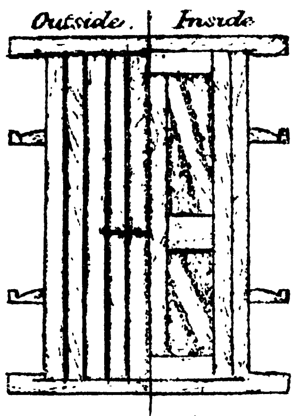
— Section of Sash Bar -



— DOOR PLANKED OR LEDGED —



— DOOR FRAMED & BRACED —



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Sizes and weights of copper conductors.

Rods—

Per ft. run.		Ozs.
$\frac{3}{8}$ inch	...	6·88
$\frac{1}{2}$,,	...	12·16
$\frac{5}{8}$,,	...	19·0
$\frac{3}{4}$,,	...	27·0

Tubes, $\frac{1}{8}$-inch metal—

Per ft. run.		
$\frac{5}{8}$ inch	...	16·5
$\frac{3}{4}$,,	...	21·4
1 ,,	...	27·0
$1\frac{1}{8}$,,	...	30·0

Tapes—

Per ft. run.		
$\frac{5}{8} \times \frac{1}{12}$ inch	...	3·2
$\frac{3}{4} \times \frac{1}{8}$,,	...	5·73
$1 \times \frac{1}{8}$,,	...	7·64
$1\frac{1}{4} \times \frac{1}{8}$,,	...	9·55
$1\frac{1}{2} \times \frac{1}{8}$,,	...	11·46
$2 \times \frac{1}{8}$,,	...	15·28

DOORS AND WINDOWS.

General.

1. Internal doors should not, as a rule, be less than 2 feet 9 inches wide × 6 feet 6 inches high.

A common rule for the size of doors, as used in India, is, height = width + 3 to $3\frac{1}{2}$ feet.

2. The size of doors named on the drawings, shall be the size of the clear opening between the door frames, the size of the opening through the wall being greater.

3. Doors of greater width than 3 feet are generally divided into two parts, that is, they are "hung folding".

4. Doors are described according to the arrangement of the shutter forming the door and are also called "right handed" or "left handed" according as they open inwards to the right or to the left.

5. The usual forms of doors are—

(*a*) Panelled.

(*b*) Panelled and glazed.

(*c*) Ledged or battened.

(*d*) Plain planked.

(*e*) Framed and braced.
(*f*) Planked and iron barred.
(*g*) Venetianed.
(*h*) Doors battened and framed.

6. Doors will generally be paid for by a rate on the shutter area between the frame pieces, the measurement being taken at the unrebated part of the frame. The rate for the door includes the cost of the frame, and fixing in the wall, by means of wall plugs.

7. Size of windows will depend on the object of the room in which they are to be placed. The following rules are given among others* :—

The breadth of window = $\frac{1}{8}$ (width of room + height of room).—(Chambers.)

There should be 1 foot superficial of window space to every 100 or 125 cubic feet of contents of the room in dwelling houses or 1 foot superficial to 50 or 55 cubic feet in hospitals.—(Galton.)

The window sill should generally be about 2 feet 6 inches from the inside floor level.

8. All windows not protected by a verandah should be provided with a stone sill properly weathered on the outside to prevent rain-water lodging.

9. Windows may be provided either for the purpose of lighting only or for both ventilation and lighting.

In the former case, they may be—

(*a*) Fixed so that they cannot be opened ;

and in the latter—

(*b*) hinged on either side,
(*c*) hinged to top or bottom rail,
(*d*) hung on pivots near their centres.

The methods (*c*) and (*d*) are generally adopted for clerestory windows or windows high up in the wall, method (*b*) being adopted in the case of ordinary windows.

DOOR AND WINDOW FRAMES.

Specification No. 121.

1. **Wood.**—Moulmein teak, of the scantlings shown in the drawings or as specified in tables LXXXIII, LXXXIV and LXXXV.

2. **Fixing.**—To be properly framed and morticed together, the head and sill being provided with horns 6 inches long and the uprights to have additional supports if required. All parts set in masonry to be well coated with boiling coal tar.

3. **Moulding.**—To be rebated on one side $\frac{1}{2}$ inch wide and of the full thickness of the shutter, and to have a return bead on the other or to be chamfered as may be directd.

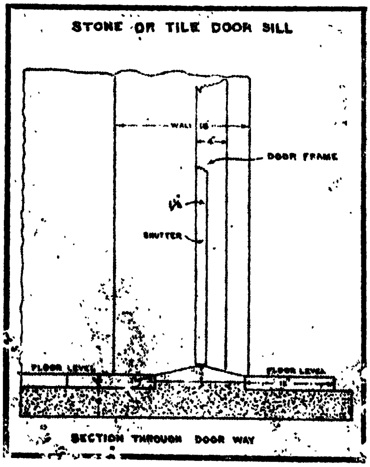
---

* From note on *Practice of Building*.

TABLE LXXXIII.

SCANTLINGS OF DOOR FRAMES.

Size of door.	Description.	Number.	Length.	Breadth in inches.	Thick-ness in inches.	Cubic contents in c. feet without sill.	Cubic contents of sill in c. feet.
Feet.			Ft. in.	In.	In.	C. F.	C. F.
4½ × 7½	Posts ..	2	8 2	5	4	3·15	·53
	Head ..	1	6 4	5	4		
	Sill ..	1	6 4	3	4		
4 × 7	Posts ..	2	7 6½	4½	4	2·62	·48
	Head ..	1	5 9	4½	4		
	Sill ..	1	5 9	3	4		
3½ × 7	Posts ..	2	7 6½	4½	4	2·56	·44
	Head ..	1	5 3	4½	4		
	Sill ..	1	5 3	3	4		
3½ × 6½	Posts ..	2	7 1½	4½	3½	2·13	·38
	Head ..	1	5 3	4½	3½		
	Sill ..	1	5 3	3	3½		
3 × 6½	Posts ..	2	7 1¼	4¼	3½	1·95	·34
	Head ..	1	4 8½	4¼	3½		
	Sill ..	1	4 8½	3	3½		
3 × 6	Posts ..	2	6 7	4	3½	1·73	·34
	Head ..	1	4 8	4	3½		
	Sill ..	1	4 8	3	3½		
2½ × 6	Posts ..	2	6 7	4	3½	1·68	·30
	Head ..	1	4 2	4	3½		
	Sill ..	1	4 2	3	3½		



Note.—These frames are suitable for the doors detailed in tables LXXXVI to XC. The breadth or greater dimension of the frame is in the plane of the door.

Wooden sills for doors should not be used, as far as possible, being objectionable especially in public buildings. Stone sills should be raised 1″, to enable doors to fit close and still pass over a carpet or rug. Sills should be sloped both ways as per sketch to facilitate sweeping, a hole being drilled in the sill for the bolt.

Recent trend is all for the complete elimination of sills in all buildings. This facilitates sweeping and washing of floors.

Note.—Very frequently sizes in whole inches are used for door frames, and in such cases the size 3″ × 5″ is adopted for all scantlings in the frame, for doors of sizes 4′ × 4′, 3½′ × 7′, 3½′ × 6½′ and 3′ × 6½′, and 3″ × 4″ for doors of sizes 3′ × 6′ and 2½′ × 6′. The quantities of wood work are then as follows:—

Door size.	4′ × 7′	3½′ × 7′	3½′×6½″
Cubic feet (excluding sill)	2·16	2·11	2·02
Cubic feet sill	0·60	0·55	0·55
Total C. ft. ..	2·76	2·66	2·57

Door size	3′ × 6½′	3′ × 6′	2½′ × 6′
Cubic feet (excluding sill)	1·97	1·47	1·43
Cubic feet sill ..	0·50	0·39	0·35
Total C.ft. ..	2·47	1·86	1·78

TABLE LXXXIV.

SCANTLINGS OF WINDOW FRAMES.

Size of window.	Description.	Number	Length.		Breadth.	Thickness.	Cubic contents of frame.	Remarks.
Feet.			Ft.	in.	In.	In.	C. F.	
4 × 5	Posts ..	2	5	8	4	3½	2·20	*Note.*—These frames are suitable for windows detailed in tables XCII to XCIV. The "breadth" or greater dimension is in the plan of the window.
	Head and sill ..	2	5	8				
3½ × 5	Posts ..	2	5	8	4	3½	2·11	
	Head and sill ..	2	5	2				
3½ × 4½	Posts ..	2	5	2	4	3½	2·01	
	Head and sill ..	2	5	2				
3 × 4½	Posts ..	2	5	1	3½	3¼	1·53	
	Head and sill ..	2	4	7				
3 × 4	Posts ..	2	4	7	3½	3	1·34	
	Head and sill ..	2	4	7				
2½ × 3½	Posts ..	2	4	0	3	3	1·00	
	Head and sill ..	2	4	0				
2 × 3	Posts ..	2	3	6	3	3	0·88	
	Head and sill ..	2	3	6				
5 × 3	Posts ..	2	3	8	4	3½	2·01	
	Head and sill ..	2	6	8				
3 × 1½	Posts ..	2	2	0	3	3	0·81	
	Head and sill ..	2	4	6				

Note.—Very frequently sizes in whole inches are used for window frames, and in such cases the size 3″ × 5″ is adopted for all scantlings in the frame, for windows for sizes 4′ × 5′, 3½′ × 5′, 3½′ × 4½′ and 5′ × 3′, and 3″ × 4″ for windows of sizes 3′ × 4½′ and 3′ × 4′.

The quantities of wood are then as follows:—

Window size.	4′ × 5′	3½′ × 5′	3½′ × 4½′	5′ × 3′	3′ × 4½′	3′ × 4′
Cubic feet including sill .. Total ..	2·36	2·25	2·14	2·14	1·60	1·52

TABLE LXXXV.

SCANTLINGS OF WINDOW FRAMES (IRON-BARRED.)

Size of window.	Description.	Number	Length	Breadth	Thick-ness.	Cubic contents of frame.	Remarks.
Feet.			Ft. in.	In.	In.	C. F.	*Note.*—These frames are suitable for windows, iron-barred, with glazed shutters. The "breadth" or less dimension is in the plane of the window.
4 × 5	Posts ..	2	5 8	4	4½	2·83	
	Head and sill ..	2	5 8				
3½ × 5	Posts ..	2	5 8	4	4½	2·71	
	Head and sill ..	2	5 2				
3½ × 4½	Posts ..	2	5 2	4	4½	2·33	
	Head and sill ..	2	5 2				
3 × 4½	Posts ..	2	5 1	3½	4	1·88	
	Head and sill ..	2	4 7				
3 × 4	Posts ..	2	4 7	3½	4	1·78	
	Head and sill ..	2	4 7				
2½ × 3½	Posts ..	2	4 1	3	3¾	1·25	
	Head and sill ..	2	4 1				
2 × 3	Posts ..	2	3 6	3	3¾	1·09	
	Head and sill ..	2	3 6				

For windows-iron-barred, the sizes for all scantlings, for windows 4′ × 5′ ; 3½′ × 5′ ; 3½′ × 4½′, 3′ × 4½′ and 3′ × 4′ shall be 3″ × 5″, and 3″ × 4″ for windows 2½′ × 3½′ and 2′ × 3′. The quantities of wood are then as follows :—

Window size.	4′ × 5′	3½′ × 5′	3½′ × 4½′	3′ × 4½′	3′ × 4′	2½′ × 3½′	2′ × 3′
Cubic feet including sill ..	2·36	2·25	2·14	2·01	1·90	1·36	1·16

In all cases the first scantling dimension is for ' breadth ' *i.e.*, dimension in the plane of the wall, and the second is for the ' depth ' the dimension at right angles to the wall plane.

DOORS, PANELLED, FIRST CLASS.

Specification No. 122.

1. **Description.**—Doors to be "hung folding", to be of 6 panels of sizes as designed, 3 panels in height and 2 in breadth.

2. **Styles and rails.**—The styles, top, bottom, lock and frieze rails to be moulded on both sides with ovolo and fillet moulding, or as may be otherwise specified.

3. **Panels.**—The panels to be raised, feather-tongued into styles and rails, with beaded edges on both sides. The corners of the raised panels to be rounded off or finished as shown in the drawings.

4. **Furniture.**—Each leaf to be hung with 3 brass butt (or back flap) hinges with brass screws, and furnished with brass mortice lock with patent handles, brass flush bolts, and brass hooks with brass eyes in frame.

Note.—If special ornamental furniture is required, it should be specified in detail or should be excluded from the contract, which will then only include the fixing of the furniture.

5. Unless otherwise specified, the frames and shutters will be of the dimensions shown in tables LXXXIII and LXXXVI.

6. The doors shall be finished by oiling, varnishing, bees-waxing or painting as specified.

Note.—For first class doors in residences, either varnishings or painting are usual, according as the doors are inside ones or exposed to the weather.

For Rate Abstract see p. 378.

DOORS, PANELLED, SECOND CLASS.

Specification No. 123.

1. **Description.**—To be similar to doors, first class, except in the following respects:—

2. **Styles, rails, and panels.**—Styles and rails to be chamfered on both sides instead of moulded, and the raised panels to have square corners and edges on both sides.

3. The doors will be provided with brass hinges and the rest of the furniture similar to 1st class, but of iron instead of brass.

4. The doors shall be finished by oiling, varnishing, bees waxing or painting as specified.

Note.—For second class doors, either oiling or painting are usual, according as the doors are inside ones or exposed to the weather. The rebates of frames shall not be oiled.

For Rate Abstract p. 378.

TABLE LXXXVI

DOORS PANNELLED.

Size of door.	Description.	Number.	Length. Ft.	In.	Breadth. In.	Thickness. In.	Cubic contents. C. F.	Strong butt hinges. No.	Tower bolt 12". No.	Tower bolt 10". No.	Tower bolt 8". No.	Tower bolt 7". No.	Mortice locks. No.	Hooks and eyes, 10". No.
Feet.														
4½ × 7½	Styles ..	4	7	7	4	1½	1·26							
	Top rail ..	2	2	4	4	1½	0·19							
	Frieze ..	2	2	4	4¾	1½	0·21							
	Lock ..	2	2	4	8	1½	0·39	3 pairs. 5 inches.	2	..	1	..	1	2
	Bottom ..	2	2	4	6	1½	0·29							
	Top panels ..	4	1	9	11	1¼	0·67							
	Central ..	4	2	4	11	1¼	0·89							
	Bottom ..	4	2	2	11	1¼	0·83							
		Total cubic feet					4·73							
4 × 7	Styles ..	4	7	1	3¾	1½	1·11							
	Top rail ..	2	2	1	3¾	1½	0·16							
	Frieze ..	2	2	1	4½	1½	0·20							
	Lock ..	2	2	1	7¾	1½	0·34	3 pairs. 4½ inches.	..	2	1	..	1	2
	Bottom ..	2	2	1	5¾	1½	0·25							
	Top panels ..	4	1	7	10	1¼	0·55							
	Central ..	4	2	2	10	1¼	0·76							
	Bottom ..	4	2	0	10	1¼	0·69							
		Total cubic feet ..					4·06							
3½ × 7	Styles ..	4	7	1	3¾	1½	1·10							
	Top rail ..	2	1	1	3¾	1½	0·14							
	Frieze ..	2	1	1	4½	1½	0·17							
	Lock ..	2	1	1	7¾	1½	0·29	3 pairs. 4 inches.	..	2	1	..	1	2
	Bottom ..	2	1	1	5¾	1½	0·22							
	Top panels ..	4	1	7	8½	1	0·37							
	Central ..	4	2	2	8½	1	0·51							
	Bottom ..	4	2	0	8½	1	0·47							
		Total cubic feet ..					3·27							
3½ × 6½	Styles ..	4	6	7	3¾	1½	1.02							
	Top rail ..	2	1	10	3¾	1½	0·14							
	Frieze ..	2	1	10	4¼	1½	0·16							
	Lock ..	2	1	10	7	1½	0·26	3 pairs. 4 inches.	..	2	1	..	1	2
	Bottom ..	2	1	10	5	1½	0·19							
	Top panels ..	4	1	5	8½	1	0·33							
	Central ..	4	2	1	8½	1	0·49							
	Bottom ..	4	1	11	8½	1	0·45							
		Total cubic feet ..					3·04							
3 × 6½	Styles ..	4	6	7	3½	1½	0·96							
	Top rail ..	2	1	7	3½	1½	0·12							
	Frieze ..	2	1	7	4¼	1½	0·14							
	Lock ..	2	1	7	7	1½	0·23	3 pairs. 4 inches.	..	..	2	1	1	2
	Bottom ..	2	1	7	5	1½	0·16							
	Top panels ..	2	1	5	12	1	0·24							
	Central ..	2	2	1	12	1	0·35							
	Bottom ..	2	1	11	12	1	0·32							
		Total cubic feet ..					2·52							

DOORS, PANELLED AND GLAZED, FIRST CLASS.

Specification No. 124.

1. **Description.**—To be similar, to doors, panelled, 1st class except in the following respects :—

The four upper panels to be glazed. The styles and rails to be rebated ½ inch wide on the inside to receive the glass instead of being moulded.

2. **Sash bars.**—Sash bars to be moulded and mitred on the outside, and rebated ½ inch wide on the inside to receive the glass.

3. **Glazing.**—Glazing to be of best English crown glass, 21 oz. Each pane to be cut to fit the rebates truly and to be secured with iron sprigs and putty in the usual manner.

For Rate Abstract see p. 379.

DOORS, PANELLED AND GLAZED, SECOND CLASS.

Specification No. 125.

1. **Description.**—To be similar to above, but the edges of styles, rails, etc., to be chamfered and the raised panels to have square edges and corners.

2. **Furniture.**—Furniture to be of iron throughout instead of brass, with the exception of the lock, which will be as above.

For Rate Abstract see p. 379.

TABLE LXXXVII.

DOORS, PARTLY PANELLED AND PARTLY GLAZED.

Size of door.	Scantlings of doors. Description.	Number.	Length.		Breadth.	Thickness.	Cubic contents.	Glass. Number of panes.	Glass. Dimensions.	Fastenings. Strong butt hinges.	Tower bolts, 12 inches.	Tower bolts, 10 inches.	Tower bolts, 8 inches.	Tower bolts, 7 inches.	Mortise locks.	Hooks and eyes, 10 inches.
Feet.			Ft.	in.	In.	In	C.F.		In. In.	No.	No.	No.	No.	No.	No.	No.
4½×7½	Styles ..	4	7	7	4	1½	1·26	16	11¼×9⅝	3 pairs 5 ins.	2	..	1	..	1	2
	Lock rails ..	2	2	4	8	1½	0·39									
	Top and bottom rails ..	4	2	4	4	1½	0·39									
	Panels ..	4	2	6	11	1¼	0·95									
	Sash bars, vertical ..	2	4	1	1	1½	0·09									
	Sash bars, horizontal ..	6	1	9½	1	1½	0·11									
	Total cubic feet ..						3·10									

TABLE LXXXVII—*contd.*

Size of door.	Scantlings of doors. Description.	Number.	Length.	Breadth.	Thickness.	Cubic contents.	Glass. Number of panes.	Dimensions.	Fastenings. Strong butt hinges.	Tower bolts, 12 inches.	Tower bolts, 10 inches.	Tower bolts, 8 inches.	Tower bolts, 7 inches.	Mortise locks.	Hooks and eyes, 10 inches.
Feet.			Ft. in.	In.	In	C.F.		In. In.	No.	No.	No.	No.	No.	No.	No.
4×7	Styles ..	4	7 1	3¾	1½	1·11	16	10½ × 8¾	3 pairs 4½ ins.	..	2	1	..	1	2
	Lock rails ..	2	2 1	7¾	1½	0·34									
	Top and bottom rails ..	4	2 1	3¾	1½	0·33									
	Panels ..	4	2 4	10	1¼	0·81									
	Sash bars, vertical ..	2	3 10	1	1½	0·08									
	Sash bars, horizontal ..	6	1 7	1	1½	0·10									
	Total cubic feet ..					2·77									
3½×7	Styles ..	4	7 1	3½	1½	1·03	16	10½ × 7⅛	3 pairs 4 ins.	..	2	1	..	1	2
	Lock rails ..	2	1 10	7¾	1½	0·29									
	Top and bottom rails ..	4	1 10	3½	1½	0·26									
	Panels ..	4	2 4½	8½	1	0·56									
	Sash bars, vertical ..	2	3 10	1	1½	0·08									
	Sash bars, horizontal ..	6	1 4½	1	1½	0·08									
	Total cubic feet ..					2·30									
3½×6½	Styles ..	4	6 7	3½	1½	0·96	16	9¼ × 7⅛	..	..	..	2	1	1	2
	Lock rails ..	2	1 10	7	1½	0·26									
	Top and bottom rails ..	4	1 10	3½	1½	0·26									
	Panels ..	4	2 4	8½	1	0·55									
	Sash bars, vertical ..	2	3 5	1	1½	0·07									
	Sash bars, horizontal ..	6	1 4½	1	1½	0·08									
	Total cubic feet ..					2·18									
3×6½	Styles ..	4	6 7	3¼	1½	0·89	16	9¼ × 5⅞	..	..	..	2	1	1	2
	Lock rails ..	2	1 7	7¼	1½	0·23									
	Top and bottom rails ..	4	1 7	3¼	1½	0·22									
	Panels ..	2	2 4½	14	1	0·46									
	Sash bars, vertical ..	2	3 5½	1	1½	0·07									
	Sash bars, horizontal ..	6	1 2½	1	1½	0·07									
	Total cubic feet ..					1·94									

DOORS, LEDGED OR BATTENED.

Specification No. 126.

1. **Description.**—To consist of vertical boards connected together by 2 or 3 horizontal ledges nailed or screwed across the back of the door.

2. **Boards.**—The board's to be planed, tongued and grooved, or rebated together, as may be specified. One edge of each board to be beaded on the outside.

3. **Hung folding.**—Doors to be hung folding when the width is greater than 3 feet.

4. **Ledges.**—Edges and ends of ledges to be chamfered.

5. **Furniture.**—Each leaf to be hung with iron cross garnet or strap hinges, screwed to the ledges. To be provided with iron bolts, hooks and eyes, and an all-drop bolt and padlock.

6. **Finishing.**—The doors shall be finished by oiling or painting as specified. Oiling is usual for interior work, and painting for doors exposed to the weather. The rebates of the frame shall not be oiled.

For Rate Abstract see p. 380.

Note.—This door may be strengthened in large doors by diagonal braces and by framing the ledges into vertical styles.

DOORS, PLAIN PLANKED.

Specification No. 127.

1. **Description.**—To consist of 4 vertical boards connected together by three horizontal ledges, screwed across the front of the door.

2. **Boards.**—The boards to be planed and rebated together.

3. **Hung folding.**—Doors to be hung folding, when the width exceeds 3 feet.

4. **Ledges.**—The door to have one vertical and three horizontal ledges, with edges and ends chamfered.

5. **Furniture.**—Each leaf to be hung with three strong iron butt or strap and staple hinges, and the door to be provided with iron chain and staple fastenings on either side, and hooks and eyes, for keeping the doors open.

6. **Finishing.**—As in specification above.

For Rate Abstract see p. 380.

Note.—This class of door is generally used in inferior buildings, such as police lines, out-houses, etc.

TABLE LXXXVIII.

SCANTLINGS OF DOORS, LEDGED.

Size of door.	SCANTLINGS OF DOORS.						Strong strap hinges.	FASTENINGS.					
	Description.	Number.	Length.	Breadth.	Thickness.	Cubic contents.		Tower bolts, 10 inches.	Tower bolts, 8 inches.	Tower bolts, 7 inches.	Handles.	Hooks and eyes, 10 inches.	All-drop bolt and padlock.
Feet.			Ft. in	In.	In.	C.F.	No.	No.	No.	No.	No.	No.	No.
4 × 7	Planks ..	8	7 1	6¾	1½	3·98	3 pairs	2	1	..	1	2	1
	Ledges ..	6	1 11	3	1½	0·36							
	Total cubic feet ..					4·34							
3½ × 7	Planks ..	8	7 1	6	1½	3·54	3 pairs	2	1	..	1	2	1
	Ledges ..	6	1 8	3	1½	0·31							
	Total cubic feet ..					3·85							
3½ × 6½	Planks ..	8	6 7	6	1½	3·29	3 pairs	..	2	1	1	2	1
	Ledges ..	6	1 8	3	1½	0 31							
	Total cubic feet ..					3·60							
3 × 6½	Planks ..	8	6 7	5½	1	1·92	3 pairs	..	2	1	1	2	1
	Ledges ..	6	1 5	3	1½	0·26							
	Total cubic feet ..					2·18							
3 × 6	Planks ..	8	6 1	5¼	1	1·77	3 pairs	..	2	1	1	2	1
	Ledges ..	6	1 5	3	1½	0·26							
	Total cubic feet ..					2·03							
2½ × 6	Planks ..	6	6 1	5¾	1	1·46	3 pairs	..	2	1	1	2	1
	Ledges ..	6	2 5	3	1½	0·23							
	Total cubic feet ..					1·69							

TABLE LXXXIX.

SCANTLINGS OF DOORS, PLAIN PLANKED.

Size of door.	Description.	SCANTLINGS OF DOORS. Number.	Length.	Breadth.	Thickness.	Cubic contents.	Strong butt hinges.	FASTENINGS. Chain and staple.	
Feet.			Ft. in.	Inches.	Inches.	C.F.	No.	No.	This class of doors is generally used for police lines and out-houses.
3 × 6	Planks ..	2	6 1	9	1	0·76	3 pairs	2	
	Do. ..	2	6 1	10	1	0·84			
	Ledge, vertical ..	1	6 0	3	1½	0·18			
	Do. top and bottom ..	2	2 10	3	1½	0·18			
	Do. middle ..	1	2 10	4	1½	0·12			
				Total cubic feet ..		2·08			
2½ × 6	Planks ..	4	6 1	8	1	1·33	3 pairs	2	
	Ledge, vertical ..	1	6 0	3	1½	0·18			
	Do. top and bottom ..	2	2 4	3	1½	0·14			
	Do. middle ..	1	2 4	4	1½	0·09			
				Total cubic feet ..		1·74			

DOORS, BATTENED, FRAMED AND BRACED.

Specification No. 128.

1. **Description.**—To consist of a frame-work, the spaces being filled in with vertical or diagonal boards.

2 **Frame-work**.—The frame-work to consist of styles, top, bottom and centre rails, with a diagonal brace between the top and centre and the centre and bottom rails respectively. The brace should be arranged to slope downwards towards the hinge. The edges to be chamfered or beaded on the inside. A rebate, one inch wide, to be cut on the inside of the styles, top, bottom and centre rails to take the boards.

3. **Boards.**—The boards to be planed, rebated together, and fixed flush with the inside of the frame work. One edge of each board to be beaded on both the faces. A moulding is provided on the inside to cover the joint between the boards and the frame work.

4. **Dimensions.**—Frame-work to be 1½″ to 2″ thick according to the size of door: battens or boards from ⅝″ to ⅛″ thick.

5. **Hung folding**.—Door to be "hung folding", when its width exceeds 3 feet.

6. **Furniture.**—Each leaf to be hung with iron cross garnet or strap hinges to the top, centre and bottom rails. To be provided with iron bolts, hooks and eyes, and an all-drop bolt and padlock.

For Rate Abstract see p. 381.

7. **Finishing.**—The doors shall be finished by oiling or painting as specified. Oiling as usual for interior work, and painting for doors exposed to the weather. The rebates of the frame shall not be oiled.

TABLE XC

SCANTLINGS OF DOORS, BATTENED, FRAMED AND BRACED.

Size of door.	SCANTLINGS OF DOORS. Description.	Number.	Length.	Breadth.	Thickness.	Cubic contents.	Strong strap hinges.	FASTENINGS. Tower bolts, 12 inches.	Tower bolts, 10 inches.	Tower bolts, 8 inches.	Tower bolts, 7 inches.	All-drop bolt and padlock or rimlock.	Hooks and eyes, 10 inches.
Feet.			Ft. in.	In.	In.	C.F.	No.	No.	No.	No.	No.	No.	No.
4½ × 7½	Styles ..	4	7 7	4	1½	1·27	3 pairs	2	..	1	..	1	2
	Centre rails ..	2	2 4	8	1½	0·38							
	Top and bottom rails ..	4	2 4	4	1½	0·38							
	Battens ..	10	6 8	4½	¾	1·29							
	Diagonals ..	4	3 9	4	¾	0·31							
	Total cubic feet ..					4·04							
4 × 7	Styles ..	4	7 1	3¾	1½	1·11	3 pairs	–	2	1	..	1	2
	Centre rails ..	2	2 1	7¾	1½	0·34							
	Top and bottom rails ..	4	2 1	3¾	1½	0·33							
	Battens ..	10	6 3½	4¼	¾	1·39							
	Diagonals ..	4	3 5	3¾	⅝	0·27							
	Total cubic feet ..					3·44							
3½ × 7	Styles ..	4	7 1	3¾	1½	1·10	3 pairs	..	2	1	..	1	2
	Centre rails ..	2	1 10	7¾	1½	0·29							
	Top and bottom rails.	4	1 10	3¾	1½	0·28							
	Battens ..	8	6 3¼	4¼	⅝	0·93							
	Diagonals ..	4	3 4	3¾	⅝	0·22							
	Total cubic feet ..					2·82							
3½ × 6½	Styles ..	4	6 7	3¾	1½	1·02	3 pairs	..	..	2	1	1	2
	Centre rails ..	2	1 10	7	1½	0·26							
	Top and bottom rails ..	4	1 10	3¾	1½	0·28							
	Battens ..	8	5 9	4¼	⅝	0·85							
	diagonals ..	4	3 1½	3¾	⅝	0·20							
	Total cubic feet ..					2·61							
3 × 6½	Styles ..	4	6 7	3½	1½	0·96	3 pairs	..	..	2	1	1	2
	Centre rails ..	2	1 7	7	1½	0·23							
	Top and bottom rails ..	4	1 7	3⅜	1½	0·23							
	Battens ..	6	5 9½	4¾	⅝	0·72							
	Diagonals ..	4	3 1	3¼	⅝	0·20							
	Total cubic feet ..					2·34							

DOORS BATTENED AND FRAMED.

Specification No. 129.

1. **Shutters.**—The shutter to be prepared by fitting styles and rails (top, bottom, lock and frieze) as for pannelled sides, with simple chamfers on edges only. The styles and rails are grooved as for receiving panels, and plain panels of metal sheeting, asbestos sheeting, or planks filled in.

2. **Fitting.**—The thickness of the sheeting, or planks after planning shall not be greater than ½″. The ends of the planks fitting into the grooves shall be reduced by planning on both sides equally to fit the grooves. The planks will have halved joints.

3. **Dimensions**—The styles and rails shall have the same dimensions as are given for panelled doors.

4. **Hangirg.**—The doors to be hung folding when the width exceeds 3 feet.

5. **Furniture.**—As for doors battened.

6. **Finishing.**—As for doors framed and braced.

DOORS, BATTENED AND FRAMED.

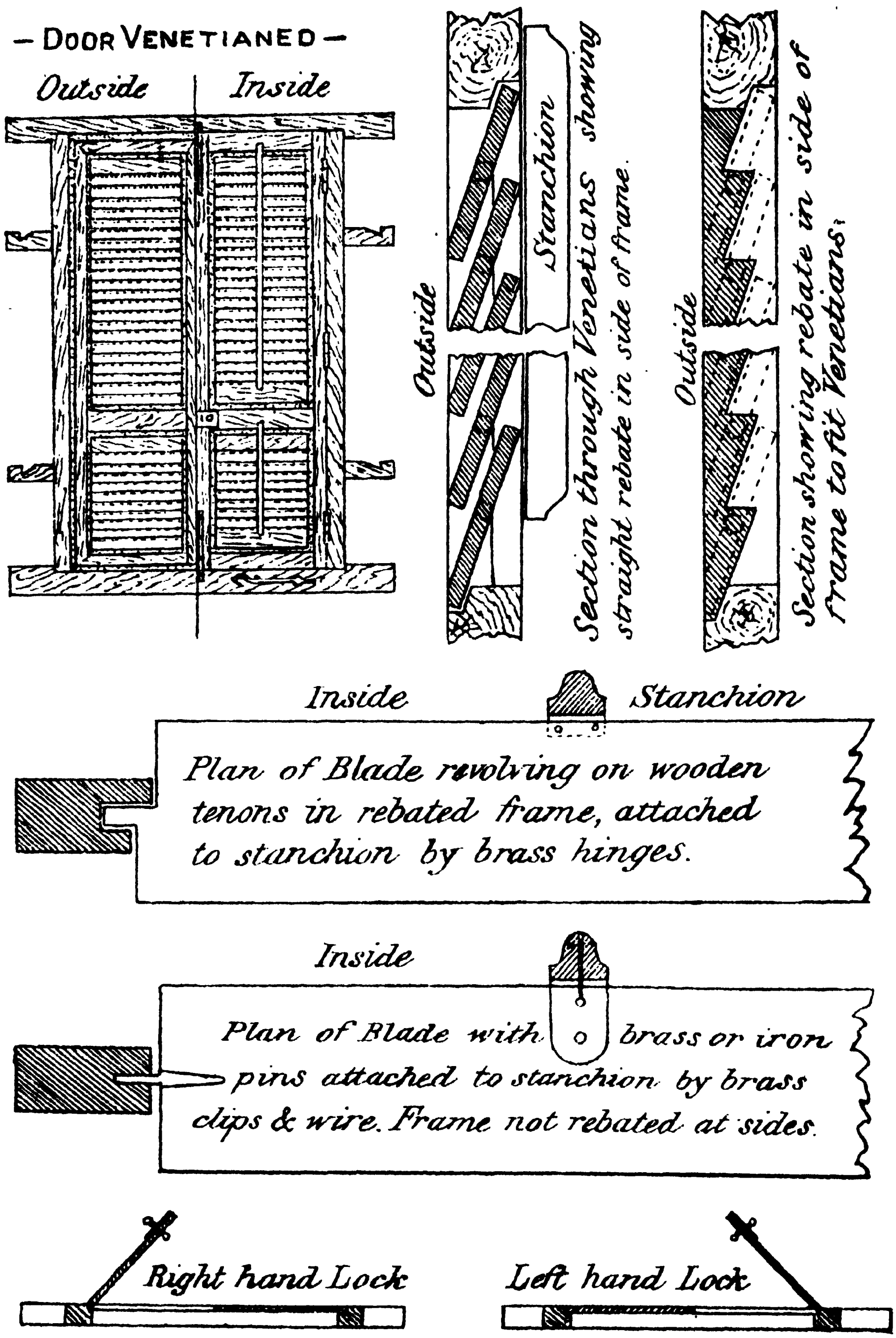
Scantlings for styles and rails and furniture shall be as given in table for doors panelled. The woodwork of the panels, when boards are used is given below :—

TABLE XCI.

Size of door.	Situation.	Number.	Length	Breadth	Thickness	Quantity in cft.
4½′×7½′	Top panel	4	1′-9″	0′-11″	0′-½″	0-96
	Central panel ..	4	2′-4″			
	Bottom panel ..	4	2′-2″			
4′ ×7′	Top panel	4	1′-7″	0′-10″	0′-½″	0-80
	Central panel ..	4	2′-2″			
	Bottom panel ..	4	2′-0″			
3½″×7′	Top panel	4	1′-7″	0′-8½″	0′-½″	0-68
	Central panel ..	4	2′-2″			
	Bottom panel ..	4	2′-0″			
3½′×6½′	Top panel	4	1′-5″	0′-8½″	0′-½″	0-54
	Central panel ..	4	2′-1″			
	Bottom panel ..	4	1′-11″			
3′ ×6½′	Top panel	2	1′-5″	0′-12″	0′-½″	0-45
	Central panel ..	2	2′-1″			
	Bottom panel ..	2	1′-11″			

Note.—This type has recently come in great vogue in private middle class buildings. The fitting may either be vertical or diagonal.

Plate XXXVIII.



Govt. Photozinco Office, Poona 1949.

DOORS WITH IRON-BARRED AND PLANK SHUTTERS.

Specification No. 130.

1. **Description.**—The doors shall be provided with double shutters, the outer pair planked and the inner filled in with round iron bars.

2. **Frame.**—The frame should measure not less than 6″ × 4½″ and should be rebated ½ inch wide all round on both the sides, to the full thickness of the respective shutters.

3. **Plank shutters.**—The plank shutters to be similar to doors ledged, but to be provided with 3 pairs of strong back flap hinges, so that they may open back against the wall.

4. **Iron-barred shutters.**—Styles, top, bottom and lock rails to be 2¼ inches thick, framed together and filled in with round iron bars ¾ inch to 1 inch diameter or ¾ inch square iron bars fixed at 4 to 6 inches central distances apart. The bars to be housed into the top and bottom rails to a depth of 1 inch and to be passed through the lock rail. To be hung with 3 pairs of strong iron butt hinges.

5. **Furniture.**—Iron bolts, hooks and eyes and an all-drop bolt and padlock to be provided for each pair of shutters.

6. **Finishing.**—As for doors ledged and battened. Iron bars shall be japanned or painted.

Note (1).—For additional security an iron bar 2 × ¾ inch may be fixed to the top and bottom rails and to the two sides of the central rail through which all the bars will pass.

Note (2).—For better Class residential buildings a wrought-iron grille generally replaces the bars. Many types of grilles are to be seen in Town buildings.

For Rate Abstract see p. 381.

DOORS, VENETIANED, FIRST CLASS

Specification No. 131.

1. **Description.**—To be the same in all respects to door, panelled, except that the panels (of which there will be 4 only, the frieze rail being omitted) shall be filled in with venetians.

2. **Blades.**—The blades to be 3½ inches wide and ⅜ inch thick, and to overlap about half their width. To be secured to a moulded stanchion by brass hinges 1 inch wide, and to have rounded edges.

3. **Frame.**—The frame of each shutter to be rebated *outside* all round on the sides and bottom rail and *inside* on top rail. Ends of blades to be rounded off at centre to ⅜ inch diameter and ¾ inch long, to fit into holes in the rebated portion of the frame.

For Rate Abstract see p. 382.

DOORS, VENETIANED, SECOND CLASS.

Specification No. 132.

1. **Description.**—As above, except that the blades of the venetians, will will be attached to the stanchions by wire clips instead of brass hinges.

2. **Furniture.**—Furniture to be iron throughout except the lock, which will be of brass.

For Rate Abstract see p. 382.

Note.—Scantlings will be as for doors, pannelled.

WINDOWS, GLAZED, FIRST CLASS.

Specification No. 133.

1. **Frame.**—Frame to be as in specification No. 121.

2. **Shutters.**—To open in two shutters.

3. **Styles and rails.**—Styles, top and bottom rails to be moulded on one side and rebated ½ inch on the other to receive the glass.

4. **Sash bars.**—Sash bars to be moulded and mitred on one side and rebated ½ inch on the other side to receive the glass.

5. **Furniture.**—Brass butt hinges, brass bolts, handles and hooks and eyes to be provided.

6. **Dimension.**—Unless otherwise specified, dimensions of the several parts to be as stated in table XCII.

7. **Finishing.**—To be as for doors panelled, 1st class. Care should be taken not to stain panes.

For Rate Abstract see p. 383.

WINDOWS, GLAZED, SECOND CLASS.

Specification No. 134.

1. **Description.**—To be similar in all respects to the above, except that styles and rails will be chamfered instead of moulded.

2. **Furniture.**—Furniture to be of iron instead of brass.

3. **Finishing.**—To be as for doors panelled, 2nd Class. Care should be taken not to stain panes.

For Rate Abstract see p. 383.

TABLE XCII.

SCANTLINGS OF WINDOWS, GLAZED.

Size of window.	Scantlings of windows. Description.	Number.	Length. Ft.	Length. in.	Breadth.	Thickness.	Cubic contents.	Glass. Number of panes.	Glass. Dimensions.	Strong butt hinges.	Fastenings. Tower bolts, 10 inches.	Fastenings. Tower bolts, 8 inches.	Fastenings. Tower bolts 6 inches.	Fastenings. Handles.	Fastenings. Hooks and eyes.
Feet.			Ft.	in.	In.	In.	C. F.		In.	No. & size.	No.	No.	No.	No.	No. & size.
4 × 5	Styles ..	4	5	1	3	1½	0·63								
	Rails ..	4	2	1	3	1½	0·26								
	Sash bars, vertical.	2	4	9	1	1½	0·09	20	10⅝ × 9¼	2 pairs 4 ins.	..	2	1	1	2 10 ins.
	Do. horizontal.	8	1	9	1	1½	0·14								
	Total cubic feet ..						1·12								
3½ × 5	Styles ..	4	5	1	3	1½	0·63								
	Rails ..	4	1	10	3	1½	0·22								
	Sash bars, vertical.	2	4	9	1	1½	0·09	20	10⅝ × 7¾	2 pairs 4 ins.	..	2	1	1	2 10 ins.
	Do. horizontal.	8	1	6	1	1½	0·12								
	Total cubic feet ..						1·06								
3½ × 4½	Styles ..	4	4	7	3	1½	0·57								
	Rails ..	4	1	10	3	1½	0·22								
	Sash bars, vertical.	2	4	3	1	1½	0·08	20	9⅜ × 7¾	1 pair 4 ins.	..	2	1	1	2 10 ins.
	Do. horizontal.	8	1	6	1	1½	0·12								
	Total cubic feet ..						0·99								
3 × 4½	Styles ..	4	4	7	2¾	1½	0·52								
	Rails ..	4	1	7	2¾	1½	0·18								
	Sash bars, vertical.	2	4	3½	1	1½	0·08	20	9⅜ × 6½	2 pairs 3½ ins.	..	2	1	1	2 9 ins.
	Do. horizontal.	8	1	3½	1	1½	0·10								
	Total cubic feet ..						0·88								
3 × 4	Styles ..	4	4	1	2¾	1½	0·46								
	Rails ..	4	1	7	2¾	1½	0·18								
	Sash bars, vertical.	2	3	9½	1	1½	0·07	20	8¼ × 6½	2 pairs 3½ ins.	..	..	3	1	2 9 ins.
	Do. horizontal.	8	1	3½	1	1½	0·10								
	Total cubic feet ..						0·81								

TABLE XCII—*contd.*

WINDOWS, GLAZED—*contd.*

Size of window.	Description.	Number. (Scantlings of windows)	Length.	Breadth.	Thickness.	Cubic contens.	Number of panes (Glass)	Dimensions. (Glass)	Strong butt hinges.	Tower bolts, 10 inches. (Fastenings)	Tower bolts, 8 inches.	Tower bolts, 6 inches.	Handles.	Hooks and eyes.
Feet.			Ft. in.	In.	In.	C.F.		In.	No. & size.	No.	No.	No.	No.	No. & size.
2½ × 3½	Styles ..	4	3 7	2½	1¼	0·31	20	7⅓ × 5¼	2 pairs 3 ins.	..	..	3	1	2 8 ins.
	Rails ..	4	1 4	2½	1¼	0·11								
	Sash bars, vertical.	2	3 4	1	1¼	0·05								
	Do. horizontal.	8	1 1	1	1¼	0·07								
	Total cubic feet ..					0·54								
2* × 3	Styles ..	2	3 1	2¾	1¼	0·14	6	10⅛ × 9½	1 pair 3½ ins.	..	..	2	1	1 8 ins.
	Rails ..	2	2 1	2¾	1¼	0·09								
	Sash bars, vertical.	1	2 9½	1	1¼	0·02								
	Do. horizontal.	2	1 9½	1	1¼	0·03								
	Total cubic feet .					0·28								
* 1½ × 2½	Styles ..	2	2 7	2½	1¼	0·11	6	8¼ × 6¾	1 pair 3 ins.	..	..	2	1	1 8 ins.
	Rails ..	2	1 7	2½	1¼	0·06								
	Sash bars, vertical.	1	2 4	1	1¼	0·02								
	Do. horizontal.	2	1 4	1	1¼	0·02								
	Total cubic feet ..					0·21								
5 × 3	Styles ..	2	3 1	3	1½	0·19	15	10 × 10⅜	1 pair 4 ins.	..	2	..	1	1 12 ins.
	Rails ..	2	5 1	3	1½	0·31								
	Sash bars, vertical.	4	2 9	1¼	1¼	0·11								
	Do. horizontal.	2	4 2	1¼	1¼	0·09								
	Total cubic feet ..					0·70								
3* × 1½	Styles ..	2	1 7	2½	1¼	0·06	6	10¼ × 6¾	1 pair 3 ins.	..	..	2	1	1 9 ins.
	Rails ..	2	3 1	2½	1¼	0·13								
	Sash bars, vertical.	2	1 4	1	1¼	0·02								
	Do. horizontal.	1	2 10	1	1¼	0·02								
	Total cubic feet ..					0·23								

*To open in one leaf,

WINDOWS, PLANK SHUTTERS.

Specification No. 135.

1. **Description.**—To be similar in all respects to doors, ledged.
2. Furniture, iron.

For Rate Abstract see p. 384.

TABLE XCIII.

SCANTLINGS OF WINDOWS, PLANK SHUTTERS.

Size of window.	Description.	Scantlings of windows. Number	Length	Breadth.	Thickness.	Cubic contents.	Strong butt hinges.	Fastenings. Tower bolts, 8 inches.	Tower bolts, 6 inches.	Handles.	Hooks and eyes.
Feet.			Ft. in.	In.	In.	C.F.	No. & size.	No.	No.	No.	No &. size.
4 × 5	Planks ..	8	5 1	6¾	1½	2·86	2 pairs 4½ ins.	2	1	1	2 10 ins.
	Ledges ..	6	1 10	3	1½	0·69					
	Total cubic feet ..					3·55					
3½ × 5	Planks ..	8	5 1	6	1½	2·54	2 pairs 4½ ins.	2	1	1	2 10 ins.
	Ledges ..	6	1 7	3	1½	0·29					
	Total cubic feet ..					2·83					
3½ × 4½	Planks ..	8	4 7	6	1½	2·29	2 pairs 4 ins.	2	1	1	2 10 ins.
	Ledges ..	6	1 7	3	1½	0·29					
	Total cubic feet ..					2·58					
3 × 4½	Planks ..	8	4 7	5¼	1	1·34	2 pairs 4 ins.	2	1	1	2 9 ins.
	Ledges ..	6	1 4	3	1	0·17					
	Total cubic feet ..					1·51					
3 × 4	Planks ..	8	4 1	5¼	1	1·19	2 pairs 3½ ins.	..	3	1	2 9 ins.
	Ledges ..	6	1 4	2¾	1	0·15					
	Total cubic feet ..					1·34					
2½ × 3½	Planks ..	6	3 7	5¾	1	0·86	2 pairs 3½ ins.	..	3	1	2 8 ins.
	Ledges ..	4	1 1	2½	1	0·08					
	Total cubic feet ..					0·94					
*2 × 3	Planks ..	4	3 1	6¾	1	0·58	1 pair	..	2	1	1 8 ins.
	Ledges ..	2	1 10	2½	1	0·06					
	Total cubic feet ..					0·64					
*1½ × 2½	Planks ..	4	2 7	5	1	0·36	1 pair	..	2	1	1 8 ins.
	Ledges ..	2	1 4	2½	1	0·05					
	Total cubic feet ..					0·41					

*To open in one leaf.

WINDOWS WITH IRON BARS AND PLANK SHUTTERS.

Specification No. 136.

1. **Description.**—Similar in all respects to the above, with the addition only that round iron bars ¾ inch diameter or ¾ inch square iron bars are passed through a central rail and fixed vertically at 3 inch central distances apart into the head and sill of the window frame. For better class buildings wrought iron grilles are used.

2. **Finishing.**—As for doors with ironbarred and plank shutters.

For Rate Abstract see p. 384.

WINDOWS, GLAZED, WITH VENETIAN SHUTTERS, FIRST CLASS.

Specification No. 137.

1. **Description.**—There shall be double shutters. the outer pair venetained, the inner glazed.

2. **Frame.**—Frame to be rebated ½ inch, on both the sides to the full thickness of shutters.

3. **Venetian shutters.**—Venetians to be similar to doors venetained, first class.

4. **Glazed shutters.**—Glazed shutters to be similar to windows, glazed first class.

5. **Finishing.**—As for doors panelled, 1st class.

For Rate Abstracts see p. 385.

WINDOWS, GLAZED WITH VENETIAN SHUTTERS, SECOND CLASS.

Specification No. 138.

1. **Description.**—To be similar in all respects to the above, except that the blades of the venetian are attached to the moulded stanchions by clips of wire instead of by brass hinges, and the styles and rails of the glazed shutters are chamfered instead of moulded.

2. Furniture, iron.

For Rate Abstract see p. 385.

TABLE XCIV.

SCANTLINGS OF WINDOWS, VENETIANED SHUTTERS.

Size of window.	SCANTLINGS OF WINDOWS. Description.	Number.	Length.	Breadth.	Thickness.	Cubic contents.	Strong butt hinges.	FASTENINGS. Tower bolts, 8 inches.	Tower bolts, 6 inches.	Handles.	Hooks and eyes.
Feet			Ft. in.	In.	In.	C.F.	No.	No.	No.	No.	No.
4 × 5	Styles ..	4	5 1	3½	1½	0·74	2 pairs 4 ins.	2	1	1	2 10 ins.
	Rails ..	6	2 1	3½	1½	0·45					
	Venetian blades ..	60	1 8½	3½	⅜	0·94					
	Stanchion ..	4	2 1	¾	½	0·02					
		Total cubic feet ..				2·15					
3½ × 5	Styles ..	4	5 1	3¼	1½	0·68	2 pairs 4 ins.	2	1	1	2 10 ins.
	Rails ..	6	1 10	3¼	1½	0·37					
	Venetian blades ..	60	1 6	3½	⅜	0·82					
	Stanchion ..	6	2 1	¾	½	0·02					
		Total cubic feet ..				1·89					
3½ × 4½	Styles ..	4	4 7	3¼	1½	0·62	2 pairs 4 ins.	2	1	1	2 10 ins.
	Rails ..	6	1 10	3¼	1½	0·37					
	Venetian blades ..	52	1 6	3½	⅜	0·71					
	Stanchion ..	4	1 10	¾	½	0·02					
		Total cubic feet. ..				1·72					
3 × 4½	Styles ..	4	4 7	3	1½	0·57	2 pairs 3½ ins.	2	1	1	2 9 ins.
	Rails ..	6	1 7	3	1½	0·29					
	Venetian blades ..	52	1 3½	3½	⅜	0·61					
	Stanchion ..	4	1 10	¾	½	0·02					
		Total cubic feet ..				1·49					
3 × 4	Styles ..	4	4 1	3	1½	0·51	2 pairs 3½ ins.	..	3	1	2 9 ins.
	Rails ..	6	1 7	3	1½	0·29					
	Venetian blades ..	48	1 3½	3½	⅜	0·57					
	Stanchion ..	4	1 7	¾	½	0·02					
		Total cubic feet ..				1·39					

WINDOWS, IRON-BARRED, WITH GLAZED, AND PLANK SHUTTERS.

Specification No. 139.

1. **Description.**—The glazed shutters to be fixed on the inside, the plank shutters on the outside, with the iron bars let into the frame of the window between the two.

2. **Glazed shutters.**—To be as for glazed windows, 2nd class.

3. **Bars and plank shutteıs.**—Iron bars and plank shutters to be in all respects as for windows, iron-barred, with plank shutters, but without the centre rail.

For Rate Abstract see p. 386.

Note.—(1) For better class buildings wrought iron grilles replace iron bars.

Note (2).—The scantlings of frames will be the same as in Table LXXXV at page 289 except that the thickness will be 5″ for all sizes of windows.

VENETIAN BLINDS.

(PLATE XXXVIII.)

In a plank about 4½ inches wide and 1 inch thick, screwed securely to the top of the opening, are cut slots to receive pulleys about 1 inch diameter, either of brass or box-wood. Care must be taken not to make these slots wider than is necessary to permit of the pulley working freely.

Slots, 1¾ inch long ½ inch wide, are also cut in this plank to receive the rollers, round which tapes of cotton webbing fastened by brass-headed studs to the bottom of the top blade, 3 inches wide, work freely.

Ordinary blades are about ⅜ inch thick; the top blade should be somewhat thicker. The blades, when the blind is closed, overlap about ¾ inch.

The two cords by which the blinds are raised or lowered are fixed to the bottom blade; they pass through all the blades of the venetians and over the two pulleys in the top plank, and are then taken down and fastened or regulated at a hook in the jambs, or by patent clips which keep the blind up to any required height.

The ends of tapes, about 1½ inch wide, of cotton webbing, are fastened to the top blade on either side of the holes through which the cords pass, and the blades are supported on narrow tapes, the same length as the width of the blades, sewn across from the alternate sides of the broad tape; the bottom of the latter is fastened by brass-headed studs to the bottom of the lowest blade. Two tapes are generally sufficient, but if the opening is broad, three are sometimes used.

PAINTING, PAPERING AND GLAZING

PAINTERS' WORK.

General.

1. The materials used for painting shall be such as have already been described under paints in chapter II, pages 95 to 98 sect. I. In purchasing materials, which can now all be obtained in India, it is essential that the best qualities only should be bought. The best white zinc paint is Hubbock's, which is easily procurable in the bazars, but inferior stuff is frequently put into Hubbock's tins and sold as being of his manufacture.

2. The best white zinc paint should be able to take 1 lb. of linseed oil and ½ lb. of turpentine to each 2 lbs. of the zinc paint. Should the mixture in the above proportions be too liquid and run down the surface of vertical work in lines, it shows the paint is not of the best quality.

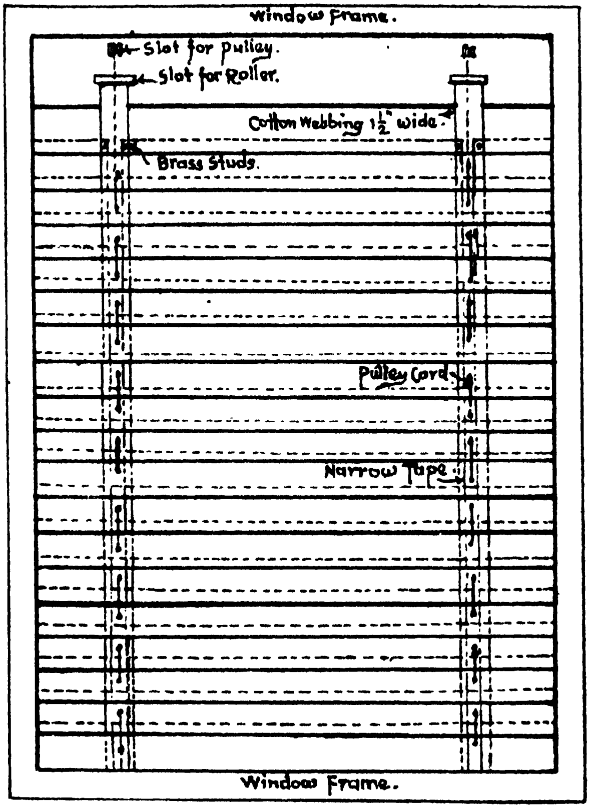
Care is also required in the purchase of boiled linseed oils. The best boiled linseed oil should, in dry weather, become hard and set in 24 to 36 hours. Inferior oils will frequently never really harden and will became sticky in damp weather.

3. The following gives the quantities of materials required with the area which will probably be covered :—

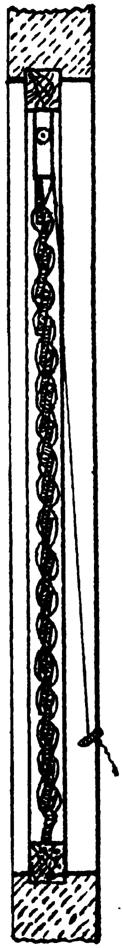
——	Zinc paint.	Linseed oil.	Turpentine.	Pigment and driers.	Area covered.
1st coat	2 lbs.	1 lb.	½ lb.	As required.	112 sq. feet.
2nd and 3rd coats ..	2lbs.	1 lb.	½ lb.	As required.	168 sq. feet.

VENETIAN-BLIND.

XXXVIIIA



FRONT ELEVATION.



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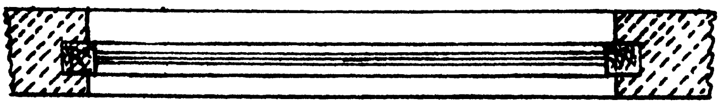


PLAN.

To face page 306

1 lb. of oxide of iron paint will cover 8 to 12 square yards on iron.

1 gallon of tar mixed with 1 lb. of pitch will cover 12 square yards first coat and 16 to 17 square yards subsequent coats.

1 pint of oil varnish will cover 8 to 9 square yards.

4. When the work to be painted is subjected to a strong light and is not of very high finish, oil painting shows up every defect, and in such cases, it is desirable to have the painting done in turpentine instead of oil, the result being a flat instead of a shiny surface. The proportions to be used are 2 lbs. of white zinc, 1 lb. turpentine and $\frac{1}{2}$ lb. of boiled linseed oil. The mixture covers a somewhat larger area than when an excess of oil is used.

5. For painting plaster work, a coat of plain linseed oil should first be applied, after that white zinc paint, and then the zinc paint with the required tints added, oil and turpentine being used in the same proportions as already stated.

6. The pigments should be ground fine by rubbing on a stone, if a grinding mill is not available, and should then be thinned with oil and gradually added to the mixture of zinc paint and oil until the required tint is accurately obtained; after this, the turpentine is to be added, and the whole mixture should be thoroughly stirred and it will be ready for use.

7. It thould be noted that small samples of colour look much paler than when precisely the same shades are applied to large surfaces such as the walls of a room. The idea to aim at is to give a suggestion of the desired colour instead of covering a large surface with a dark and unmistakable mass of colour, which is sure to be displeasing to the eye.

Notes for guidance.

1. **Knotting.**—Consists in "killing" the knots in wood-work or covering them with a substance through which the resin cannot exude. This is done *before* the priming coat of paint is applied, in one of the three following ways :—

(*a*) **Ordinary or size knotting.**—To be applied in two coats. The first to be made by grinding red lead in water and mixing it with strong glue size, used hot. Dries in about ten minutes. The second coat to consist of red lead ground in oil, and thinned with boiled oil and turpentine.

(*b*) **Patent knotting.**—To consist of two coats of a varnish made by dissolving shellac in methylated spirits of wine.

(*c*) **Lime knotting**—Cover the knot with hot lime and leave on for 24 hours; then scrape off and coat the surface with size knotting as per (*a*) above.

2. **White lead.**—To be English "stack" made of genuine quality and well matured, and to be in original packages which are to be clearly marked on the outside as "genuine".

"If lead paint is used in the internal painting of buildings, the dry rubbing of lead painted surfaces must invariably be prohibited."

3. **Zinc white.**—To be zinc oxide 99 per cent. pure, whitest quality, and to be completely soluble in dilute sulphuric acid without any effervescence.

4. **Linseed oil.**—To be genuine linseed oil obtained from the seed of the flax plant (***linum usitatissimum***).

(*a*) **Raw linseed oil.**—To be slightly viscid but clear and of a yellowish colour with a slight brown tinge. Its specific gravity at a temperature of 60° F. to be between 0·932 and 0·937. It should be soluble in petroleum spirit, naphtha, turpentine and in alcohol.

(*b*) **Boiled linseed oil.**—To be more viscid than the raw oil, to have a reddish tinge and a specific gravity ranging between 0·940 and 0·950 at 60° F. Should dry with a glossy surface and be soluble as raw oil.

(*c*) **Pale boiled oil.**—Should be the same as ordinary boiled oil except that it should not be dark in colour.

5. **Turpentine.**—To be genuine standard American turpentine except in cases where the use of the Indian Government turpentine is specially approved by the Executive Engineer.

6. **Stopping.**—To be done with ordinary putty made from whiting and linseed oil, *after* the priming coat of paint is applied, and not before, as otherwise, the wood absorbs the oil in the stopping and so defeats the purpose.

7. **Hard stopping.**—Shall be used for high class interior work in place of the ordinary stopping, shall consist of an admixture of ⅓ of white lead to ⅔ of ordinary putty.

8. **Ready mixed paint.**—Shall be used exactly as received from the manufacturers and without any admixture whatsoever except with the previous approval of the Executive Engineer.

9. **Enamels.**—Shall be used exactly as received from the manufacturers and without any admixture whatsoever except with the previous approval of the Executive Engineer.

10. **Stainers or pigments.**—This shall be of the best quality ground in genuine linseed oil.

11. **Driers.**—Shall be either litharge, or such patent driers as may be approved by the Executive Engineer.

12. **Paints.**—Except with the express permission of the Executive Engineer nothing but ready mixed paints of a make and brand to be approved by him shall be used, but in cases when he gives permission for stiff paint to be used, the procedure laid down in clause 13 below shall be followed.

13. **Preparing a pot of paint.**—Take sufficient stiff paint from the cask or tin, and cover what is left in the cask or tin with a layer of linseed oil. Place it in a clean paint pot with linseed oil (raw, boiled or pale boiled as the case may be) mix up with a stick, and then add the other ingredients. When a colour is desired add the necessary stainer or pigment, and mix up again thoroughly. Then take a second clean paint pot, cover it with canvas tied on tightly, and work the mixed paint through this canvas with a brush, into this second paint pot. The paint is then ready for use except when a flat finish is desired for the final coat, when a little more turpentine may be added.

14. **Removing old paint or varnish.**—This shall be done with a blow lamp and scraper, or with a paint solvent or remover of a nature that shall be approved by the Executive Engineer. In the event of a solvent containing alkali being used, the surface shall subsequently be washed down with a weak acid such as dilute vinegar so as to neutralize the alkali. Particular care is necessary in using a blow-lamp to remove paint from wood to avoid burning it.

15. **Rubbing down.**—All greasy places shall be brushed over with turpentine, and then washed with soap and water. Before the priming coat and also before

each and every subsequent coat of paint is applied, the work shall be rubbed smooth with sand paper or fine pumice stone or water.

16. Priming coat—

(*a*) **On inside wood-work.**—Shall consist of the following proportions :—

½ lb. of red lead ;

8 lbs. of white lead ;

2 pints boiled linseed oil ;

1 pint raw linseed oil ;

1½ oz. of litharge or patent driers ;

and shall be applied *before* the wood-work is fixed in place.

(*b*) **On outside wood-work.**—Shall consist of the following proportions :—

10 lbs. white lead ;
4 pints raw linseed oil ;
1 oz. red lead ;
2 oz. litharge or patent driers ;

and shall be applied *before* the wood-work is fixed in place.

(*c*) **On plaster work.**—Shall consist of equal parts of white and red lead mixed in boiled linseed oil. As a rule new plaster should not be primed or painted for 12 months after it is made, so as to allow it to dry thoroughly.

(*d*) **Steel or iron.**—Shall be primed with red lead and boiled linseed oil, all rust and mill scale being first removed.

(*e*) **Galvanized iron.**—First apply a coat of 6 oz. of copper acetate added to a gallon of water or 2 oz. of muriatic acid added to a mixture of 2 oz. each of copper chlovide, copper nitrate and sal-ammoniac dissolved in a gallon of soft water (sufficient for 2,500 to 3,000 square feet). Then prime with red lead and boiled linseed oil.

(*f*) **Portland cement.**—To be first treated with a wash of dilute white vitriol and then primed as for plaster in (*c*) *ante.*

17. **Additional coats.**—Shall be of ready mixed paints as in clause 12 *ante* or (when permitted by the Executive Engineer), of stiff paint prepared as in clause 13 *ante.* They shall be applied as in clause 18 *post.*

18. **Application of paint.**—The paint shall be applied with brushes, which in each case shall be approved by the Executive Engineer. It shall be spread as smoothly evenly as possible. To effect this, as soon as the whole or a convenient quantity and of the work is covered, the brush should be passed over it in a direction contrary to that in which it is finally to be laid off; this is called "crossing". After "crossing", it should be laid off in a direction contrary to the "crossing" but (in the case of wood-work) with the grain of the wood, taking care that the "crossing" brush marks are not left visible. The finished surface should be perfectly smooth and even and no brush marks should be visible. Every coat should be perfectly dry, rubbed down and passed by the Sub-Divisional Officer, before the succeeding one is laid over it.

19. **White paint.**—When white paint is specified, (except for the priming coat for which see clause 16 above), when the work is outside and likely to be exposed to the weather, white lead shall be used ; when the work is in side and not likely to be exposed to the weather, white zinc shall be used.

VARNISHING.

1. **Rubbing down.**—The surface to be made perfectly smooth with sandpaper or pumice stone.

2. **Knotting.**—To be done as described under painting.

3. **Stopping.**—The surface of the wood to be then stopped, with hot weak glue size (a lb. of glue making about one gallon of size) so as to close up the pores, and when dry, the surface should be again well sandpapered.

4. **Varnishing.**—The varnish to be then applied in very thin coats with special fine haired varnishing brushes and *not* with ordinary paint brushes. None but the best copal vernish is to be used.

5. **Measuring.**—The routine of varnishing shall be described as " clean, rub down, knot, stop and apply one (or more as the case may be) coats of best copal varnish " . The measurements shall be taken in the manner described for painting.

PAINTING.

Specification No. 140.

1. **Number of coats.**—All wood and iron-work exposed to the weather will receive four coats of paint ; in the interior of a building, three coats will suffice. Paint should not be applied to wood-work unless it is well seasoned.

2. **Cleaning.**—Surfaces to be painted or varnished to be thoroughly dry, clean and smooth, free from rust and dirt.

3. **Mixing.**—The paint to be thoroughly ground up in oil and mixed with the proper proportion of double-boiled linseed oil and spirits of turpentine. Mineral turpentine on no account to be used.

4. A priming coat without colouring matter shall first be applied, after which all holes, cracks, etc. shall be stopped with putty, and all knots properly killed with quick- lime.

5. **Fine work.**—For fine work, each coat should be carefully rubbed down with pumice-stone or glass-paper, and dusted before the next coat is added.

6. **Execution of work.**—All coats to be laid on evenly and properly with English-made brushes ; the work should show no hair marks, or drops of paint, and shall be allowed to dry thoroughly before the next is laid on.

7. *Measurement.*—Painting will be paid for at a rate per 100 square feet, the number of coats being specified.

Moulded work of all kinds, unless otherwise stated, will be measured by running the tape over and into all elevations and depressions, but doors and windows will be measured flat over all, including architraves, etc., if any.

Venetians and louvres will be measured as one and a half times the area of a flat surface of the same size ; trellis work will be measured without any deduction for open spaces ; and glazed portions of doors, windows, etc., will be allowed for by deducting half of the glazed part from the total flat surface.

Painting old work.

Clean with lime wash and rub down with pumice, filling all holes with putty. If old paint is blistered, rub down and scrape and then bring forward with 3 or 4 touchings before the general surface is begun. If old paint is greasy with smoke, mix the first coat with spirits of turpentine instead of oil.

Recipes.

Satin-wood paint.	Mahogany.	Red paint.	Green paint.
16 parts, white lead 1 part, chrome yellow. 1 „ red lead. 2 parts, red brown. 2 „ amber brown ¾ part, terra sienna. 8 parts, Europe linseed oil. 4 „ turpentine 1 part, varnish. Yellow painting to be laid on in two coats and figures carefully inscribed after it is dry.	To be mixed as for satin-wood, with addition of a little ivory black. To be laid in the same manner.	2 parts, red ochre. 3 „ mineral red lead. 4 „ wood oil. *Black Paint.* 1 part, chalk. ½ „ white lead. ¼ „ wood oil. mixed with lamp-black.	Use best Brunswick or marine green, not verdigris, as the latter loses its colour. if verdigris is used, take— 13 parts, mineral verdigris, } by weight. 22 „ white lead, } grind separately, screen and mix.

VARNISHING.

Specification No. 141.

1. **Preparing surface.**—The wood-work, when cleaned and rubbed down, to receive two coats of clean boiled linseed oil, or two coats of size, laid on at sufficient intervals of time. When dry, the varnish is to be smoothly laid on in thin coats.

2. **Copal varnish.**—The varnish, used, to be the best English copal, unless otherwise specified.

The following are good recipes for varnish.

(*a*)	Resin	2 parts.
	Europe linseed oil	2 parts for common works
	Spirits of turpentine	1 part.
(*b*)	Copal	3 parts.
	Oil of turpentine	5 parts.
	Linseed oil	2 parts.
(*c*)	Amine resin	2 ℔s.
	Litharge	1 oz.
	Sugar of lead	1 oz.
	Spirits of turpentine	5½ quarts.
	Linseed oil	2 quarts.
(*d*)	Pale shellac	7½ parts.
	Mastic	6½ parts.
	Spirits of wine	10 parts.

Varnish for iron-work and outdoor work.—In about 2 lbs. of tar oil dissolve ½ lb. of asphaltum and an equal quantity of pounded resin, heat in an iron kettle and mix, taking care to prevent contact with flame. When cold, use.

Varnish for common work.—Take 3 ℔s. of lamp resin, powder it, place it in a tin can, add 2½ pints of spirits of turpentine, shake well and let it stand with occasional shaking for a day or two. Then add five quarts of boiled linseed oil, or Tung oil, shake well together and allow it to stand in a warm room till clear. Decant clear portion and use, or reduce with spirits of turpentine until of the proper consistency. This varnish is intended for protecting surfaces exposed to the climate. It has been used with advantage for coating wood and iron-work.

The preparation of varnishes is a difficult matter, and it is better to purchase varnishes ready prepared.

For Rate Abstract see p. 357.

Specification.

1. **Varnishes.**—The material shall be a clear and transparent varnish suitable for use on interior or exterior work as specified and shall give a uniform and glossy coating free from runs and specks.

2. In respect of colour it shall be extra pale, pale or ordinary as specified.

3. The material shall become surface dry in not more than 6 hours for interior work and 8 hours for exterior work, and hard dry in not more than 18 hours.

4. The loss in weight on heating in a suitable oven, after placing on a metal dish, at a temperature of 105° — 110° C, for 3 hours, shall not exceed 50 per cent.

French polish.

1. A good French polish suitable for the Indian climate can be made with the fol owing ingredients :—

Dissolve in methylated spirit (12 bottles) ...	3	gallons.
Shellac black (*chapati kari lakh*)	3	℔s.
Olibanum (*isesa*)	½	℔.
Gamboge (*revanchino shiro*)...	½	,,
Copal or *sandarach* (*chandrusa*)	½	,,
Gum benzoin (*lobana*)	½	,,

The gums are pounded fine and added to the spirit and the mixture is agitated until the gums are dissolved. A warm bath aids the operation.

The wood, to be polished, should be first painted with a filler composed of 5 ℔s. of whiting mixed in ½ of a gallon of methylated spirit, and then sand-papered. A thin coat of the polish should then be applied, and this sand-papered prior to the second and third coats.

Varnishing should, as far as possible, be done in dry weather.

2. Take plaster of Paris, red ochre or dragon's blood (sufficient to tint it), and linseed-oil : mix to a stiff paste, moisten a piece of rag with linseed oil, rub on wood and then apply mixture sparingly, rubbing it hard in to fill up the pores of the wood. Wait a few hours and then rub down with fine glass-paper. Then put on the polish. Two coats will be sufficient. To finish off, roll a piece of flannel into the form of a rubber, cover with a piece of rag slightly damp with methylated spirit, and rub lightly and quickly with a circular motion : if the rag sticks, touch the wood with linseed oil. French polish is made by dissolving ¼ ℔. brown shellac in 1 pint of spirits of wine or naptha.

3. The following is an excellent wood or furniture polish :—

16 qts. linseed oil.	1 qt. turpentine.
2 qts. spirits of wine.	1 qt. copal varnish.
1 qt. vinegar.	1½ pts. muriatic acid.

The oil to be heated and the whole mixed up.

Brass lacquer.

Pale shellac	... 1 lb.
Gamboge	... 1 oz.
Cape aloes	... 3 ozs.
Alcohol	... 2 gals.

Gold lacquer.

Pale shellac	... ¾ lb.
Sandarach	... 3½ lbs.
Turmeric	... 1 lb.
Gamboge	... 2½ ozs.
Alcohol	... 2 gals.

OILING WOOD WORK.

Specification No. 142.

1. The following is a good mixture for oil coating wood-work :—

3 lbs. double-boiled linseed oil.
1 lb. turpentine.
1 lb. bees' wax.

The oil and the wax to be heated in a vessel over a slow fire till the wax is melted. After the mixture has cooled, turpentine to be added and the mixture applied in two coats.

2. **Sweet oiling.**—Mix equal parts of common vinegar, country sweet oil and turpentine.

(This gives a darker effect than linseed oiling).

WAXING.

Specification No. 143.

Waxing is to be done as follows :—

Take of—

Bees' wax	... 2 lbs.
Turpentine	... 1 lb. (8 lbs. to a gallon).

Melt the wax and add it to the turpentine, mix well, and allow to cool. Smear the wood-work with the mixture and allow it to remain over night so as to soak into the pores of the wood. Then in the morning, wipe off the superfluous and rub up with a soft flannel to a fine polish.

COAL TARRING.

Specification No. 144.

1. For wood or iron work, the surface is first well cleaned, and the coal tar heated nearly to boiling point, thinned by the addition of half a pint of common country spirit to each gallon of tar, and while still very hot, applied like paint with a brush and covered with fine coal powder. When it is possible to remove iron-work for the purpose, it shall be heated to nearly a red heat and then brushed over with coal

tar ; iron-work which cannot be thus heated, shall be painted with hot tar and spirit as specified for wood. The quantity to be used is not to be less than 10 lbs. per 100 superficial feet.

2. In using coal tar, 2 lbs. of unslaked lime should be mixed with one gallon of tar, to prevent running.

The cost of tarring, including labour and materials, in the city of Bombay is as follows :—

	Rate per 100 supl. ft.		
	Rs.	a.	p.
Tarring wood-work with common tar, 1 coat	1	0	0
Do. do. do. 2 coats	1	12	0
Do. do. do. 3 „	2	8	0
Do. do. with Stockholm tar, 1 coat	1	12	0
Do. do. do. 2 coats	2	8	0

DAMMERING ON ROOF.

Specification No. 145.

A coat of melted pitch is to be applied to the upper surface of the boarding on this and before it hardens, tack down old tarpaulins smoothly and carefully with proper laps. On this another coat of pitch, with a smaller quantity of tar mixed in it to take away its brittleness' is to be carefully laid on, thoroughly spread, and well worked in.

The cost of dammering, including labour and materials, in the city of Bombay is as follows :—

	Rate per 100 supl. ft.		
	Rs.	a.	p.
Dammering with 2 coats of half dammer, half pitch on new dungry cloth, one coat on each side. ..	10	0	0
Dammering with 2 coats of half dammer, half pitch without cloth ..	4	0	0
Dammering with one coat of half dammer, half pitch without cloth ..	2	12	0
Dammering with 2 coats of half dammer, half pitch over old cloth ..	2	12	0

DISTEMPERS.

General.

None of the distempers stand exposure to heavy rain, nor can any of them be described as washable. However, Hall's Shalimar and Muraline, when carefully applied on perfectly dry lime-plastered walls, after three months admit of very slight stains being removed from the surface, by a soft wet cloth without perceptible injury.

Muraline and Shalimar have a slight advantage over Hall's, as they are easier to work, and present a more even surface. Muraline has the greatest covering power, and can be applied to wood with good results. Distempers, apart from other advantages, should invariably be used in preference to whitewash, as the cost of distempers compares favourably with that of whitewash in the long run. They should, however, only be used in dry climates, as they give poor results in wet localities. To get the full advantage out of these distempers, it is necessary to have a priming coat as recommended by the makers. Distempers grow dark with age.

Specification No. 146.

1. Distempers should not be mixed in a large quantity than is actually required for a day's work, and hot water should be used in preparing the mixture.

2. On newly lime-plastered walls, distempers should be applied in two coats over one coat of priming.

3. On old lime-plastered walls, covered with one or two coats of hard dry white-wash free from efflorescene or *kàlàr*, one coat of distemper without priming should be used : but distempers which are lime-proof should alone be used.

4. When the lime plaster is very smooth, and no priming coat is used, a coating of warm glue should first be applied, but if rough, a coat of Spanish white or chalk mixed with a solution of glue is employed to render the surface smooth, the coating when dry being rubbed as clean and as even as possible.

5. Inequalities and holes must be filled with gypsum, which should be allowed to set hard before the distemper is applied. Unless the ground to be worked upon is perfectly clean, no pleasing effect can ever result from distempers.

For local made distempers a priming coat of milk (1½ lbs. per 100 sq. ft.) may be used with good results.

6. Distempers should be applied in dry weather, with a broad stiff brush, and only after the first coat has thoroughly dried, another should be laid on. The first coat should always be of a lighter tint, and should be applied with care. The brushes used should never be allowed to rest on the bristles, and after use they should be carefully and thoroughly cleaned.

7. Great care should be taken in choosing a suitable colour for a light or a dark room.

8. Old distempered walls may be lightly washed in dry weather with a soft cloth and plenty of water. No attempt should be made to wash distempered walls during the monsoon.

(*a*) The following distemper has been successfully used at Mahabaleshwar :—

14 lbs. of finely ground pipeclay and 14 lbs. of whiting are first mixed and then made into a thick paste by the admixture of 22 lbs. of buffalo milk 1 lbs. of gum and 1 lb. of sago are then boiled together in about 3½ gallons of water, and made into thin size, which is strained through a piece of unbleached cloth into the milk paste. The whites of three dozen eggs are then beaten into a froth, 1 lb. of sugar mixed with it and the mixture is beaten till it becomes a syrup, and added to the paste.

Finally the colouring matter is added 2 lbs. of emerald green for a green tint—and the distemper stirred up ready for use. The uncoloured distemper is of a dull white colour.

Old lime wash is first thoroughly removed from the walls, which are then sand-papered. A wash of pure milk is then applied, and after this has dried, a coat of the uncoloured distemper is applied to form the ground coat. The colouring matter is then mixed in a little size (gum and sago water), strained, and mixed with the distemper. This is then applied to the wall with a broad brush in two coats.

This distemper, which is washable, lasts for about 10 years, if the walls are carefully protected from damp during the monsoon. It adheres satisfactorily to corrugated iron, wood and oil-painted walls, provided, in every instance, that the surface is treated with a wash of pure milk.

(*b*) The following is taken from *S. K. Notes on Building Construction*, Vol. III:—

"Take 6 lbs. best whiting and soak it in soft water, sufficient to cover it, for several hours. Pour off the water and stir the whiting into a smooth paste, strain the material and add one quart of size in the state of weak jelly, mix carefully not breaking the lumps of jelly, then strain through muslin before using; leave in a cold place, and the material will become a jelly, which is diluted with water when required for use. Colouring pigments are then added as required."

(*c*) The following description of distempering refers to the work as executed in Calcutta. The surface of the plaster is to be rendered smooth, and then thick curd or *chana* mixed with lime water or simply milk and water of equal proportions, is to be washed over the surface to form a body for the water colouring.

The water colouring is to be mixed with half milk and half water with white of eggs and pure China glue, the latter previously boiled in water and made into a liquid. The colour so prepared is to be laid carefully on the walls in one coat with an English brush.

For Rate Abstracts see pp. 387 and 388.

TABLE XCV.

STATEMENT SHOWING INGREDIENTS FOR DIFFERENT DESCRIPTIONS OF WATER COLOURING, BORDERS, ETC.

		Tolas.
Stone colour	Whiting	80
	Umber, burnt	2·50
	Chrome, yellow	10
	Glue	10
	Vermilion, China	0·25
Canary	Whiting	80
	Glue	10
	Chrome, yellow	10
Buff	Whiting powder	80
	Glue	10
	Chrome, yellow	10
	Yellow ochre	5
Green	Whiting	80
	French green	20
	Glue	10
Brown	Whiting	80
	Glue	10
	Burnt umber	10
	Meena	10
Blue	Whiting	80
	Glue	10
	Prussian blue	10
Purple	Whiting	80
	Glue	10
	Meena	10
	Vermilion, China	10

Note.—One tola is equal to the weight of one rupee.

WHITE-WASHING.

Specification No. 147.

1. **White-washing.**—To be prepared from fresh burnt white stone-lime, or shell-lime if available. The lime to be dissolved in a tub with a sufficient quantity of water, and the whole well and thoroughly mixed, and strained through a clean cloth water, and the whole well and thoroughly mixed, and strained through a clean cloth; clean gum dissolved in hot water to be then added in the proportion of 2 ozs. of gum arabic to 1 cubic foot of lime, or rice size may be used in place of gum.

2. Each coat to be laid on with a brush: one coat with a stroke of the brush from the top downwards, another from the bottom upwards over the first stroke, and similarly, one stroke from the right and another from the left over the first brush before it dries. Three coats to be applied.

3. Before white-wash is laid on the surface of new walls, the walls to be well cleaned nad brushed.

4. On walls which have been once white-washed, the old loose white-wash to be first removed and the plaster repaired.

Generally, Surti lime is used in white-washing. *Recipe* for white-wash which does not easily rub off :—

To 1 cwt. clean white or shell-lime slaked thoroughly with hot water in a covered vessel,

add 14½ lbs. salt dissolved in hot water;

8½ lbs. coarse rice pounded or boiled to a thick paste;

1½ lbs. glue cleaned by dissolving in hot water, the dirty scum and dregs being rejected.

Ingredients to be well mixed and brought to the required consistency by the addition of hot water, allowed to simmer over a fire for a few hours, and then strained and laid on hot.

For Rate Abstract see pp. 389 to 391.

COLOUR-WASHING.

Specification No. 148.

1. **Colour-washing.**—Usually prepared by adding the necessary colouring matter, to the white-wash which has been strained. Only wash sufficient for the day's work should be prepared each morning.

2. Colour-wash shall be applied in the same way as white-wash. The wash should be stirred continually during use. To test colour-washing, when finished rub with the fingers. If the surface is powdery and comes off readily, or if the general appearance is streaky, the work should be rejected.

3. A suitable pale green colour-wash may be prepared as follows :—

(*a*) Slake 4 lbs. of lime in 18 pints of water.

(*b*) Boil 7 lbs. of fresh mango bark in 4 pints of water for 2 minutes.

(*c*) Boil 2 ozs. gum in 1 pint of water.

(*d*) Boil 4 ozs. of rice in 3 pints of water.

(*e*) Boil 2 lbs. of "tootya" (blue stone or copper sulphate) in pints of water.

After the lime has been slaked, and the 'tootya' partially cooled, strain all the ingredient in the order given in a non-absorbent tub or drum, thoroughly mixing them by stirring. The liquid should then be again strained, to remove any lumps that may have formed.

PAPERING.

Specification No. 149.

1. **Pattern.**—The paper to be of the pattern approved by the Executive Engineer.

2. **Cleaning and sizing.**—The walls to be properly scraped and rubbed down quite free from any colour-wash or dirt and then to be sized with parchment size or rice " congee ".

3. **Lining paper.**—If expensive paper is used, the walls to be first covered with a coating of lining paper. Wall to be quite dry before the paper is applied.

4. **Paste.**—The paper to be applied with paste made of the best wheat flour and water, a little size or glue, blue stone (sulphate of copper) being added to prevent the attacks of insects. A little alum may also be added, to make the paste spread and flow more easily.

The greatest care shall be taken in fitting the pattern so as to keep all quite clean.

5. **Roller.**—The paper when applied to the wall, to be smoothed down by a roller covered with clean flannel, and not be the hand, as the latter method completely ruins any delicate paper.

6. **Papering.**—Papers to be hung true to pattern and close to the walls, and well pressed into all the angles. Any paper showing air blisters or other defects will have to be stripped and relaid.

7. To prevent stripping, tape may be tacked on with copper tacks, over the paper but under the border, along the top and bottom of wall.

The following is a useful memorandum :—

A piece of English wall paper is 12 yards long and 21 inches wide, and contains 63 square feet.

A French wall paper is 9 yards long and 18 inches wide, and contains 40½ square feet.

A dozen of borders equals 12 yards run.

To obtain the number of pieces required for a room, divide the superficial area to be papered by the square feet contained in one wall paper and add one-seventh for wastage occasioned by the necessity of matching breadths, and having various lengths of cuts.

To hang one piece of wall paper requires ¼ lb. of flour, ¼ oz. of alum and ¾ pint of rice size.

8. The contractor shall provide his own scaffolding without extra charge.

The cost of papering walls in the city of Bombay is generally as follows :—

	Rs.	a.	p.	
With common paper, including paper of not more than Rs. 1-5 per roll and border, and removing old paper	3	15	0	per 100 supl. feet.
Do. if Government supply the paper	1	5	0	Ditto.
With superior paper of value not more than Rs. 2-10-0 per roll, including border, suppling paper and removing the old paper ..	6	9	0	Ditto.
Removing paper border and re-pasting new on walls (paper border to be supplied by Government) ..	0	11	0	Ditto.

GLAZIER'S WORK.

Specification No. 150.

1. **Glass.**—Unless otherwise specified, all glass supplied to officers' quarters, dwelling houses, and important Government buildings, shall be patent flattened sheet glass of the best quality known in the trade as " seconds " , weighing 21 ozs. to the foot (superficial) for panes up to 24″ × 24″ , and shall be free from flaws, specks or bubbles.

For panes up to 30″ × 30″ use glass weiging not less than 26 ozs. to the sq. ft.

For bigger panes upto 36″ × 36″ use glass weighing not less than 32 ozs. to sq ft.

Above that size, plate glass to be used.

2. When crown glass is specified, it should be of the " best " kind ; " seconds ', and " thirds " will not be accepted. It should be at least 1/16 inch thick and weigh not less than 13 ounces per superficial foot.

N.B.—Crown glass is said to be more free from colour than sheet glass, and has a finer surface as it does not come into contact with any other substance during the process of manufacture ; but it is being rapidly superseded by the latter, in consequence of the demand for large sizes, and some of the principal manufactures have ceased to make crown glass altogether.

3. When plate glass is specified, it should be unless otherwise described, " polished patent plate glass " of the best quality. It should be of the usual light colour ; glass of the " second " quality will not be accepted, unless such glass is described in the tender.

The plate glass should be of the thickness mentioned in the specification or in the tender. If glass of the specified thickness be not used, it will either be rejected or a lower price paid for it. at the option of the Executive Engineer.

4. All glass panes shall be properly cut to fit the rebates of the sashes truly, shall be bedded flush in soft putty, shall be sprigged in with proper glazing sprigs, and firmly back-puttied with a good putty of whiting and linseed oil and nails. The rebate to be neatly chamfered, and the whole glazing finished in a workmanlike manner.

5. **Putty.**—The putty to consist of pure linseed oil and best whiting well mixed up by hand ; the whiting to be specially dry and passed through a sieve of 45 meshes to the inch and to be mixed with as much linseed oil as will form it into a stiff paste. This, after being well kneaded, shall be left for 12 hours and worked up in small pieces till quite smooth. If the putty become dry, it sould be restored by heating and working it up again while hot. The putty to be coloured to suit the colour of the door or window, and all putty shall be given a coat of oil paint to protect it from the air.

Plate glass to be fitted to the frames with wooden battens without extra charge. When " dry " glazing is specified, the glass shall be held in place by moulded wooden fillets fixed with brass screws ; round the end of the glass and between it and wood fillets a piece of chamois leather or wash leather shall be inserted to act as a cushion.

6. No glass to be inserted in frames until they have been primed and prepered for painting, so that the putty may adhere properly.

If frosted glasses are used, they are to be fixed with the frosted face away from the putty.

7. All glass squares that may have been set by the contractor shall if they become loose during one year, be re-fixed and puttied by the contractor without extra charge.

All the windows shall be cleaned, all damaged putty or glazing be repaired, and the whole left perfect at the completion and rendering up of the work.

9. In measuring the glazier's work all fractional parts under half an inch will be omitted, and all above that, taken as one inch. Curved or irregularly shaped pieces will be measured as the least rectangle from which they can be cut. Measurments to be net from rebate to rebate.

Job work, such as re-fixing old glasses will be paid for at so much per job ; or the contractor will have to supply labour and material at the schedule rates, the work being executed under departmental supervision.

To soften putty for removing panes.

Take 3 lbs of quicklime, slake in water, add 1 lb. pearl ash, and make the whole of the consistency of paint ; apply to both sides of the glass and let it remain twelve hours, when the putty will be so softened that the glass may be taken out.

To render glass opaque or frosted.

Clean the sheet of glass ; and, if only portions of it are to be frosted, protect the portions not to be frosted by mechanical means in any simple maner. Some fluor-spar is ground to a fine powder, and mixed with concentrated sulphuric acid so as to form a thin paste, and this is rubbed by means of a piece of lead upon the parts to be rendered opaque. This process is known as " etching on glass by hydrofluoric acid. "

Gently heat the glass, when noxious fumes will be given off. On cooling, the plate is washed with dilute solultion of soda and potash to remove any acid yet remaining, and is then rinsed in water.

Care should be taken that the fluoric acid does not get on the skin.

Interception of light by glass.

The effects of different descriptions of glass on the diminution of light have been shown by experiment to be as follows :—

British polished plate, ¼ inch thick,	intercepts	13	per cent. of light.
Rough cast plate, ¼ inch thick	do.	30	do.
Rough rolled, 4 flutes to an inch	do.	53	do.
Sheet glass, 32 do.	do.	22	do.

Flutted or ribbed glass.

This is specially suited for windows in dark places, as it diffuses the light better than plain glass. Horizontal ribs give more light in the middle and less at the sides. Upright ribs give more light at the sides and less in the middle. The brilliancy of the light with horizontal ribs is much greater than with the upright. The diffusion of heat is the same as the diffusion of light, but the ribbed glass becomes hotter than the plain glass.

Wired glass.

This is a comparatively recent invention, in which wire netting is embedded in a sheet of glass about ¼ inch thick. It has a melting point higher than that of ordinary glass, and does not give in great heat. It is used for fire-resisting doors, windows in lift shafts, sky-lights, etc. One great advantage of this glass is, that it does not fall when cracked, as the embedded wires hold it seecurely together.

Leaded lights and stained glass.

Plain square leading for living rooms should be arranged in panes of not less than 7 inches by 5 inches, and the leads should be about $\frac{7}{16}$ inch wide.

In designing leaded lights, care should be taken that the construction of the leading is strong, and that the lights will withstand lateral pressure without bulging. The pieces of glass should bind well and the leads tie.

Leaded lights should be glazed in pure vice-drawn leads, with the joints properly soldered on both sides.

Glazing leads should be of an H section. The middle bar is termed the heart and should be stouter then the sides or leaves.

Leads for external work should be from $\frac{1}{4}$ inch to $\frac{1}{2}$ inch in breadth of leaf.

Beaded leads are preferable for general work, as they are water-tight, the beads allowing the cement to be pressed into the crevice between the lead and glass.

The broader leads are used for outside margins, and should entirely fill the rebate or groove, and project $\frac{1}{8}$ inch beyond the beads or pointing.

Lead glazing in sheet glass should not be in heavy glass; good selected 15-oz. sheet is the best for the purpose.

Leaded lights should be cemented by brushing under the leads a cement composed of oil mastic or whiting and red lead, and afterwards brushed with black lead.

The lights should be supported in position by horizontal saddle-bars of square or round iron, steel, zinc, or copper.

The bars should be placed not more than 18 inches apart, and well secured to the lights by wire bands or ties soldered to the leads.

Broad lights more than 30 inches across require additional support by stanchion bars, fixed to the frame vertically, to which the iron bars should be attached.

All leaded lights should be bedded in putty; whether they are pointed up or beaded in, lead lights need expert handling, otherwise the cement may be disturbed.

TABLE XCVI.

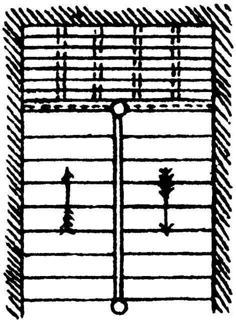
DIFFERENT KINDS OF GLASS AND SIZES AVAILABLE IN THE BOMBAY MARKET.

Serial No.	Description of glass.	Thickness.	Market sizes.
1	Window glass (16 oz.)	$\frac{1}{16}$"	8" × 10"; 10" × 12"; 10" × 14"; 12" × 12"; 12" × 14"; 12" × 16"; 14" × 14"; 14" × 16"; 14" × 18"; 14" × 20"; 16" × 16"; 16" × 18"; 16" × 20"; 16" × 22"; 18" × 18"; 18" × 20"; 18" × 22"; 18" × 24"; 20" × 30"; 22" × 32"; 24" × 32"; 24" × 36"; 30" × 36"; 30" × 40";
2	Sheet glass (24 oz.) ..	$\frac{1}{8}$"	8" × 10"; 10" × 12"; 10" × 14"; 12" × 12"; 12" × 14"; 12" × 16"; 14" × 14"; 14" × 16"; 14" × 18"; 14" × 20"; 16" × 16"; 16" × 18"; 16" × 20"; 16" × 22"; 18" × 18"; 18" × 20"; 18" × 22"; 18" × 24"; 20" × 30"; 22" × 32"; 24" × 32"; 24" × 36"; 30" × 36"; 30" × 40";
3	Plate glass ..	$\frac{1}{4}$"	8" × 10"; 10" × 12"; 10" × 14"; 12" × 12"; 12" × 14"; 12" × 16"; 14" × 14"; 14" × 16"; 14" × 18"; 14" × 20"; 16" × 16"; 16" × 18"; 16" × 20"; 16" × 22"; 18" × 18"; 18" × 20"; 18" × 22"; 18" × 24"; 20" × 30"; 22" × 32"; 24" × 32"; 24" × 36"; 30" × 36"; 30" × 40"; 15" × 48"; 18" × 48"; 24" × 48"; 30" × 48"; 36" × 48"; 36" × 54"; 36" × 60"; 40" × 60"; 48" × 72"; 36" × 96"; 48" × 96"; 54" × 96"; 76" × 108"; 54" × 108"; 60" × 108".
4	Fluted glass ..	$\frac{1}{8}$"	36" × 48" and 40" × 60".
5	Ribbed glass (prism glass).	$\frac{1}{8}$", $\frac{3}{16}$, $\frac{1}{4}$".	18"; 20"; 22"; 24"; 26"; 30"; 36"; 40" wide × 72" long.
6	Wired glass ..	$\frac{1}{4}$"	24"; 30"; 36" wide × 72" long.
7	Rough glass ..	$\frac{1}{4}$"	36" × 60", only one size.
8	Coloured glass (green, blue, red).	$\frac{1}{16}$", $\frac{1}{8}$"	8" × 10"; 10" × 12"; 10" × 14"; 14" × 14".

Plate XXXIX. — WOODEN STAIRCASES. —

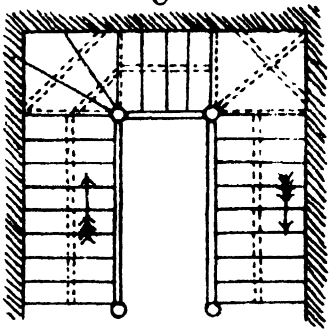
Dog-legged

Fig. 1



Open newel

Fig. 2



Sections of Hand Rail

FIG. 5

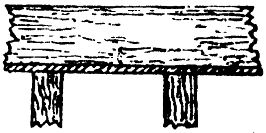
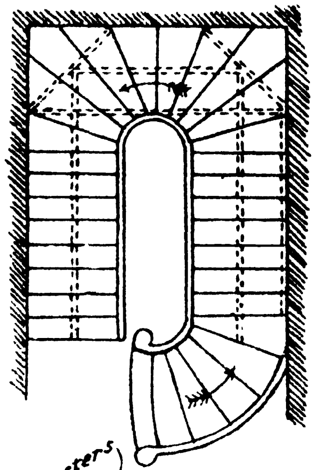


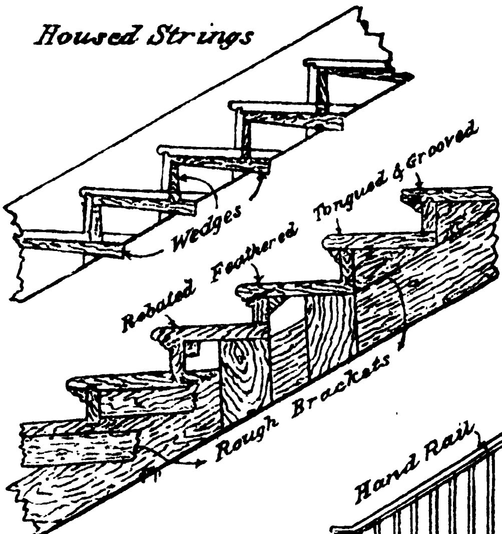
FIG. 4

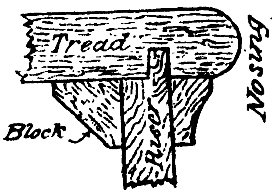
Geometrical

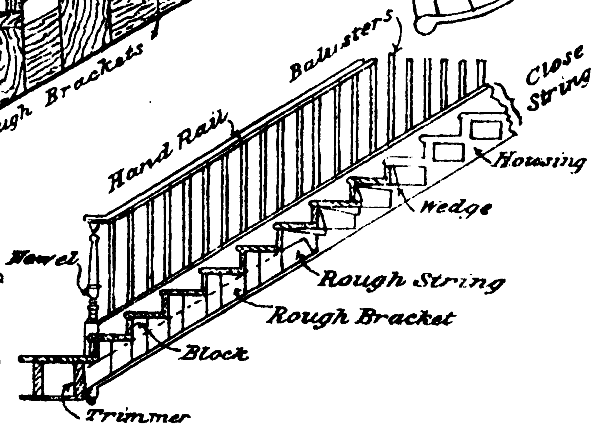
FIG. 3



Housed Strings







Govt Photozinco Office Poona 1929.

WOODEN STAIRS.

General notes.

1. The rincipal types of staircases are the following :—

"Dog-legged," "open well or open newel" and "geometrical."

2. **Dog-legged.**—In dog-legged stairs (figure 1, plate XXXIX) the flights run in opposite directions and in plan there is no space between them.

3. **Open newel.**—In open newel stairs (figure 2), there is a space between the flights called a well.

4. The form of the landings, and presence or absence of winding stairs at the turns, do not affect this distinguishing feature of the two varieties. In both cases posts or newels, occur at each change of direction in the stairs and hand-rail.

5. **Geometrical.**—Geometrical stairs (figure 3) have no newel posts, but the hand rail continues without interruption and without angular turns.

6. In all types the individual steps are built into inclined pieces, measuring 14″ × 3″ called strings. Usually they are housed about half an inch into the string placed against the wall, and the other string is notched so that the treads and risers which form the steps can be fitted over it. Other pieces called carriages are often fitted in intermediate positions, running parallel with the strings which give intermediate support to the steps.

7. Flights should, when possible, consist of not more than 12 steps after which there should be a landing. Two consecutive flights ought not to be in the same direction.

8. **Landings.**—Landings are supported by joists from the walls as in floors. Strings are either tenoned into newels, or notched and bolted in trimmers or joists of the floors and landings.

Note.—When the floor is continued under the lowest flight of a stair the space between the soffit of the stairs and the floor is the spandrill into which a cupboard can be fitted. In such a case, the landing and the parts of all the steps should be put together with tongued joists to prevent the passage of dust.

9. **Tread and rise.**—The following rule is often adopted for steps of the dimensions ordinarily required in practice, *i,e.*, those with treads from 9 to 14 inches wide :—Width of the tread × height of riser = 66 inches.

Another rule is, tread + twice rise = 22 inches to 25 inches. The planning of stairs will depend on the width available. In the case of winding stairs the width of tread is taken at a point 18 inches from the hand-rail.

10. Winding stairs have a separate bearer under each step, extending from wall to newel. Cross bearers or carriages are also employed as with straight flights.

11. **Hand-railing.**—Hand-railing is secured to newels and balusters, or in geometrical stairs to balusters only, by means of a flat W. I. bar ¼ inch thick, and of a width equal to that of the top of the balusters, as shown in figures 4 and 5. The rail follows the inclination of the stairs, rising more rapidly over the narrow ends of winders than over the full-width straight treads. It should be several inches higher on the level, than it is when inclined. In stairs

with newels it is usually in straight lengths, sometimes curved at the ends to raise or lower its height as it reaches a level.

Note.—(*a*) The balusters are sometimes fixed to the outer strings, being bent or kneed so as to clear the ends of the steps in order to give as much width as possible to the stairs. Generally there are two balusters fixed on the end of each step, one flush or as nearly as possible flush with the face of the riser, the other midway between the risers. On each of the narrow ends of winders one baluster only is required.

(*b*) The height from the treads (at the nosings) to the upper surface of the hand-rail should be 2 feet 7½ inches; to this there should be added at the landings the height of half a riser.

12. **Curves.**—In geometrical stairs the curves of the railing are complex, as it is required to wind in order that its cross-section may be normal to the stairs while rising and simultaneously following the lateral bends.

13. **Joints.**—It is jointed in lengths with plain butt joints, dowelled and held together by hand-rail bolts.

14. The rate will depend entirely on the type of stair chosen, but generally for straight and curved strings the following may be taken :—

For straight based strings ..	¾ carpenter .. ¾ coolie ..	per c. ft. of teakwood.
For curved strings	2 carpenters .. 2 coolies ..	do. do.
1-inch planking for risers ..	¼ carpenter .. ¼ coolie ..	....
1½-inch planking for heads including nosings.	⅓ carpenter .. ⅓ coolie ..	....
Wooden balusters Re. 1-8 to Rs. 7-8 per r. ft. according to design.		
For cut strings ..	¼ carpenter .. ¼ coolie ..	per c. ft. of teak wood.

Specification No. 151.

1. **Risers and treads.**—To be of best Moulmein teak with risers 1¼″ thick, tongued and grooved top and bottom into treads 1¾″ thick, with moulded nosings along the fronts and returns. All risers to be of the same height.

2. **Soffits.**—The soffits to be boarded, if so specified, with ¾ inch teak planks framed with V-joints, or tongued and grooved.

3. **Strings.**—For important work, risers and treads to be housed into the strings and supported by wedges. Strings to be 14″×3″. For common work the strings to be cut to receive the risers and treads. For steps over 4 feet wide one or more rough strings to be used for additional support of the steps.

4. **Landing.**—Landings to have nosing and soffit corresponding to steps.

5. **Curtail.**—The bottom steps to be finished with a proper curtail.

6. **Balusters.**—The steps to be provided with proper teak hand-rail and balusters, of the pattern shown in the drawing, properly fixed into heads.

MISCELLANEOUS.

GALVANIZED CORRUGATED IRON WALLING.

Specification No. 152.

1. **Description.**—Sheets to be sound galvanized corrugated sheet-iron, of 24 B. W. G. or as may be specified by the Executive Engineer, uninjured in any way, fixed on a country teak-wood or steelwork framing with overlaps of two corrugations.

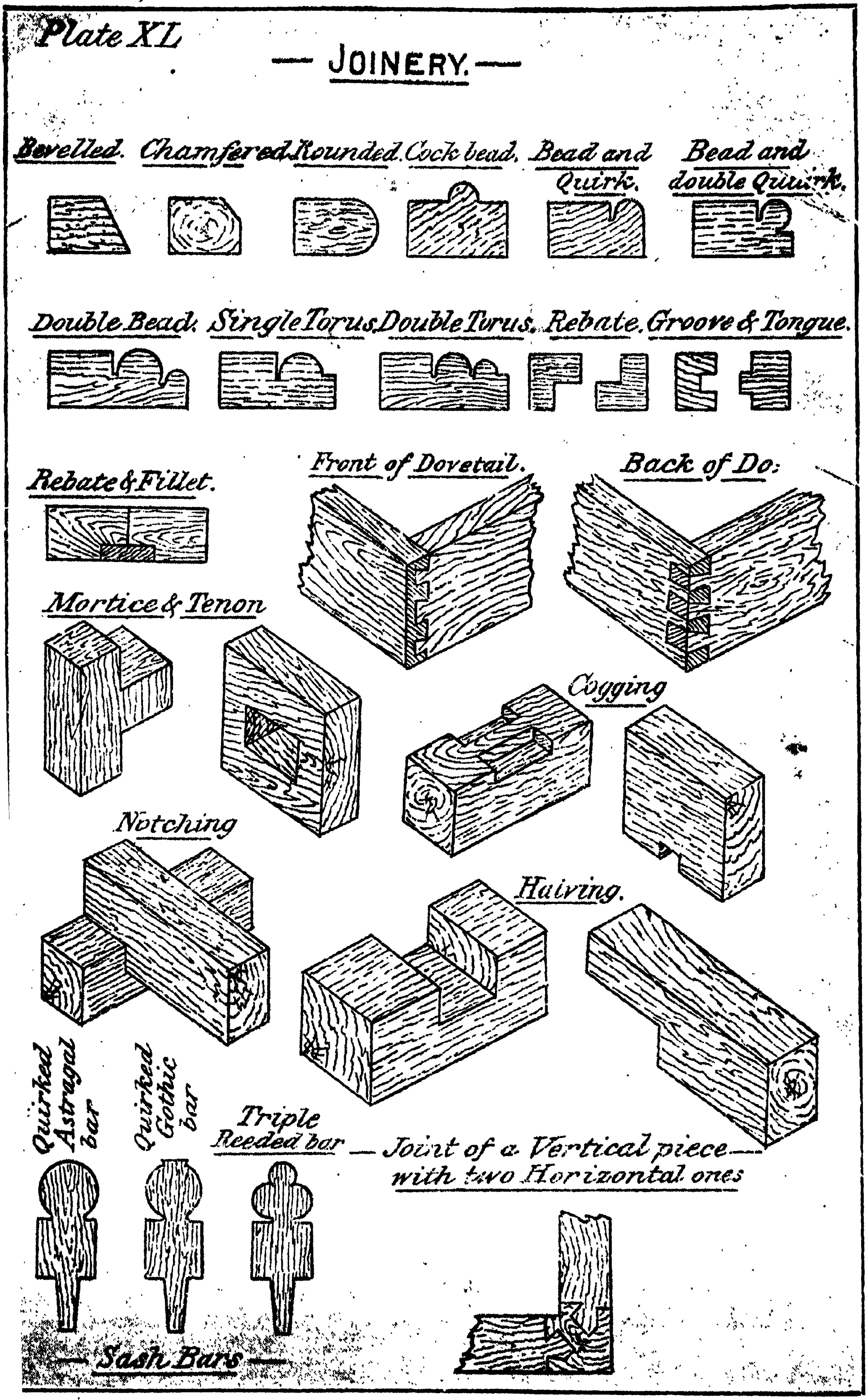


Plate XL
— JOINERY. —
Bevelled.
Chamfered.
Rounded.
Cock bead.
Bead and Quirk.
Bead and double Quirk.
Double Bead.
Single Torus.
Double Torus.
Rebate.
Groove & Tongue.
Rebate & Fillet.
Front of Dovetail.
Back of Do:
Mortice & Tenon
Cogging
Notching
Halving.
Quirked Astragal bar
Quirked Gothic bar
Triple Reeded bar
— Joint of a Vertical piece — with two Horizontal ones
— Sash Bars —

2. **Framing.**—The framing to which the Galvanized Corrugation sheets are to be fixed shall consist of teak-wood posts or angle or I-beam uprights, to which are fixed horizontal rails or steelwork framing.

3. **Posts.**—The posts shall be fixed at specified intervals, and shall be well-bedded, in concrete or in any other material specified. The portions of the posts below the ground level shall be coal-tarred.

4. **Sheet fixing.**—The sheets will be fixed either to the posts or vertically to the rails using galvanized iron screws for woodwork and bolts for steelwork. The sheets shall overlap two corrugations and shall be joined to each other by galvanized iron bolts. Zinc or lead washers shall be used with all screws and bolts.

5. **Painting.**—The walling shall be given such coats of paint as specified.

6. **Rate.**—The rate for the work is an overall rate, covering framing, sheets, concrete fixing, painting and all other contingent work, and is usually quoted per 100 square feet.

TEAKWOOD PARTITION.

Specification No. 153.

1. **Description.**—To consist of best Moulmein teak framing, with uprights ordinarily 3 × 3 inches, top and central pieces 4 × 3 inches, and the bottom piece 3 × 2 inches. The ends of the horizontal pieces shall be let into masonry.

2. The intermediate bays shall either be wholly filled in with $\frac{3}{4}$ inch teak boarding fixed diagonally, tongued and grooved, or will have teak panels in the lower half and glazed panels in the upper half. The glazing will be done as per specifications described in the item of " glazier's work, " page 211.

3. For important works, teakwood ornamental cresting will be provided over the horizontal top pieces and will teakwood ornamental knobs be fixed at the heads of all the uprights.

4. The teakwood partition will be paid for per 100 square feet and the rate shall include fixing in place, and either painting, oiling or polishing as the case may be on both faces.

WIRE FENCING.

Specification No. 154.

1. **Description.**—To consist of 7 strand galvanized iron fencing wire in five rows and supported either on T iron standards, or R. C. C. posts, or teak posts, the standards or posts being spaced 7 to 8 feet centre to centre.

2. The standards at angles and those at every 100 feet shall be suitably strutted. All standards and struts should have a lime concrete foundation.

3. The fencing wire shall pass through the T and other posts or be fixed to them by staples. Galvanized iron straining bolts, 12 inches in length and $\frac{5}{8}$ incn in diameter will be provided for standards at angles.

4. All iron work must be painted.

5. The fencing will be paid for per 100 running feet.

6. No barbed wire to be used for fencing purposes.

For Rate Abstract see p. 392.

PIPE RAILING.

Specification No. 155.

1. **Description.**—To consist of best wrought-iron pipes, from ¾ to 1 inch in diameter, in 4 or 5 rows, as the height may vary. The height above the ground level will be from 3 feet to 4 feet 6 inches, according to circumstances.

2. The railing shall be supported either on bulb-tee standards or standards of railways rails or R. C. C. posts at a central distance of 6 to 8 feet apart.

3. **Mode of fixing.**—The standards will be sunk into the ground from 1′-6″ to 2′-6″ according to the nature of soil. They must have a lime concrete foundation, and should be provided with a roughly dressed bedstone 12″ × 12″ × 6″.

4. Posts at angles must be well strutted and struts also shall have lime concrete foundation.

5. **Painting.**—Portions of standards below ground level will be coal-tarred and those above ground level will be painted ; R. C. C. posts will be cement-washed.

6. **How paid for.**—The railing will be paid for per 100 running feet.

Note.—Railing of the above description supported on standards of railway rails and with piping 1″ in diameter costs about Rs. 3-5 per foot run, in Bombay.

TILE SKIRTINGS.

Specification No. 156.

To be plain skirting tiles, of an approved make and of such colour as may be directed, to be set in Portland cement, and to project ¼ inch from the surface of the plaster.

HOOP IRON TRELLIS WORK.

Specification No. 157.

1. **Description.**—To consist of hoop iron 1 inch broad, 18 B. W. G., weighing 1·6 lbs. per 10 lineal feet, interlacing diagonally at a pitch of 45°, leaving clear openings of 2 inches square. To be secured to a light framework of teakwood. The whole to be painted on both sides with two coats of green or other paint which will be measured as if there were no openings.

2. **Iron.**—The iron to be heated and rubbed over with boiled linseed oil, before being worked up.

For Rate Abstract see p. 392.

TEAWOOD TRELLIS WORK.

Specification No. 158.

1. *Description.*—Teak battens, 1″ × ½″, to be crossed diagonally in opposite directions at an angle of 45°, or at right angles as speacified leaving 2-inch openings between them. To be secured to the verandah posts and postplates, or to be framed by fixing vertical and horizontal battens to the diagonals.

In the case of openings in masonry work, teak battens 1½″ × ½″ to be crossed diagonally in opposite directions at an angle of 45° or at right angles as specified leaving 1½ inch openings between them. To be secured to frames, the scantlings of which should be 3″ × 2″.

2. The whole to be painted two coats green, or other approved paint. The painter's work to be measured solid on each side to allow for extra labour.

For Rate Abstract see p. 393.

EXPANDED METAL NETTING.

Specification No. 159.

1. **Description.**—Expanded metal No. 19, $\frac{3}{4}$-inch mesh, $\frac{1}{8}$ inch × 16 G, should be secured to the verandah posts and post-plates by wrought-iron clips or should be framed by fixing vertical and horizontal teak mouldings or battens, 2″ × 1″. The netting should be fixed with the long way of mesh vertical.

2. **Painting.**—The whole should be painted on both sides with two coats of green, dark oak or other approved paint, which shall be measured on one side only to allow for openings.

For Rate Abstract see p. 393.

TABLE XCVII.

STANDARD SIZES OF EXPANDED METAL.

No.	Section.	Sectional area per 12-inch width.	Size L. W. M. and S. W. M.
		Sq. in.	
13	6″ mesh, ¼″ × 3/16″	0·187	Standard 12′ × 8′ Standard length width.
10	3″ mesh, ¼″ × 3/16″	0·375	8′ × 8′
10	Do. do.	....	12′ × 8′
61	3″ mesh, 5/16″ × ⅛″	0·312	8′ × 8′
	Do. do.	....	12′ × 8′
8	3″ mesh, ¼″ × ⅛″	0·250	8′ × 8′
	Do. do.	....	12′ × 8′
	Do. do.	....	7′ × 12′
	Do. do.	....	6′ × 12′
9	3″ mesh, 3/16 × ⅛″	0·187	8′ × 8′
	Do. do.	....	8′ × 12′
	Do. do.	....	7′ × 12′
	Do. do.	....	6′ × 12′
	Do. do.	....	4½′ × 12′
	Do. do.	....	5½′ × 12′
15	3″ mesh, ⅛″ × ⅛″	0·125	6′ × 6′
	Do. do.	....	8′ × 8′
	Do. do.	....	7′ × 12′
34	1½″ mesh, ¼″ × 3/16″	0·750	8′ × 8′
23	1½″ mesh, ¼″ × ⅛″	0·500	8′ × 8′
	Do. do.	....	8′ × 12′
24	1½″ mesh, ⅛″ × ⅛″	0·250	8′ × 6′
	Do. do.	....	8′ × 12′
	Do. do.	....	7′ × 12′
6	1½″ mesh, ⅛″ × 16 B. S. W. G	0·125	6′ × 6′
5	1½″ mesh, 3/32″ × 18 B. S. W. G.	0·072	8′ × 12′
20	¾″ mesh, ⅛″ × ⅛″	....	8′ × 12′
73	¾″ mesh, 3/16″ × 16 B. S. W. G.	....	8′ × 12′
	Do. do.	....	8′ × 8′
19	¾″ mesh, ⅛″ × 16 B. S. W. G.	....	6′ × 6′
18	¾″ mesh, 3/32″ × 18 B. S. W. G.	....	7′ × 12′
38	¾″ mesh, 3/32″ × 24 B. S. W. G.	....	8′ × 8′
1	Lathing	....	7′ × 2′
	Do.	....	8′ × 2′3″

N.B.—L. W. M. stands for long way of mesh, and S. W. M. for short way of mesh. When ordering expanded metal it is necessary to specify clearly which dimension refers to L. W. M. and S. W. M. Size of mesh is the short length of diamond.

TABLE XCVIII.

MISCELLANEOUS DATA.

(1) Size of coach house :—

Depth (or length of room)	18′
Height to top of rafters measured along the inner face of the wall.	9′
Width of doorway	8′
Width of room	12′

(2) Size of motor garage :— ...

Depth (or length of garage)	18′
Width	12′
Height (to top of rafters measured along the inner face of wall).	9′

(3) Size of motor pit :—

Length	12′
Breadth	2′—9″
Depth	4′—0″
Covered with	0′—1½″ planks.
Approach ramp	1 in 8 to 1 in 10.

(4) Size of coal store :—

For every ton of coals allow	45 c.ft.
Doors and gates to coal stores should open outwards.	

(5) Size of cattle sheds (open in front) :—

Average area of building for every head ...	100 sq. ft. including verandah.
Depth from wall to wall	10′ (exclusive of verandah).
Height to top of rafters measured along the inner face of wall.	12′
Width of stalls	5′ to 6′

(6) Corn barns (for thrashing, etc.) :—

Size exclusive of space for machinery ...	26′ × 18′
Do. of doorway	3½′ × 7½′

(7) Cattle sheds (shelter only) :—

For every sheep allow floor space ...	10 sq ft.
" pig " " ...	10 "
" bullock, small " ...	40 "
" " large " ...	60 "

TABLE XCVIII—*contd.*

(8) Churches :—

Accommodation including passages, communion table, etc. for every person	5 to 7 sq. ft.
Width of pews	33″ to 36″
Length of seats for each person ...	18″ to 24″
Height of seats from floor	18″
Width of seats	13″ to 15″
Book boards, height from floor ...	32″
,, ,, width	$4\frac{1}{2}$″

(9) Ball room :—

For each person allow a minimum, exclusive of ante rooms.	16 sq. ft.

(10) Ice store :—

For every 112 lbs. of rough ice allow a space of.	6 c. ft.

(11) Ovens :—

For every bushel of bread allow a floor space of.	7 sq. ft.

(12) Stables (open in front) :—

Width of the building	10′ clear.
Height from floor to top of rafters measured along the inner face of wall.	9′
Stalls should not be less in width than ...	7′
Loose boxes	12′ × 10′
Stable doors should be	5′ wide.
Partition to consist of two bars, one above the other and fixed at heights of 2′ and about $3\frac{1}{2}$′ to 4′ respectively. Floor level to be at least 1 foot higher than ground level. Paved floor to have a slope of 1 in 48.	

(13) Dog kennels :—

Size	5′ × 4′ × $6\frac{1}{2}$′ height to top of rafters measured along the inner face of wall.

(14) Pitches of roofs :—

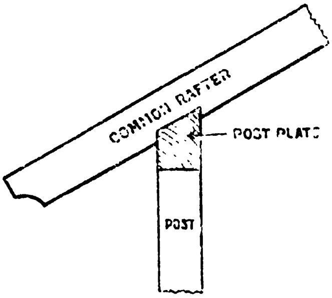
Flat and pan tiles	$\frac{1}{4}$ to 1/3 span.
Plain pan tiles	$\frac{1}{4}$ to 1/3 ,,
Mangalore tiles with flat tiles and air spaces	$\frac{1}{4}$ to 1/3 ,,
Mangalore tiles bedded in mortar over flat tiles.	$\frac{1}{4}$ to 1/3 ,,
Plain Mangalore tiles ...	$\frac{1}{4}$ to 1/3 ,,
20 B. W. G. corrugated iron or boarding with Mangalore tiles.	$\frac{1}{4}$ to 1/6 ,,

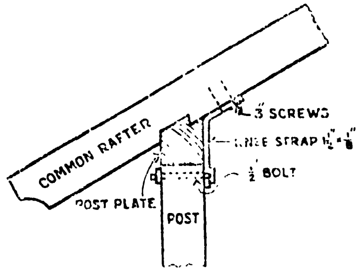
TABLE XCVIII—*contd.*

(In districts of heavy rainfall pitch of roofs should be 1/3.)

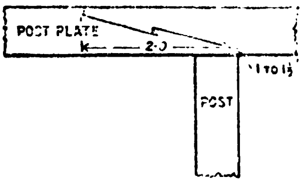
Thatched roofs	... ½	minimum pitch.
Corrugated iron roofs ...	... 1/10	
Asphalted felt	... 1/6	
Slates (ordinary) ...	... ¼	
Thin slabs of stones ...	... ¼	

(15) The two sketches illustrate note 3, below table LXVI.

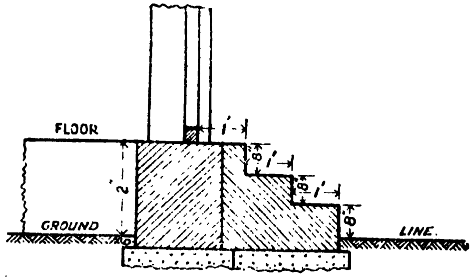




(16) The sketch shows the correct method of making a scarf joint in the post-plate over a post.



(17) Correct method of building steps in front of a door sill.



(18) Tennis courts :—

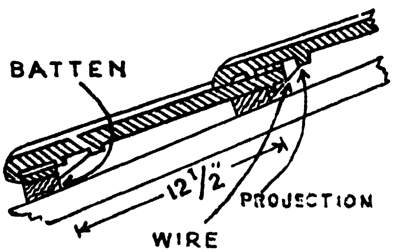
Outer lines	36′ × 78′
Size of court	44′ × 90′ to 94′

Courts to be oriented north and south.

Height of net poles	3′-6″
Height of screens behind service lines	... 8′ to 10′

(19) Preventing blowing off of Mangalore tiles by high winds :.

The sketch shows the arrangement adopted for tying down Mangalore tiles available in the market to battens. For Government works, only tiles having projections should be used, and the tying down by wire invariably specified.



DETAIL OR RATES OF DIFFERENT ITEMS OCCURRING IN CHAPTER III.

Concrete.

RATE ABSTRACT No. 10.

CONCRETE OF TRAP METAL.

Materials for 100 cubic feet.	Quantity.	Rate.	Per	Amount.	Labour for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Trap metal.. C.ft.	100	..	..	..	Grinding Chunam .. C.ft.	46	..	..	..
Sand ,,	46	..	..	..	Coolies .. No.	6	..	..	..
Lime, slaked ,,	23	..	..	..	Bhistie ..	$\frac{1}{4}$	..	..	..
Sundries ..	..	..	..	..	Sundries ..	..	..	..	..
						Total, labour ..			
	Total, materials ..					Total,materials ..			
					Total for 100 C. ft. of concrete ..				

RATE ABSTRACT No. 11.

CONCRETE OF BROKEN BRICK.

Materials for 100 cubic feet.	Quantity.	Rate.	Per	Amount.	Labour for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Broken brick C.ft.	100	..	..	..	Grinding chunam .. C.ft.	25	..	..	..
Sand or *surki* ,,	25	..	..	..	Coolies No.	6	..	..	..
Lime, slaked ,,	25	..	..	..	Women ,,	2	..	..	..
Sundries ..	..	..	..	..	Bhistie ,,	$\frac{3}{4}$	..	..	..
					Sundries ..	..	..	..	..
						Total, labour ..			
	Total, materials ..					Total,materials ..			
					Total for 100 C. ft. of concrete ..				

RATE ABSTRACT No. 12.

CEMENT CONCRETE.

(1 part cement, 2 sand and 5 broken stone).

Materials for 100 cubic feet.	Quantity.	Rate.	Per	Amount.	Labour for 100 cubic feet.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Broken stones C.ft.	100	..	..	..	Coolies No.	6	..	..	..
Sand ,,	40	..	..	..	Bhistie ,,	1	..	..	..
Portland cement, 5 casks or ,,	20	..	..	..	Sundries ..	..	..	..	..
Sundries ..									
	Total, materials ..					Total, labour ..			
						Total, materials..			
					Total for 100 C. ft. of Portland cement concrete ..				

"*Note.*—Cement is now sold in sacks, each sack containing 1·2 c. ft. of cement, taking cement at 90 lbs. per cubic foot."

RATE ABSTRACT No. 13.

LATERITE CONCRETE.

Materials for 100 cubic feet.	Quantity.	Rate.	Per	Amount.	Labour for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Laterite stone metal at site (size 2″) .. C.ft.	78	..	..	..	Grinding chunam ..C.ft.	52	..	..	..
Lime, slaked ,,	26	..	..	..	Coolies No.	4	..	..	..
Sand .. ,,	52	..	..	..	Bhistie .. ,,	½	..	..	..
Sundries ..	..	..	..	..	Sundries ..	..	..	..	..
						Total, labour ..			..
	Total, materials ..					Total, materials..			
					Total for 100 C. ft. of laterite concrete ..				

*Stone masonry

RATE ABSTRACT No. 14.

ASHLAR. FINE.

Materials for 100 cubic feet.	Quantity.	Rate.	Por	Amount.	Labour for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
					Masons, first class, for dressing .. No.	44	..	..	..
Trap stone, rough, 12″ thick, averaging 4½ c. ft. each .. C. ft.	100	..	..	..	Masons, first class, for setting .. ,,	12	..	..	..
Lime, slaked ,,	8	..	..	..	Naugannies ,,	12	..	..	..
					Coolies .. ,,	2	..	..	..
Sand, fine .. ,,	8	..	..	..	Women .. ,,	6	..	..	..
					Bhistie .. ,,	¼	..	..	..
Charcoal .. Lbs.	120	..	..	..	Smiths .. ,,	2	..	..	..
					Bellows boys ,,	2	..	..	..
Steel, etc. .. ,,	8	..	..	..	Grinding chunam .. C. ft.	10	..	..	..
Sundries	..	..	..	..	Scaffolding ..	..	..	..	..
					Sundries	..	..	..	..
						Total, labour ..			..
	Total, materials ..					Total, materials..			
						Total for 100 C. ft. ..			

RATE ABSTRACT No. 15.

ASHLAR, ROUGH-TOOLED.

Materials for 100 cubic feet.	Quantity.	Rate.	Per	Amount.	Labour for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
	Rs. a.		Rs. a.				Rs. a.		Rs. a.
					Masons, first class, for dressing .. No.	25	..	..	..
					Smiths .. ,,	1½	..	..	..
Trap stone, rough, 12″ thick, averaging 4½ c. ft. each C. ft.	100	..	..	..	Bellows-boys	1½	..	..	..
Lime, slaked ,,	12	..	..	..	Grinding				
Sand .. ,,	18	..	..	..	chunam .. C. ft.	18	..	..	..
Charcoal .. Lbs.	90	..	..	..	Cost of remaining items same as in Rate Abstract No. 14	..	..	..	..
Steel .. ,,	4	..	..	..					
Sundries	..	..	..	..					
						Total, labour ..			..
	Total, materials ..					Total, materials..			..
						Total for 100 C ft. ..			..

*In stone masonry trap or blue basalt is meant except when otherwise stated. The rates of stone are based on the supposition that stone quarries are situated within three miles of works.

RATE ABSTRACT No 16.

ASHLAR, ROCK RUSTIC OR QUARRY-FACED.

Materials for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Same as in Rate Abstract No. 15..	..	..	..	..	Masons, first class, for dressing .. No.	22	..	..	..
					Rest same as in Rate Abstract No. 15	..	..	..	..
	Total, materials ..					Total, labour ..			..
						Total, materials..			
						Total for 100 C. ft. ..			

RATE ABSTRACT No. 17.

ASHLAR, CHAMFERED.

Materials for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Same as for ashlar, rough-tooled, in Rate Abstract No. 15 ..	..	..	..	..	Masons, first class, for dressing .. No.	27	..	..	..
					Rest same as for rough-tooled ashlar in Rate Abstract No. 15	..	..	..	..
	Total, materials ..					Total, labour ..			
						Total, materials..			..
						Total for 100 C. ft. ..			

RATE ABSTRACT No. 18.

ASHLAR, FACING, ROUGH-TOOLED.

Materials for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Trap stone, rough. 12" thick, averaging 4 c.ft. each .. C. ft.	125	..	..	..	Masons for dressing .. No.	15	..	..	..
Lime, slaked ,,	16	..	..	..	Masons for setting .. ,,	10	..	..	..
Sand ,,	24	..	..	..	Naugannies ,,	12	..	..	..
Charcoal .. Lbs.	60	..	..	..	Coolies .. ,,	2	..	..	..
Steel .. ,,	3	..	..	..	Women .. ,,	6	..	..	..
Sundries ..	..	..	..	..	Bhistie .. ,,	½	..	..	..
					Smith .. ,,	1	..	..	..
					Bellows-boy ,,	1	..	..	..
					Grinding chunam .. C. ft.	24	..	..	..
					Scaffolding ..	..	..	..	..
					Sundries ..	..	..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials ..			..
						Total for 100 C. ft. ..			..

RATE ABSTRACT No. 19

ASHLAR FACING, RUSTIC, WITH CHISEL DRAFT.

Materials for 100 cubic feet.	Number or quantity.	Rate	Per	Amount.	Labour for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs.
Same as for ashlar facing, rough-tooled, in Rate Abstract No. 18..	..	..	..	..	Masons for dressing .. No.	12	..	..	..
					Rest same as for ashlar facing, rough-tooled, in Rate Abstract No. 18	..	..	..	..
						Total, labour ..			..
	Total, materials ..					Total, materials ..			..
						Total for 100 C. ft. ..			..

RATE ABSTRACT No. 20.

ASHLAR, FACING CHAMFERED.

Materials for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Same as for ashlar facing, rough-tooled, in Rate Abstract No. 18 ..	..	..	..	..	Masons for dressing .. No.	17	..	..	..
					Rest same as for ashlar facing, rough-tooled, in Rate Abstract No. 18	..	..	..	..
							Total, labour ..		..
	Total, materials ..			..			Total, materials..		..
							Total for 100 C. ft. ..		..

RATE ABSTRACT No. 21.

BLOCK IN COURSE.

Materials for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Trap stone, rough, 9″ high .. C. ft.	100	..	..	..	Same as for ashlar facing, rough-tooled, in Rate Abstract No. 18	..	..	..	..
Lime, slaked ..	13	..	..	..					
Sand .. „	20	..	..	..					
Charcoal .. Lbs.	90	..	..	..					
Steel .. „	4	..	..	..					
Sundries ..	..	..	..	..					
							Total, labour ..		..
	Total, materials ..			..			Total, materials..		..
							Total for 100 C. ft. ..		..

RATE ABSTRACT No. 22.

BLOCK IN COURSE FACING.

Materials for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Trap stone, rough, about 1¼ C. ft. each, and 9" high .. C. ft.	125	..	..	..	Same as for ashlar facing, rough tooled, in Rate Abstract No. 18..	..	..	..	.
Rest same as for ashlar facing, rough tooled in Rate Abstract No. 18 ..									
						Total, labour ..			..
	Total, materials ..			..		Total, materials ..			..
						Total for 100 C. ft. ..			..

String courses, Copings, etc.

RATE ABSTRACT No. 23.

STRING COURSE CUT-STONE, 1ST SORT, 6 INCHES HIGH, 4 INCHES PROJECTION, DRESSED FINE.

Materials for 100 Rg. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 Rg. ft.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Trap stone, roughly dressed .. S. ft.	125	..	..	..	Masons for dressing .. No.	20	..	..	..
					Masons for setting .. ,,	12	..	..	..
Lime, slaked C. ft.	6	..	..	..	Naugannies ,,	4	..	..	..
					Coolies .. ,,	2	..	..	..
Sand, fine ..	6	..	..	..	Women .. ,,	6	..	..	..
					Smiths .. ,,	1¼	..	..	..
Steel .. Lbs.	4	..	..	..	Bellows boys ,,	1¼	..	..	..
					Bhistie .. ,,	¼	..	..	..
Charcoal ,,	75	..	..	..	Grinding chunam C. ft.	6	..	..	..
Sundries ..	..	..	..	..	Scaffolding ..	..	..	..	..
					Sundries ..	..	..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials .			..
						Total for 100 Rg. ft. ..			..

RATE ABSTRACT No. 24.

STRING COURSE, CUT-STONE, SECOND SORT.

(Description same as first sort.)

Materials for 100 Rg. ft.	Number or quantity.	Rate.	Per	Amount	Labour for 100 Rg. ft.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Trap stone, roughly dressed .. S. ft.	125	..	..	..	Masons for dressing .. No.	12	..	..	..
					Masons for setting ,,	10	..	..	..
Lime, slaked C. ft.	10	..	..	..	Naugannies ,,	4	..	..	..
					Coolies .. ,,	2	..	..	..
Sand .. ,,	15	..	..	..	Women .. ,,	6	..	..	..
					Bhistie .. ,,	½	..	..	..
Charcoal .. Lbs.	60	..	..	..	Smith .. ,,	1	..	..	..
					Bellows-boy ,,	1	..	..	..
Steel .. ,,	3	..	..	..	Grinding chunam .. C. ft.	15	..	..	..
Sundries ..	..	..	..	..	Scaffolding ..	..	..	..	..
					Sundries ..	..	..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials ..			..
						Total for 100 Rg. ft. ..			..

RATE ABSTRACT No. 25.

COPING, CUT-STONE, RECTANGULAR, FIRST SORT.

(9 inches high and 1 foot 9 inches wide.)

Materials for 100 Rg. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 Rg. ft.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Trap stone, rough .. C. ft.	131	..	..	..	Masons for dressing .. No.	80	..	..	..
					Masons for setting ,,	12	..	..	..
Lime, slaked ,,	10	..	..	..	Naugannies ,,	12	..	..	..
					Coolies .. ,,	2	..	..	..
Sand, fine .. ,,	10	..	..	..	Women .. ,,	6	..	..	..
					Bhistie .. ,,	½	..	..	..
Charcoal .. Lbs.	160	..	..	..	Smiths .. ,,	3	..	..	..
					Bellows boys ,,	3		..	..
Steel .. ,,	8	..	..	..	Grinding chunam .. C. ft.	10	..	..	..
Sundries	..	..	..	..	Scaffolding ..	..	..	..	..
					Sundries ..	..	..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials ..			..
						Total for 100 Rg. ft. ..			..

RATE ABSTRACT No. 26.

COPING, CUT-STONE, RECTANGULAR, SECOND SORT.

(Description same as first sort.)

Materials for 100 Rg. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 Rg. ft.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Trap stone, rough .. C. ft.	131	..	..	..	Masons for dressing .. No.	50	..	..	..
Lime, slaked ,,	12	..	..	..	Masons for setting .. ,,	10	..	..	..
Sand .. ,,	18	..	..	..	Naugannies ,,	12	..	..	..
Charcoal .. Lbs.	120	..	..	..	Coolies .. ,,	2	..	..	..
Steel .. ,,	8	..	..	..	Women .. ,,	6	..	..	..
Sundries ..	..	..	..	..	Bhistie ,,	½	..	..	..
					Smiths .. ,,	2	..	..	..
					Bellows-boys ,,	2	..	..	..
					Grinding chunam .. C. ft.	18	..	..	..
					Scaffolding ..	..	..	..	..
					Sundries	..	..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials..			..
						Total for 100 Rg. ft. ..			..

RATE ABSTRACT No. 27.

COPING, CUT-STONE, SEMI-OCTAGONAL, FIRST SORT.

(9 inches high and 1 foot 6 inches wide.)

Materials for 100 Rg ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 Rg. ft.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Trap stone rough .. C. ft.	.2	..	..	..	Masons for dressing .. No.	88	..	..	..
Lime, slaked ,,	10	..	..	..	Masons for setting .. ,,	12	..	..	..
Sand .. ,,	10	..	..	..	Naugannies ,,	12	..	..	..
Charcoal .. Lbs.	180	..	..	..	Coolies .. ,,	2	..	..	..
Steel .. ,,	10	..	..	..	Women .. ,,	6	..	..	..
Sundries	..	..	..	..	Bhistie .. ,,	¼	..	..	..
					Smiths .. ,,	4	..	..	..
					Bellows boys ,,	4	..	..	..
					Grinding chunam .. C.ft.	10	..	..	..
					Scaffolding ..	..	..	..	..
					Sundries	..	..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials ..			..
						Total for 100 Rg. ft. ..			..

RATE ABSTRACT No. 28.

COPING, CUT-STONE, SEMI-OCTAGONAL, SECOND SORT.

(Description same as first sort.)

Materials for 100 Rg. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 Rg. ft.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Trap stone, rough .. C. ft.	112	..	..	..	Masons for dressing .. No.	58	..	..	..
Lime, slaked ,,	12	..	..	..	Masons for setting .. ,,	10	..	..	..
					Naugannies ,,	2	..	..	..
Sand, fine .. ,,	18	..	..	..	Coolies .. ,,	2	..	..	..
					Women .. ,,	6	..	..	..
Charcoal .. Lbs.	140	..	..	..	Bhistie .. ,,	½	..	..	..
					Smiths .. ,,	2½	..	..	..
Steel .. ,,	8	..	..	..	Bellows-boys ,,	2½	..	..	..
Sundries	..	..	..	..	Grinding chunam .. C. ft.	18	..	..	..
					Scaffolding ..	..	..	..	..
					Sundries	..	..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials ..			..
						Total for 100 Rg.ft. ..			..

RATE ABSTRACT No. 29.

COPING, CUT-STONE, SEMI-CIRCULAR, FIRST SORT.

(9 inches high and 1 foot 9 inches wide.)

Materials for 100 Rg. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 Rg. ft.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Trap stone, rough .. C. ft	112	..	..	..	Masons for dressing .. No.	67	..	..	..
					Smiths ,,	3	..	..	..
Lime, slaked ,,	10	..	..	..	Bellow-boys ,,	3	..	..	..
Sand .. ,,	10	..	..	..	Rest same as for coping, cut-sto n e, semi-octagonal, 1st sort, ir Rate Abstract No 28 ..	..	..	..	..
Charcoal .. Lbs.	180	..	..	..					
Steel .. ,,	10	..	..	..					
Sundries	..	..	..	..					
						Total, labour ..			..
	Total, materials ..			..		Total, materials ..			..
						Total for 100 Rg. ft. ..			..

RATE ABSTRACT No. 30.

COPING, CUT-STONE, SEMI-CIRCULAR, SECOND SORT.

(Description same as for first sort.)

Materials for 100 Rg. ft.	Quantity.	Rate.	Per	Amount.	Labour for 100 Rg. ft.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Trap stone, rough .. C. ft.	112	..	..	..	Masons for dressing .. No.	40	..	..	..
Cost of remaining items which are same as for coping, cut-stone rectangular, 2nd sort, in Rate Abstract No. 31(c)	..	..	..	..	Cost of remaining items which are same as in Rate Abstract No. 26	..	..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials ..			..
						Total for 100 Rg. ft. ..			..

RATE ABSTRACT No 31.

STONE-STEPS.

Stone steps should be paid as ashlar, fine or rough-tooled, or block-in-course according to the method of dressing surfaces and size of stones.

RATE ABSTRACT No. 32.

STONE STAIRS.

(If the step is 5 feet out of the wall.)

Materials for 5 Rg. ft.	Quantity.	Rate.	Per	Amount.	Labour for 5 Rg. ft.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Trap stone, rough ..Rg.ft.	5	..	..	..	Masons for dressing No.	5	..	..	..
					Masons for setting .. ,,	2	..	..	..
Other materials, such as chunam, etc.	..	..	..	..	Naugannies ,,	4	..	..	..
					Woman .. ,,	1	..	..	..
					Smith .. ,,	¼	..	..	..
					Bellows-boy	¼	..	..	..
					Centering ..	..	..	..	..
					Sundries ..	..	..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials ..			..
						Total for 5 Rg. ft. ..			..

Rubble masonry.

RATE ABSTRACT No. 33.

COURSED RUBBLE FIRST SORT.

(Walls 18 inches thick*.)

Materials for 100 Rg. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 Rg. ft.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Trap headers or through stones ..No. ..	35	..	..	..	Masons, 2nd class, for dressing No.	6	..	..	..
Face stones „	284	..	..	..	Masons, 2nd class, for setting .. „	5	..	..	..
Rubble stone, large .. C. ft.	17	..	..	..	Coolies .. „	5	..	..	..
Lime, slaked „	14	..	..	..	Women „	5	..	..	..
Sand .. „	21	..	..	..	Grinding chunam .. C. ft.	21	..	..	..
Sundries	..	..	..	..	Bhistie .. No.	$\frac{1}{2}$	..	..	..
					Smith .. „	$\frac{1}{4}$	..	..	..
					Bellows-boy „	$\frac{1}{4}$	..	..	..
					Scaffolding ..	..	..	..	..
					Sundries ..	..	..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials ..			..
						Total for 100 C. ft. ..			..

Note.—Additional allowance for corner stones at outside corners and at doors and windows should be added as required.

*When the height of wall exceeds 10 feet, add, for every additional 4 feet in height, rupees per 100 cubic feet to the whole cost.

RATE ABSTRACT No. 34.

COURSED RUBBLE, SECOND SORT.

(Walls 18 inches thick).

Materials for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Trap headers or through stones .. No.	35(*a*)*	..	..	..	Masons, 2nd class, for dressing .. No.	3	..	..	..
Face stones ,,	142(*b*)	..	..	..	Masons, 2nd class, for setting .. ,,	5	..	..	..
Rubble stone, large .. C.ft.	50(*c*)	..	..	..	Coolies .. ,,	5	..	..	..
Lime, slaked ,,	16	..	..	..	Women .. ,,	5	..	..	..
Sand .. ,,	24	..	..	..	Grinding chunam .. C.ft.	24	..	..	..
Sundries ..	..	..	..	..	Bhistie .. No.	$\frac{1}{2}$	..	..	..
					Smith .. ,,	$\frac{1}{8}$	..	..	..
					Bellows-boy ,,	$\frac{1}{8}$	..	..	..
					Scaffolding ..	..	..	..	..
					Sundries ..	..	..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials ..			..
						Total for 100 C.ft. ..			..

* The total number of headers given here is the maximum required for walls from 12″ to 18″. The actual number of headers required for 18″ walls is 24.

Note.—Additional allowance for corner stones at outside corners and at doors and windows would be added as required.

Note :—(*a*) For walls thicker than 12 inches number $= \dfrac{V \times 0 \cdot 35}{x}$

(*b*) Do. do. number $= \dfrac{V \times 2 \cdot 32}{x}$ or $\dfrac{V \times 2 \cdot 3}{x}$ nearly

(*c*) Do. do. quantity $= \dfrac{V\,(x - 0 \cdot 75).}{x}$

Where V = total volume of masonry.

x = mean thickness of the wall.

RATE ABSTRACT No. 35.

COURSED RUBBLE, THIRD SORT.

(Walls 18 inches thick.)

Materials for 100 cubic feet.	Number or quantity.	Rate	Per	Amount	Labour for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Trap headers or through stones .. No.	25	..	..	..	Masons, 2nd class .. No.	5	..	..	..
Rubble stone .. C.ft.	100	..	..	..	Coolies .. „	5	..	..	..
Lime, slaked „	20	..	..	..	Women .. „	5	..	..	..
Sand .. „	30	..	..	..	Bhistie .. „	½	..	..	..
Sundries	..	..	..	..	Grinding chunam .. C.ft.	30	..	..	..
					Scaffolding ..	..	..	..	..
					Sundries	..	..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials ..			
						Total, for 100 C.ft. ..			..

N.B.—See note under Rate Abstract No. 33.

Note.—For stone and lime mortar or stone and mud walls of 15 inches in breadth allow an increase of 25 per cent. for labour over that shown in Rate Abstracts Nos. 35 to 39, as the work turned out per day in thinner walls is less.

RATE ABSTRACT No. 36.

RANDOM RUBBLE, FIRST SORT.

Materials for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Trap quoins No.	4	..	..	..	Mason, 2nd class .. No.	16	..	..	..
Headers or through stones .. „	35	..	..	..	Coolies .. „	5	..	..	..
Rubble stone C.ft.	120	..	..	..	Women .. „	5	..	..	..
Lime, slaked „	14	..	..	..	Bhistie .. „	¼	..	..	..
Sand .. „	21	..	..	..	Smith .. „	½	..	..	..
Charcoal .. Lbs.	20	..	..	..	Bellows-boy „	½	..	..	..
Sundries	..	..	..	..	Grinding chunam .. C.ft.	21	..	..	..
					Scaffolding ..	..	..	..	..
					Sundries ..	..	..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials ..			..
						Total for 100 C. ft. ..			..

N.B.—See note under Rate Abstract Nos. 33 and 35.

RATE ABSTRACT No. 37.

RANDOM RUBBLE, SECOND SORT.

The rate or cost of this class of work is about the same as for coursed rubble second sort.

RATE ABSTRACT No. 38.

UNCOURSED RUBBLE.

Materials for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Trap headers or through stones .. No.	20	..	..	..	Masons, 2nd class .. No.	4	..	..	..
Rubble stone, large .. C.ft.	50	..	..	..	Coolies .. ,,	4	..	..	..
					Women ,,	2	..	..	..
Rubble stone, small .. ,,	70	..	..	..	Bhistie .. ,,	½	..	..	..
Lime, slaked ,,	20	..	..	..	Grinding chunam .. C.ft.	30	..	..	..
Sand .. ,,	30	..	..	..	Scaffolding ,,	..	..	..	..
Sundries ..	..	..	..	..	Sundries ..	..	..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials ..			..
						Total for 100 C.ft. ..			..

N.B.—See note under Rate Abstract Nos. 33 and 35.

RATE ABSTRACT No. 39.

STONE AND MUD MASONRY.

Materials for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount	Labour for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Trap headers No.	25	..	..	..	Masons, 2nd class No.	4	..	..	..
Rubble stone C.ft.	100	..	..	..	Coolies .. ,,	4	..	..	..
Earth .. ,,	24	..	..	..	Women .. ,,	2	..	..	..
Sand .. ,,	12	..	..	..	Bhistie .. ,,	¼	..	..	..
Sundries	..	..	..	..	Scaffolding ..	..	..	..	..
					Sundries	..	..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials ..			..
						Total for 100 C.ft. ..			..

***N.B.*—See note under Rate Abstract Nos. 33 and 35.**

RATE ABSTRACT No. 40.

DRY STONE MASONRY.

Materials for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Trap headers or through stones .. No.	25	..	..	..	Masons, 2nd class .. No.	3	..	..	..
Rubblestone C.ft.	125	..	..	..	Coolie ,,	1	..	..	..
Sundries	..		..	..	Women .. ,,	2	..	..	..
					Sundries		..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials ..			..
						Total for 100 C.ft. ..			..

N.B.—See note under Rate Abstract Nos. 33 and 35.

RATE ABSTRACT No. 41.

*DRY RUBBLE RETAINING WALLS.

Materials for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Trap headers or through stones .. No.	40	..	..	..	Masons, 2nd class .. No.	4	..	..	..
Rubble stones C.ft.	120	..	..	..	Coolies .. ,,	4	..	..	..
Gunpowder.. Lbs.	8	..	..	..	Smith ,,	½	..	..	..
Sundries	..	..	..	..	Sundries ..	..	..	..	..
						Total, labour ..			..
	Total, materials ..			...		Total, materials ..			..
						Total for 100 C.ft. ..			..

***Note.—The above rate is for walls not exceeding 30 feet in height.**

RATE ABSTRACT No. 42.

LATERITE CORNICE, 8 INCHES HIGH.

Materials for 100 Rg. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 Rg. ft.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Laterite stones rough, 21″ × 12″ × 8″, delivered at site .. No.	120	..	..	..	Masons for dressing .. No.	10	..	..	..
					Masons for setting .. „	6	..	..	..
Lime, slaked C.ft.	12	..	..	..	Coolies .. „	6	..	..	..
Sand .. „	18	..	..	..	Women .. „	4	..	..	..
Sundries	..	..	..	..	Grinding chunam .. C. ft.	18	..	..	..
					Bhistie .. No.	½	..	..	..
					Sundries		..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials ..			..
						Total for 100 Rg. ft. ..			..

RATE ABSTRACT No. 43.

LATERITE STONE COPING, 8 INCHES THICK, SEMI-OCTAGONAL TOP.

Materials for 100 Rg. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 Rg. ft.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Laterite stones rough, 15″ × 18″ × 8″, delivered at site .. No.	100	..	..	..	Masons for dressing .. No.	12	..	..	..
					Masons for setting .. „	6	..	..	..
					Coolies .. „	6	..	..	..
Lime, slaked C. ft.	12	..	..	..	Women .. „	4	..	..	..
Sand .. „	18	..	..	..	Bhistie .. „	½	..	..	..
Sundries	..	..	..	..	Grinding chunam .. C. ft.	18	..	..	..
					Sundries ..		..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials ..			..
						Total for 100 Rg. ft. ..			..

RATE ABSTRACT No. 44.

LATERITE AND LIME MASONRY (FOUNDATION).

Materials for 100 cubic feet.	Number or quantity.	Rate	Per	Amount.	Labour for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Laterite stones 30″× 10″× 8″, squared and delivered at site .. No.	72	..	..	..	Masons for setting .. No.	6	..	..	..
Lime, slaked C. ft.	12	..	..	..	Coolies .. „	6	..	..	..
Sand .. „	18	..	..	..	Women .. „	5	..	..	..
Sundries	..	..	..	..	Grinding chunam .. C. ft.	18	..	..	..
					Bhistie .. No.	½	..	..	..
					Sundries ..	..	..	..	..
	Total, materials ..			..		Total, labour ..			..
						Total, materials ..			..
						Total for 100 C. ft. ..			..

RATE ABSTRACT No. 45.

LATERITE AND LIME MASONRY (PLINTH).

Materials for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Laterite stones 24″× 12″ × 8″, squared and delivered at site .. No.	.. 75	..	..	..	Masons for setting .. No.	6	..	..	..
Lime, slaked C. ft.	12	..	..	..	Coolies .. „	6	..	..	..
Sand .. „	18	..	..	..	Women .. „	5	..	..	..
Sundries ..	..	..	..	..	Grinding chunam .. C. ft.	18	..	..	..
					Bhistie .. No.	½	..	..	..
					Sundries	..	..	..	..
	Total, materials ..			..		Total, labour ..			..
						Total, materials ..			
						Total for 100 C. ft. ..			..

RATE ABSTRACT No. 46.

Laterite superstructure (block in course).

Materials for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount	Labour for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Laterite stones 18″×9″×8″ squared and delivered at site .. No.	134	..	..	..	Masons for setting .. No.	6	..	..	..
Lime, slaked C. ft.	12	..	..	..	Coolies .. ,,	6	..	..	..
Sand .. ,,	18	..	..	..	Women ,,	4	..	..	..
Sundries	..	..	..	..	Bhistie .. ,,	½	..	..	..
					Grinding chunam .. C. ft.	18	..	..	..
					Scaffolding ..	..	..	..	..
					Sundries ..	..	..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials..			..
						Total for 100 C. ft. ..			..

RATE ABSTRACT No. 47.

LATERITE ARCHING OVER DOORS AND WINDOWS.

Materials for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount	Labour for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Laterite stones 18″×18″×7″ rough, delivered at site .. No.	100	..	..	..	Masons for dressing .. No.	16	..	..	..
					Masons for setting .. ,,	6	..	..	..
					Coolies .. ,,	6	..	..	..
					Women ,,	4	..	..	..
Lime, slaked Cft. ..	12	..	..	..	Bhistie .. ,,	½	..	..	..
Sand .. ,,	18	..	..	..	Carpenter ,,	½	..	..	..
					Grinding chunam .. C. ft.	18	..	..	..
Sundries	..	..	..	..	Scaffolding ..	..	..	..	..
					Sundries ..	..	..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials..			..
						Total for 100 C. ft. ..			..

Brick Masonry

RATE ABSTRACT No. 48.

BRICKWORK, FIRST CLASS.

Materials for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Bricks, 9"×4½"×2½", allowing 5 per cent. for wastage .. No.	1,520	..	..	..	Bricklayers No.	6	..	..	..
Limes, slaked C. ft.	16	..	..	..	Coolies .. ,,	2	..	..	..
Sand .. ,,	24	..	..	..	Women .. ,,	6	..	..	..
Sundries	..	..	..	..	Bhistie .. ,,	½	..	..	..
					Grinding chunam .. C. ft.	24	..	..	..
					Scaffolding up to 12′ in height	..	..	..	..
					Sundries	..	..	..	..
	Total, materials ..			..		Total labour ..			..
						Total, materials ..			..
						Total for 100 C. ft. ..			..

N.B.—When the height of wall exceeds 12 ft., add, for every additional 5 ft., in height annas 8 per 100 cubic feet to the whole cost.

For brick walls of 9 inches, allow an increase of 33⅓ per cent. for labour in Rate Abstract Nos. 48, 49 and 50, as the work turned out for the thin wall per day is less.

RATE ABSTRACT No. 49.

BRICKWORK SECOND CLASS.

Materials for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Bricks (moulded on ground), 9"×4½"×2½" allowing 5 per cent. for wastage .. No.	1,350	..	..	..	Bricklayers No.	4	..	..	..
Lime, slaked C. ft.	20	..	..	..	Coolies .. ,,	2	..	..	..
Sand .. ,,	30	..	..	..	Women .. ,,	6	..	..	..
Sundries	..	..	..	..	Bhistie ,,	½	..	..	..
					Grinding chunam .. C. ft.	30	..	..	..
					Scaffolding ..	..	..	..	..
					Sundries	..	..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials..			..
						Total for 100 C. ft. ..			..

Note.—**The remarks as for brickwork, 1st class are applicable to this also.**

RATE ABSTRACT No. 50.

BRICK AND MUD WORK.

Materials for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Bricks, 9″ × 4½″ × 2½″, allowing 5 per cent. for wastage .. No.	1,350	..	..	..	Bricklayers No.	4	..	..	..
					Coolies .. "	3	..	..	..
Mud .. C. ft.	30	..	..	..	Women .. "	6	..	..	..
					Bhistie .. "	¼	..	..	..
Sundries	..	..	..	..	Scaffolding ..	..	..	..	..
					Sundries	..	..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials ..			..
						Total for 100 C. ft. ..			..

N.B.—See note under Rate Abstract No. 48.

RATE ABSTRACT No. 51.

BRICK NOGGING.

Materials for 60 Sq. feet.	Quantity.	Rate.	Per	Amount.	Labour for 60 Sq. feet	Quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Teakwood .. C. ft.	7.16	..	..	..	*On wrought timber .. C. ft.	7.16	..	..	..
					Sundries	..	..	..	..
Nails, etc. ..	..	..	..	..	*Add*—				
Burnt brick masonry, 2nd class C. ft.	30	..	..	..	Plastering ½″ thick, with fine coat on both sides .. S. ft.	120	..	..	..
Sundries	..	..	..	..					
						Total, labour ..			..
	Total, materials ..			..		Total, materials ..			..
						Total for 60 Sq. ft. ..			..
						or for 100 Sq. ft. ..			..

**N.B.*—Labour on wrought timber = ½ Carpenter.
½ Cooly.

Arching.

RATE ABSTRACT No. 52.

***ASHLAR ARCHING.**

Materials for 100 cubic feet.	Quantity.	Rate.	Per	Amount.	Labour for 100 cubic feet.	Quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Trap stones, rough, averaging 4½ cubic feet each .. C. ft.	100	..	..	..	Masons, 1st class, for dressing (2 for each stone) .. No.	48	..	..	..
Lime, slaked ,,	10	..	..	..	Do. for setting .. ,,	12	..	..	..
Sand ,,	10	..	..	..	Naugannies ,,	12	..	..	..
Charcoal .. Lbs.	140	..	..	..	Coolies .. ,,	2	..	..	..
Steel .. ,,	8	..	..	..	Women .. ,,	6	..	..	..
Sundries	..	..	..	..	Bhistie .. ,,	½	..	..	..
					Smiths .. ,,	2½	..	..	..
					Bellows-boys ,,	2½	..	..	..
					Grinding chunam .. C. ft.	10	..	..	..
					Scaffolding and centres ..	..	..	..	..
					Sundries	..	..	..	..
	Total, materials ..			..		Total, labour ..			..
						Total, materials..			..
						Total for 100 C. ft. ..			..

*This class of arching is suitable for large works but often stones will be smaller; the thickness of stone should not be less than 10 inches for large works. For smaller works, stones 12" × 12" × 6" at a cheaper rate will do.

RATE ABSTRACT No. 53.

BLOCK IN COURSE ARCHING.

Materials for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Trap stone, rough .. C. ft.	100	..	..	..	Masons for dressing .. No.	25	..	..	..
Lime, slaked ,,	13	..	..	..	Masons for setting .. ,,	12	..	..	..
Sand .. ,,	20	..	..	..	Coolies .. ,,	2	..	..	..
Charcoal .. Lbs.	90	..	..	..	Naugannies ,,	12	..	..	..
Steel .. ,,	4	..	..	..	Women .. ,,	6	..	..	..
Sundries .. ,,	..	..	..	..	Bhistie .. ,,	½	..	..	..
					Smiths .. ,,	1½	..	..	..
					Bellows-boys ,,	1½	..	..	..
					Grinding chunam .. C. ft.	20	..	..	..
					Scaffolding and centre ..	..	..	..	..
					Sundries	..	..	..	..
	Total, materials ..			..		Total, labour ..			..
						Total, materials..			..
						Total for 100 C. ft. ..			..

RATE ABSTRACT No. 54.

RUBBLE ARCHING.

Materials for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.
Slabs, rough, about 18″ × 12″ × 9″ each C. ft.	100	..	..	..
Lime, slaked ,,	16	..	..	..
Sand .. ,,	24	..	..	..
Charcoal .. Lbs.	30	..	..	..
Sundries	..	..	..	..
	Total, materials ..			..

Labour for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.
Masons, 2nd class, for dressing .. No.	10	..	..	..
Masons, 2nd class, for setting .. ,,	6	..	..	..
Nauganníes ,,	6	..	..	..
Coolies .. ,,	2	..	..	..
Women .. ,,	6	..	..	..
Bhistie .. ,,	½	..	..	..
Smith .. ,,	½	..	..	..
Bellows-boys ,,	½	..	..	..
Grinding chunam .. C. ft.	24	..	..	..
Scaffolding and centre ..	..	..	..	..
Sundries	..	..	..	..
	Total, labour ..			..
	Total, materials ..			..
	Total for 100 C. ft. ..			..

RATE ABSTRACT No. 55.

BRICK ARCHING OVER DOORS AND WINDOWS, FIRST CLASS.

Materials for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.
Bricks, 9″ × 4½″ × 2½″, allowing 5 per cent. for wastage .. No.	1,550	..	..	..
Lime, slaked C. ft.	16	..	..	..
Sand .. ,,	24	..	..	..
Timber for centering	..	..	..	..
Sundries	..	..	..	..
	Total, materials ..			..

Labour for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.
Bricklayers for dressing bricks .. No.	4	..	..	..
Brick layers for laying ,,	6	..	..	..
Coolies .. ,,	2	..	..	..
Women .. ,,	6	..	..	..
Bhistie .. ,,	½	..	..	..
Grinding chunam .. C. ft.	24	..	..	..
Carpenter for centering	½	..	..	..
Scaffolding ..	..	..	..	..
Sundries ..	..	..	..	..
	Total, labour ..			..
	Total, materials ..			..
	Total for 100 C. ft. ..			..

RATE ABSTRACT No. 56.

BRICK ARCHING OVER DOORS AND WINDOWS, SECOND CLASS.

Materials for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
					Brick layers for dressing No.	3	..	..	..
					Brick layers for laying ,,	5	..	..	..
					Coolies .. ,,	2	..	..	..
					Women .. ,,	6	..	..	..
					Bhistie .. ,,	½	..	..	..
Brick, 9″ × 4½″ × 2¼″, allowing 5 per cent. for wastage .. No.	1,425	..	..	..	Grinding chunam .. C. ft.	30	..	..	..
Lime, slaked C. ft.	20	..	..	..	Carpenter for centering .. ,,	½	..	..	..
Sand .. ,,	30	..	..	..	Scaffolding ..	..	..	..	..
Centering .. ,,	..	..	..	..	Sundries	..	..	..	..
Sundries	..	..	..	..					
						Total, labour ..			..
	Total, materials ..			..		Total, materials..			..
						Total for 100 C. ft. ..			..

RATE ABSTRACT No. 57.

CONCRETE ARCHING IN AQUEDUCTS, ETC.

Materials for 4288 cubic feet.	Number or quantity.	Rate.	Per	Amount.	Labour for 4288 cubic feet.	Number.	Rate.	Per	Amount
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
					Coolies .. No.	181	..	..	..
Metal .. C. ft.	4,288	..	..	..	Women .. ,,	204	..	..	..
*Mortar .. ,,	2,144	..	..	..	Mucadam .. ,,	8	..	..	..
					Sundries .. ,,	..	..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials..			..
						Total for 4,288 C. ft. ..			..
						or per 100 C. ft. ..			..
						Centering per 100 C. ft. ..			..
						Total for 100 C. ft. ..			..

* *N.B.*—Sand, Rs. + Lime, Rs. + Grinding mortar, = Rs.

Pointing.

RATE ABSTRACT No. 58.

LIME POINTING (MASONRY).

Materials for 100 sq. feet.	Quantity.	Rate.	Per	Amount.	Labour for 100 sq. feet.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Lime, slaked.. C. ft.	1¼	..	..	..	Brick-layers No.	1½	..	..	..
Sand .. ,,	1¼	..	..	..	Women .. ,,	2	..	..	..
Sundries	..	..	..	..	Bhistie .. ,,	¼	..	..	..
					Sundries ..	.. ..	..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials ..			..
						Total for 100 Sq. ft. ..			..

RATE ABSTRACT No. 59.

LIME POINTING (BRICK-WORK).

Materials for 100 sq. feet.	Quantity.	Rate.	Per	Amount.	Labour for 100 sq. feet.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Lime, slaked C. ft.	2	..	..	..	Brick-layers No.	2	..	..	..
Sand .. ,,	2	..	..	..	Women .. ,,	2	..	..	..
Sundries	..	..	..	..	Bhistie .. ,,	¼	..	..	..
					Sundries	..	..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials ..			..
						Total for 100 Sq. ft. ..			..

RATE ABSTRACT No. 60.

CEMENT POINTING.

Materials for 100 sq. feet.	Quantity.	Rate.	Per	Amount.	Labour for 100 sq. feet.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Portland cement, $\frac{1}{6}$ cask or .. C. ft.	$\frac{2}{3}$	..	..	..	Brick-layers No.	$1\frac{1}{2}$	..	..	..
Sand .. ,,	$\frac{2}{3}$	..	..	..	Women .. ,,	2	..	..	..
Sundries ..	..	..	..	..	Bhistie .. ,,	$\frac{1}{3}$	..	..	..
					Sundries	..	..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials..			..
						Total for 100 Sq. ft. ..			..

Plastering.

RATE ABSTRACT No. 61.

PLASTERING, ROUGH, $\frac{3}{4}$ INCH THICK.

Materials for 100 sq. feet.	Quantity.	Rate.	Per	Amount.	Labour for 100 sq. feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Lime, slaked C. ft.	6	..	..	..	Brick-layers. No.	$1\frac{1}{2}$	..	..	..
					Coolie .. ,,	1	..	..	..
Sand .. ,,	6	..	..	..	Women .. ,,	3	..	..	..
					Bhistie .. ,,	$\frac{1}{4}$	..	..	..
Sundries, such as *gugal*, etc.	..	..	..	..	Grinding chunam twice .. C. ft.	6	..	..	..
					Sundries	..	..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials..			..
						Total for 100 Sq. ft. ..			..

RATE ABSTRACT No. 62.

FINE COAT (OVER ROUGH PLASTER).

Materials for 100 sq. feet.	Quantity.	Rate.	Per	Amount.	Labour for 100 sq. feet.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Lime, fine .. C. ft.	2	..	..	..	Brick-layers No.	1½	..	..	..
Sundries	..	..	..	..	Coolie .. „	1	..	..	..
					Women .. „	3	..	..	..
					Bhistie .. „	¼	..	..	..
					Sundries		..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials ..			..
						Total for 100 Sq. ft. ..			..

RATE ABSTRACT No. 63.

LIME PLASTER, ROUGH CAST, ½ INCH THICK.

Materials for 100 supl. feet.	Quantity.	Rate.	Per	Amount.	Labour for 100 supl. feet.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Lime, slaked C. ft.	4	..	..	..	Brick layer No.	¾	..	..	..
Gravel, coarse „	3	..	..	..	Coolie .. „	¾	..	..	..
Lime screenings .. „	3	..	..	..	Women .. „	½	..	..	..
					Bhistie .. „	⅛	..	..	..
Sundries	..	..	..	..	Sundries	..	..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials..			..
						Total for 100 Supl. ft. ..			..

RATE ABSTRACT No. 64.

ROUGH CASTE CEMENT PLASTER (1ST COAT; EQUIVALENT TO ¼" THICK).

Materials for 100 Supl. ft.	Quantity.	Rate.	Per	Amount.	Labour for 100 Supl. feet.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Port land cement, ½ cask or .. C. ft.	2	..	..	..	Masons .. No.	1½	..	..	..
Clean sharp sand .. C. ft.	2	..	..	..	Coolies (including those for raking out joints) ,,	2	..	..	..
					Women .. ,,	1	..	..	
					Bhistics .. ,,	¼	..	..	..
Sundries .. ,, ..	..	..	..	..	Sundries	..	..	..	..
	Total, materials ..			..		Total, labour ..			..
						Total, materials ..			..
					Total for 100 Supl. ft. ..				..

RATE ABSTRACT No. 65.

ROUGH CAST CEMENT PLASTER ½" THICK (2ND COAT).

Materials for 100 Supl. ft.	Quantity.	Rate.	Per	Amount.	Labour for 100 Supl. feet.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Portland cement, ½ cask, or .. C. ft.	2	..	..	..	Masons .. No.	2	..	..	..
					Coolies	2	..	..	..
Fine sand and coarse sand or ¼" gravel..C. ft.	4	..	..	..	Women .. ,,	1	..	..	..
					Bhistie .. ,,	¼	..	..	..
Sundries	..	..	..	..	Sundries	..	..	..	..
	Total, materials ..			..		Total, labour ..			..
						Total, materials ..			..
					Total for 100 Supl. ft. (2nd coat) ..				..
					Do. do. (1st coat) ..				..
					Total for 100 Supl. ft. (two coats)				..

RATE ABSTRACT No. 66.

CEMENT PLASTER.

Materials for 100 Supl. ft.	Quantity.	Rate.	Per	Amount.	Labour for 100 Supl. feet.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Portland cement, 1 cask or .. C. ft.	4	..	..	..	Brick-layers No.	3	..	..	..
Sand .. „	4	..	..	..	Coolie .. „	1	..	..	..
Sundries	..	..	..	..	Women .. „	3	..	..	..
					Bhistie	¼	..	..	..
					Sundries	..	..	..	..
	Total, materials ..			..		Total, labour ..			..
						Total, materials ..			..
						Total for 100 Supl. ft. ..			..

RATE ABSTRACT No. 67.

MADRAS PLASTER.

Materials for 240 Sq. ft.	Quantity number.	Rate.	Per	Amount.	Labour for 240 Sq. feet.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Shell lime .. C. ft.	6	..	..	..	Masons .. No.	9	..	..	..
*Sand ground fine .. „	4½	..	..	..	Men .. „	5	..	..	..
Powdered marble .. „	½	..	..	..	Women .. „	50	..	..	..
Powdered soap-stone lbs. .. „	3	..	..	..	Boys .. „	7	..	..	..
Grinding stones .. „	..	..	..	..					
	Total, materials ..					Total, labour ..			..
						Total, materials ..			..
						Total for 240 sq. ft. ..			..
						or for 100 sq. ft. ..			..

* *Note.*—The sand from Tiravatur (Madras) is specially recommended for this kind of plaster. The above rate is exclusive of ½ rough coat of lime plaster.

Floors

RATE ABSTRACT No. 68.

WOODEN FLOORING FOR GROUND FLOOR.

Materials for 100 Supl. feet.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 Supl. feet.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Teak planking, 1½" thick 5½" clear of tongue, Rg.					Carpenters No.	5	..	..	..
ft. 220 or S. ft.	110	..	..	..	Coolies .. ,,	5	..	..	..
Joists, 4"×4" C. ft.	6	..	..	..	Sundries ..	..	..	..	..
Screws, 2½" Doz.	8	..	..	..					
Concrete, 6" including blocks for joists .. C. ft.	50	..	..	..					
Sundries	..	..	..	..					
						Total, labour ..			..
	Total, materials ..			..		Total, materials ..			..
						Total for 100 Supl. ft. ..			..

RATE ABSTRACT No. 69.

FLOOR OR TEAKWOOD PLANKING, 1½ INCHES THICK.

Materials for 100 Supl. feet.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 Supl. feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
					Carpentors No.	3	..	..	..
					Coolies .. ,,	3	..	..	..
					Sundries	..	..	..	..
Teak planking, 1½" thick, 5½" clear of tongue, R. ft. 220 or S. ft.	110	..	..	..					
Screws, 2½" .. Doz.	8	..	..	..					
Sundries	..	..	..						
						Total, labour ..			..
	Total, materials..			..		Total, materials ..			..
						Total for 100 Supl. ft. ..			..

RATE ABSTRACT No. 70.

STONE PAVING, FIRST SORT.*

Materials for 100 Supl. feet.	Quantity.	Rate.	Per	Amount	Labour for 100 Supl. feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Trap stone, rough, 12½″ × 12½″ each Supl. ft.	106	..	..	..	Masons for dressing .. No.	25	..	..	..
Lime, slaked C. ft.	6	..	..	..	Masons for setting ,,	12	..	..	..
Sand .. ,,	6	..	..	..	Coolies .. ,,	6	..	..	..
Charcoal .. Lbs.	80	..	..	..	Women .. ,,	6	..	..	..
Steel .. ,,	6	..	..	..	Bhistie .. ,,	¼	..	..	..
Concrete .. C. ft.	50	..	..	..	Smiths .. ,,	1½	..	..	..
Sundries ..	..	..	..	..	Bellows-boys ,,	1½	..	..	..
					Grinding chunam .. C. ft.	6	..	..	..
					Sundries		..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials ..			..
					Total for 100 Supl. ft. ..				

Note.—Suitable for architectural buildings.

RATE ABSTRACT No. 71.

STONE PAVING, SECOND SORT.*

Materials for 100 Supl. foet.	Quantity.	Bate.	Per.	Amount.	Labour for 100 Supl. feet.	Number or quantity.	Rate.	Per	Amount.
							Rs. a.		Rs. a.
Trap stone, rough, 12½″ × 12½″ each. Supl. ft.	106	..	..	..	Masons for dressing .. No.	12	..	..	..
Lime, slaked C. ft.	9	..	..	..	Masons for setting .. ,,	10	..	..	..
Sand .. ,,	13	..	..	..	Coolies .. ,,	5	..	..	..
Charcoal Lbs.	60	..	..	..	Women .. ,,	5	..	..	..
Steel .. ,,	4	..	..	..	Smith .. ,,	1	..	..	..
Concrete .. C. ft.	50	..	..	..	Bellows-boy ,,	1	..	..	..
Sundries	..	..	..	..	Bhistie .. ,,	¼	..	..	..
					Grinding chunam .. C. ft.	13	..	..	..
					Sundries	..	..	..	..
						Total, labour ..			..
	Total, materials ..					Total, materials ..			..
					Total for 100 Supl. ft. ..				..

*These rates are for trap or other similar stone requiring surface dressing and that item should be omitted with Tandur and Rutlam stones. The rate per 100 superficial feet, delivered in Bombay, is

For Tandur stone slabs, 1½″ thick .. .. Rs.
,, ,, ,, ,, polished .. .. ,,
,, Cuddapah ,, ,, ,,

RATE ABSTRACT No. 72.

STONE PAVING, THIRD SORT.

Materials for 100 Supl. ft.	Quantity.	Rate.	Per	Amount.	Labour for 100 Supl. ft.	Number or quantity.	Rate.	Per	Amount
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Trap stone, rough, 12"×12" each S. ft.	100				Masons for dressing .. No.	8	..	..	..
					Masons for setting .. ,,	8	..	..	..
Lime, slaked C. ft.	12	..	..	..	Coolies .. ,,	5	..	..	..
Sand .. ,,	18	..	..	..	Women .. ,,	5	..	..	..
Charcoal .. Lbs.	30	..	..	..	Smith .. ,,	½	..	..	..
Steel .. ,,	2	..	..	..	Bellows-boy ,,	½	..	..	..
Concrete .. C. ft.	25	..	..	..	Bhistie .. ,,	¼	..	..	..
Sundries	..	..	..	..	Grinding chunam .. C. ft.	18	..	..	..
					Sundries		..	..	..
	Total, materials ..			..		Total, labour ..			..
						Total, materials ..			..
						Total for 100 Supl. ft...			..

RATE ABSTRACT No. 73.

STONE PAVING, FOURTH SORT.

Materials for 100 Supl. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 Supl. ft.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Trap stone, rough .. S. ft.	100	..	..	..	Same as for paving, 3rd sort, in Rate Abstract No. 72..	..	..	..	..
Rest same as for paving, 3rd sort, in Rate Abstract No. 72 ..	..	..	..	..					
	Total, materials ..			..		Total, labour ..			..
						Total, materials ..			..
						Total for 100 Supl. ft. ..			..

Note.—Stone pavings, 3rd and 4th sorts, are only suited for minor buildings, such as cook houses, *dharamsalas*, etc.

RATE ABSTRACT No. 74.

BRICK FLOOR LAID ON EDGE ON 6 INCHES CONCRETE.

Materials for 100 Supl. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 Supl. ft.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Bricks, 9″ × 4½″ × 2½″, allowing 5 per cent. for wastage No.	650	..	..	..	Brick-layers No.	3	..	..	..
Lime, slaked C. ft.	6	..	..	..	Coolies for rubbing bricks .. ,,	5	..	..	..
Sand .. ,,	9	..	..	..	Women .. ,,	5	..	..	..
Concrete .. ,,	50	..	..	..	Bhistie .. ,,	¼	..	..	..
Sundries ..	..	..	..	..	Grinding chunam .. C. ft.	9	..	..	..
					Sundries	..	..	..	..
	Total, materials ..			..		Total, labour ..			..
						Total, materials ..			..
						Total for 100 Supl. ft. ..			..
Cement .. C. ft.	0.8	..	..	..	Mason .. No.	1	..	..	..
Sand .. ,,	1	..	..	..	Women .. ,,	1½	..	..	..
	Total, materials ..			..		Total, labour ..			..
						Total, materials ..			..
						Total for cement pointing for 100 Supl. ft. ..			..
						Total for flooring including cement pointing for 100 Supl. ft. ..			..

RATE ABSTRACT No. 75.

BRICK FLOOR LAID FLAT ON 6 INCHES CONCRETE.

Materials for 100 Supl. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 Supl. ft.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Bricks, 9″ × 4½″ × 2½″, allowing 5 per cent. for wastage No.	375	..	..	..	Brick-layers No.	5	..	..	..
Lime, slaked C. ft.	4	..	..	..	Coolies for rubbing bricks .. ,,	3	..	..	..
Sand .. ,,	6	..	..	..	Women .. ,,	3	..	..	..
Concrete ,,	50	..	..	..	Bhistie ,,	¼	..	..	..
Sundries	..	..	..	..	Grinding chunam .. C. ft.	6	..	..	..
					Sundries	..	..	..	..
	Total, materials ..					Total, labour ..			..
						Total, materials ..			..
						Total for 100 Supl. ft. ..			..

RATE ABSTRACT No. 76.

CHUNAM OR TERRACED FLOORING.

Materials for 100 Supl. feet.	Quantity.	Rate.	Per	Amount.	Labour for 100 Supl. feet.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
					Extra Labour.				
Concrete, 6″ thick .. C. ft.	50				Coolies for ramming concrete .. No.	5	..	..	..
Plaster, $\frac{3}{4}$″ thick, rough S. ft.	100	..	..	..	Women for tapping plaster .. ,,	6	..	..	..
Plaster, fine coat .. ,,	100	..	..	..	Sundries	..	..	..	..
Sundries, as *gugal*, etc. ..	..	..	..	..					
	Total, materials ..			..		Total, labour ..			..
						Total, materials ..			..
						Total for 100 Supl. ft. ..			..

RATE ABSTRACT No. 77.

MINTON TILE FLOOR.

Materials for 100 Supl. feet.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 Supl. feet.	Number.	Rate	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Minton tiles, allowing 8 s.ft. for breakage and delivered up-country .. S.yds	12	..	..	..	Tile-layers No.	4	..	..	..
					Women .. ,,	2	..	..	..
					Sundries	..	..	..	..
Portland cement, $\frac{1}{4}$ cask or .. C. ft.	3	..	..	..					
Lime, slaked ,,	4	..	..	..					
Sand .. ,,	4	..	..	..					
Sundries .. ,,	..	..	..	..					
	Total, materials ..			..		Total, labour ..			..
						Total, materials ..			..
					Add— Concrete, 6″ thick .. C. ft.	50	..	..	..
						Total for 100 Supl. ft. ..			..

RATE ABSTRACT No. 78.

ASPHALT FLOORING, ½ INCH THICK ON 6 INCHES CONCRETE.

Materials for 100 Supl. feet.	Quantity.	Rate.	Per	Amount.	Labour for 100 cubic feet.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Concrete, 6″ thick, including extra labour of ramming .. C. ft.	50	..	..	..	Men for spreading No.	4	..	..	..
					Coolies .. „	4	..	..	..
					Women .. „	2	..	..	..
Asphalt Claridge .. Cwt.	4	..	..	..	Conveyance of asphalt, etc., up-country .. Say	..	..	..	..
Bitumen .. Lbs.	14	..	..	..	Sundries	..	..	..	..
Sand, lbs. 224 or .. C. ft.	2¼	..	..	..					
Firewood .. Lbs.	320	..	..	..					
Sundries ..	..	..	..	..					
						Total, labour ..			..
	Total, materials ..			..		Total, materials ..			..
						Total for 100 Supl. ft. ..			..

N.B.—8 lbs. of asphalt composition will cover 1 square foot, ¼ inch thick. Claridge's patent asphalt (Pyremont Seyssel) costs in square cakes about Rs. 250 per ton delivered in Bombay.

RATE ABSTRACT No. 79.

BASTARD ASPHALT FLOORING.

Materials for 350 Supl. feet.	Quantity.	Rate.	Per	Amount.	Labour for 350 Supl. feet.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Coal tar, 720 lbs. Casks	2	..	..	..	Men for spreading No.	2	..	..	..
Pitch .. „	½	..	..	..	Coolies .. „	24	..	..	..
Road metal, 1″ .. C. ft.	175	..	..	..	Women .. „	12	..	..	..
Lime, slaked „	4	..	..	..	Conveyance of coal tar up-country .. Say	..	..	..	..
Firewood .. Lbs.	560	..	..	..					
Sundries	..	..	..	..					
						Total, labour ..			..
	Total, materials ..			..		Total, materials ..			..
						Total for 350 Supl. ft. ..			..
						or for 100 Supl. ft. ..			..

RATE ABSTRACT No. 80.

CONCRETE JACK ARCHES.

Materials for 300 cubic feet.	Number or quantity.	Rate.	Per	Amount.	Labour for 300 cubic feet.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Metal (1"& ½" gauge) .. C. ft.	300	..	..	..	Ghanis for grinding mortar .. No.	6	..	..	..
Sand .. „	150	..	..	..	Masons for spreading & ramming „	2	..	..	..
Lime .. „	75	..	..	..	Carpenter „	1	..	..	..
					Rammers .. „	3	..	..	..
Cement .. „	25	..	..	..	Coolies for mixing and filling baskets .. „	16	..	..	..
					Women cariers .. „	20	..	..	..
Castor oil .. Lbs.	12	..	..	..	Mucadams „	2	..	..	..
					Washing and stacking materials on platform & bhisties „	..	..	..	..
					Scaffolding, etc.	..	..	..	..
					Sundries	..	..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials ..			..
						Total for 300 C. ft. of concrete ..			..
						or per 100 C. ft. of concrete ..			..
						or per 100 Sq. ft. of floor (6" thick) ..			..

Note.—Cost of plastering the intrados and painting the beams should be added to the above rate.

Ceilings.

RATE ABSTRACT No. 81.

PLANK CEILING, ½ INCH THICK.

Materials for 100 Supl. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 Supl. ft.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Teak planking, ½", planed, tongued and grooved, 5½"* clear of tongue, allowing 5 per cent. for wastage. Rg. ft. 230 or S.ft.	115	..	..	..	Carpenters . No.	2	..	..	..
Screws, brass, 1½" .. Doz.	10	..	..	..	Coolies .. „	2	..	..	..
Sundries	..	..	..	..	Varnishing (2 coats) .. S. ft.	100	..	..	..
					Sundries	..	..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials ..			..
						Total for 100 Supl. ft. ..			..

RATE ABSTRACT No. 82.

PLANK CEILING, ½ INCH THICK, WITH TEAK JOISTS.

Materials for 100 Supl. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 Supl. ft.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Teakwood joists .. C. ft.	2	..	..	..	Carpenter.. No.	1	..	..	..
Cost of rest same as above in Rate Abstract No. 80 ..	..	..	..	..	Rest same as above in Rate Abstract No. 80 ..	..	..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials ..			..
						Total for 100 Supl. ft. ..			..

* Smaller width is preferable for half-inch planks.

RATE ABSTRACTS No. 83.

CLOTH CEILING (INCLUDING FRAMEWORK.)

Materials for 100 Supl. feet.	Quantity.	Rate.	Per	Amount.	Labour for 100 Supl. feet.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Teakwood for frame work. C. ft.	2	..	..	..	Carpenters . No.	3	..	..	..
Cloth dungry, 2¼′ wide.. Yds.	17	..	..	..	Coolies	3	..	..	..
Nails .. Lbs.	1	..	..	..					
Tacks, tinned „	¼	..	..	..	Tailor .. „	¼	..	..	..
Tape, cotton, Rg.ft.	40	..	..	..					
Whitewashing S. ft.	100	..	..	..					
Sundries	..	..	..	..	Sundries	..	..	..	..
						Total, labour ..			..
	Total, materials ..			..		Total, materials..			..
						Total for 100 Supl. ft. ..			..

Roofs.

RATE ABSTRACTS No. 84.

DOUBLE-TILED ROOF COVERING

Materials for 100 Supl. feet.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 Supl. feet.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Battens ..Rg.ft.	300	..	..	..					
Nails for battens and rafters .. Lbs.	6	..	..	..	Tile-turners.. No.	2	..	..	..
					Women .. „	3	..	..	..
					Carpenter.. „	1	..	..	..
Country round tiles. No.	2,200	..	..	..	Coolie .. „	1	..	..	..
					Bhistie .. „	¼	..	..	..
Sundries	..	..	..	..	Sundries .. „	..	..	..	..
Carriage of battens ..	..	..	..	..					
						Total, labour ..			..
	Total, materials ..			..		Total, materials..			..
						Total for 100 Supl. ft. ..			..

Note.—Cost of setting hips and ridges in chunam over double-tiled roofing will be the same as per Rate Abstract No. 87, as, in future, ridge tiles of Mangalore pattern are to be laid in lieu of country ridge tiles.

RATE ABSTRACT No. 85.

SETTING DOUBLE EAVES IN CHUNAM.

Materials for 100 Rg. ft.	Quantity.	Rate	Per	Amount	Labour for 100 Rg. ft.	Number or quantity	Rate	Per	Amount
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Lime, slaked ...C.ft.	8	...	...	...	Brick layers... No.	3	...	...	...
Sand ... ,,	12	...	...	...	Coolie ... ,,	1	...	...	...
Sundries	...	...	...	...	Women ... ,,	3	...	...	...
					Bhistie ... ,,	¼	...	...	...
					Grinding chunam ...C.ft.	12	...	...	...
					Sundries	...	...	...	...
						Total, labour ...			...
	Total, materials...					Total, materials...			...
						Total for 100 Rg. ft. ...			...

RATE ABSTRACT No. 86.

FIXING EAVES BOARD.

Materials for 100 Rg. ft.	Quantity.	Rate	Per	Amount	Labour for 100 Rg. ft.	Number.	Rate	Per	Amount
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Teak plank, 6″ × ⅝″ ...Rg.ft.	103	...	...	...	Carpenters ... No.	2	...	...	...
Screws, 1½″ ...Doz.	4	...	...	...	Coolies ... ,,	2	...	...	...
Sundries	...	...	...	...	Sundries	...	...	...	...
						Total, labour ...			...
	Total, materials...			...		Total, materials...			...
						Total for 100 Rg. ft. ...			...

RATE ABSTRACT No. 87.

MANGALORE-TILED ROOF COVERING.

Materials for 100 Supl. ft.	Number or quantity	Rate	Per	Amount	Labour for 100 Supl. ft.	Number.	Rate	Per	Amount
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Battens, 1″ × 1¾″ ...Rg.ft.	100	...	...	...	Carpenter ... No.	1	...	...	...
Nails for rafters and battens ...Lbs.	5	...	...	...	Tile-layer ... ,,	1	...	...	...
Tiles, 16″×9½″, including 10 per cent. for breakage, freight and carriage ... No.	150	...	...	...	Coolies ... ,,	2	...	...	...
					Women ... ,,	2	...	...	...
Carriage of battens	...	...	...	...	Sundries	...	...	...	...
Sundries	...	...	...	...					
							Total, labour ...		...
	Total, materials...			...			Total, materials...		...
							Total for 100 Supl. ft. ...		...

RATE ABSTRACT No. 88.

MANGALORE RIDGE TILES LAID DRY AND POINTED WITH CEMENT MORTAR.

Materials for 100 Rg. ft.	Number or quantity	Rate	Per	Amount	Labour for 100 Rg. ft.	Number or quantity	Rate	Per	Amount
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Ridge tiles, including freight and carriage ... No.	100	...*	...	...	Bricklayers ... No.	2	...	...	...
					Coolies ... ,,	2	...	...	...
Portland cement ¼ cask or ...C.ft.	1	...	...	...	Women ... ,,	2	...	...	...
Sand ... ,,	1½	...	...	...	Grinding chunam ...C.ft.	9	...	...	...
Sundries	...	...	...	...	Sundries	...	...	...	...
							Total, labour ...		...
	Total, materials...			...			Total, materials...		...
							Total for 100 Rg. ft. ...		...

* *Note.*—The high rate is to include breakage in transit.

RATE ABSTRACT No. 89.

FIXING GALVANIZED CORRUGATED IRON ROOF COVERING.

(LABOUR AND MATERIALS ONLY).

Materials for 100 Supl. ft.	Quantity	Rate.	Per	Amount	Labour for 100 Supl. ft.	Number	Rate	Per	Amount
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Lead-washers...Lbs.	1	...	...	...	Carpenters ... No.	3	...	...	...
G. I. bolts and nuts ... ,,	$1\frac{1}{2}$	...	...	...	Coolies ... ,,	3	...	...	...
G. I. screws ... ,,	1	...	...	...	Smith ... ,,	$\frac{3}{4}$	...	...	...
Iron for bolts, etc. ... ,,	3	...	...	...	Bellows-boy... ,,	$\frac{3}{4}$	...	...	...
Charcoal ... ,,	30	...	...	...	Sundries	...	...	...	...
Sundries	...	...	...	...					
						Total, labour ...			...
	Total, materials ...			...		Total, materials ...			...
						Total for 100 Supl. ft. ...			...

RATE ABSTRACT No. 90.

FIXING GALVANIZED IRON RIDGE.

Labour for 100 Rg. ft.	Number	Rate	Per	Amount
		Rs. a.		Rs. a.
Carpenters ... ... No.	5	...	...	...
Coolies ... ... ,,	5	...	...	...
Sundries	...	...	...	...
Total for fixing 100 Rg. ft. of ridge ...				...

RATE ABSTRACT No. 91.

GALVANIZED CORRUGATED IRON ROOF COVERING.

Mterials for 2,100 Supl. ft.	Quantity	Rate	Per	Amount	Labour for 2,100 Supl. ft.	Quantity	Rate	Per	Amount
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
					Fixing as shown in Rate Abstract No. 88 ...S.ft.	2100	...	...	...
Galvanized corrugated iron, 20 B.W.G., in Bombay ...Cwt.	49·10*	...	...	...	Cutting sheets.Cwt.	49·10	...	...	...
Ridge capping, 20 B.W.G., 12″ ...Rg.ft.	84	...	...	...	Fixing ridge as shewn in Rate Abstract No. 89 ...Rg.ft.	34	...	...	...
Other materials, such as washers, screws, etc., as shewn in Rate Abstract No. 89 ...S.ft.	2,100	...	...	...	Sundries	...	...	...	...
						Total, labour ...			...
						Total, materials ...			...
	Total, materials ...			...	*Add*— Carriage ...Cwt.	49·10		Cwt.	...
					Total for 2,100 Supl. ft. ...				...
					or for 100 Supl. ft. ...				...

RATE ABSTRACT No. 92.

ROOF OF SINGLE (COUNTRY ROUND) TILES OVER GALVANIZED CORRUGATED IRON SHEETS, 22 B.W.G.

Materials for 2,100 Supl. ft.	Number of quantity	Rate	Per	Amount	Labour for 2,100 Supl. ft.	Number of quantity	Rate	Per	Amount
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Country round tiles ... No.	23,100	...	...	...	Fixing sheets as in Rate Abstract No. 88 ...S.ft.	2,100	...	...	...
Galvanized corrugated iron, 22 B.W.G. in Bombay ...Cwt.	39·28	...	...	...	Cutting sheets.Cwt.	39·28	...	...	...
					Tile-turners ... No.	21	...	...	...
					Coolies ... ,,	21	...	...	...
					Women ... ,,	21	...	...	...
Other materials as in Rate Abstract No. 88 ...S.ft.	2,100	...	...	...	Bhisties ... ,,	5¼	...	...	
Mangalore ridge tiles as in Rate Abstract No. 87 ...Rg.ft.	84	...	...	...	Fixing Mangalore ridge tiles as in Rate Abstract No. 87 ...Rg.ft.	84	...	...	...
						Total, labour ...			...
	Total, materials ...			...		Total, materials ...			...
					Add— Carriage ...Cwt.	39·28		Cwt.	...
					Total for 2,100 Supl. ft. ...				...
					or for 100 Supl. ft. ...				...

* *Vide* for details page 155.

RATE ABSTRACT No. 93.

BELGAUM-TILED ROOF COVERING.

Materials for 100 Supl. ft.	Number or quantity.	Rate.	Per.	Amount.	Labour for 100 Supl. ft.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Teak battens, 2″×½″ ...Rg.ft.	240	...	...	...	Masons ... No.	2	...	...	...
Nails for battens and rafters ...Lbs.	1½	...	...	...	Carpenters ... ,,	1½	...	...	...
Flat tiles, 6″×4½″ ... No.	575	...	...	...	Coolies ... ,,	3	...	...	...
Round tiles, 13½″ × 4½″... ,,	675	...	...	...	Bhistie ... ,,	¼	...	...	...
Lime, slaked ...C.ft.	4	...	...	...	Grinding chunam ...C.ft.	6	...	...	...
Sand ... ,,	6	...	...	...					
Sundries	...	...	...	...	Sundries	...	...	...	...
						Total, labour ...			...
	Total, materials ...			...		Total, materials...			...
						Total for 100 Supl. ft. ...			...

RATE ABSTRACT No. 94.

TERRACED ROOFING, 8 FEET SPAN.

Materials for 80 Supl. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 80 Supl. ft.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Teakwood in scantling ...C.ft.	10	...	...	...	Carpenters ... No.	3½	...	...	...
Flat tiles, 12″×6″×1″ ... No.	480	...	...	...	Masons for setting tiles... ,,	3	...	...	...
Lime, slaked ...C.ft.	5	...	...	...	Coolies ... ,,	6½	...	...	...
Sand ... ,,	7½	...	...	...	Bhistie ... ,,	½	...	...	...
Concrete ... ,,	20	...	...	...	Grinding chunam ...C.ft.	7½	...	...	...
Sundries	...	...	...	...	Whitewash ...S.ft.	200	...	...	...
					Sundries	...	...	...	...
						Total, labour ...			...
	Total, materials ...			...		Total, materials...			...
						Total for 80 Supl. ft. ...			...
						or for 100 Supl. ft. ...			...

RATE ABSTRACT No. 95.

TERRACED ROOFING, 12 FEET SPAN.

Materials for 120 Supl. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 120 Supl. ft.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Teakwood in scantling ...C.ft.	19½	...	...	...	Carpenters ... No.	7	...	...	...
Flat tiles, 12″×6″×1″ ... No.	720	...	...	...	Masons for setting tiles... ,,	5	...	...	...
Lime, slaked ...C.ft.	8	...	...	...	Coolies ... ,,	12	...	...	...
Sand ... ,,	12	...	...	...	Bhistie ... ,,	½	...	...	...
Concrete ... ,,	30	...	...	...	Grinding chunam ...C.ft.	12	...	...	...
Sundries	...	...	...	...	Whitewash ...S.ft.	300	...	...	...
					Sundries	...	...	...	...
							Total, labour ...		...
	Total, materials ...			...			Total, materials...		...
							Total for 120 Supl. ft. ...		...
							or for 100 Supl. ft. ...		...

RATE ABSTRACT No. 96.

TERRACED ROOFING, 16 FEET SPAN.

Materials for 160 Supl. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 160 Supl. ft.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Teakwood in scantling ...C.ft.	32	...	...	...	Carpenters ... No.	12	...	...	...
Flat tiles, 12″×6″×1″ No.	960	...	...	...	Masons for setting tiles ,,	6	...	...	...
Lime, slaked ...C.ft.	10	...	...	...	Coolies ... ,,	18	...	...	...
Sand ... ,,	15	...	...	...	Bhistie ... ,,	½	...	...	...
Concrete ... ,,	40	...	...	...	Grinding chunam ...C.ft.	15	...	...	...
Sundries	...	...	...	...	Whitewash ...S.ft.	400	...	...	...
					Sundries	...	...	...	...
							Total, labour ...		
	Total, materials ...			...			Total, materials...		...
							Total for 160 Supl. ft. ...		...
							or for 100 Supl. ft. ...		...

RATE ABSTRACT No. 97.

GUTTERS AND VALLEYS OF SHEET LEAD.

Materials for 100 Rg. ft.	Quantity.	Rate.	Per	Amount.	Labour for 100 Rg. ft.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Teakwood 100′×2½′×1″ C.ft.	21	...	...	...	Carpenters ... No.	8	...	...	...
Sheet lead, 6 lbs. to the Sq. ft. ...Cwt.	13·39	...	...	...	Coolies ... ,,	8	...	...	...
Dammering	...	...	...	...	Sundries	...	...	...	...
Sundries, such as nails, etc. ...	...	...	...	...					
						Total, labour ...			...
	Total, materials ...			...		Total, materials ...			...
						Total for 100 Rg. ft. ...			...
						or per Rg. ft. ...			...

RATE ABSTRACT No. 98.

VALLEYS OF SHEET IRON.

Materials for 100 Rg. ft.	Quantity.	Rate.	Per	Amount.	Labour for 100 Rg. ft.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Teakwood ...C.ft.	21	...	...	...	Carpenters ... No.	6	...	...	...
Sheet iron, 110′ ×3′×[illegible]′ ...Cwt.	7½	...	...	...	Coolies ... ,,	6	...	...	...
Charcial ...Lbs	240	...	...	...	Smiths ... ,,	4	...	...	...
Dammering to wood and iron	...	...	...	...	Bellows-boys ... ,,	4	...	...	...
Sundries	...	...	...	...	Sundries	...	...	...	...
						Total, labour ...			...
	Total, materials ...			...		Total, materials ...			...
						Total for 100 Rg. ft. ...			...
						or per Rg. ft. ...			...

Doors and windows

RATE ABSTRACT No. 99.

*DOORS, PANELLED, FIRST CLASS.

4 × 7 feet.

Materials for 28 Sq. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 28 Sq. ft.	Number or quantity.		Rate.	Per	Amount.
		Rs. a.		Rs. a.				Rs. a.		Rs. a.
Teakwood ...C.ft.	7·10	...	...	...	Carpenters	10	...	...	...	...
Butt hinges, brass, 4½″ ...Pairs.	3	...	...	...	Coolies	10	...	...	...	...
Mortise lock, brass ... No.	1	...	...	...	Sundries		...	...	...	...
Bolts, tower, brass, 10″ ... ,,	2	...	...	...						
Bolts, tower, brass, 8″ ... ,,	1	...	...	...						
Hooks, brass, 10″ ,,	2	...	...	...						
Sundries	...	...	...	...						
							Total, labour ...			...
	Total, materials ...			...			Total, materials			...
						Total for 28 Sq. ft. ...				...
						or per Sq ft. ...				...

RATE ABSTRACT No. 100.

*DOORS, PANELLED, SECOND CLASS.

4 × 7 feet.

Materials for 28 Sq. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 28 Sq. ft.	Number	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Teakwood ...C.ft.	7·1	...	...	...	Carpenters ...	9	...	...	...
Butt hinges, iron, 4½″ ...Pairs.	3	...	...	...	Coolies ...	9	...	...	...
Mortise lock, brass ... No.	1	...	...	...	Sundries ...	...	...	...	...
Bolts, iron, 10″ ... ,,	2	...	...	...					
Bolts, iron 8″ ... ,,	1	...	...	...					
Hooks, iron 10″ ... ,,	2	...	...	...					
Sundries ...	...	...	...	...					
						Total, labour ...			...
	Total, materials ...			...		Total, materials			...
						Total for 28 Sq. ft. ...			...
						or per Sq. ft.			...

* *N.B.*—The above rate per square foot is with frames. The dimensions in this rate relate to clear openings.

RATE ABSTRACT No. 101.

*DOORS, PANELLED AND GLAZED, FIRST CLASS.

4 × 7 feet.

Materials for 28 Sq. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 28 Sq. ft.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Teakwood ...C.ft.	5·87	...	...	...	Carpenters ...	10		...	...
Butt hinges, brass, 4½" ...Pairs.	3	...	...	...	Coolies ...	10	...	...	...
Mortise lock, brass ...No.	1	...	...	...	Sundries (glazier, etc.) ...		...	...	...
Bolts, tower, brass, 10" ... ,,	2	...	...	..					
Bolts, tower, brass, 8" ... ,,	1	...	...	...					
Hooks and eyes, brass ,,	2	...	...	...					
Panes of glass, 10½" × 8¾" ,,	16	...	...	...					
Sundries	...	...	...	...					
	Total, materials ...			...		Total, labour ...			...
						Total, materials			...
						Total for 28 Sq. ft. ...			...
						or per Sq. ft. ...			...

RATE ABSTRACT No. 102.

*DOORS, PANELLED AND GLAZED, SECOND CLASS.

4 × 7 feet.

Materials for 28 Sq. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 28 Sq. ft.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Teakwood ...C.ft.	5·87	...	...	...	Carpenters ... No.	9	...	...	...
Butt hinges, iron, 4½" ...Pairs.	3	...	...	...	Coolies ... ,,	9	...	...	...
Mortise lock, brass ...No.	1	...	...	...	Sundries ...	...	...	...	...
Bolts, iron, 10" ,,	2	...	...	...					
Bolts, iron, 8" ,,	1	...	...	...					
Hooks, iron, 10" ,,	2	...	...	...					
Panes of glass, 10½" × 8¾"... ,,	10	...	...	...					
Sundries	...	...	...	...					
	Total, materials ...			...		Total, labour			...
						Total, materials			...
						Total for 28 Sq.ft. ...			...
						or per Sq. ft. ...			...

* *N. B.*—The above rate per square foot is with frames. The dimensions in this rate relate to clear openings.

RATE ABSTRACT No. 103.

*DOORS, LEDGED.

4 × 7 feet.

Materials for 28 Sq. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 28 Sq. ft.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Teakwood ...C.ft.	7·44	...	...	...	Carpenters ...No.	4	...	...	...*
Strap hinges, iron ...Pairs	3	...	...	...	Coolies ... ,,	4	...	...	...
Bolts, iron, 10″ No.	2	...	...	...	Sundries	...	...	...	...
Bolts, iron, 8″ ,,	1	...	...	...					
Handles ,,	1	...	...	...					
Hooks, iron ... ,,	2	...	...	...					
Alldrop bolt and padlock ,,	1	...	...	...					
Sundries	...	...	...	...					
	Total, materials ...			...		Total, labour ...			...
						Total, materials			...
						Total for 28 Sq.ft ...			...
						or per Sq.ft. ...			...

RATE ABSTRACT No. 104.

* DOORS PLAIN PLANKED.

$2\frac{1}{2}$ × 6 feet.

Materials for 15 Sq.ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 15 Sq. ft.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Teakwood ...C.ft.	3·72	...	...	...	Carpenters ...No.	3	...	...	...
Butt hinges, iron, 3″ ...Pairs	3	...	...	...	Coolies ... ,,	3	...	...	...
Chain and staples, country, iron ... No.	2	...	...	...					
Sundries	...	...	...	...					
	Total, materials ...			...		Total, labour ...			...
						Total, materials ...			...
						Total for 15 Sq.ft. ...			...
						or per Sq.ft. ...			...

* *N. B.*—The above rate per square foot is with frames. The dimensions in this rate relate to clear openings.

RATE ABSTRACT No. 105.

*DOORS, BATTENED, FRAMED AND BRACED.

4 × 7 feet.

Materials for 28 Sq. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 28 Sq. ft.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Teakwood C. ft.	6·54				Carpenters ... No.	7			
Strap hinges iron ...Pairs.	3				Coolies ... ,,	7			
Bolts, iron, 10″ ... No.	2				Sundries	...	...	...	...
Bolts, iron, 8″ ... ,,	1	...	...	...					
Alldrop bolt and padlock ... ,,	1	...	...	...					
Hooks and eyes, iron ,,	2	...	...	...					
Sundries	...	...	...	...					
					Total, labour ...				...
Total, materials ...				...	Total, materials ...				...
					Total for 28 Sq. ft. or per Sq. ft. ...				

RATE ABSTRACT No. 106.

*DOORS WITH IRON-BARRED AND PLANK SHUTTERS.

4 × 7 feet.

Materials for 28 Sq. ft.	Number or Quantity.	Rate.	Per	Amount.	Labour for 28 Sq. ft.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Teakwood C. ft.	13·5	...	...	...	Carpenters ... No.	9	...	...	...
Butt hinges, iron, 4″ ...Pairs.	3	...		...	Blacksmith ,,	1	...	...	...
Hinges, back flap, iron, 4″ ,,	3	...	...	...	Coolies ... ,,	10	...	...	...
Bolts, iron, 10″ No.	4	...	...	...					
Bolts, iron, 8″ ,,	2	...	...	...	Sundries	...	...	...	...
Hooks, iron ... ,,	4	...	...	...					
All drop bolts and padlock ,,	2	...	...	...					
Iron bars, square, ¾″ ...Lbs.	127	...	...	...					
Iron bar, flat 2″×¼″ ... ,,	12	...	...	...					
Sundries	...	...	...	...					
					Total, labour ...				...
Total, materials ...				...	Total, materials ...				...
					Total for 28 Sq.ft. ... or per Sq. ft.				

***N.B.—The above rate per square foot is with frames. The dimensions in this rate relates to clear openings.**

RATE ABSTRACT No. 107.

*DOORS, VENETIANED, FIRST CLASS.

4 × 7 feet.

Materials for 28 Sq. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 28 Sq. ft.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Teakwood ...C.ft.	6·50	...	...	...	Carpenters ...No.	12	...	...	...
Hinges, back flap, 4″, brass.Prs.	3	...	...	...	Coolies ... „	12	...	...	...
Bolts, tower, brass, 10″ ...No.	2	...	...	...	Sundries	...	...	...	...
Bolts, tower, brass, 8″ ... „	1	...	...	...					
Handle, brass... „	1	...	...	...					
Hooks, brass ... „	2	...	...	...					
Hinges, brass, for venetians Doz. prs.	3	...	...	...					
Mortise lock, brass ...No.	1	...	...	...					
Sundries	...	...	...	...					
	Total, materials ...			...		Total, labour ...			...
						Total, materials ...			...
						Total for 28 Sq. ft. ...			
						or per Sq. ft.			

RATE ABSTRACT No. 108.

*DOORS, VENETIANED, SECOND CLASS.

4 × 7 feet.

Materials for 28 Sq. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 28 Sq. ft.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Teakwood ...C.ft.	6·5	...	...	...	Carpenter ...No.	12	...	...	...
Hinges, back flap, iron, 4″ Prs.	3	...	...	...	Coolies ... „	12	...	...	...
Bolts, iron, 10″ No.	2	...	...	...	Sundries ...	...	...	...	...
Bolts, iron, 8″ „	1	...	...	...					
Handle, iron ... „	...1	...	...	...					
Hooks, iron ... „	2	...	...	...					
Clips and wire for fasterning blades ...Lot.	...	...	...	...					
Mortise lock, brass ...No.	1	...	...	...					
Sundries	...	...	...	...					
	Total, materials ...			...		Total, labour ...			...
						Total, materials ...			...
						Total for 28 Sq. ft. ...			
						or per Sq. ft. ...			

***N.B.—The above rate per square foot is with frames. The dimensions in this rate relates to clear openings.**

RATE ABSTRACT No. 109.

*WINDOWS, GLAZED, FIRST CLASS.

4 × 5 feet.

Materials for 20 Sq. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 20 Sq. ft.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Teakwood ...C.ft.	3·32	...	...	...	Carpenters ...No.	6	...	...	...
Panes of glass, 11″ × 9½″ ...No.	20	...	...	...	Coolies ... ,,	6	...	...	...
Butts, hinges, brass, 4″ ...Prs.	2	...	...	...	Sundries	...	...	...	...
Bolts, tower, brass, 8″ ...No.	2	...	...	...					
Bolts, tower, brass, 6″ ... ,,	1	...	...	...					
Handle, brass ,,	1	...	...	...					
Hooks, brass ,,	2	...	...	...					
Sundries	...	...	...	...					
						Total, labour ...			...
	Total, materials ..			...		Total, materials ...			...
						Total for 20 Sq. ft. ...			...
						or per Sq. ft. ...			...

RATE ABSTRACT No. 110.

*WINDOWS, GLAZED, SECOND CLASS

4 × 5 feet.

Materials for 20 Sq. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 20 Sq. ft.	Number	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Teakwood ...C.ft.	3·32	...	...	...	Carpenters ...No.	5	...	...	...
Panes of glass, 11″ × 9½″ ...No.	20	...	...	...	Coolies ... ,,	5	...	...	...
Butt hinges, iron, 4″ ...Prs.	2	...	...	...	Sundries ...	...	...	...	...
Bolts, iron, 8″...No.	2	...	...	...					
Bolts, iron, 6″ ,,	1	...	...	...					
Handle, iron ... ,,	1	...	...	...					
Hooks, iron ... ,,	2	...	...	...					
Sundries	...	...	...	...					
						Total, labour ...			...
	Total, materials ...					Total, materials ...			...
						Total for 20 Sq. ft. ...			
						or per Sq. ft. ...			

**N.B.*—The above rate per square foot is with frames. The dimensions in this rate relate to clear openings.

RATE ABSTRACT No. 111.

*WINDOWS WITH PLANK SHUTTERS.

3 × 4 feet.

Materials for 12 Sq. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 12 Sq. ft.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Teakwood ...C.ft.	2·68	...	...	...	Carpenters No.	1½	...	...	...
Butt hinges, iron, 3½" ...Prs.	2	...	...	...	Coolies ... ,,	1½	...	...	...
Bolts, iron, 6" No.	3	...	...	...	Sundries	...	...	...	...
Handle, iron ,,	1	...	...	...					
Hooks, iron, 9" ,,	2	...	...	...					
Sundries	...	...	...	...					
	Total, materials ...					Total, labour ...			
						Total, materials ...			
						Total for 12 Sq. ft. ...			
						or per Sq. ft. ...			

RATE ABSTRACT No. 112.

*WINDOWS WITH IRON BARS AND PLANK SHUTTERS.

3 × 4 feet.

Materials for 12 Sq. ft.	Number or quantity.	Rate	Per	Amount.	Labour for 12 Sq. ft.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Teakwood ...C.ft.	3·12	...	...	...	Carpenters ...No.	1½	...	...	...
Butt hinges, iron, 4½" ...Prs.	2	...	...	...	Coolies ... ,,	2½	...	...	...
Bolts, iron, 6" No.	3	...	...	...	Blacksmith ... ,,	1	...	...	...
Handle, iron ... ,,	1	...	...	...					
Hooks, iron, 9" ,,	2	...	...	...	Sundries	...	...	...	...
Iron bars, square, ¾" ...Lb.	87	...	...	...					
Iron, flat, 2" ×⅜" central ,,	8	...	...	...					
Iron, flat, 2" ×¼" top and bottom ,, ,,	11	...	...	...					
Sundries	...	...	...	...					
	Total, materials ...					Total, labour ...			
						Total, materials ...			
						Total for 12 Sq. ft. ...			
						or per Sq. ft. ...			

**N.B.*—The above rate per square foot is with frames. The dimensions in this rate relate to clear openings.

RATE ABSTRACT No. 113.

*WINDOWS, GLAZED, AND VENETIANED SHUTTERS, FIRST CLASS.

4 × 5 feet.

Materials for 20 Sq. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 20 Sq. ft.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Teakwood ...C. ft.	5·47	...	...	...	Carpenters ...No.	14	...	...	...
Glass panes, 11" × 9" ...No.	20	...	...	...	Coolies ... ,,	14	...	...	...
Butt hinges, brass ...Prs.	2	...	...	...	Sundries	...	...	...	...
Back flap hinges, 4" ... ,,	2	...	...	...					
Bolts, tower, brass, 8" ...No.	4	...	...	...					
Bolts, tower, 6" ,,	2	...	...	...					
Handles, brass. ,,	2	...	...	...					
Hooks, brass ... ,,	4	...	...	...					
Hinges, brass, for venetian, Doz. prs.	2½	...	...	...					
Sundries	...	...	...	...					
						Total, labour ...			
	Total, materials			...		Total, materials..			...
						Total for 20 Sq. ft. ...			...
						or per Sq. ft. ...			...

RATE ABSTRACT No. 114.

*WINDOWS, GLAZED AND VENETIANED SHUTTERS, SECOND CLASS.

4 × 5 feet.

Materials for 20 Sq. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 20 Sq. ft.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Teakwood ...C. ft.	5·47	...	...	...	Carpenters ...No.	14	...	...	...
Glass panes, 11" × 9½" ...No.	20	...	...	...	Coolies ... ,,	14	...	...	...
Butt hinges, iron, 4" ...Prs.	2	...	...	...	Sundries	...	...	...	...
Black flap hinges, iron, 4" ,,	2	...	...	...					
Bolts, iron, 8" No.	4	...	...	...					
Bolts, iron, 6" ,,	2	...	...	...					
Handles, iron, 6" ,,	2	...	...	...					
Hooks, iron, 6" ,,	4	...	...	...					
Slips and wire for fastening blades ...Lot.	...	...	...	...					
Sundries	...	...	...	...					
						Total, labour ...			...
	Total, materials ...			...		Total, materials...			...
						Total for 20 Sq.ft ...			...
						or per Sq. ft. ...			...

**N.B.*—The above rate per square foot is with frames. The dimensions in this rate relates to clear openings.

RATE ABSTRACT No. 115.

*WINDOWS, IRON-BARRED, GLAZED, WITH PLANK SHUTTERS.

3 × 4 feet.

Materials for 12 Sq. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 12 Sq. ft.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Teakwood ...C. ft.	3·93	...	...	...	Carpenters ...No.	4	...	...	...
Glass panes, 8¼" ×6½" ...No.	20	...	...	...					
Butt hinges, iron, 3½" ...Prs.	2	...	...	...	Coolies ... ,,	4½	...	...	...
Back flap hinges, 3½" ... ,,	2	...	...	...	Blacksmith ... ,,	1	...	...	...
Bolts, iron, 6" No.	6	...	...	...					
Handles, iron ,,	2	...	...	...					
Hooks, iron ... ,,	4	...	...	...	Sundries	...	...	...	...
Iron bars, square, ¾" ...Lbs.	87	...	...	...					
Iron bars, flat, 2" × ⅜", central. ,,	8	...	...	...					
Iron, flat, 2"×½' top and bottom ..	11	...	...	...					
Sundries	...	...	...	...					
						Total, labour ...			...
	Total, materials			...		Total, materials..			...
						Total for 12 Sq. ft. ..			...
						or per Sq. ft. ..			...

**N.B.*—The above rate per square foot is with frames. The dimensions in this rate relate to clear openings.

Painting, Papering, Glaziers' work, etc.

RATE ABSTRACT No. 116.

PAINTING, THREE COATS.

Materials for 100 Sq. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 Sq. ft.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Hubbock's white zinc paint ..Lbs	4¼	...	...	...	Painter ...No.	1	...	...	...
Linseed oil, boiled* ...Pts.	2½	...	...	...	Coolie ... ,,	1	...	...	...
					Woman ... ,,	1	...	...	...
Spirits of turpentine ... ,,	1	...	...	...	Sundries	...	...	...	...
Sundries, such as driers, putty, etc.	...	...	...	...					
						Total, labour ...			...
	Total, materials ...			...		Total, materials ..			...
						Total for 100 Sq. ft. ...			...

Note.—Eight pints make one gallon.

RATE ABSTRACT No. 117.

VARNISHING, TWO COATS.

Materials for 100 Sq. ft.	Number.	Rate.	Per	Amount	Labour for 100 Sq. ft.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Varnish, copal, superior ...Pts.	2	...	...	...	Painter ...No.	1	...	...	...
Linseed-oil boiled ... ,,	$1\frac{1}{2}$	...	...	...	Coolie ... ,,	1	...	...	...
Sundries	...	...	. .	...	Sundries	...	...	...	...
						Total, labour ...			...
	Total, materials ...			...		Total, materials...			...
						Total for 100 Sq. ft. ..			...

RATE ABSTRACT No. 118.

DISTEMPERING, TWO COATS.

Hall's No. 5 (middle green).

Materials for 100 Sq. ft.	Number.	Rate.	Per	Amount.	Labour for 100 Sq. ft.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Hall's distemper ...Lbs.	$2\frac{3}{4}$	...	...	...	Painter ...No.	$\frac{1}{2}$	...	...	...
					Coolie ... ,,	$\frac{1}{2}$	...	...	...
					Woman ... ,,	$\frac{1}{2}$	...	...	...
Sundries, such as brushes, buckets, scaffolding, etc.	...	...	...	...	Bhistie ... ,,	$\frac{1}{8}$	...	...	...
					Sundries	...	...	...	...
						Total, labour ...			...
	Total, materials ...			...		Total, materials..			...
						Total for 100 Sq. ft. ..			...

RATE ABSTRACT No. 119.

SCRAPING WALLS AND DISTEMPERING, 2 COATS.

Muraline.

Materials for 672 Sq. ft.	Number.	Rate.	Per	Amount.	Labour for 672 Sq. ft.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Muraline distemper ...Lbs.	10½	...	...	...	Coolies for scraping and polishing walls ...No.	3	...	...	...
Sundries, such as brushes, buckets, scaffolding etc.	...	...	...	...	Mason for filling up holes and cracks ... ,,	½	...	...	...
					Painters ... ,,	2	...	...	...
					Women ... ,,	2	...	...	.
					Bhistie ... ,,	⅞	...	...	...
					Sundries ... ,,	...	...	...	...
	Total, materials ...			...		Total, labour ...			...
						Total, materials ..			...
						Total for 672 Sq.ft. ...			...
						or for 100 Sq.ft....			...

RATE ABSTRACT No. 120.

SCRAPING WALLS, PRIMING ONE COAT, AND DISTEMPERING 2 COATS.

(Shalimar light green.)

Materials for 100 Sq. ft.	Number.	Rate.	Per	Amount.	Labour for 100 Sq. ft.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Priming ...Gals.	⅛	...	...	...	Coolie for scraping and polishing walls ...No.	½	...	...	...
Shalimar distemper ...Lbs.	4½	...	...	...	Mason for filling up holes and scracks in walls ... ,,	⅛	...	...	...
Sundries, such as brushes, buckets, scaffolding etc.	...	...	...	...	Painter for priming ... ,,	¼	...	...	...
					Painter for distempering ,,	½	...	...	...
					Woman ... ,,	½	...	...	...
					Bhistie ... ,,	⅛	...	...	...
					Sundries	...	...	...	...
	Total, materials ...			...		Total, labour ...			...
						Total, materials ...			...
						Total for 100 Sq. ft. ...			...

RATE ABSTRACT No. 121.

WHITE WASHING, THREE COATS.

Materials for 100 Sq. ft.	Number.	Rate.	Per	Amount.	Labour for 100 Sq. ft.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Lime, fine ...Lbs.	6	...	...	...	Mason ...No.	¼	...	...	...
Rice ... ,,	¼	...	...	...	Coolie ... ,,	¼	...	...	...
Sundries, such as earthen pots, etc.	...	...	...	...	Bhistie ... ,,	⅛	..	...	...
					Sundries	...	...	...	...
							Total, labour ...		...
	Total, materials ...			...			Total, materials ...		...
							Total for 100 Sq. ft. ...		...

N.B.—For repairs take ⅔rds of this.

RATE ABSTRACT No. 122.

YELLOW-WASH.

Materials for 100 Sq. ft.	Quantity.	Rate.	Per	Amount.	Labour for 100 Sq. ft.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Yellow earth Mooltani ...Lbs.	5	...	...	...	Mason ...No.	¼	...	...	...
Lime, fine ... ,,	5	...	...	...	Coolie ... ,,	¼	...	...	...
Rice ,,	¼	...	...	...	Bhistie ... ,,	⅛	...	...	...
Sundries	...	...	...	...	Sundries	...	...	...	...
							Total, labour ...		...
	Total, materials ...			...			Total, materials...		...
							Total for 100 Sq. ft. ...		...

RATE ABSTRACT No. 123.

BLUE-WASH.

Materials for 100 Sq. ft.	Quantity.	Rate.	Per	Amount.	Labour for 100 Sq. ft.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Coco-anut shells ...Lbs.	3	...	...	...	Mason ...No.	¼	...	...	...
Lime, fine ... „	5	...	...	...	Coolie ... „	¼	...	...	...
Rice ... „	¼	...	...	...	Bhistie ... „	⅛	...	...	...
Sundries	...	...	...	...	Sundries	...	...	...	...
						Total, labour ...			...
	Total, materials ...			...		Total, materials ...			...
						Total for 100 Sq. ft. ...			...

RATE ABSTRACT No. 124.

PINK-WASH.

Materials for 100 Sq. ft.	Quantity.	Rate.	Per	Amount.	Labour for 100 Sq. ft.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Vermilion ... Lbs.	⅛	...	...	...	Mason ... No.	¼	...	...	...
Lime, fine ... „	6	...	...	...	Coolie ... „	¼	...	...	...
Sugar ... „	¼	...	...	...	Bhistie ... „	⅛	...	...	...
Sundries, such as glue, etc. ...	...	...	...	...	Sundries ...	...	...	...	...
						Total, labour ...			...
	Total, materials...			...		Total, materials...			...
						Total for 100 Sq. ft. ...			...

RATE ABSTRACT No. 125.

GREEN-WASH.

Materials for 100 Sq. ft.	Quantity.	Rate.	Per	Amount.	Labour for 100 Sq. ft.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Green colour powder ... Lbs.	2	...	...	...	Mason ... No.	$\frac{1}{4}$	...	...	...
Lime, fine ... „	5	...	...	...	Coolie ... „	$\frac{1}{4}$	...	...	...
Sugar ... „	$\frac{1}{4}$	...	...	...	Bhistie ... „	$\frac{1}{8}$	...	...	...
Sundries, such as glue, etc. ...	...	...	...	...	Sundries	...	...	...	...
						Total, labour ...			...
	Total, materials ...			...		Total, materials ...			...
						Total for 100 Sq. ft. ...			...

RATE ABSTRACT No. 126.

BUFF-WASH.

Materials for 100 Sq. ft.	Quantity.	Rate.	Per	Amount.	Labour for 100 Sq. ft.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Yellow earth ...Lbs.	$\frac{1}{3}$	...	...	...	Mason ... No.	$\frac{1}{4}$	...	...	...
Lime, fine ... „	6	...	...	...	Coolie ... „	$\frac{1}{4}$	...	...	...
					Bhistie ... „	$\frac{1}{8}$	...	...	...
Sundries, such as prickly pear juice, etc.	...	...	...	...	Sundries	...	...	...	...
						Total, labour ...			...
	Total, materials ...			...		Total, materials ...			...
						Total for 100 Sq. ft. ...			...

RATE ABSTRACT No. 127.

WIRE FENCING, 4 FEET ABOVE GROUND; FIVE ROWS OF WIRE.

Materials for 100 Rf. ft.	Number or Quantity.	Rate.	Per	Amount.	Labour for 100 Rg. ft.	Number.	Rate.	Per	Amount.
		Rs. a.	...	Rs. a.			Rs. a.		Rs. a.
Angle iron, intermediate standards, 5½'×2"×2"×¼" ...Cwt.	2	...	...	...	Blacksmiths ... No.	2	...	...	...
					Coolies ... „	6	...	...	...
7 strand twisted galvanized iron wire, No. 4-500 R.ft. ...Cwt.	0.56	...	...	...	Sundries	...	...	...	...
Galvanized iron straining hook bolts, 12"×⅝", with square nuts and washers...No.	7				Total, labour ...				...
					Total, materials ...				...
Sundries	...	...	...	...	*Add*—				
					Painting iron work	...	...	...	...
	Total, materials ...			...	Concrete ...C.ft.	44	...	...	...
					Total for 100 Rg. ft. wire fencing complete ...				...

RATE ABSTRACT No. 128.

HOOP IRON TRELLIS WORK.

Materials for 100 Sq. ft.	Quantity	Rate.	Per	Amount.	Labour for 100 Sq. ft.	Number.	Rate.	Per	Amoun
		Rs. a.		Rs. a.			Rs. a.		Rs. a
Hoop iron, 1" 18 B. W. G....Lbs.	128	...	...	...					
Nails, 1½" ... „	1½	...	...	...	Carpenters ...No.	2	...	...	...
Teakwood ...C.ft.	½	...	...	...	Coolies ... „	2	...	...	...
Sundries	...	...	...	...	Blacksmith „	½	...	...	...
					Sundries	...	...	...	...
					Total, labour ...				...
					Total, materials ...				...
					Add—				
	Total, materials ...			...	Painting both sides ...S.ft.	100	...	...	...
					Total for 100 Sq. ft ...				...

RATE ABSTRACT No. 129.

TEAKWOOD TRELLIS WORK.

Materials for 100 Supl. ft.	Quantity.	Rate.	Per	Amount.	Labour for 100 Supl. ft.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Battens, 1"× ½" ...Rg.ft.	800	...	...	...	Carpenters No.	3	...	...	...
Nails ...Lbs.	2	...	...	...	Coolies ... „	3	...	...	...
Teakwood ...C.ft.	½	...	...	...	Sundries ... „	...	...	...	...
Sundries	...	...	...	...					
						Total, labour ...			...
						Total, materials ...			...
					Add—				
					Planing battens where required ...S. ft.	100	...	...	...
	Total, materials...			...	Painting both sides, 2 coats „	200	...	...	...
						Total for 100 Supl. ft. ...			...

RATE ABSTRACT No. 130.

EXPANDED METAL NETTING, ¾-INCH MESH.

Materials for 96 Supl. ft.	Quantity.	Rate.	Per	Amount.	Labour for 96 Supl. ft.	Number.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
Expanded etal No. 19, ¾" mesh, ⅛ × 16. B.S.W.G., delivered at site (12 ×8) ...S. ft.	96	...	...	...	Carpenters No.	2	...	...	...
					Coolies ... „	2	...	...	...
					Sundries	...	...	...	...
Teak for moulding, 2"×1" ...C.ft.	¾	...	...	...					
Screws, iron, 2½" Doz.	4	...	...	...		Total, labour ...			...
Sundries	...	...	...	...		Total, materials ...			...
					Add—				
	Total, materials ...			...	Painting both sides, 2 coats...S. ft.	96	...	...	
					Total, for 96 Supl. ft. complete ...				...
					or for 100 Supl. ft. ...				...

P. W. D. HANDBOOK

BOMBAY

Volume I

SECTION III

REINFORCED CONCRETE

1949

CHAPTER IV—REINFORCED CEMENT CONCRETE.

GENERAL USES.

The use of reinforced concrete, in structural engineering and buildings is rapidly increasing, and with a knowledge of its advantages, application and strength, there is no limit to the structural purposes for which it can advantageously be used.

Advantages.—Among the advantages are, rigidity, comparative lightness with great strength, great durability, resistance when exposed to fire, water, white ants or an acid laden atmosphere, adaptability to curved, moulded or irregular work, saving of space, economy of cost, rapidity of erection, perfect sanitary properties, hardly any subsequent outlay for maintenance, and no appreciable depreciation of strength with age, if properly executed.

GENERAL SPECIFICATIONS. No. 160.

I. Forms.

1. **Introductory.**—It has been said, and with some truth, that we do not hear of failure in reinforced concrete work after construction, but during construction, so that it is obvious that it is essential that as much consideration should be given to the design and construction of the forms as to that of the actual concrete work itself.

The forms should invariably be carefully designed by the Executive Engineer in charge, where the contractors are a firm of repute, who specialize in this class of work, more latitude may be allowed, but even then it should be clearly understood that all forms are to be erected to the full satisfaction of the Executive Engineer in charge and to be passed by him before any concrete work is taken in hand.

2. **General requirements.**—In order to obtain satisfactory concrete work, the forms should be durable and rigid, and should be so well braced that bulging or twisting cannot occur. They should also have sufficient strength, to properly support the incumbent loads—the horizontal members such as floor-sheathing, joists, etc., must be able to support the weight of the concrete and the construction load, the vertial members such as wall-sheathing and supporting studs, should be designed to resist the hydrostatic pressure of concrete. It is this pressure which often causes the collapses of forms, and it depends on the liquidity of the concrete, the rate of filling, and the temperature. The first factor is self-evident ; the rate of pouring is important because greater head is introduced by pouring additional concrete, while the lower concrete is still fluid. If poured slowly, the lower concrete gets time to stiffen. Temperature affects the matter, because at low temperatures concrete sets slower, and therefore, necessitates slowing down of pouring, to avoid undue pressure. Column forms are the most liable to fail by rapid filling, as the quantity of concrete required for filling being small, there is a tendency to fill them up rapidly. In narrow walls, friction and arch action tend to reduce hydrostatic pressure. For column form a hydrostatic pressure equivalent to that due to a liquid weighing 125 lbs. per cubic feet should be used, and for walls, it ranges from

75 to 145 lbs. according to the thickness. For ordinary thickness the following table is a guide :—

TABLE XCIX.

Hydrostatic Pressure.

Height of wall.	Pressure exerted equivalent to a liquid weight per c. ft.
Less than 5 feet	145 lbs.
Less than 5 feet to 10 feet	125 lbs.
Less than 10 feet to 20 feet	100 lbs.
Over 20 feet	75 lbs.

In addition to bendng and shear strength, the form members must be designed to give only the permissible deflection under load. This deflection is usually laid down as under :—

For sheathing planks under vertical load.	Not exceeding $\frac{1}{8}''$ using the full live load of 75 lbs. per square foot.
For joists and beams carrying joists ...	Not exceeding $\frac{1}{8}''$ for dead load and a live load of 40 lbs. per square foot
For members under horizontal pressure e.g. vertical wall sheathing, column sheathing, etc.	Not exceeding $\frac{1}{8}''$, under the full hydrostatic pressure.

3. **Form material.**— All timber should be of the best quality obtainable, and should be sound and straight grown, free from sap, shakes, loose knots, worm-holes or other defects. Seasoning is of great importance, but partially seasoned timber is the best for formwork, as if it is too dry it will tend to swell from absortion of moisture, while green timber will tend to dry out and shrink in hot weather, causing fins and ridges on the concrete.

Norway or American Southern pine is available in all sizes, is easily worked, and is comparatively cheap. Where strength is required, particularly for large sizes, American pitch pine or spruce are best. Hardwoods are not usually used for form-work, as they are difficult to work and nail, but where there is much repetition work, these disadvantages, as well as the higher cost would, probably be more than made up by the higher frequency of use. In these cases, however, on large jobs metal forms are to be preferred, though the initial cost is heavy.

As formwork is temporary, the factor of safety can be reduced, and higher stresses can be permitted For yellow pine and spruce, a maximum fibre stress of 1,200 to 1,400 lbs. per square inch may be used for bending, for horizontal shear 200 lbs. per square inch and for bearing or crushing across the grain 400 lbs. per square inch. For American pitch pine, these stresses may safely be increased by 50 per cent. The modulus of elasticity may be taken at 1,200,000 lbs. per square inch.

4. **Timber sizes and spacing.**—The table below gives the spans, upto which different boarding thicknesses can be used with various slab depths, live load being

taken at 75 lbs. per square foot. The bending moment being obtained by the formula $M = \frac{wl^2}{10}$, and the deflection being limited to $\frac{1}{8}''$.

Table C.

Safe Span for Floor Sheathing.
(Inches).

Slab thickness.	Weight in pounds per square foot (live plus dead).	1″ Stock.	1¼″ Stock.	1½″ Stock.	2″ Stock.	Slab thickness.	Weight in pounds per square foot (live plus dead).	1″ Stock.	1¼″ Stock.	1½″ Stock.	2″ Stock.
3 in.	112·5	32	39	46	57	8 in.	175·0	29	35	41	51
4 in.	125·0	31	38	45	56	9 in.	187·5	28	35	41	50
5 in.	137·5	30	37	44	54	10 in.	200·0	28	34	40	50
6 in.	150·0	30	37	43	53	11 in.	212·5	27	33	39	49
7 in.	162·5	29	36	42	52	12 in.	225·0	27	33	39	48

A similar table for the spacing of joists is also given below in which deflection is limited to $\frac{1}{8}''$ and the bending moment is taken as $M = \frac{wl^2}{10}$.

Table C 1.

Spacing of Joists.

Distance centre to centre of joists in inches.

Slab thickness.	Size of joists (inches).	Span of joists in feet. 4·0	4·5	5·0	5·5	6·0	6·5	7·0	7·5	8·0	8·5	9·0	9·5	10·0
3 in.	2× 4	31	24	16	11	..	..	..	..	..	..	..	..	..
	2× 6	..	..	47	39	29	21	15	12	..	..	..	..	..
	2× 8	..	..	..	..	..	50	38	29	22	17	14	11	..
	2×10	..	..	..	..	..	..	..	57	44	35	28	22	18
	3× 4	47	37	25	17	12	..	..	..	..	..	..	..	..
	3× 6	..	..	..	..	43	31	23	18	14	11	..	..	..
	3× 8	..	..	..	..	..	..	57	43	33	26	21	17	14
	3×10	..	..	..	..	..	..	..	..	..	52	41	34	27
	4× 6	..	..	..	..	58	42	31	23	18	14	11	..	..
	4× 8	..	..	..	..	..	..	..	58	45	35	28	22	18
	4×10	..	..	..	..	..	..	..	..	..	..	55	45	36

TABLE C I—*contd.*

Slab thickness.	Size of joists (inches).	Span of joists in feet. 4·0	4·5	5·0	5·5	6·0	6·5	7·0	7·5	8·0	8·5	9·0	9·5	10·0
6 in.	2× 4	23	18	12	..	..	..	..	..	..	..	..	..	..
	2× 6	55	43	35	29	21	15	11	..	..	..	..	..	..
	2× 8	..	..	..	53	44	38	28	21	17	13	10	..	..
	2×10	..	..	..	..	..	..	51	43	33	26	21	17	13
	3× 4	35	27	18	12	..	..	..	..	..	..	..	..	..
	3× 6	..	..	53	43	32	23	17	13	10	..	..	..	..
	3× 8	..	..	..	..	..	56	43	32	25	20	15	12	10
	3×10	..	..	..	..	..	..	..	..	50	39	31	25	20
	4× 6	..	..	..	..	43	31	23	18	13	11	..	..	..
	4× 8	..	..	..	..	..	..	57	43	33	26	21	17	14
	4×10	..	..	..	..	..	..	..	..	..	52	41	34	27
9 in.	2× 4	18	15	10	..	..	..	..	..	..	..	..	..	..
	2× 6	44	35	28	23	17	12		..	..	..	..	..	..
	2× 8	..	..	51	42	35	30	23	17	13	10	..	..	..
	2×10	..	..	..	..	55	48	41	34	27	21	16	13	11
	3× 4	28	22	15	10	..	..	..	..	..	..	..	..	..
	3× 6	..	52	42	35	26	19	14	10	..	..	..	..	..
	3× 8	..	..	..	..	53	45	34	26	20	16	12	10	..
	3×10	..	..	..	..	..	..	..	52	40	31	25	20	16
	4× 6	..	..	56	46	34	25	18	14	11	..	..	..	..
	4× 8	..	..	..	..	..	..	46	35	27	21	16	13	11
	4×10	..	..	..	..	..	..	..	..	53	42	33	27	22
12 in.	2× 4	15	12	..	..	..	..	..	..	..	..	..	..	..
	2× 6	36	29	23	19	14	10	..	..	..	..	..	..	..
	2× 8	..	49	42	35	29	25	19	14	11	..	..	..	..
	2×10	..	..	..	50	46	40	34	29	22	17	14	11	..
	3× 4	23	18	12	..	..	..	..	..	..	..	..	..	..
	3× 6	55	43	35	29	21	15	11	..	..	..	..	..	..
	3× 8	..	..	..	53	44	38	28	22	17	13	10	..	..
	3×10	..	..	..	..	..	..	52	43	33	26	21	17	13
	4× 6	..	..	47	39	29	21	15	12	..	..	..	..	..
	4× 8	..	..	..	..	..	50	38	29	22	17	14	11	..
	4×10	..	..	..	..	..	..	..	57	44	35	28	22	18

For columns the boarding requires support at intervals. The table below gives the spans of sheathing or boarding between supports for various heights of columns.

Maximum span of column sheathing for various heights of column.

TABLE—C II.

Height of column.			1½″	2″
6 feet	...	...	25½ inches.	33½ inches.
8	...	...	22	31
10	...	...	20	27½
12	...	...	18	25
14	...	...	17	23
16	...	...	15½	21½
18	...	...	15	20½
20	...	...	14	19½
22	...	...	13½	18½
24	...	...	13	17½
26	...	...	12½	17
28	...	...	12	16½
30	...	...	11½	16

W = 125.

In general, for floor sheathing, 1″ dressed down to 13/16″ is the usaul practice; for wall sheathing and beam and column sides the thickness may vary from 1″ to 2″ stock, dressed 3/16″ or ¼″. Beam bottoms are generally 2″ stock.

Joists may be any size from 2″ by 4″ to 3″ by 10″, 2″ by 6″ being the commonest size; column yokes are usually 3″ or 4″ by 4″.

Studs and wales vary from 2″ by 4″ to 6″ by 6″; posts from 3″ by 4″ to 6″ by 6″.

In ordinary work the smaller sizes mentioned above are used, extra strength being obtained by doubling up.

5. **Preparation of timber.**—(*a*) All timber in contact with concrete, should be specified as wrought on two edges and one face, the material being assembled with the unwrought face outside. If a face free from defects due to badly aligned board is desired, wrought tongued and grooved boarding is justified.

(*b*) All forms coming in contact with concrete should be oiled with crude oil or petroline, preferably before being set in place. This oiling allows easy stripping of forms, as the concrete does not stick to the boards. If the concrete is to be plastered however, oil should not be used as it prevents the adhesion of plaster. Wetting with water or soft-soap and water, will suffice in this case. Apply oil or solution with a white wash brush.

6. **Arrangement of forms.**—The various parts of the falsework should be so assembled, as to allow striking in a proper manner, i.e. in such a manner, as to permit the least essential part for support to be struck first, and proceeding later to other parts. Thus for floors, the beam sides should be stripped first, followed by the slab soffit boards, and last by the beam bottom boards and props.

7. **Re-use of forms.**—As forms are generally to be re-used, the surfaces in contact with concrete should be brushed or scraped clean of scale, and then oiled or wetted as in the case of new forms. The jointing of boards should also be gone over and defects removed. If carefully handled, wooden forms can be used several times. Economy in form use is attained, by seeing at the time of erection, that the components of the form can be stripped without damage. For this reason, clamps should be used in preference to nails and spikes, wherever possible. Where nails must be used, they should be left projecting a little, to permit withdrawal with a claw-hammer without damage to the wood.

If forms are to be left unused for some time, they should be oiled and stored under shade, to minimize warping and opening out of joints.

8. **Supports to forms.**—All posts or shores should rest on large hardwood wedges, driven in pairs, so as to get even bearing. Hard driving of wedges should be prohibited, as it will jar concrete which is setting under them. When posts, etc., are to be lowered, the wedges should be gently eased. When posts rest on sills, great care should be taken that the area of sill and its thickness, are sufficient to guard against settlement of ground or fracture of the sill.

9. **Striking of forms.**—The temperature and humidity of the air, the nature of stress to which the member will be subjected whether direct compression as in columns or flexure as in beams and slabs, and the relative proportions of dead and live load, influence the time of removal of forms. In cold or wet weather, hardening of concrete is retarded and the forms must be kept longer. Also they must be kept longer in these cases, where flexure or bending stresses occur (as in slabs and beams), than where direct compression acts, as in columns. If the dead load-live load ratio is high, the concrete will be called upon to bear a greater proportions of the design load, immediately forms were removed. Generally with temperatures above 60° F, the following intervals (after laying of concrete) are adopted :—

TABLE—C III.

Forms Striking (With temparature about 60° F).	With normal Portland Cement.	Cement concrete with Rapid hardening Portland Cement.
Beam sides, walls, columns (unloaded) ...	3	2
Slabs (props left under)	4	3
Props to slabs	10	5
Beam Soffits (props left under) ...	8	5
Props to beams	21	8

For slab and beam bottom boards, the props will be eased to separate the boarding from the concrete, but will not be removed till a week after easing.

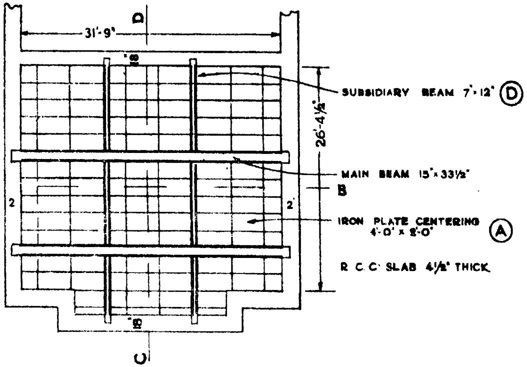
10. **Camber.**—It is necessary to give the bottom boards of beams a camber of beams of an ¼th inch in 5′, i.e. 1/240th of the span.

DETAILS OF R.C.C. CENTERING

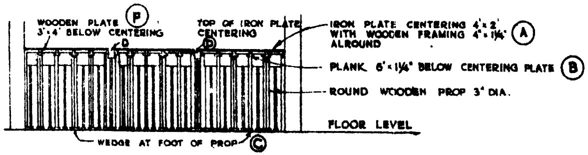
PLATE XLII

SKETCH SHOWING THE DETAILS OF CENTERING FOR R. C. C. FLOOR

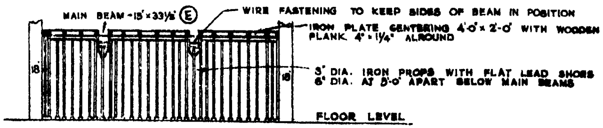
PLAN



CROSS SECTION ON A-B

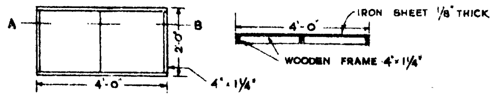


CROSS SECTION ON C-D



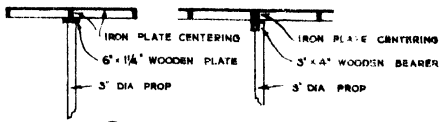
½" DETAILS OF DIFFERENT MEMBERS OF THE CENTERING FOR R. C. C. FLOOR

DETAILS AT (A)



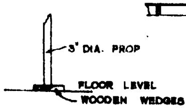
BOTTOM PLAN OF IRON PLATE CENTERING

CROSS SECTION ON A-B

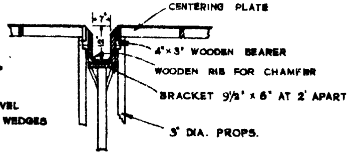


DETAILS AT (B)

DETAILS AT (F)

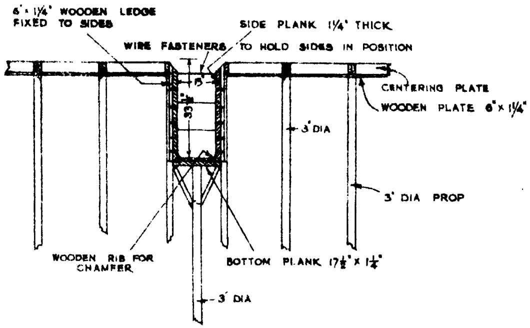


DETAILS AT (C)



DETAILS AT (D)

DETAILS AT (E)



CROSS SECTION OF MAIN BEAM AT A-B

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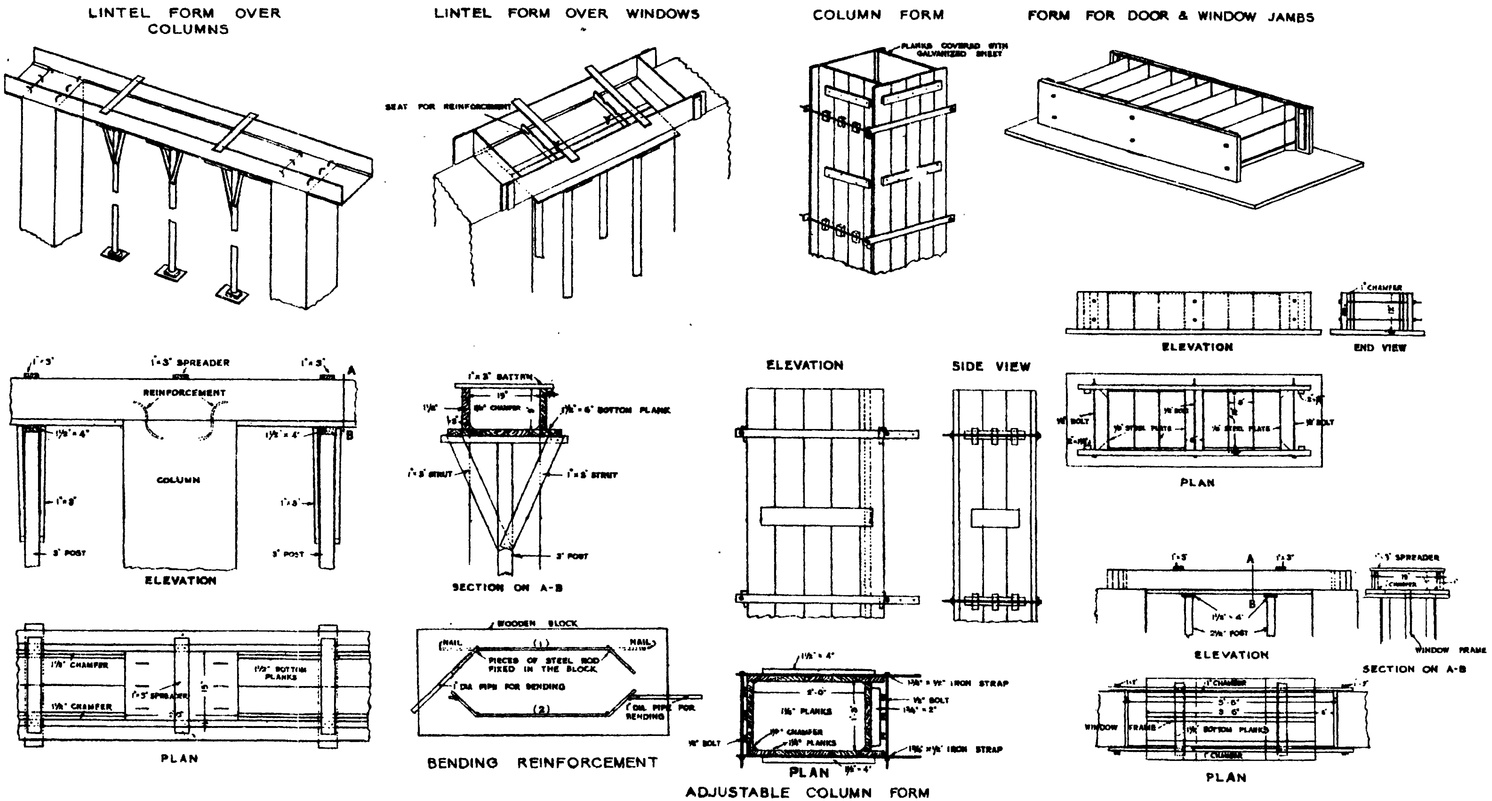
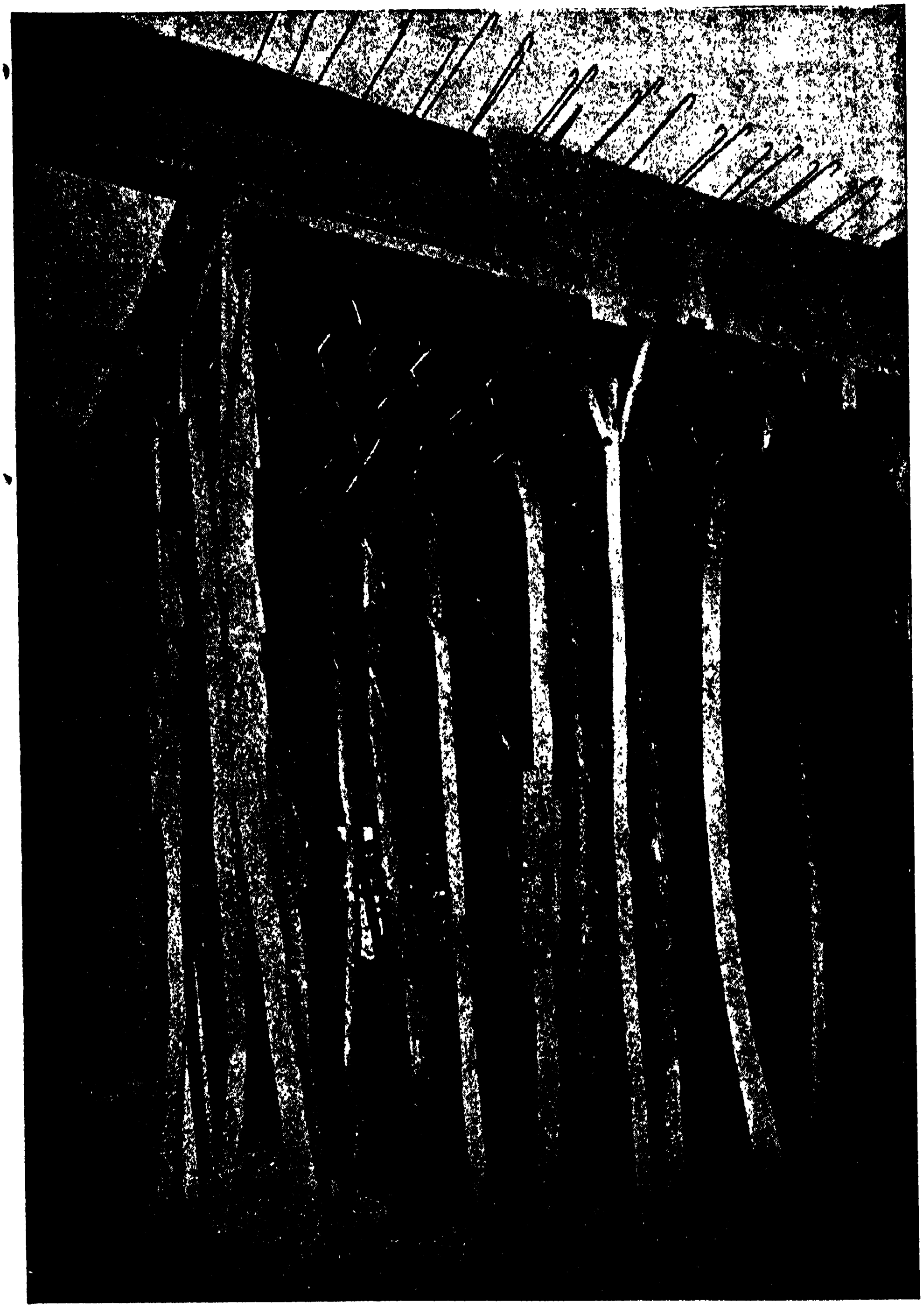
G P Z O Poona

FORMS FOR REINFORCED CONCRETE CONSTRUCTION IN CENTRAL PRISON AT NASIK ROAD



A view of the arrangement of forms under a R. C. C. floor

[To face page 401



Another view of the arrangement of forms under a R. C. C. floor

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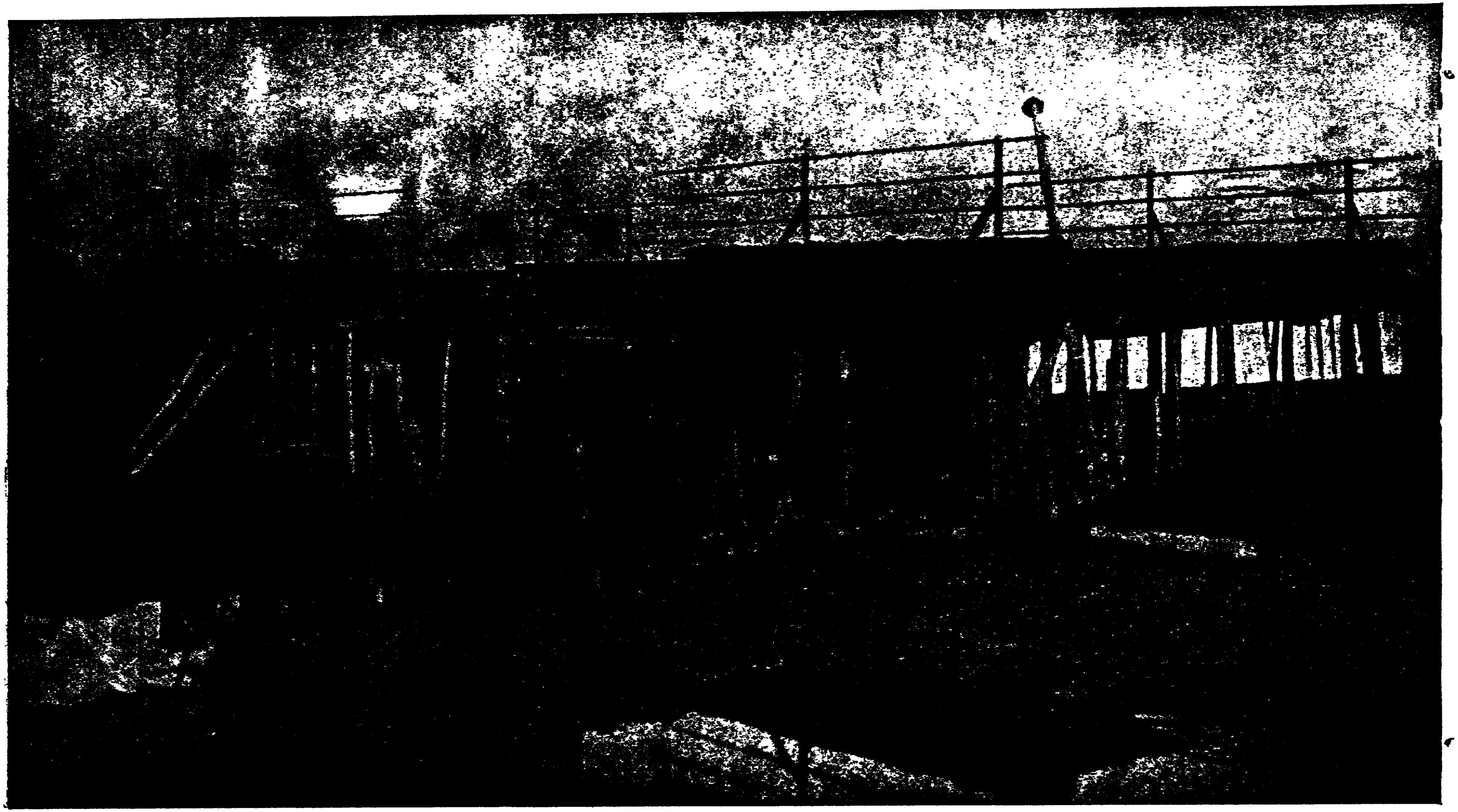
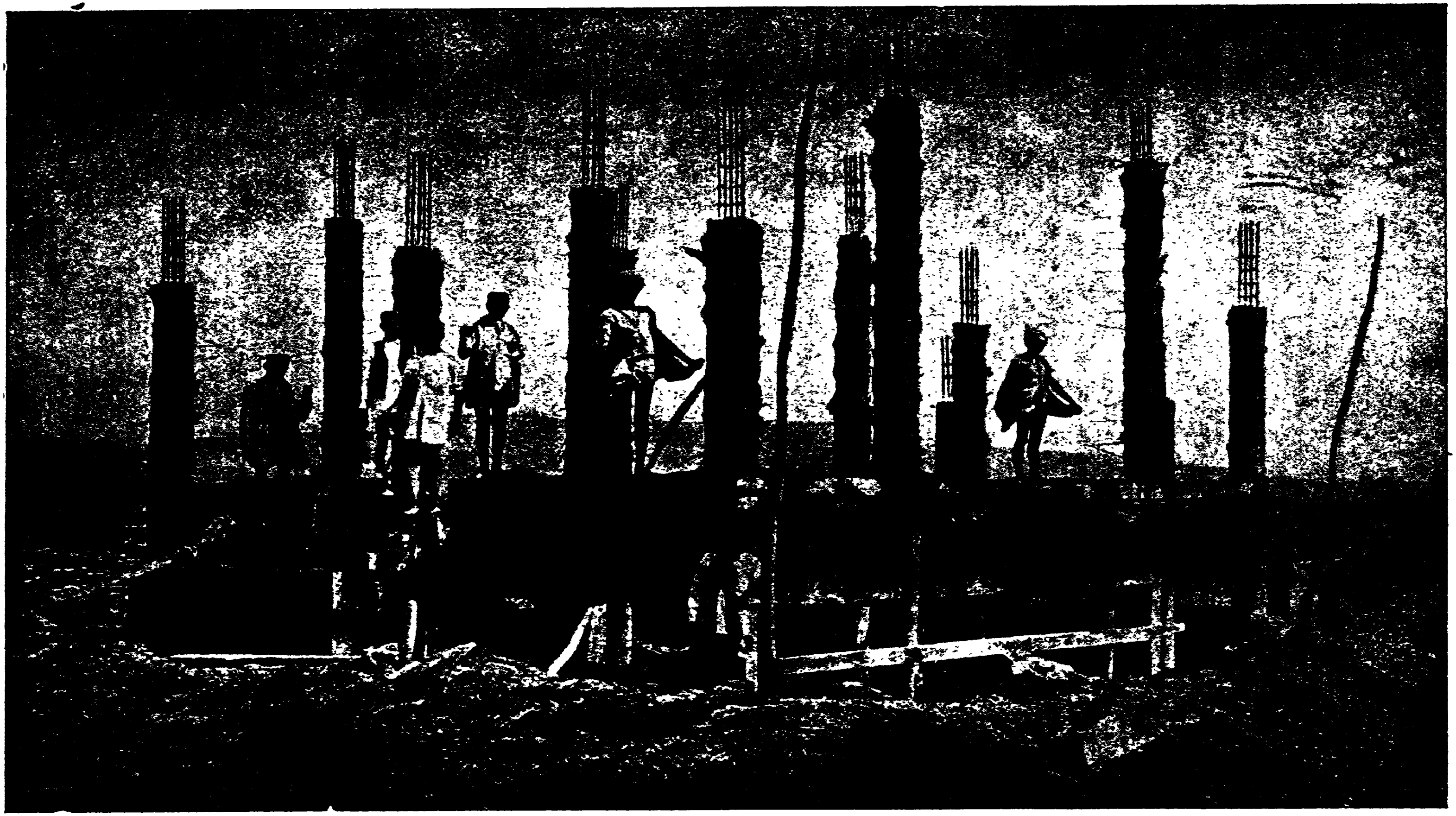
PLATE XLIII-C



A view of the arrangement of forms at the Rai Murdha Creek Bridge

[To face page 401

PLATE XLIII-D



A view of the arrangement of forms at the Karkuns' quarters at Mira

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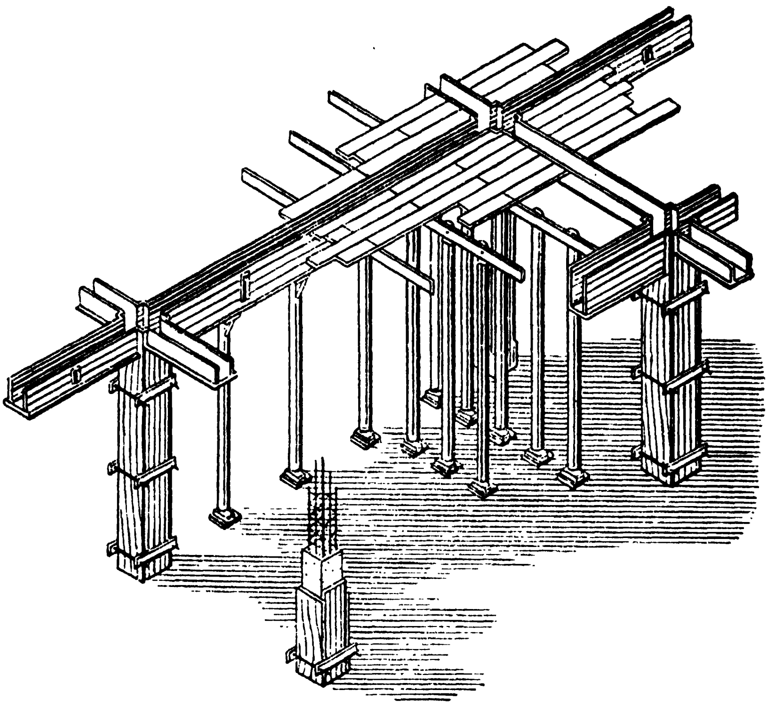
This generally comes out during the process of tamping and filling, and after this has been done, the beams should be examined to see if this camber has come out, and if so, they should be again secured by tightening up the wedges before the concrete has set.

GENERAL ARRANGEMENT OF FORMS.

(Reduced from plate XLI)



Care should also be taken to see that the sole plates under the feet of the posts are of sufficient area, so that there will be no settlement if the ground is at all soft.

11. **Checking of Forms.**—(*a*) **Measurements.**—Before commencing concreting, the forms should be carefully gone over to see that their inside measurements are correct and that they correspond to the plans.

(*b*) **Alignment.** The forms should be carefully examined to see that they are truly vertical and horizontal and that the joints are closed so that no part of the mixture can escape.

(*c*) **Cracks.**—Any cracks found in the boards must be remedied by filling with plaster of Paris or with clay.

(*d*) Extra care should be taken with the forms for concrete that will afterwards be exposed to view and for these forms bevelled edge timber should be used. Undressed timber may be used for backing, but it must be watertight.

(*e*) **Clamps and nails.**—Clamps only should be used to hold forms together, as far as possible, since the use of nails and spikes destroys the timber for further use. Where nails must be used, they should be left projecting, so that they can be easily withdrawn with a claw hammer.

12. **Cleaning.**—All forms should be cleared of all sawdust, chips, etc., before pouring the concrete. For this purpose pockets or traps should be left at the bottom of the forms. If one side of a pillar form is brought up board by board as the concrete is filled in, in this case, of course, nó trap or door is necesary.

FORMS.

Specification No. 161

1. **Material.**—The forms shall be made of a wood and with the scantlings approved by the Executive Engineer, or of steel, and shall be held in shape by clamps, nails or other contrivances specified.

The props, wedges and sills shall be of the dimensions, and of the kind of wood specified, and the props will be spaced as ordered by the Executive Engineer.

2. **Spacing.**—The sizes and spacing of studs, yokes, joists, girders etc., shall be specified or approved by the Executive Engineer, and the boards, shall be wrought, tongued and grooved, etc., as specified or as ordered by the Executive Engineer.

3. **Fixing.**—The forms shall be fixed to perfect line and level for horizontal members, and in line and plumb or to the required batter for vertical members. The planks shall be close-fitting and any cracks will be well caulked. The beam forms shall be laid with the specified camber.

4. **Treatment of the inside of forms.**—The inside of the forms which comes in contact with the concrete shall be treated in a manner approved by the Executive Engineer to prevent adhesion of concrete, and all chamfers, mouldings, etc., will be fixed in place before this is done.

5. **Re-use.**—Before re-use, all forms shall be thoroughly scraped clean, joints gone over and repaired, and the insides retreated to prevent adhesion, to the satisfaction of the Executive Engineer.

6. **Arrangement.**—The forms shall be so arranged as to give facilities for removal in the ascending order of removal time for each form, without disturbing the remaining forms.

7. **Easing and striking.**—The forms shall not in any case be eased or struck before the expiration of the specified period, or after such time as the Executive Engineer orders.

8. **Approval.**—All forms shall be passed by the Executive Engineer before any concreting is commenced.

9. **Rate.**—Measurements of form work shall be taken as superficial area of exposed face running round all beam boxes, mouldings, etc., but the rate shall be inclusive of all necessary props, struts, etc.

II. Steel.

For all normal reinforced concrete work, the steel for reinforcement shall conform fully with the latest British standard specifications for mild steel. The latest specifications enforce an ultimate stress of 28 to 33 tons per square inch in tension, and an elongation not greater than 20 per cent. in a test piece. For bars over 1" diameter the bars should also be capable of being bent double cold, to a radius not greater than 1½ bar diameter, without fracture. For bars 1" or less in diameter, this bending shall be to a radius equal to the bar diameter, without fracture.

The usual reinforcement is rolled mild steel rounds, though cold-drawn mild steel, usually in the form of an electrically welded mesh, is also an economical and reliable reinforcement for slabs but this is to be used on works costing more than Rs. 10,000, where tests can be made. The cold-drawn mild steel has a higher elastic limit, and a higher ultimate tensile strength, viz 37 to 42 tons per square inch. These cold-drawn bars must be capable of being bent cold at

A view of the Bar Bending Operation

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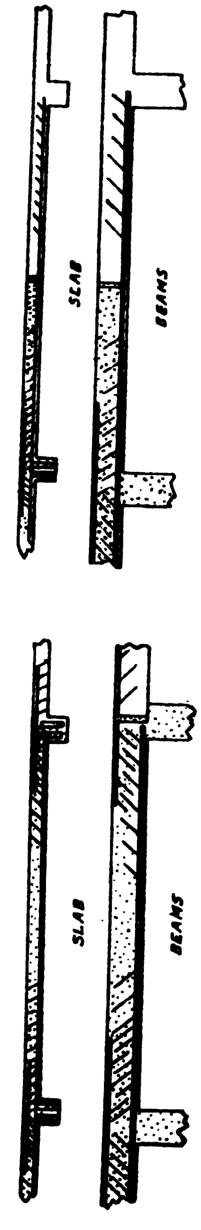
Plate XLV.



ILLUSTRATING PLACES FOR STOPPING CONCRETE.

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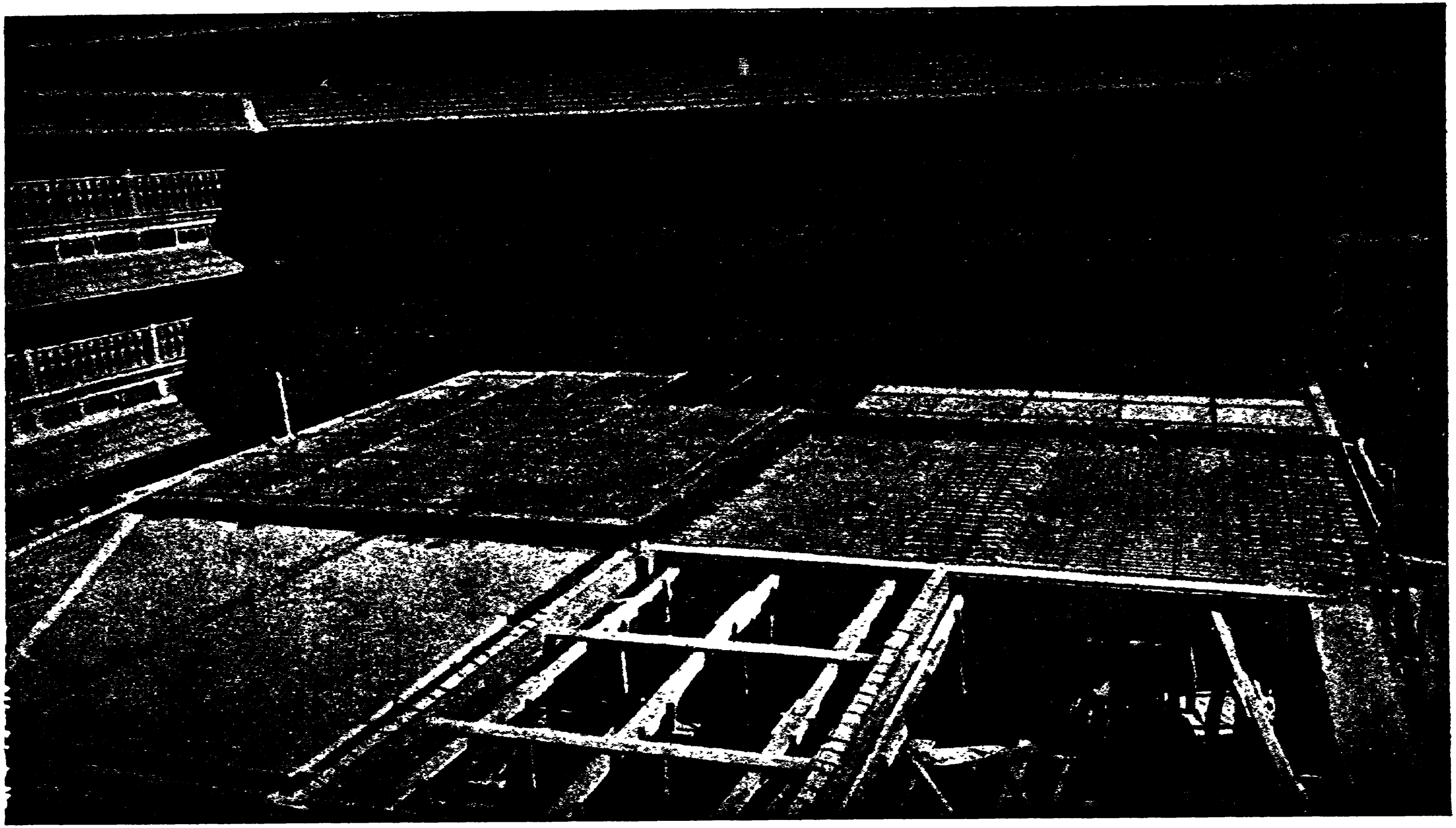
G.P.Z.O. Poona, 1949.



A view of the arrangement of reinforcement in Slabs

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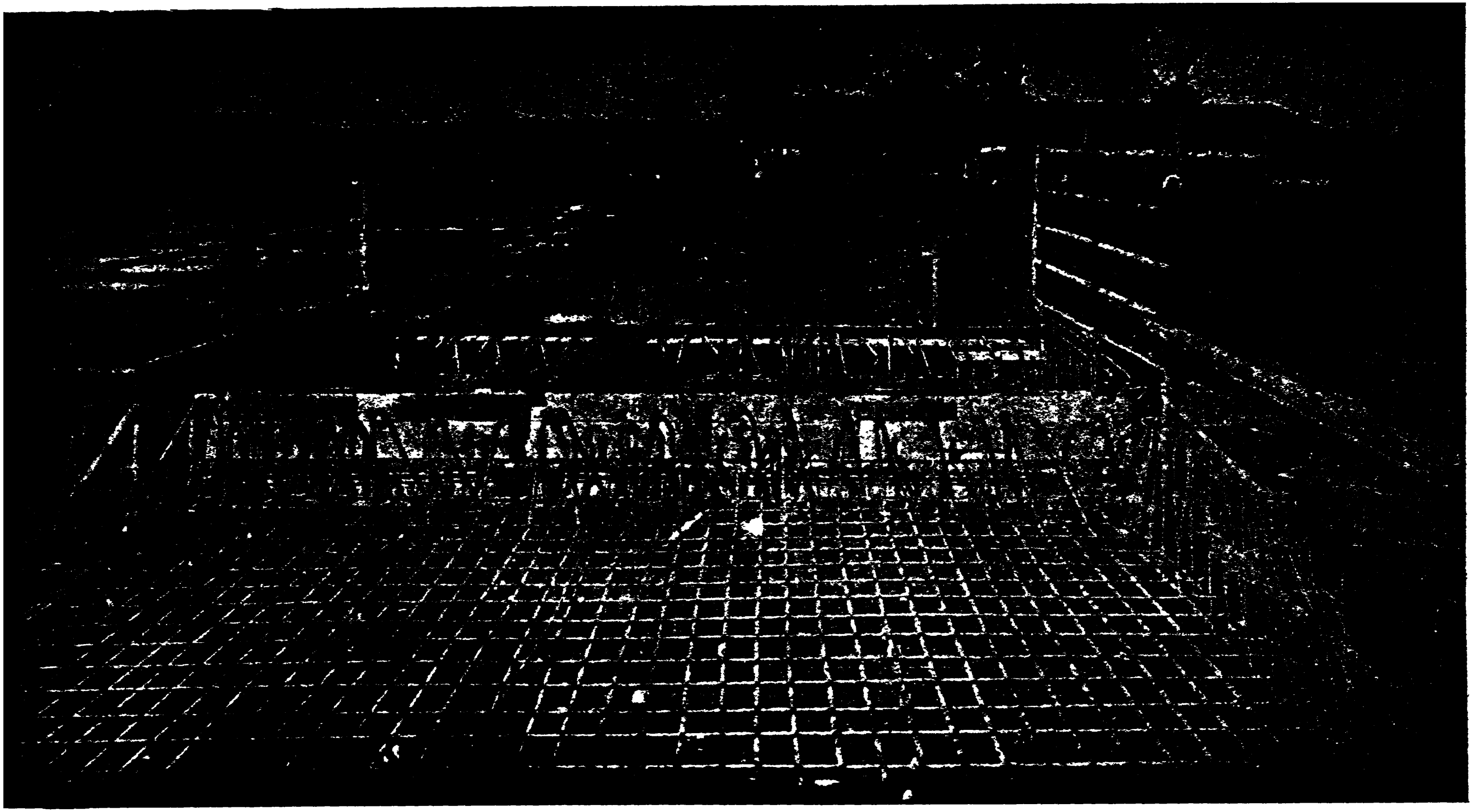

A view of the arrangement of reinforcements at the Rai Murdha Creek

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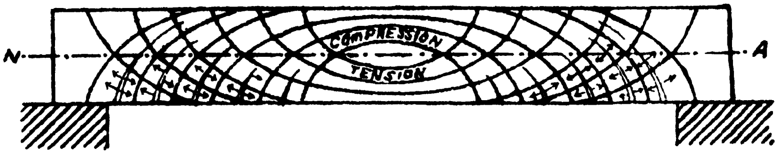
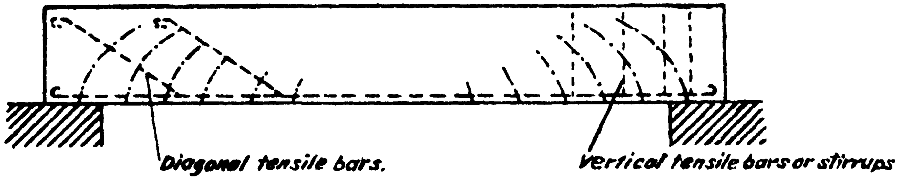
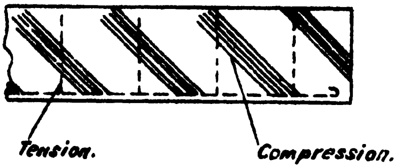
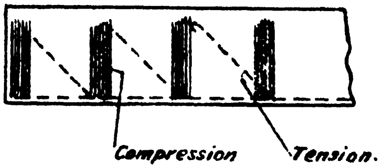
SHOWING SHEAR REINFORCEMENTS.

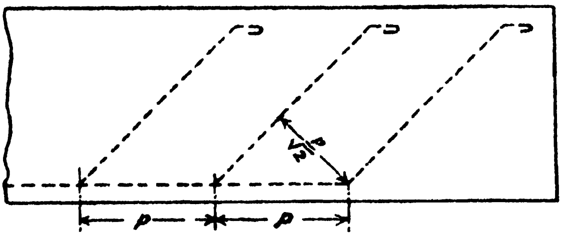


SHOWING CURVES OF PRINCIPAL STRESS IN BEAMS.









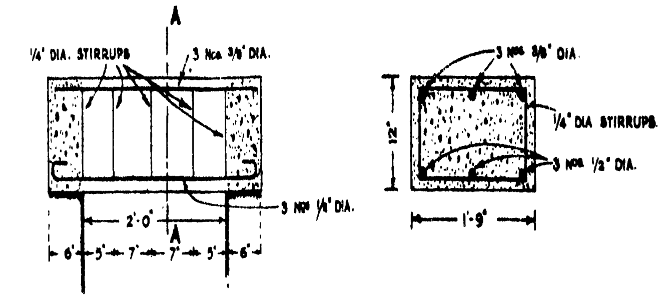
SHOWING WIDTH OF ZONE OF ACTION OF EACH INCLINED SHEAR BAR.

DETAILS OF R.C.C. LINTELS

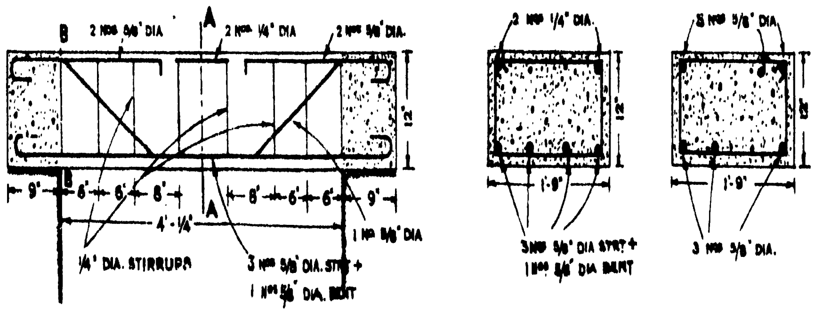
ISMAIL COLLEGE

PLATE-XLVIII

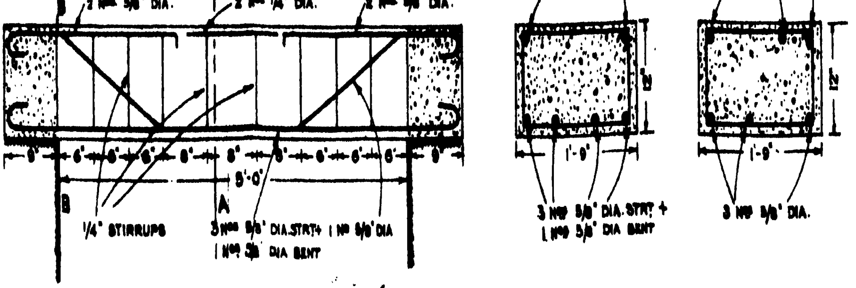
(1) LINTEL 2'-0" CLEAR SPAN SECTION ON A-A



(2) LINTEL 4'-1/4" CLEAR SPAN SECTION ON A-A SECTION ON B-B



(3) LINTEL 5'-0" CLEAR SPAN SECTION ON A-A SECTION ON B-B



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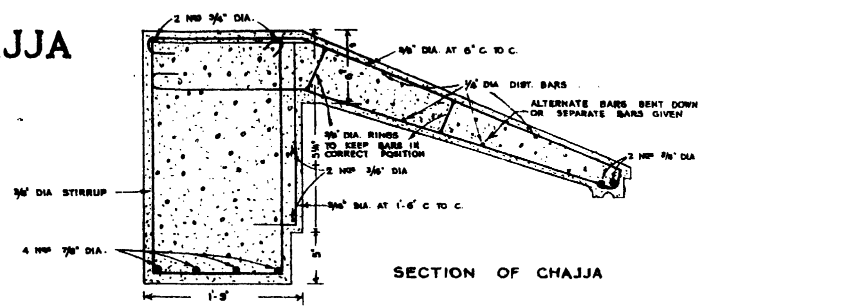
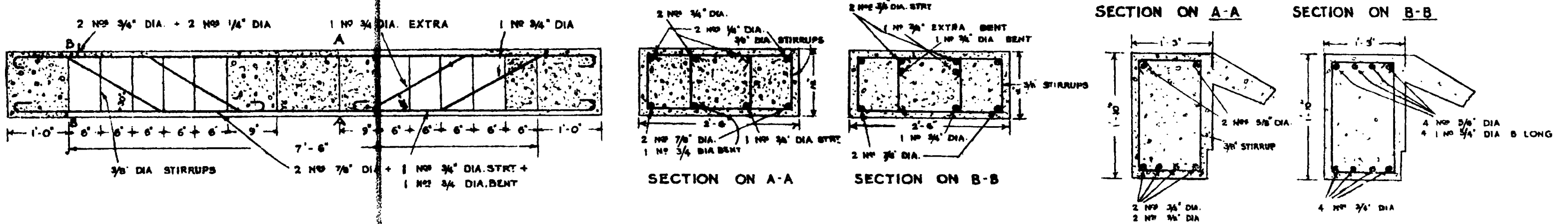
DETAILS OF R. C. C. LINTELS & CHAJJA
ISMAIL COLLEGE AT ANDHERI

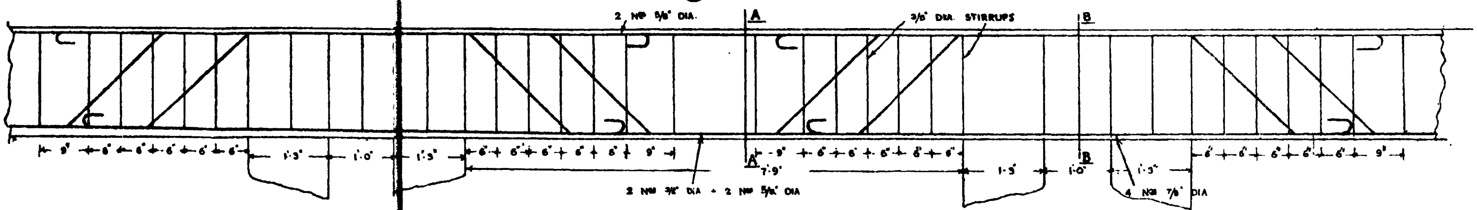


SECTION OF CHAJJA

LINTEL 7'-6" CLEAR SPAN
④



LINTEL IN THE FRONT VERANDAH, FIRST FLOOR
⑤



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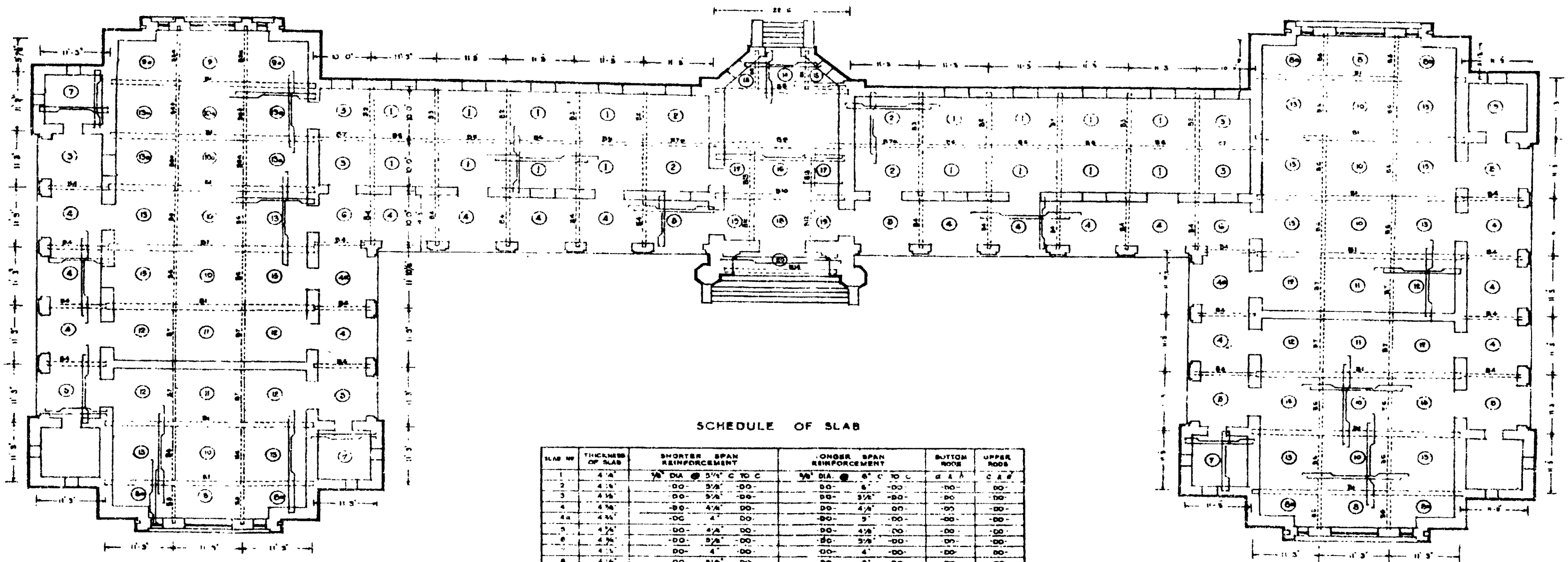
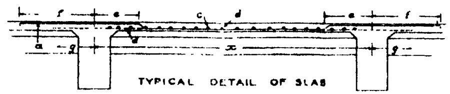
G.P.Z.O. 1949.

DETAILS OF R. C. C. SLABS
ISMAIL COLLEGE

PLATE XLVIII-B





TYPICAL DETAIL OF SLAB

e = 1/6 of the span x.
f = 1/4 do.
g = 12"
a & b - rods of shorter span
c & d - " longer "

a & c - bent rods
b & d straight rods
cover to slab = 1/2"

SCHEDULE OF SLAB

SLAB No	THICKNESS OF SLAB	SHORTER SPAN REINFORCEMENT			LONGER SPAN REINFORCEMENT			BOTTOM RODS	UPPER RODS
1	4 1/2"	3/8" DIA @	5½"	C TO C	3/8" DIA. @	6"	C TO C	a & b	c & d
2	4 1/2"	-DO-	5½"	-DO-	DO-	6"	-DO-	-DO-	DO-
3	4 1/2"	-DO-	5½"	-DO-	DO-	5½"	-DO-	-DO	-DO-
4	4 3/4"	-DO-	4½"	DO-	DO-	4½"	DO-	-DO	-DO-
4a	4 3/4"	-DO	4"	DO.	-DO-	5"	-DO-	-DO-	-DO-
5	4 1/2"	-DO-	4½"	DO-	-DO-	4½"	-DO-	-DO-	-DO-
6	4 3/4"	-DO-	5½"	-DO-	-DO-	5½"	-DO-	-DO-	-DO-
7	4 1/2"	DO-	4"	-DO-	-DO-	4"	-DO-	-DO-	DO-
8	4 1/2"	-DO-	5½"	-DO-	-DO-	6"	-DO-	-DO-	-DO-
8a	4 1/2"	-DO-	6"	-DO	-DO-	6"	-DO-	-DO-	-DO-
9	4 1/2"	-DO-	5½"	-DO-	-DO-	5"	-DO-	-DO-	-DO-
9a	4 1/2"	-DO-	4½"	-DO	-DO-	5"	-DO-	-DO-	-DO-
10	4 1/2"	-DO-	5"	-DO-	-DO-	5"	-DO-	-DO-	-DO-
10a	4 1/2"	-DO-	5"	-DO-	DO-	5"	-DO-	-DO-	-DO-
11	4 1/2"	DO-	4½"	-DO-	-DO-	5"	-DO-	-DO-	-DO-
12	4 1/2"	-DO-	4½"	-DO-	-DO-	4½"	-DO-	-DO	-DO
13	4 1/2"	-DO-	4½"	-DO-	-DO-	5"	-DO-	-DO	-DO-
13a	4 1/2"	-DO-	5½"	-DO-	-DO-	5½"	-DO	-DO	-DO-
14	4"	-DO-	6"	-DO-	-DO-	4½"	-DO-	-DO-	DO-
15	4"	-DO-	6"	-DO-	-DO-	6"	-DO-	-DO-	-DO-
16	4 1/2"	-DO-	5½"	-DO-	-DO-	5½"	-DO-	-DO-	-DO-
17	4 1/2"	-DO-	5½"	-DO-	-DO-	5½"	-DO-	-DO-	-DO-
18	4 1/2"	-DO-	5½"	-DO-	-DO-	5½"	-DO-	-DO-	-DO-
19	4 1/2"	-DO-	5½"	-DO-	DO-	5½"	-DO-	-DO-	-DO-
20	4"	-DO-	6"	-DO-	-DO-	6"	-DO-	-DO-	-DO-

SCHEDULE OF BEAM FOR CENTERING

BEAM No	DEPTH BELOW SLAB	WIDTH	BEAM No	DEPTH BELOW SLAB	WIDTH	BEAM No	DEPTH BELOW SLAB	WIDTH
1	33½"	15"	6, 6a, 6b	12"	7"	10	16½"	15"
2	25¼"	12"	7 7a	12"	7"	11	12"	7"
3	25½"	12"	8	14"	15"	12 13	12"	7"
4-5	12"	7"	9	16½"	15"	14	18"	12"

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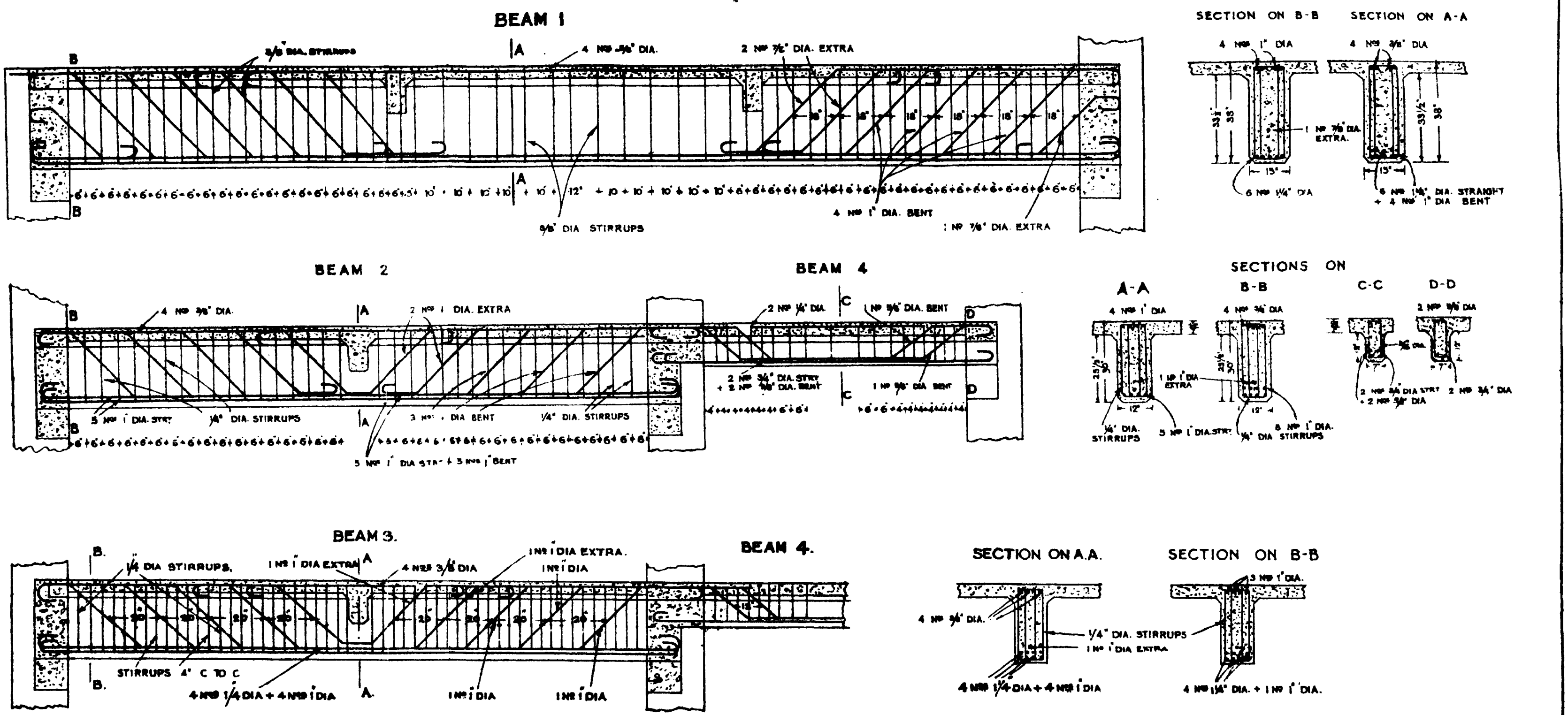
DETAILS OF BEAMS, ISMAIL COLLEGE
AT ANDHERI.



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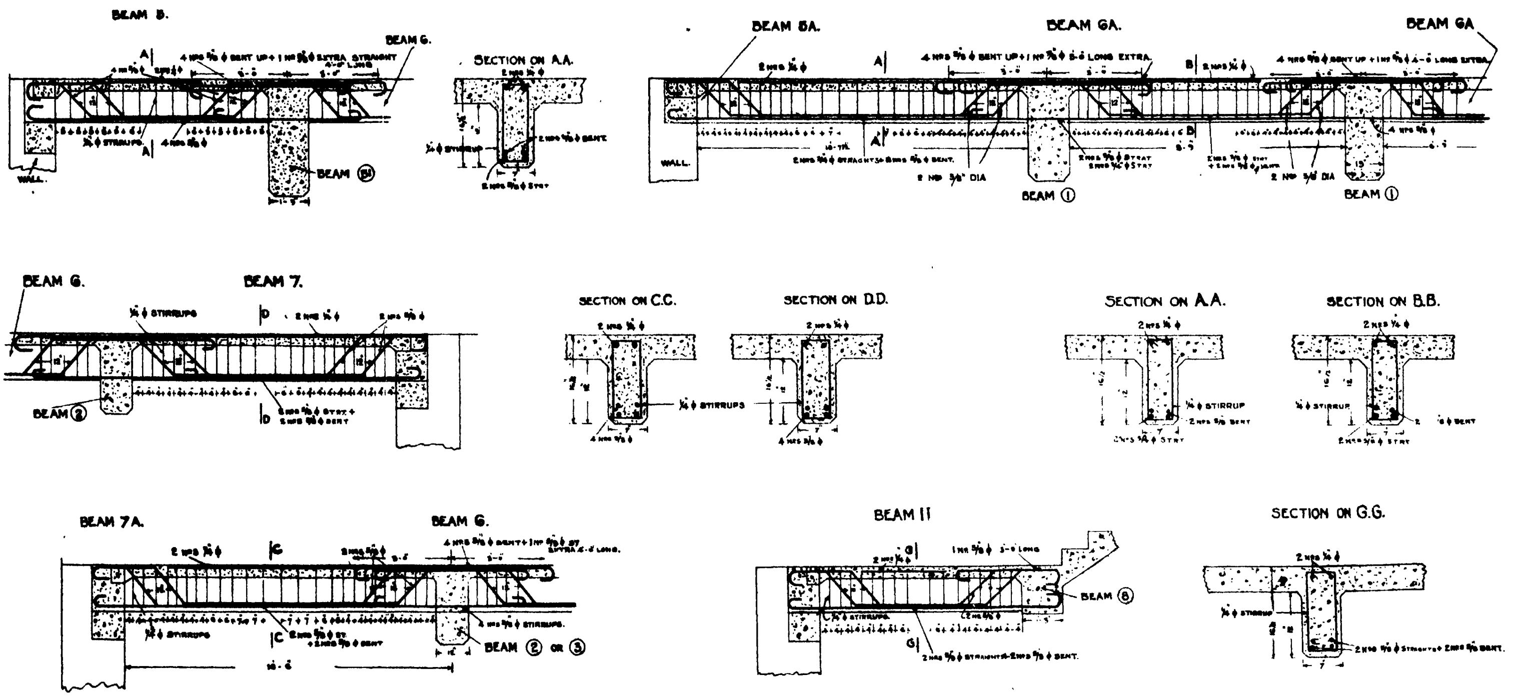
DETAIL OF BEAMS

PLATE XLVIII-D.



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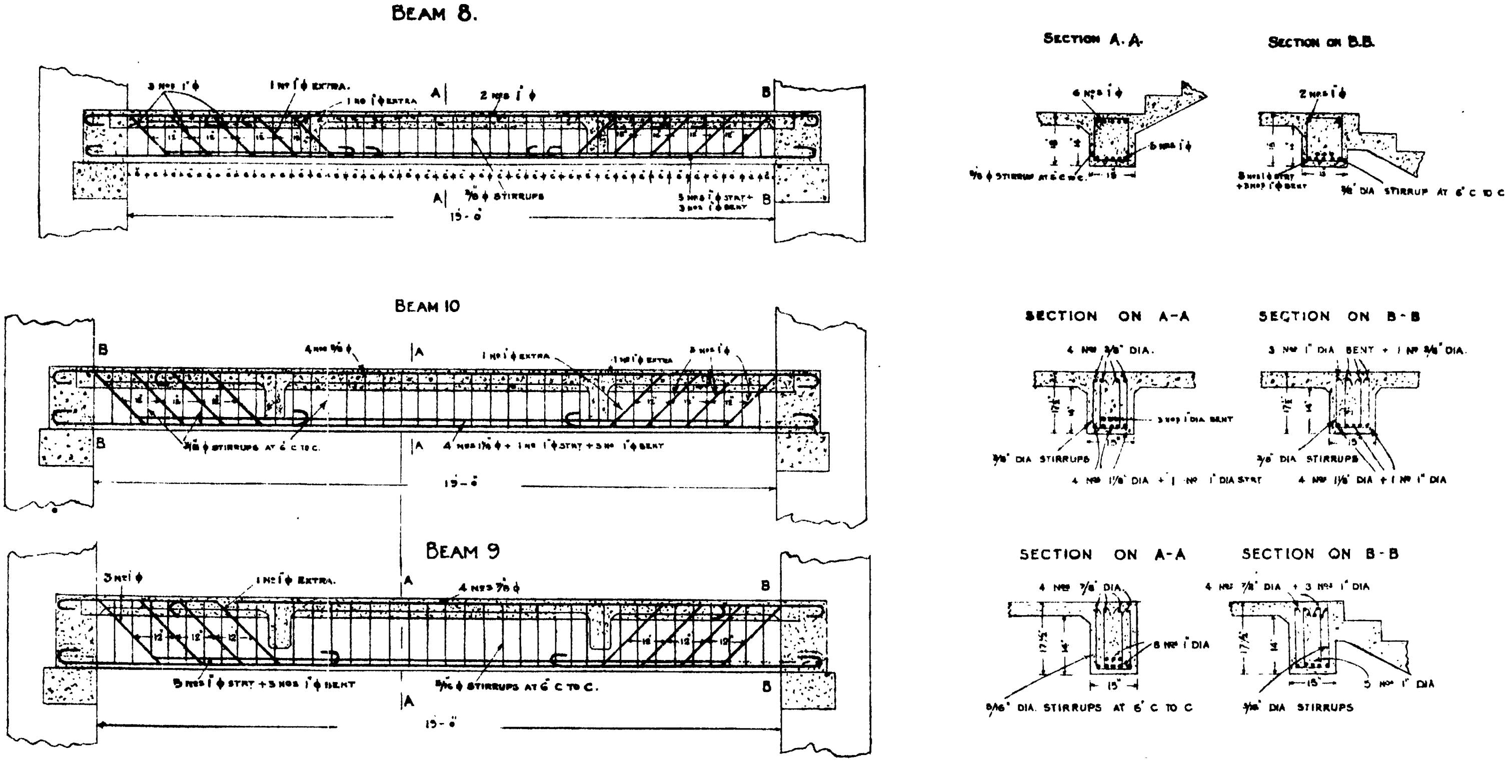
DETAILS OF BEAMS



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For columns the boarding requires support at intervals. The table below gives the spans of sheathing or boarding between supports for various heights of columns.

Maximum span of column sheathing for various heights of column.

TABLE—C II.

Height of column.			1½″	2″
6 feet	...	...	25½ inches.	33½ inches.
8	...	...	22	31
10	...	...	20	27½
12	...	...	18	25
14	...	...	17	23
16	...	...	15½	21½
18	...	...	15	20½
20	...	...	14	19½
22	...	...	13½	18½
24	...	...	13	17½
26	...	...	12½	17
28	...	...	12	16½
30	...	...	11½	16

W = 125.

In general, for floor sheathing, 1″ dressed down to 13/16″ is the usaul practice; for wall sheathing and beam and column sides the thickness may vary from 1″ to 2″ stock, dressed 3/16″ or ¼″. Beam bottoms are generally 2″ stock.

Joists may be any size from 2″ by 4″ to 3″ by 10″, 2″ by 6″ being the commonest size; column yokes are usually 3″ or 4″ by 4″.

Studs and wales vary from 2″ by 4″ to 6″ by 6″; posts from 3″ by 4″ to 6″ by 6″.

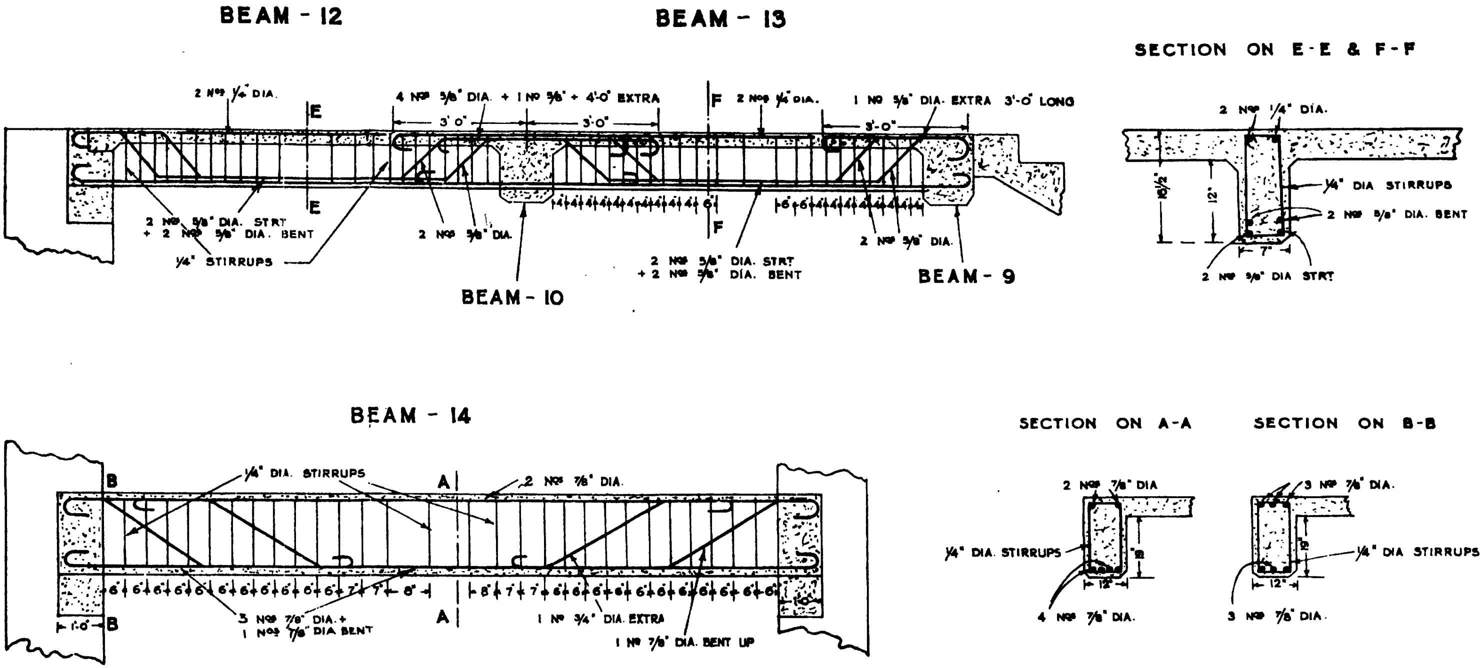
In ordinary work the smaller sizes mentioned above are used, extra strength being obtained by doubling up.

5. **Preparation of timber.**—(*a*) All timber in contact with concrete, should be specified as wrought on two edges and one face, the material being assembled with the unwrought face outside. If a face free from defects due to badly aligned board is desired, wrought tongued and grooved boarding is justified.

(*b*) All forms coming in contact with concrete should be oiled with crude oil or petroline, preferably before being set in place. This oiling allows easy stripping of forms, as the concrete does not stick to the boards. If the concrete is to be plastered however, oil should not be used as it prevents the adhesion of plaster. Wetting with water or soft-soap and water, will suffice in this case. Apply oil or solution with a white wash brush.

6. **Arrangement of forms.**—The various parts of the falsework should be so assembled, as to allow striking in a proper manner, i.e. in such a manner, as to permit the least essential part for support to be struck first, and proceeding later to other parts. Thus for floors, the beam sides should be stripped first, followed by the slab soffit boards, and last by the beam bottom boards and props.

DETAILS OF BEAMS



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right angles, to a radius equal to the bar diam, and then bent back in the opposite direction at right angles, and finally to the straight position, without showing any signs of fracture.

The yield point of rolled mild steel is at about 32,000 lbs. per square inch, while with cold-drawn mild steel, the yield point is at a stress of about 75,000 lbs. per square inch.

Cleansing.—All reinforcement shall be free from loose mill scale, rust, oil, grease, dirt, paint or other deleterious matter, when examined immediately before placing the concrete.

Placing.—All reinforcement shall be of the full sizes specified placed and maintained in the exact positions specified or shown in drawings.

Bending.—All reinforcement shall be bent to the exact shapes specified without injuring the material. For bending large bars, heating to a dull red or Cherry red (temp. not exceeding 1550° F.) may be permitted, but bars thus bent shall not be cooled by quenching.

After all steel has been placed in position, it should be checked over passed by the Executive Engineer in charge or by his duly authorised representative before any concrete is poured.

The rate shall be for steel fixed in place, and shall include all necessary bending which shall be done without heating, and also all necessary wiring to keep the steel in place.

Note.—In estimating the quantity of mild steel rods, add an allowance for hooked ends as under :—

rod diam.	allowance.
$\frac{1}{4}''$	5″
$\frac{3}{8}''$	7″
$\frac{1}{2}''$	10″
$\frac{5}{8}''$	12″
$\frac{3}{4}''$	14″
$\frac{7}{8}''$	16″
1″	18″ and so on.

III. Cement.

1. This is to comply in every respect with the latest British standard specification for slow setting Portland cement. One cubic foot of cement shall be taken to weigh 90 lbs.

2. Notices will invariably be given in writing by the contractor to the Executive Engineer or his agent, of the arrival on the site of the work of any consignment of cement, and if the Executive Engineer or his agent finds it to be not up to specification, he shall request the contractor in writing to remove it from the site of the work within 24 hours ; failing compliance it may be removed departmentally at the contractor's expense.

3. The proportion of cement in a concrete will be determined by the strength required, the consistency specified for the mix ; and the nature of the aggregates. The specification will run :

> The proportion of cement to be used in the concrete shall be that specified by the Executive Engineer or his agent, and shall on no account be varied without his express permission.

IV. Water.

1. The water for concrete must be clean and uncontaminated with organic matter or salts. Generally natural waters suitable for drinking shall be used.

2. **Proportion.**—The strength of a concrete depends to a very great extent on the amount of water used in mixing, but for facility in laying, concretes of different consistencies are usually necessary. Thus the amount of water necessary for mass concrete is much less than that required for reinforced concrete work in thin vertical sections, as in the latter case, the concrete has to flow easily round the reinforcement in all directions. The consistency is measured by slump tests and the general recommendations are :—

Mass concrete	2″ maximum slump.
Roads and pavements	4″ ,, ,,
Thin vertical reinforced sections	6″ ,, ,,
Thin confined horizontal sections	8″ ,, ,,

3. The water used for mixing shall be that approved by the Executive Engineer or his agent, and the quantity to be used shall be that fixed by the Executive Engineer or his agent having due regard to the strength to be developed, and the consistency required for placing.

Note.—It has been proved that the strength of a concrete is governed by the ratio of gauging water to the cement in the concrete. The idea behind proportioning and grading is to get as much coarse aggregate into the mix as possible without affecting its workability. It has been shown that it is possible to make a well-graded 1 cement : 8 aggregate mix, as strong as a badly graded 1 cement : 6 aggregate mix. From the type of materials available in a locality, the best graded mix should be devised by the "fineness modules" method, and it should then be seen that this mix is adhered to within permissible variations. The specification will run :—The coarse and fine aggregates shall be obtained from approved locations and of the best quality and shall be mixed with the gradings specified. Neither the nature of the material nor its grading shall be changed without the express written permission of the Executive Engineer or his agent.

V. Aggregates.

General.—(1) Aggregates shall consist of natural sands and gravels, crushed stone, or other suitable material. They shall be hard, strong, and durable, and shall be clean and free from clay films, and other adherent coatings.

Aggregates shall contain no deleterious material which reduces the strength or durability of the concrete, or attacks steel reinforcement.

Coarse aggregate of a porous nature with a percent increase of over 10 per cent. on dry we ght, after immersion in water for 24 hours, fine aggregate containing organic material in sufficient quantity to show a darker colour on test than the standard colour, fine or coarse aggregate containing clay lumps exceeding 1 per cent. by weight, fine material containing more than 3 per cent by weight of material such as loam, silt, clay, etc., removable by decantation, shall not be used.

(2) **Grading.**—(*a*) Coarse aggregate shall be normally of 3/4th inch maximum size for heavily reinforced work, but a bigger size may be used, provided

(*i*) that the maximum size is not greater than three-quarters, of the cover or of the minimum clear lateral distance, between any two reinforcing bars, whichever is less.

(*b*) Fine aggregate shall be of such a size that it will pass through a mesh 3/16th inch square, measured in the clear.

The grading between these limits shall be such, as to produce a dense concrete of the specified proportions and consistency. In the preparation of special grade concrete, the "fineness Modulus" method shall be used for determining the limits for fine and coarse aggregates, to produce the densest conctete with the materials available.

VI. Storage of materials.

All materials shall be stored in such a manner as to prevent deterioration or contamination. Special care shall be taken in storing cement, any material damaged or deteriorated being immediately removed from the work.

VII. Mixing Concrete.

1. Generally the more thoroughly a concrete is mixed, the greater its strength. For all important work the concrete must be machine-mixed, as hand-mixing is less efficient and the resulting concrete is less likely to be of uniform quality. The aggregate and cement are placed in the drum and mixed dry for a short period. The specified quantity of water is then added and the whole mixed for not less than two minutes. Each time the work stops, the mixer should be cleaned out, and when next commencing mixing, the first batch should have 10 per cent. additional cement to allow for sticking losses.

2. If the quantity to be mixed is so small that the requisitioning of a mixer is inadvisable, mixing shall be done by hand, and the following procedure shall be adopted :—

The stone or shingle and the sand shall be washed free of all dust or earthy matter before being used, and the materials shall first be mixed dry thoroughly and then be mixed together with the amount of water that shall be ordered by the Executive Engineer either in a mixing machine of approved pattern or else on a clean platform by hand.

The materials should be measured out in proper forms, in order of stone, sand and cement, cement being kept at the top. The materials should then be turned over twice in a dry state on a separate, clean, close boarded platform, or on a cement floor. Water shall then be added until the mixture obtains a plastic consistency and it should again be turned over twice in the wet condition. The mixture should have the colour of cement uniformly distributed, and be of the consistency specified.

3. Care should be taken not to spend too much time on mixing operations after the addition of water, and as concrete is ready, it should be carried away and laid. The wooden or cement platforms should be near the work, so that no time is lost in putting the wet mixture in the mould.

VIII. Placing concrete.

1. The concrete shall be placed in its final position before setting has commenced, and shall not be subsequently disturbed. A record of the time and date of placing concrete in each position shall be maintained.

2. Concreting shall be carried out continuously up to construction joints, the position and arrangement of which shall be as specified by the Executive Engineer or his agent. Excess of water or laitance shall be removed from the surface of the concrete after it is deposited and before it has set.

3. When resuming work on a hardened surface the old surface shall be freed from laitance, well roughened, swept clean with wire brushes, thoroughly wetted, and grouted with mortar composed of equal volumes of cement and sand.

4. In filling columns, the concrete shall be poured into the moulds in three inch layers and constantly tamped and puddled with a rod to expel air bubbles. The work must not stop until the column has been completed.

5. **Places for stopping concreting.**—The work of filling in beams and slabs shall be completed in one operation as quickly as possible, so as to form one homogeneous whole. If concreting must be stopped before the entire portion is completed, then it must be stopped according to either one of the following two methods :—

Method No. 1.—For stopping beams and girders.—Stop concrete at the centre of the beam with a vertical plane at right angles to the direction of the beam.

For stopping slabs.—Stop concrete at the middle of span making the plane perpendicular and at right angles to the direction of the span.

Method No. 2.—For beams and girders.—Stop concrete in beams and girders directly over the centre of the column, making a vertical joint, and allowing one-half of the column to become the bearing surface for the future adjoining beam.

For slabs.—Break the concrete directly over the centres of the beams, making a vertical joint and allowing for the future adjoining slab.

In either of the above mentioned methods a sufficient number of continuity bars must be left to tie the beam or slab to the opposite side. In no case shall work be terminated in beams or slabs where future shearing action will be great, as, for example, near the ends or directly under a concentrated load.

Diagrams illustrating the suggestions are given in plate XLV. On recommencing to lay concrete, all edges of previously deposited concrete shall be thoroughly cleaned, and, if ordered, roughened with a chisel. The edges then must be well flooded with cement grout.

IX. Compacting concrete.

1. Concrete shall be thoroughly compacted during the operation of placing and thoroughly worked around the reinforcement, around embedded fixtures, and into the corners of the formwork. In normal weather the compacting must be finished within half an hour of adding water to the mix, but in hot weather this period must be reduced to that specified.

X. Curing concrete.

1. **General.**—Concrete attains its best strength, if it is hardened in a warm damp atmosphere. When the temperature of the atmosphere reaches 80°F. or goes beyond, the concrete sets in a short time and it is very important that covering wetting should start immediately after laying, which latter operation also should be expedited.

2. If it is allowed to dry out too rapidly, the water required by the cement for hardening is evaporated, and the hardening is spoiled, and there is a great tendency to contraction cracks.

3. Steam curing is quick and effective, but is not often employed, as there are great difficulties in its application.

4. Curing by an application of asphaltic emulsion is sometimes used for road slabs. The emulsion acts by confining the moisture in the concrete.

5. Concrete shall be protected during the first stages of hardening from the harmful effects of sunshine, drying winds and cold, and also from running or surface water, and shocks. The concrete shall be prevented from drying out and moist conditions maintained for at least 14 days when normal Portland cement is used for at least 7 days when rapid hordening Partland Cements are used. Concrete made with high alumina cement shall be kept thoroughly wet for the first two days.

XI. Making good.

1. The surface of the concrete shall be gone over immediately after the forms are removed, and any pitting or hollows shall be filled up, chipped edges made good, and projections removed.

2. All the concrete surfaces shall be washed over with neat cement wash or given a coat of cement plaster, if so ordered by the Executive Engineer, so as to make them up smooth, and any surfaces that the Executive Engineer shall so desire shall also be given three coats of whitewash without any extra charge.

XII. Finish or Surfacing.

It is preferable to lay the surfacing at the same time as the main slab, and while it is still green, so that a good bond is obtained between the slab and the surfacing. This surfacing may be merely a cement mortar finish, floated and travelled or for hardwear a granolithic finish made by laying a mortar of 1 part cement to 3 parts washed granite, or other hard stone chippings from ⅜″ down, ground after setting by a machine to a fine finish. This immediate laying of the surfacing however retards work, as till it is cured, further work in higher stages cannot be carried on, as otherwise the surfacing would be damaged.

XIII. Water-proofing.

1. The term " water-proofing " is rather misleading ; what is implied is making the concrete impermeable to the penetration of water. There is no agent, which added to concrete prepared without care, is capable of closing the passageways through which water penetrates. The first requisite, therefore, is to obtain a dense concrete with a minimum of air-holes, and this can only be obtained, by (1) using clean preferably graded sand or fine aggregate, tough durable graded coarse aggregate, and clean water, (2) proportioning the aggregates by the " fineness modulus " method, (3) using cement paste prepared with the minumum amount of water consistent with workability, (4) mixing aggregates and paste thoroughly to obtain an even mixture, (5) placing carefully in forms so as to avoid segregation of material, (6) expelling as much of the air as possible by rodding, puddling, and vibration of forms, (7) avoiding " laitance " at joints, by either proceeding continuously, or removing " laitance " from top of a layer and roughening it before putting another layer, (8) curing well, and for as long a period as possible.

2. After the above precautions are observed, in certain cases, e.g. in the case of water tanks, it may be advisable to take further steps to prevent water penetration. This may be done either by " integral " water proofing, or by surface applications. In the first method, various proprietary compounds, such as Pudlo, Medusa, Ceresit, Ironite etc., are incorporated with the cement or water for mixing. In certain cases the materials are added to the cement during manufacture. All are claimed to have " void filling " and lubricating properties.

3. Soap solutions act as lubricants, and also form insoluable fillers by reaction with cement. They may be incorporated or applied as a coat while the concrete is green.

4. Lime-soap with alum, and hydrated lime in the form of a dry powder, is also mixed with cement to attain the same object. The hydrated lime aids lubrication.

5. As regards surface applications the method depends on the quality of the concrete. If the pores are very small, silt or fine clay may fill them ; or a soap and alum mixture may be applied. For somewhat greater pores parafin, or bitumen, or an asphaltic oil may be brushed on. Bitumens may be used either as a solution, or hot, or incorporated in paints. The concrete surfaces to which bitumens are applied, should be thoroughly dry, and preferably warm, at the time of application. The bitumen in solution, melted, or in paint, should be well rubbed into corners and recesses, and must form a continuous film.

6. Membranous water-proofings are also employed sometimes, continuous sheets covering the surface, but this type is usually employed in water-profing structures in course of erection, such as subways, tunnels, etc.

No part of the reinforcing metal in a building shall be used for conducting electrical currents.

RULES FOR DESIGN.

The following are the more important of the rules which govern the design of slabs, beams and pillars.

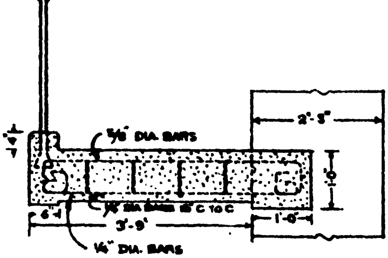
XIV. Floor and roof loads.

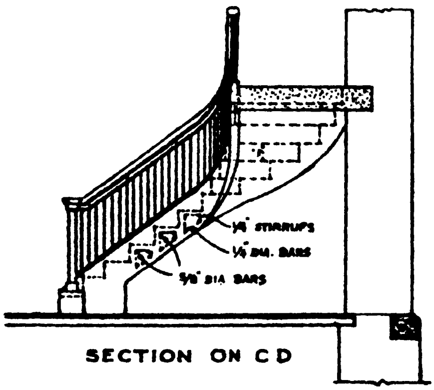
TABLE CIV.

SUPERIMPOSED LOADS.						
SLABS.			TYPE of BUILDING or FLOOR.	BEAMS.		
Alternative minimum load.	Load lb. per sq ft.	Span or panel width.		Load lb. der sq. ft.	Minimum area of floor carried.	Alternative minimum load.
		ft. in.				
	112	5 0				
	94	6 0				
¼ ton distributed	80	7 0	Domestic rooms.			1 ton distributed.
	70	8 0	Hotel bed-rooms.	40	56 Sq. ft	
	62	9 0	Hospital rooms.			
	56	10 0	Hospital wards.			
	50	11 0 and over				
			Offices : upper floors ...	50	90 sq. ft.	
	168	5 0	Offices : entrance and below.	80	56 sq. ft.	
	140	6 0				
	120	7 0	Churches }			
⅜ ton distributed	105	8 0	Schools. }	70	64 sq. ft.	2 tons distributed.
	94	9 0	Reading rooms }			
	84	10 0	Art galleries.			
	80	10 6 and over.	Garages : cars less than 2 tons weight.	80	56 sq. ft.	

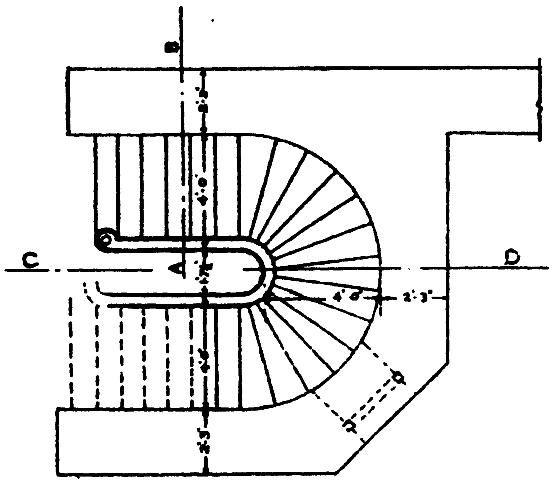
DETAILS OF R. C. C. STAIRCASE
(CANTILEVERED)

SECTION ON A-B





SECTION ON C D



PLAN

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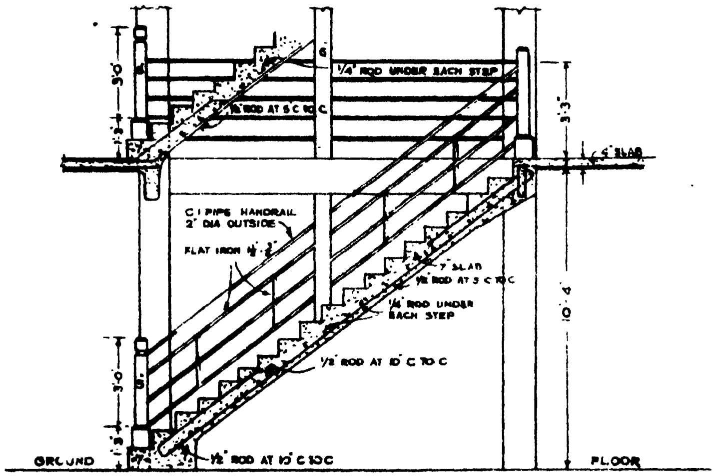
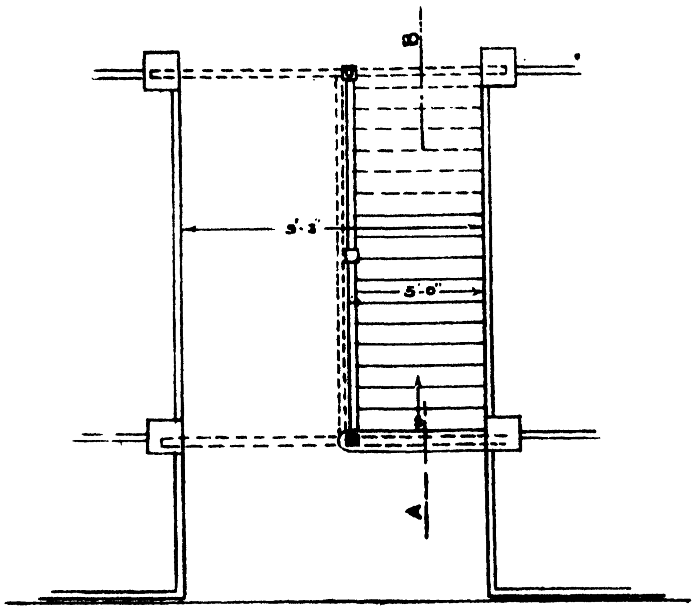
G. P. E. B. Patna, 1943

DETAIL OF R.C.C. STAIRCASE (AS SLAB)



SECTION ON A-B



PLAN

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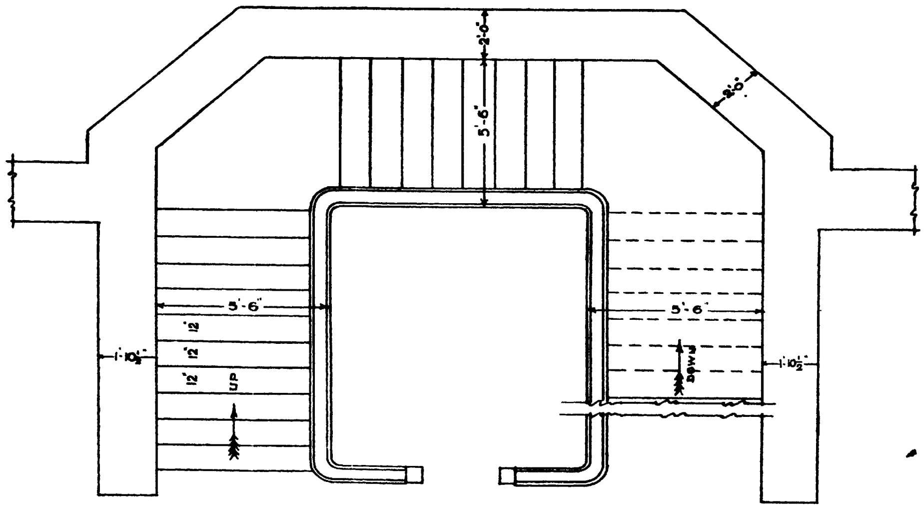
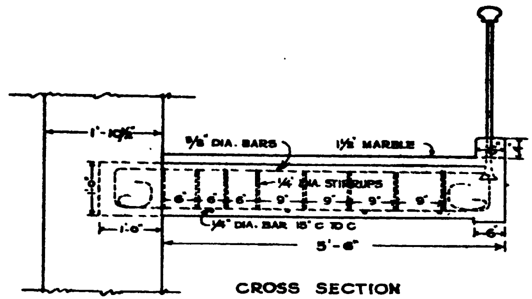
G.P.Z.O. Poona, 1949.

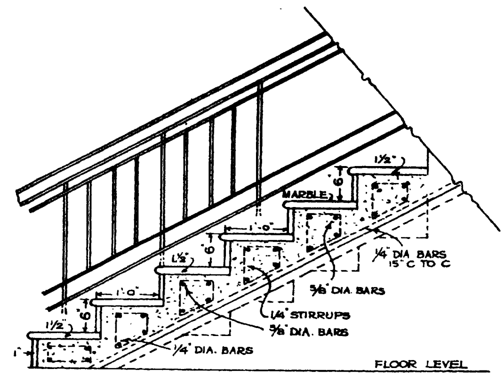
DETAILS OF R. C. C STAIRCASE (CANTILEVERED)



PLAN



CROSS SECTION



LONGITUDINAL SECTION

G. P. Z. O. 1949

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TABLE CIV—*contd.*

SUPERIMPOSED LOADS.						
SLABS			TYPE of BUILDING or FLOOR.	BEAMS.		
Alternative minimum load.	Load lb. per sq. ft.	Span or panel width		Load lb. per sq. ft.	Minimum area of floor carried.	Alternative minimum load.
$\frac{3}{8}$ ton distributed.	200 168 140 120 105 100	4 3 5 0 6 0 7 0 8 0 8 6 and over.	Assembly halls, Drill halls, Dance halls. Gymnasia, Light workshops, Public spaces ... hotels, etc. Staircases and landings. Theatres. Cinemas. Restaurants. Grandstands.	100	45 sq. ft.	2 tons distributed
$\frac{5}{8}$ ton distributed.	240 200	3 6 4 3 and over	Ware house Book stores. Stationery stores ... Garages: cars more than 2 tons weight.	200	$22\frac{1}{2}$ sq.ft.	2 tons distributed.

Alternative load for heavy garages: 1·5 maximum wheel load, but not less than 1 ton distributed over floor area 2 ft. 6 in. square.

(1) In all cases where the positions of partitions are known, the actual weight of partitions shall be included in the dead-load on the floor. Where the position of the partition is not definitely located, a uniformly distributed load must be added to the dead-load on the floor. For offices this added allowances shall be at the rate of 20 lbs. per square foot of floor-area.

(2) In any case where the super-imposed load exceeds the loads specified, such greater load must be provided for.

(3) For flat roofs, and roofs inclined at an angle with the horizontal of not more then 20°, the super-imposed loads are to be taken as under :—

Slabs.—50 lbs. per square foot of covered area,

Beams.—30 lbs. per square foot of covered area.

(4) On roofs inclined at a greater angle than 20° to the horizontal, a minimum super-imposed load (deemed to include the wind-load) of 15 lbs. per square foot of surface shall be assumed, acting normal to the surface *inwards* on the windward-side, and 10 lbs. per square foot of surface acting similarly normal to the surface, but *outwards* on the leeward-side ; provided that this requirement shall apply only in the design of the roof-structure. To estimate the super-imposed roof-load on other parts of construction, a vertical-load of 10 lbs. per square foot of covered area shall be adopted (in addition to the dead-loads).

For details of staircase, *vide* Plates XLVIII-G, XLVIII-H and XLVIII-J.

5. **Rolling loads.**—In cases where a rolling load actuated by mechanical power is to be provided for, such rolling load shall be taken as equivalent to a static load 50 per cent. in excess of the actual rolling load. The positive and negative bending moment at every cross-station due to every position of the rolling load shall be properly provided for.

6. **Angle of dispersion.**—For calculating the resistance moment, the angle of dispersion of a point load through hard filling and concrete shall not be taken at more than 45° from the vertical.

7. **Reductions in superimposed loads on columns, piers, walls and foundations.**—For the purposes of calculating the total load to be carried on columns, piers, walls and foundations, in buildings of more than one storey in height, the superimposed loads for the roof and top-most storey, shall be taken in full in accordance with the table of superimposed loads; but for the lower storeys a reduction of the superimposed loads may be allowed in accordance with the following table:—

Storey.	Reduction of its super-load.
	per cent.
Next storey below top-most storey	10
Next storey below	20
Next storey below	30
Next storey below	40
Each succeeding storey	50

8. The above reductions are to be applied on the proportion of the floor area carried by each foundation column, pier, or wall. No reductions are to be applied in the last types of buildings detailed in the table for superimposed loads viz., Ware-houses, Book stores, Stationery stores and Garages, and any other floors carrying a load exceeding 100 lbs. per square foot.

Wind pressure.

9. **Wind pressure.**—If the height of a building is less than twice its width, wind-pressure may be neglected, provided the building is stiffened by floors and/or walls.

Other buildings shall be so designed, as to resist safely a wind-pressure in any horizontal direction, of not less than 15 lbs. per square foot upon the upper ⅔rds of the vertical projection of the surface of such buildings, with an additional pressure of 10 lbs. per square foot, upon all projections above the general roof level.

10. **Temperature effects.**—Expansion and contraction of concrete structures shall either be provided for at suitable intervals in the structure or shall be taken into account in the calculations.

In exposed surfaces more than 6 feet in any direction, not otherwise reinforced, sufficient steel shall be placed in that direction, as near the surface as permissible, to resist a stress due to a fall in setting temperature of 30 degrees. Usually steel of sectional area 0·4 per cent. of the concrete is sufficient.

Weight.

11. **Weight.**—For purposes of calculations, the average weight of reinforced concrete shall be taken at 144 lbs. per cubic foot.

Ratio of span to depth of a beam.

12. The effective depth shall be measured from the compressed edge of concrete to the common centre of gravity of the tensile reinforcement.

13. In order to keep the safe stresses in the concrete and steel at 600 lbs. and 16,000 lbs. per square inch, respectively, the effective depth of a beam shall not be less than 1/20th of the span. In practice take effective depth equal to 1/12th span, i.e., the effective depth in inches should be equal to the clear span in feet. With steel working stresses higher than 16,000 lbs. per square inch, the minimum effective depth can be increased to a value $= \dfrac{\text{Span} \times f_t}{320{,}000}$ where f_t is the working stress in steel.

The breadth of rectangular beams and the breadth of the rib of T or I beams usually vary from $\frac{1}{3}$rd to once the *total* depth for rectangular beams. A good average figure for breadth is one-half the *total* depth.

14. The length of a cantilever shall not exceed 5 times the effective depth at the bearing.

15. **Effective span.**—Of a beam or slab shall be taken as the distance between the main vertical sides of the supporting members plus the effective depth of the beam or slab at the supports, or the space between the centres of the necessary bearing surfaces, whichever is the lesser.

The bending moments to be provided for in continuous spans at every cross section shall be the maximum positive and negative moments at such cross section for the following conditions of loading :—

(*i*) alternative spans loaded and all other spans unloaded ;

(*ii*) adjacent spans loaded and all other spans unloaded.

Nevertheless, provided that the maximum position moments so obtained in any two adjacent spans are increased by an amount not exceeding 15 per cent. of the maximum intermediate support moment, this latter moment may be reduced by the same amount, and the bending moment curves adjusted accordingly.

Bending moments.

16. For calculating the bending moments on a beam or on a slab the effective span and the whole load on the effective span shall be taken into account.

Three grades of concrete are recognised, viz., ordinary grade, high grade and special grade depending on the control exercised in its ingradients and mixing, placing or laying, compacting and curing. For each the minimum crushing strength, the permissible stresses and approximate values for the modular ratios are specified.

In the case of ordinary grade concrete, strength and consistence tests are carried out when required by the designer ; in the other two cases preliminary tests are required. For high grade concrete special continuous expert supervision, testing of two test cubes daily or whenever the material or the mix are changed, and one, testing of consistence at least once, are specified, and the grading of the aggregates and the proportions of the mix are carefully controlled throughout by the " fineness modulus" method. For special grade concrete in addition to preliminary tests and expert supervision, provision is made for—

(1) calculating and designing the structure in which it is used as a monolithic structure.

(2) ensuring a uniform supply of cement throughout the work.

(3) controlling the water content of each mix so that the water ratio shall not exceed the ratio used in preliminary tests by more than 10 per cent.

(4) controlling the grading and mixing of the aggregate by the "fineness Modulus" method to conform closely with preliminary tests.

(5) carrying out works tests for strength and consistence tests daily or with a change in the mix or materials or when required by the Executive Engineer.

(6) basing the permissible stresses on the results of preliminary cube tests, and limiting values to 25 per cent. more than values for similar mixes of high grade concrete, shear and bond stresses being limited to 150 pounds per square inch.

(7) carrying out work under favourable conditions of temperature and humidity (temperature never below 50°F.) and guaranteeing curing for 14 days for ordinary portland cement and 7 days for rapid hardening cement, when requirements in columns 5, 6 and 7 of Table may be reduced by 20 per cent.

The following tables give mixes, preliminary and works tests results, modular ratio and permissible stresses for the three grades :—

TABLE CV.

Ordinary Grade Concrete.

Mix. reference	Nominal Mix.	Proportions cubic feet of aggregate per 112 pound bag of cement		Minimum cube strength requirements at 28 days and 7 days [Optional tests see clause D 9 (b) (i)] pounds per square inch.			Modular Ratio.	Permissible concrete stresses pounds per square inch.			
		Fine	Coarse.	Preliminary Tests.		Works Tests		Bending.	Direct.	Shear.	Bond.
				28 days.	7 days.	7 days.					
				4·5x	3x	2x	40,000 / 3x	x	0·8x	0·1x	0·1x +25
I	1 : 1 : 2	1¼	2½	4,338	2,925	1,950	14	975	780	98	123
II	1 : 1·2 : 2·4	1½	3	4,163	2,775	1,850	14	925	740	93	118
III	1 : 1·5 : 3	1⅞	3¾	3,825	2,550	1,700	16	850	680	85	110
IV	1 : 2 : 4	2½	5	3,375	2,250	1,500	18	750	600	75	100

TABLE CVI.

High Grade Concrete.

Mix. reference.	Nominal Mix.	Proportions cubic feet of aggregate per 112 pound bag of cement.		Minimum cube strength requirements at 28 days and 7 days pounds per square inch.			Modular Ratio.	Permissible concrete stresses pounds per square inch.			
		Fine.	Coarse.	Preliminary Tests.		Works Tests.		Bending.	Direct.	Shear.	Bond.
				28 days.	7 days.	7 days.					
				4·5x	3x	2x	$\frac{40,000}{3x}$	x	0·8x	0·1x	0·1x +25
I	1 : 1 : 2	1¼	2½	5,625	3,750	2,500	11	1,250	1,000	125	150
II	1 : 1·2 : 2·4	1½	3	5,400	3,000	2,400	11	1,200	960	120	145
III	1 : 1·5 : 3	1¾	3¾	4,950	3,300	2,200	12	1,100	880	110	135
IV	1 : 2 : 4	2½	5	4,275	2,850	1,900	14	950	760	95	120

TABLE CVII.

Special Grade Concrete (limiting values).

Mix. reference.	Nominal Mix.	Proportions cubic feet of aggregate per 112 pound bag of cement,		Minimum cylinder strength requirements 28 days and 7 days pounds per square inch.			Modular Ratio.	Permissible Concrete stresses pounds per square inch.			
		Fine.	Coarse.	Preliminary Test.		Works Test.		Bending	Direct.	Shelar.	Bond.
I	1 : 1 : 2	...	...	28 days	7 days	7 days	$\frac{40,000}{3x}$	x	0·8x	0·1x	0·1x + 25
II	1 : 1·2 : 2·4										
III	1 : 1·5 : 3	...	...	5x	3·3x	3x	...	...	...	But not greater than 150.	
IV	1 : 2 : 4										

For ordinary grade concrete and high grade Concrete and special grade concrete where other proportions of fine to coarse aggregate are used, the minimum requirements in columns 5, 6 and 7 shall be based on the ratio of the sum of the volumes of the fine and coarse aggregates measured separately, to the quantity of cement, and shall be obtained by proportion from the two nearest tabled mixes.

The tabulated values of the modular ratio in the case of ordinary and high grade concretes are given to the nearest whole number, but exact values may be calculated and used from the formula in column 8.

The strength requirements in columns 5, 6 and 7 and the modular ratio in column 8 and the permissible stresses in columns 9, 10, 11 and 12 shall be calculated from above factors, being based on the preliminary test results.

Note.—According to current Government Orders only two grades of concrete are to be adopted—the usual grade correspondineg to the concrete complying with the current specifications, and a higher grade equivalent to the Code of Practice specification "ordinary grade". The usual grade is to be specified for small works, i.e , works costing not more than Rs. 10,000 or in the alternative, slabbed bridges up to 15 feet span, in which deck girders are not used.

The permissible stresses for steel shall be those permitted by existing orders, but for large works costing not less than Rs. 20,000, Code of Pratice stresses are to be adopted.

For ordinary small works short columns with lateral ties should be designed with values of f_c and f_t equal to 600 lbs./sq. inch and 15 × 600 lbs. sq. inch. For large works the Code of Practice specifications are to be adopted fully.

17. **Reinforcement at points of contra flexture.**—Reinforcement shall be carried beyond the points of contra flexture under any condition of loading, by a length at least equal to half the effective depth of the beam.

In the case of beams and slabs fixed at both ends and uniformly loaded, the two points of contra flexture are at the distances, 0·21 × span, from the fixed ends.

In the case of beams and slabs fixed at one end and supported at the other and uniformly loaded, the single point of contra flexture is at a distance, 0·25 × span from the fixed end.

Working stresses.

18. **Strength of mild steel.**—The values shall be taken as per accompanying table :—

Tensile resistance at failures ...	... 33 to 37 tons per square inch.
Safe tensile stress ...	... 16,000 lbs. per square inch.
Safe tensile stress (shear members)	... 16,000 lbs. per square inch.
Modulus of elasticity ...	... 30×10^6

19. **Bar Sizes (General limits).**—The diameter of any reinforcing bar shall not exceed 2 inches.

The diameter of any reinforcing bar, including transverse ties, spirals, stirrups and all secondary reinforcement shall be at least 3/16 inch.

The diameter of main reinforcing bars in beams and slabs shall be at least ¼ inch.

The diameter of longitudinal reinforcing bars in columns shall be at least ½ inch.

The diameter of wires under tensile stress in connected mesh and similar reinforcements in slabs shall be at least 1/10th inch.

The above clauses do not exclude the use of rolled sections provided adequate bond can be obtained and steps are taken to prevent cracking of the concrete.

20. **Distance between Bars.**—The minimum lateral distance between reinforcing bars shall be the diameter of the bar or ¼ inch more than the maximum size of coarse aggregate, whichever is the greater, and at points of splice the bars shall be so disposed that this distance is maintained between each pair of lapped bars and adjacent bars.

The vertical distance between horizontal main reinforcing bars shall be at least one inch except at splices or where transverse bars are in contact.

The pitch of bars or wires of main tensile reinforcement in beams and slabs shall not exceed 12 inches or twice the effective depth, whichever is the lesser.

The pitch of distributing bars in slabs shall not exceed four times the effective depth of the slab.

All meshed reinforcement shall be of such dimensions as will enable the coarse material in the concrete to pass easily through the meshes of such reinforcement.

The spacing for transverse reinforcement in columns and for shear reinforcement in beams shall be as subsequently specified.

21. **Tying and overlapping.**—All cross rods shall be tied firmly to the longitudinal rods by soft annealed iron wire, No. 16 : S. W. G.

Rods under tensile stress shall overlap for a length of 40 diameters at splices.

Fabric reinforcement should have a lap of not less than a 15 inches longitudinally and a side lap of 3″.

22. **Clearance between bars.**—The minimum clear distance between the bars in a layer of reinforcement in beams should not be less than 1·25 time the largest aggregate size in the concrete, and not less than 1·5 time the bar diameter.

The minimum clear distance between the bars of successive layers should be ¾″, and this distance should be maintained by suitable spaces between the layers.

23. **Staggering of bars.**—The desirability of staggering tensile reinforcement, whether this reinforcement is required for negative or positive moment, is generally admitted with a view to prevent the formation of continuous cracks. The points at which bars are discontinued, shall therefore be suitably and generously staggered, (by continuing the alternate bars beyond the theoretically calculated point of discontinuation), wherever possible.

24. **Compression reinforcement (in beams).**—Where the compressive resistance of the concrete is taken into account, the compression reinforcement shall be effectively anchored (over the distance where it is required), at points not more than 16 times the anchored bar diameter apart, centre to centre. Where the compressive resistance of the concrete is not taken into account, it will be anchored laterally and vertically, at points not more than 8 times the anchored diameter apart, centre to centre.

The subsidiary reinforcement used for this purpose shall pass round or be hooked over both the compression and tension reinforcement.

25. **Camber to beams.**—Where camber is given to longer beams, care should be taken to see that the amount of camber is not taken out of the depth of the beam at the centre. The rods should be straight, and not follow the camber.

26. Beams shall be secured laterally whenever the ratio of the length of the beam to the width of its compression flange exceeds :—

$$20\left\{3-2\,\frac{\text{Calculated compressive stress}}{\text{Permissible compressive stress}}\right\}$$

Shear or web reinforcement.

(Plates XLVII and XX.)

27. **Shear.**—The vertical shear, taken by the concrete only, shall be calculated on the compressed area of the web or on the web area for a depth equal to the arm of the resistance moment of the beam. The intensity of shearing stress shall not be greater than one-tenth of the direct compressive strength for concrete, or 60 lbs. per square inch for 1 : 2 : 4 concrete. 1 R. C. specifications lay down 1/10 of the compressive strength in *bending*.

28. **Resistance to Shear.**—

(a) **General.**—

(*i*) The shear stress " v " at any cross-section in a reinforced concrete beam or slab shall be calculated from equation (1).

$$v=\frac{V}{bjd} \quad \dots \quad \dots \quad \dots \quad (1)$$

where v=total shear across any section ;

b=breadth of rectangular beam or breadth of rib of T-beam ;

and jd=arm of resistance moment.

(*ii*) Where at any cross-section the value of the shear stress, as calculated from equation (1) above, does not exceed the permissible shear stress for plain concrete, no shear reinforcement need be provided.

(*iii*) Where at any cross-section the value of the shear stress, as calculated from equation (1) above, exceeds the permissible shear stress for plain concrete, the whole shear at such cross-section shall be provided for, by the tensile resistance of the shear reinforcement acting in conjunction with the diagonal compression of the concrete in the web. In no case shall the shear stress calculated from equation (1) exceed four times the permissible sheat stress for plain concrete.

The shear or web reinforcement shall pass round the tensile reinforcement or be otherwise secured thereto, and shall be effectively anchored at both ends in such a manner, that its full working stress can be developed.

Tensile reinforcement which is inclined across the neutral plane of a beam, and which is carried through a depth equal to the arm of the resistance moment, may be taken as shear or web reinforcement, provided it is effectively anchored.

Where two or more types of reinforcement are used in conjunction, the total shearing resistance of the beam shall be assumed, as the sum of the shearing resistances computed for the various types separately.

The spacing of stirrups shall not exceed a length equal to the arm of the resistance moment ;

29. **Bond and anchorage.**—(*a*) When reinforcement in the form of plain bars is used to resist tensile stress induced by bending, the local bond stress " u " at any section, calculated from equation 3 shall not exceed twice the appropriate permissible bond stress.

End bond stresses shall also comply with the provisions below.

In members of other than uniform depth, the effect of the change in depth on the bond stress, shall also be taken into account.

$$u=\frac{V}{jd\Sigma 0} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where $\Sigma 0$=sum of the perimeters of the bars in the tensile reinforcement of a member.

(*b*) In the absence of a hook or other end anchorage a bar in tension shall extend from any section for a distance, such that the product of the permissible bond stress, the perimeter of the bar and the length measured from such section, is at least equal to the tension required in the bar. In the case of simply supported ends of beams and slabs, at least one-quarter of the main tensile reinforcement shall extend to the centre line of the support, before the hook or other end anchorage begin. Under the conditions of loading specified in the case of continuous beams, at least one-quarter of the tensile reinforcement, shall be carried for a distance not less than one-half the effective depth of the beam or slab, beyond points of contra-flexure, before the hook or other end anchorage begins.

TABLE CVIII.

End Lengths (X) in Bar Diameters.

Nominal concrete mix.	Bond stress.	Stress in bar (t) in pounds per square inch.						
		9,000	10 000	12,000	14,000	16,000	18,000	20,000
Ordinary Grade—								
1 : 1 : 2	123	33	35	39	43	47	51	55
1 : 1·2 : 2·4	118	33	36	40	44	48	52	57
1 : 1·5 : 3	110	35	37	42	46	51	55	60
1 : 2 : 4	100	37	39	44	49	54	59	64
High Grade—								
1 : 1 : 2	**150**	**29**	**31**	**34**	**38**	**41**	**44**	**48**
1 : 1·2 : 2·4	**145**	**30**	**32**	**35**	**39**	**42**	**45**	**49**
1 : 1·5 : 3	**13[illegible]**	**31**	**33**	**37**	**40**	**44**	**48**	**51**
1 : 2 : 4	**120**	**32**	**35**	**39**	**44**	**48**	**52**	**56**

With a hook in place of straight anchorage reduce values of x by 2d to obtain length to the end of bar. Values are for one end of bar only.

(*c*) A hook at the end of a bar shall be of ⊂ form and shall have an inner diameter of at least four times the diameter of the bar ; except that when the hook fits over a main reinforcing bar, the diameter of the hook may be equal to the diameter of such bar. The length of the streight part beyond the end of the curve to the end of the hook shall be at least four times the diameter of bar forming the hook. Unless suitable wrapping or other reinforcement is provided the anchorage value of the hook shall not be taken into account, if the hook is employed in a place where there is a danger of splitting the concrete.

(*d*) When a hook is not used, the end anchorage shall consist of a length of bar or any combination of suitable attachment and length of bar, having an anchorage value equivalent to the resistance produced by the permissible bond stress, acting over a length of bar equal to 14 bar diameter. The anchorage value assumed shall be such, that neither the permissible stress on the concrete in direct compression, nor the safe load on the end anchorage itself is exceeded. The permissible stress on the concrete may be increased to three times the value permitted for the concrete in direct compression, where the end anchorage is employed in a place where either the cover of the concrete is sufficient or suitable wrapping or other reinforcement is provided, to prevent local failure of the concrete.

(*e*) The total lengths of rod, including end anchorage, required to develop any given stress are shown in table.

Bends in bars.

The internal radius of a bend shall not be less than the following value :—

$$\text{bar diameter} \times \frac{\text{stress in steel at bend commencement}}{4 \times \text{permissible direct compressive strength in concrete}}$$

when the minimum concrete cover is used. The value shall not be less than $\frac{2}{3}$rds the above value, where conditions are such that there is no danger of the concrete splitting.

Slabs.

(Plates XLVIII and XX.)

30. All meshed reinforcement shall be of such dimensions as will enable the coarse material in the concrete to pass easily through the meshes of such reinforcement.

31. **Distribution reinforcement.**—For solid slabs spanning in one direction only, distribution bars shall be provided at right angles to the main tensile bars. Such distributing bars shall have an aggregate cross-sectional area of at least 20 per cent. of the main tensile reinforcement, and the pitch of such distributing bars shall be not greater than four times the effective depth of the slab.

T and L Beams and slabs.

(Plates XLVIII and XX.)

32. **Breadth of rib.**—The minimum breadth of the rib of a T (tee) or (ell) beam shall not be less than $\frac{1}{3}$rd the depth of the tee or ell beam below the slab.

T-Beams and L-Beams.—(*i*) Where in T-beams the slab takes the compression, its breadth shall not be taken to exceed the least of the following :—

(*a*) One-third of the effective span of the T-beam ;

(*b*) The distance between the centres of the ribs of the T-beams ;

(*c*) The breadth of the rib plus 12 times the thickness of the slab.

(*ii*) Where in L-beams the slab takes the compression, its breadth shall not be taken to exceed the least of the following :—

(*a*) One-sixth of the effective span of the L-beam;

(*b*) The breadth of the rib plus one-half the clear distance between ribs.

(*c*) The breadth of the rib plus four times the thickness of the slab.

(*iii*) For truncated T-beams i.e. beams which have a short free flange cantilevered out the breadth shall not be taken to exceed the following :—

(*a*) $\frac{1}{6}$th to $\frac{1}{3}$rd of the effective span as the overhang of the slab increases from nil to an overhang equal to half the clear distance between ribs, the actual width being determined according to a straight line variation,

(*b*) the breadth of the rib $+\frac{1}{2}$ clear distance between ribs + overhang, limited to half the clear distance between beams,

(*c*) breadth of the rib + 4 to 12 times the thickness of the slab, as the overhang increases from a nil to half the clear distance between ribs, according to a straight line variation.

(*iv*) The reinforcement in that portion of slab required to take the compression in a T or L-beam, shall extend its full width and shall consist of bars transverse to the beam. Such reinforcement shall not be less than 0·3 per cent. of the total cross-sectional area of the slab, and in cases where the slab is assessed to be independently spanning in the same direction as the beam, such reinforcement shall be near the top surface of the slab.

Columns.

33. **Ratio.**—In calculating the strength of a column, the ratio of the unsupported or effective length to least gyration radius or the ratio of affective length to least lateral diameter dimension shall be taken.

34. **Effective diameter.**—The effective diameter shall be measured to the outside of the outermost vertical reinforcement and shall be measured in the direction of the lateral supports which determine the length of the pillar.

35. **Reinforcement.**—All columns shall be provided with vertical and lateral reinforcements.

36. **Binding.**—Each column with lateral ties shall have at least 4 lines of vertical reinforcement throughout its entire length ; each column with curvilinear bindings shall have at least six lines of vertical reinforcement.

37. **Lateral ties.**—The pitch of the ties shall not exceed 12 inches and need not be less than 6 inches. Within these limit, the pitch shall not exceed the least lateral dimensions of the column of 12 times the diameter of any longitudinal bar.

38. Where the pitch is the maximum permitted, the diameter of the lateral tie shall at least be a quarter of the largest longitudinal bar secured by it ; with a closer pitch the diameter may be less, provided that the volume of lateral reinforcement is maintained.

39. **Spiral reinforcement.**—The pitch of the spirals shall not be *more* than 3 inches or one-sixth of the diameter of the core, whichever is less, and shall not be *less* than 1 inch, or three times the spiral bar diameter, whichever is greater.

40. *Note.*—Where spirals are used as a substitute for lateral ties, and when the column strength is calculated by the formula for columns with lateral ties, the pitch and spiral rod diameter shall be as for lateral ties.

41. The volume of lateral reinforcement or binding shall not be less than 0·4 per cent. of the volume of the column.

42. **Vertical bars.**—The diameter of vertical bars shall not be less than ½″ or greater than 2″.

43. The total cross sectional area of the vertical reinforcement in any column shall not be less than 0·8 per cent. of the area of the column, and shall not be more than 8·0 per cent. of that area.

44. **Joints.**—Joints in the vertical reinforcement of pillars shall only be made or adjacent to a floor level or other point of lateral support. The ground floor is not considered as giving lateral support.

45. On all joints in the vertical reinforcement of pillars, there shall be provided an overlap at least equal to 40 times the diameter of the upper bar.

Protection.

46. The cover shall be measured from the outer surface of the concrete to the outer surface of the metal reinforcement.

End cover.—The end cover to be provided beyond the anchored end of a bar shall not be less than 2 inches, and not less than twice the normal diameter of the bar to be covered.

For proper protection, and to provide a sufficient thickness of concrete around the bars adequately to develop adhesion, and for the efficient interaction of steel and concrete, a minimum surrounding cover of concrete is essential. The minimum permissible covers are as under :—

Slab.—½″ or not less than the bar diameter whichever is greater.

Beams.—1″ or not less than the diameter of bar for top and bottom main bars, whichever is greater,

½″ minimum for binders,

1″ side cover whatever the bar diameter.

Columns.—(1) less than 12″ square.—1″ minimum for main bars.

12″ square or over—1½″ minimum for main bars.

½″ minimum for binders.

Piles.—1½″ minimum for main bars.

Sea-work.—1½ to 2″ over main bars.

In localities where atmospheric or sub-soil conditions are known to give rise to corrosion of steel, special consideration shall be given to the amount of cover necessary.

CALCULATIONS.

GENERAL.

1. The material in steel or wooden beams is homogeneous throughout and, if a beam is made strong enough to resist the maximum bending moment, it will

safely resist any negative bending moments at the supports and also, as a general rule, the shearing stresses. Reinforced concrete is a composite substance and failures are likely to occur, unless care is taken to investigate the design of a beam, etc., in every particular, having due regard to the external conditions, *i.e.*, the methods of loading and supporting, and to the internal structure, *i.e.*, the position of the steel reinforcement provided to resist bending and shear. The design of simple columns, beams and slabs presents no great difficulty, but for more complicated structures a thorough knowledge of Applied Mechanics is essential. Apart from accurate designing the employment of good materials and careful technical supervision are absolutely necessary.

2. The design should aim at including only standard sizes of reinforcement rods, and as few variations of sections of beams, columns, etc., as possible, to minimise the sizes of moulds required.

The working formulas derived from the straight line stress variation form the basis for the diagrams and tables. The following assumptions are made :—

(*a*) Formerly the co-efficient of elasticity in compression of stone or gravel concrete, not weaker than 1 : 2 : 4, was treated as constant and taken at one-fifteenth of the coefficient of elasticity of steel.

Cofficient for concrete, $E_c=2,000,000$ lbs. per square inch.

" " steel, $E_s=30,000,000$ " " "

Modulur ratio $n=\frac{E}{E_c}=15$

It follows that, at any given distance from the neutral axis, the stress per square inch on steel will be fifteen times as great as on concrete.

As will have been seen in the paragraph regarding working stresses, a constant modulus of elasticity, 15, is not now permitted in all cases, and with different grades of concrete, the modulus varies, and the ratio of stress in steel to that in concrete at a given distance from the neutral axis also changes correspondingly.

(*b*) The resistance of concrete to tension is neglected and the steel reinforcement is assumed to carry all the tension.

(*c*) The stress on the steel reinforcement is taken as uniform on a cross section, and that on the concrete a uniformly varying.

The diagrams and tables given for slabs and beams are for the following stresses : compressive stress in concrete, $f_c=600$ lbs./inch^2 ; tensile stress in steel, $f_t=$ 16,000 lbs./inch^2, for small works, and 18,000 lbs./inch^2 ; for works costing more than Rs. 10,000, where good supervision is assured.

For column, $f_c=500$ lbs./inch^2.

The following symbols are used :—

Notation.

f_c=Unit compressive stress in outside fibre of concrete.

f_t=Unit tensile stress in steel.

b =Breadth of a rectangular beam and effective breadth in a tee or ell beam or its flange width.

b′=Breadth of rib or stem in a tee or ell beam.

t =Thickness of flange in a tee or ell beams.

D=Total depth of a beam or slab.
d=Effective depth of a beam i.e. distance from compression surface to axis of reinforcement.
l=Effective length.
jd=Lever-arm of resisting couple, where
j =Ratio of lever arm of resisting couple to effective depth d.
kd=Distance of the neutral axis from the compressed edge of a beam or slab.
$\frac{kd}{d}$=Ratio of depth of neutral axis from compression surface, to effective depth d.
z=Depth of resultant of compressive stresses from compression surface.
E_c=Modulus of elasticity of concrete in compression.
E_s=Modulus of elasticity of steel in tension.

n=Modu'ar ratio=$\frac{E_s}{E_c}$.

p=Steel ratio=$\frac{As}{bd}$, where

A_s=Area of cross-section of longitudinal steel, or area of tensile reinforcement for beams and slab.
A'_s=Area of cross-section of longitudinal steel used as compressive reinforcement in beams.

p′=Steel ratio of compression steel=$\frac{A'_s}{bd}$.

f′ =Unit compressive stress in steel.
C =*Total* compressive stress in concrete.
C′=*Total* compressive stress in steel.
d′=Depth of axis of compressive reinforcement below compression surface.
r=Depth of point of action of resultant of C and C′ below compression sur ace.
v=Unit shear.
u=Unit bond.
V=Total shear.
U=Total bond.
O=Circumstance or perimeter of a bar.
6=Sum of perimeters of all bars.
s=Horizontal spacing of shear reinforcement, or bent up bars, measured along the plane of the longitudinal reinforcement.

For columns.

A=Total Cross-sectional area of column, exclusive of fire-proofing.
As=Cross-sectional area of steel reinforcement (longitudinal).
Ac=Cross-sectional area of concrete=A (1-p), where

p=Longitudinal steel ratio=$\frac{As}{A}$.

w=Weight per unit length in a beam or unit area in a slab, in the case of uniformly distributed loads.
W=Total distributed (uniformly) load on a beam, or unit width of a slab.
W_1,=W_2, W_3, etc. =Concentıated loads on a beam or slab.

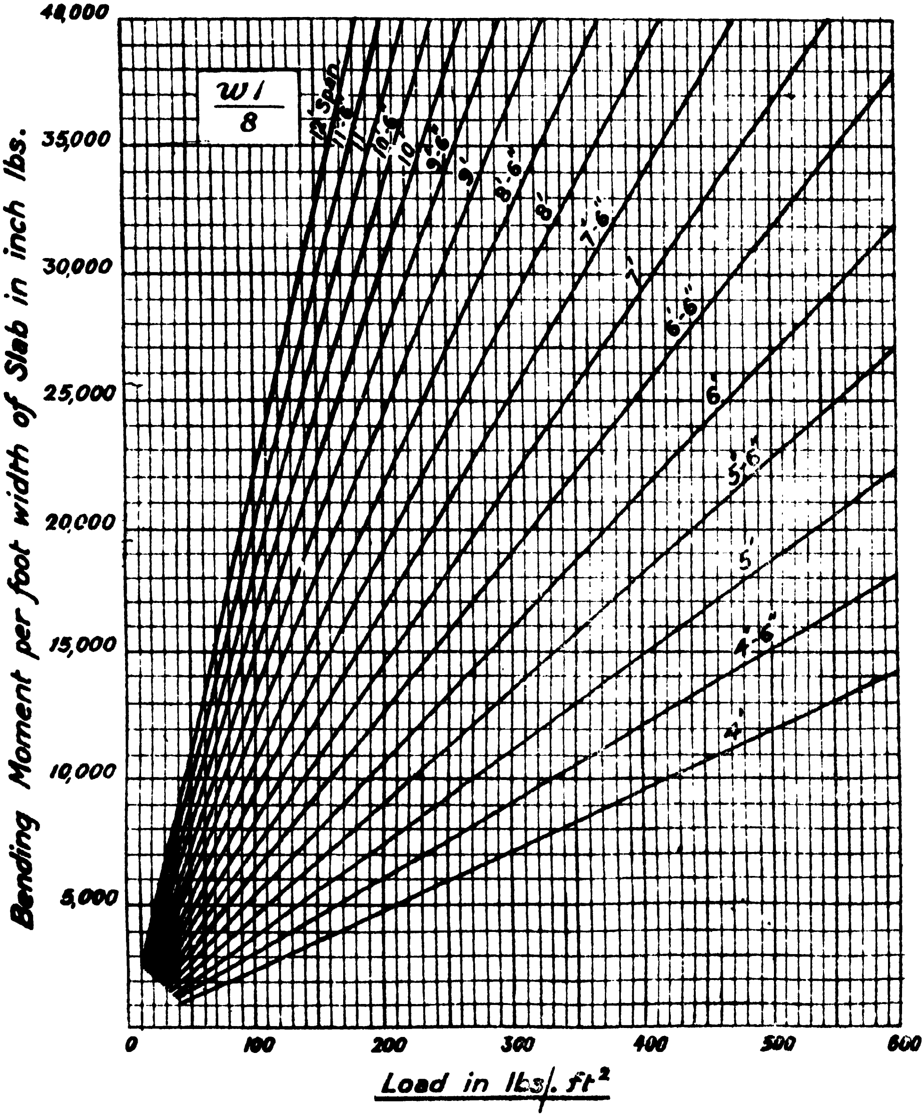

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Plate L

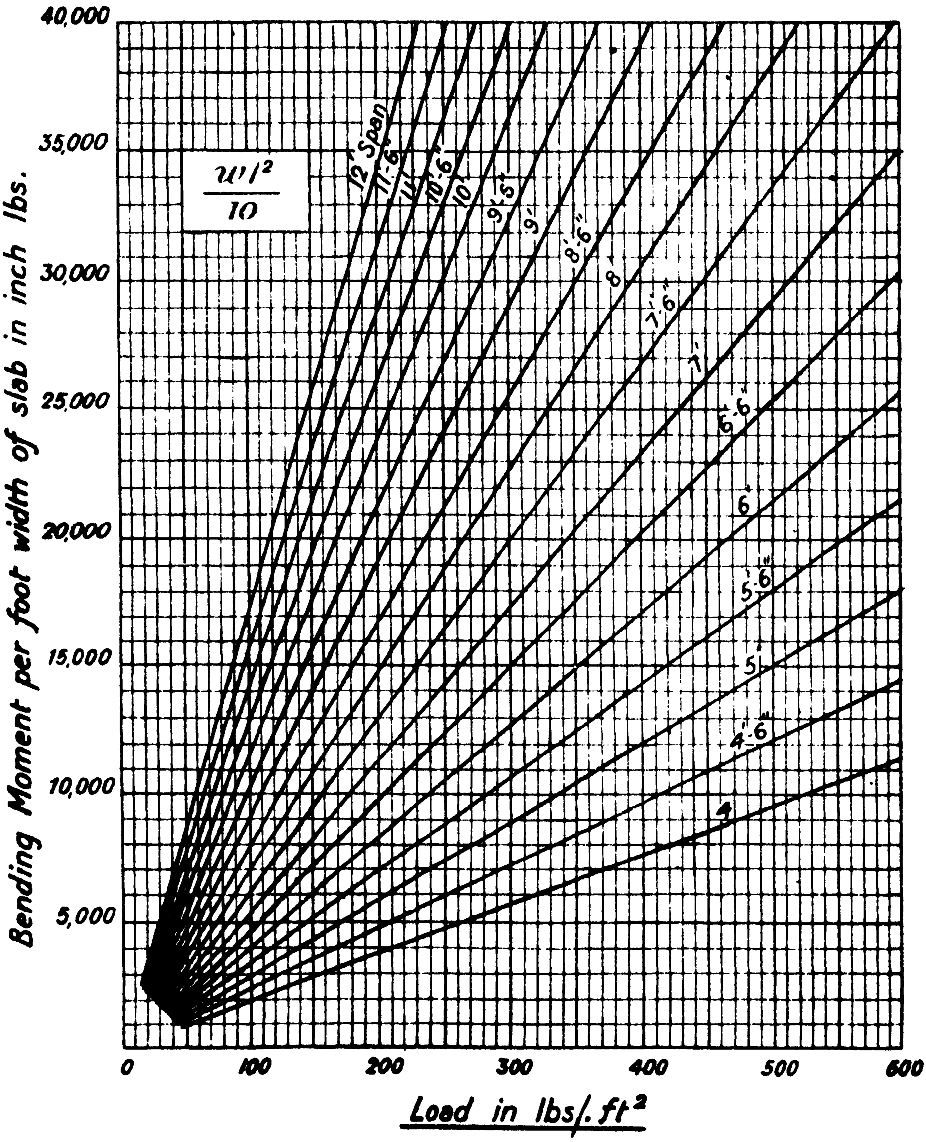

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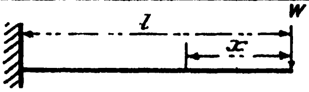
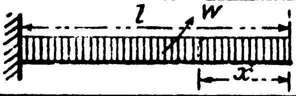
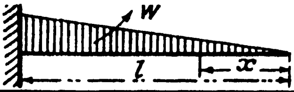
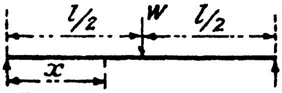
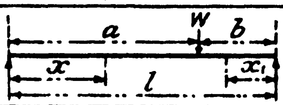
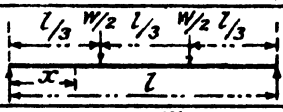
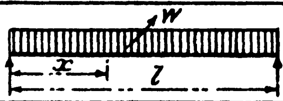
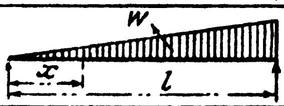
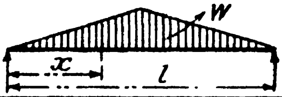
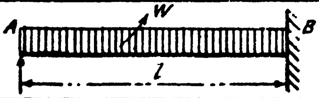
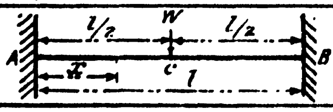
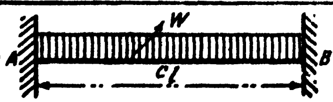
Table CIX

Bending Moments and Shearing Forces.

Method of Loading and Support. (W = Total Load)	Reactions. R_l = Left Reaction. R_r = Right Reaction.	Bending Moments.
Fig. 1 	$R_l = W$	$M_x = Wx$ $M_{max} = Wl$
Fig. 2 	$R_l = W$	$M_x = \frac{Wx^2}{2l}$ $M_{max} = \frac{Wl}{2}$
Fig. 3 	$R_l = W$	$M_x = \frac{Wx^3}{3l^2}$ $M_{max} = \frac{Wl}{3}$
Fig. 4 	$R_l = R_r = \frac{W}{2}$	$M_x = \frac{Wx}{2}$ $M_{max} = \frac{Wl}{4}$
Fig. 5 	$R_l = \frac{Wb}{l}$ $R_r = \frac{Wa}{l}$	$M_x = \frac{Wbx}{l}$ $M_{x_1} = \frac{Wax}{l}$ $M_{max} = \frac{Wab}{l}$
Fig. 6 	$R_l = R_r = \frac{W}{2}$	$M_x = \frac{Wx}{2}$ $M_{max} = \frac{Wl}{6}$
Fig. 7 	$R_l = R_r = \frac{W}{2}$	$M_x = \frac{Wx}{2}\left\{1 - \frac{x}{l}\right\}$ $M_{max} = \frac{Wl}{8}$
Fig. 8 	$R_l = \frac{W}{3}$ $R_r = \frac{2W}{3}$	$M_x = \frac{Wx}{3}\left\{1 - \frac{x^2}{l^2}\right\}$ $M_{max} = \frac{2Wl}{9\sqrt{3}}$ $= .128\ Wl$
Fig. 9 	$R_l = R_r = \frac{W}{2}$	$M_x = \frac{WX}{2}\left\{1 - \frac{4x^2}{3l^2}\right\}$ $M_{max} = \frac{Wl}{6}$
Fig. 10 	$R_l = \frac{5}{16}W$ $R_r = \frac{11}{16}W$	$M_x = \frac{5}{16}Wx$ $M_c = \frac{5}{32}Wl$ $M_B = -\frac{3}{16}Wl$
Fig. 11 	$R_l = \frac{3}{8}W$ $R_r = \frac{5}{8}W$	$M_{max} = \frac{9Wl}{128}$ $M_B = -\frac{Wl}{8}$
Fig. 12 	$R_l = R_r = \frac{W}{2}$	$M_x = \frac{Wl}{2}\left\{\frac{x}{l} - \frac{1}{4}\right\}$ $M_{max} = \frac{Wl}{8}$ $M_A = M_B = -\frac{Wl}{8}$
Fig. 13 	$R_l = R_r = \frac{W}{2}$	$M_c = \frac{Wl}{24}$ $M_A = M_B = -\frac{Wl}{12}$

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M=Bending Moment in a beam or slab.

M_x, M_y =Bending Moment at a section at a distance x or at a section at a distance y from one end in a beam or slab.

M_{max} =Maximum bending moment.

M_r =Moment of resistance of a beam or slab.

R_l R_r =Reactions at the left or right support.

BENDING MOMENTS AND SHEARING FORCES.

(See Table CIX).

In the design of reinforced concrete beams and slabs, the calculation of the bending moment is of fundamental importance. Table CIX gives the bending moments and shearing forces on isolated beams under the various methods of loading and support.

For a uniformly distributed load of w lbs. per inch, the greatest bending moment at the centre of span of l inches is $\frac{wl^2}{8}$ inch-lbs.

For beams continuous over several equal spans, the maximum bending moment near the middle of an end span is taken as $+\frac{wl^2}{10}$ while for other interior spans, it is taken $+\frac{wl^2}{12}$. The reverse bending moment at the supports should be taken as $-\frac{wl^2}{10}$ at support next to end support, and $-\frac{wl^2}{12}$ for other supports.

The diagrams on plates XLIX, L and LI give the maximum bending moments in the above cases.

Example (under diagram, plate XLIX).

A slab of 4 inches total depth is freely supported over a span of 6′ 6″. It has to support a live load of 1½ cwts. per foot super.

Finding the bending moment per foot width of slab

Live load = 168 lbs./ft.^{2}

Dead load = 50 lbs./ft.^{2} (at 150 lbs. per c. ft. of R. concrete).

Total load = 218 lbs./ft.^{2}

Then from diagram, B=13,900 in-lbs.

Example (under diagram, plate L).

A 5″ slab is continuous over several supports. It has to support a load of 2 cwt. per foot super, over a span of 7′.

Find the bending moment per foot width on the end span.

Live load = 224 lb./ft.^{2}

Dead load = 63 lb./ft.^{2}

Total load = 287 lb./ft.^{2}

Taking $B=\frac{wl^2}{10}$, then from diagram

B=16,900 in-lbs.

Example (under diagram, plate LI).

A 6″ slab is continuous over several supports. It has to support a load of 2 cwts. per foot super,, over a span of 10″. Find the bending moment per foot width of slab on a central span.

Live load=224 lb./ft.^{2}
Dead load= 75 lb./ft.^{2}

Total load=299 lb./ft.^{2}

Taking $B = \frac{wl^2}{12}$, then from diagram
B =29,000 in lbs.

TABLE CIX-A.

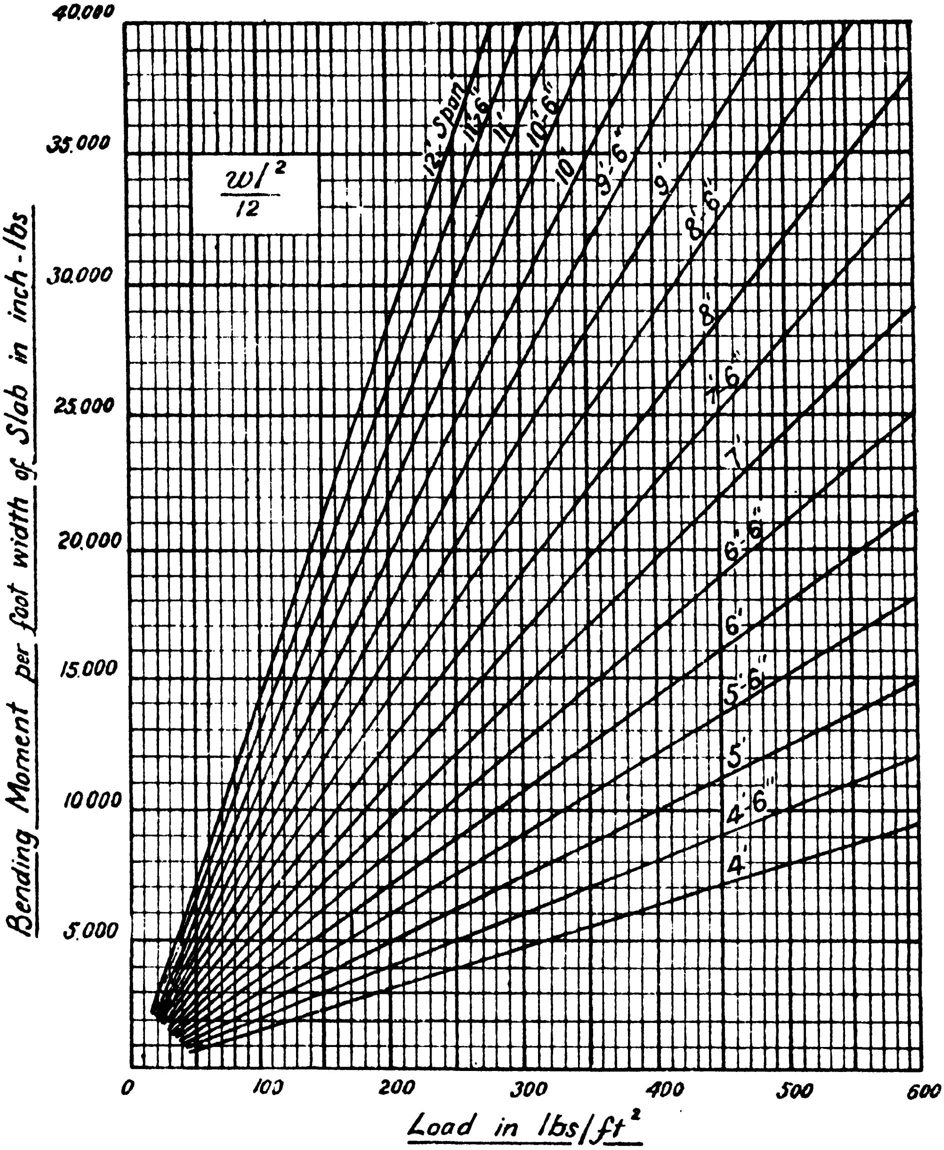
SHOWING BENDING MOMENTS OF SLABS IN INCH-LBS., FOR SPANS UP TO 13 FEET.

(See plates XLIX, L, and LI.)

Span in feet.	Condition of ends.		
	Both supported. $\frac{1}{8}$ wl^2 × 12.	One supported, other continuous. $\frac{1}{10}$ wl^2 × 12.	Both continuous. $\frac{1}{12}$ wl^2 × 12.
1	1·5 w	1·2 w	1 w
1½	3·4 w	2·7 w	2·3 w
2	6 w	4·8 w	4 w
2½	9·4 w	7·5 w	6·3 w
3	13·5 w	10·8 w	9 w
3½	18·4 w	14·7 w	12·3 w
4	24 w	19·2 w	16 w
4½	30·4 w	24·3 w	20·3 w
5	37·5 w	30 w	25 w
5½	45·4 w	36·3 w	30·3 w
6	54 w	43·2 w	36 w
6½	63·4 w	50·7 w	42·3 w
7	73·5 w	58·8 w	49 w
7½	84·4 w	67·5 w	56·3 w
8	96 w	76·8 w	64 w
8½	108·4 w	86·7 w	72·3 w
9	121·5 w	97·2 w	81 w
9½	135·4 w	108·3 w	90·3 w
10	150 w	120 w	100 w
10½	165·4 w	132·3 w	110·3 w
11	181·5 w	145·2 w	121 w
11½	198·4 w	158·7 w	132·3 w
12	216 w	172·8 w	144 w
12½	234·4 w	187 5 w	156·3 w
13	253·5 w	202·8 w	169 w

w = Load in lbs. per s. ft. l = Effective span in feet.

Plate L I.



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Bending moments on slabs reinforced in both directions.—If a slab is simply supported on all the four edges, a certain reduction factor, according to the following rules and tables is applied.

(*a*) Slabs with no provision to resist torsion at the corners.

Rule.—Let the length of the slab be *a*, and the breadth *b* (where *a* is equal to or greater than *b*).

Then calculate the bending moment on the slab, as a beam supported or fixed at the sides only, of a span *b* under the *total* load on the slab. Multiply this bending moment by the factor under *b*.

Similarly the bending moment on the other axis is ascertained, and is multiplied by the factor under *a*.

The reinforcements are to be provided in both directions to withstand the respective bending moments.

TABLE CX.

Proportion of longer span to shorter span (values of a/b).	Co-efficients to be applied in case of short span (b).	Co-efficients to be applied in case of long span (a).
1·0	·500	·500
1·1	·594	·406
1·2	·675	·325
1·3	·741	·250
1·4	·794	·206
1·5	·835	·165
1·6	·865	·135
1·7	·895	·105
1·8	·915	·085
1·9	·930	·070
2·0	·941	·059
2·1	·950	·050
2·5	·975	·032
3·0	·988	·022

Note.—Beyond the proportion of 2 : 1, there is practically no advantage in introducing double reinforcement.

Example.

A 4-inch slab is supported on all the four edges. Length 12 feet, breadth 10 feet. Load carried = 2 cwts. per square foot.

Find the bending moment to be taken in each direction.

Live load = 224 lb./ft.^{2}
Dead load = 50 lb./ft.^{2} @ 150 lb. per c.ft. of R. C.
Total load = 274 lb./ft.^{2}

From table CIX, neglecting in each case the effects of support at the other two sides—

Bending moment across the shorter span = 41,100 inch-lbs.
Bending moment across the longer span = 59,200 inch-lbs.

∴Bending moment across the shorter span = 41,100 × ·675.
= 27,700 inch-lbs.
∴Bending moment across the longer span = 59,200 × ·325.
= 19,200 inch-lbs.

(*b*) **Where the corners of the slab are fixed,**—i.e., prevented from lifting, and adequate provision is made by special reinforcement at the top and bottom, or otherwise, to resist torsion at the corners of the slab, the bending moments at the centre of a uniformly loaded simply supported slab may be assumed to have the values given below :—

TABLE CXI.

Proportion of longer span to shorter span (values of a/b).	Coefficients to be applied in case of short span (b).	Coefficients to be applied in case of long span (a).
1·0	0·295	0·295
1·1	0·358	0·237
1·2	0·419	0·191
1·3	0·477	0·154
1·4	0·532	0·127
1·5	0·581	0·107
1·75	0·681	0·071
2·0	0·757	0·051
2·5	0·869	0·032
3·0	0·940	0·022

(*c*) **Slabs fixed at or continuous over four sides.**—In this case the values given above may be reduced by 20 per cent., provided that the negative bending moments to be provided for at the supports, shall be equal to the value obtained above, *without reduction.*

DESIGN OF SLABS.

The following equations hold for the design of slabs and beams. The amount of steel to concrete should not exceed 2 to 3 per cent., otherwise the formulae will not hold good. The modular ratio is taken to be 15.

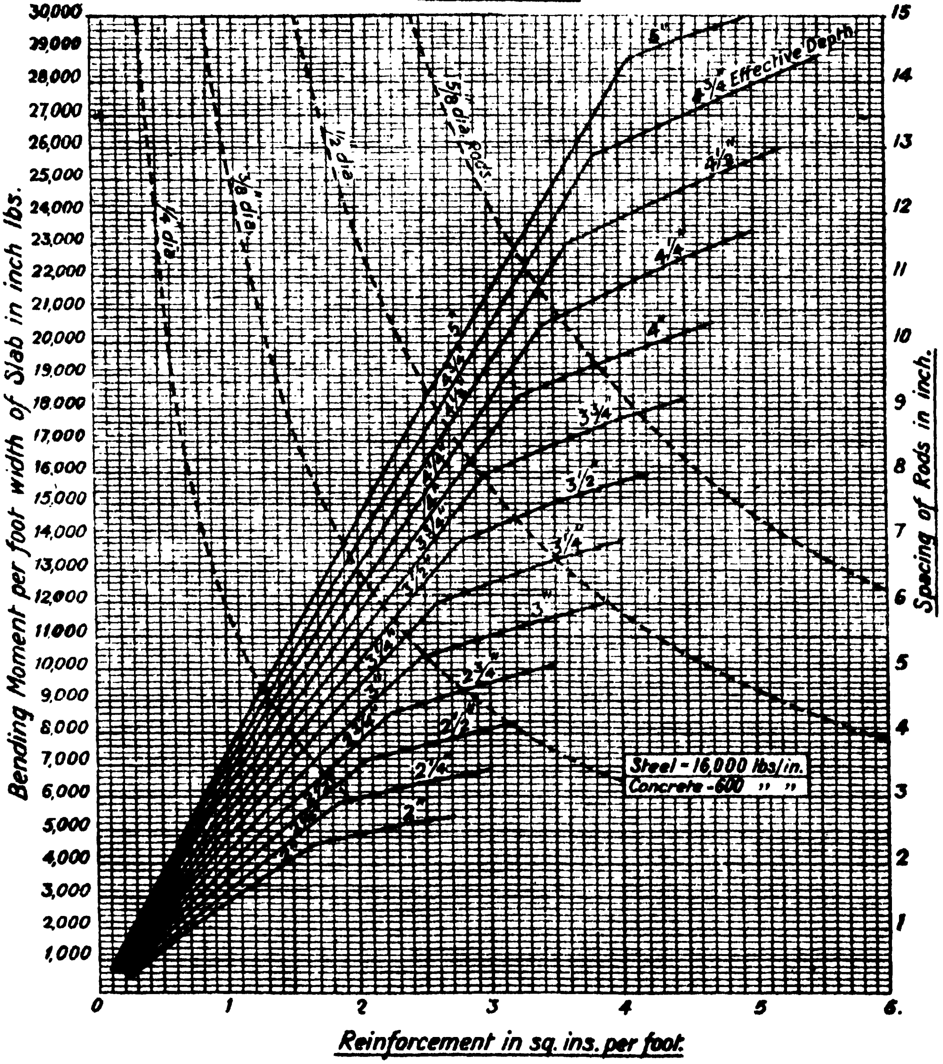
Under given stresses of steel and concrete, the depth of the neutral axis below the upper skin is given by

$$\frac{k}{d} = \frac{15f_c}{ft. + 15f_c.} \quad \text{..............(1)}$$

With a given amount of reinforcing material in a given section, the depth of the neutral axis below the upper skin is given by

$$n = \frac{15As}{b} \left\{ \sqrt{1 + \frac{2\,b\cdot d}{15As.}} - 1 \right\} \quad \text{.................(2)}$$

R. C. Slabs.



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With a given depth, breadth and reinforcement in a beam, the following formulæ give the stresses in concrete and steel under a given bending moment, M :—

$$f_c = \frac{2M}{kd/.\ b\ (d - \frac{k}{3})} \quad \ldots\ldots\ldots\ldots\ldots (3)$$

$$f_t. = \frac{M}{A_s\ (d - \frac{k}{3}).} \quad \ldots\ldots\ldots\ldots\ldots (4)$$

Diagram, plate LII, is derived from the above formulæ, and is for a value of f_t = 16,000 lb./inch² and for a value of f_c = 600 lb./inch² or less.

Use of diagram, plate LII.

1. **To find the most economical effective depth of slab.**—The most economical effective depth is that which causes both the steel and the concrete to be stressed to their maximum permissible values. This condition will only be satisfied when a point forming a cusp in one of the curves is used. In general it is desirable to work on the straighter portions of the curves, as near the cusp as possible.

To find the bending moment, it is necessary to know the total load, which includes the weight of the slab also, which, however, is unknown. Hence it is necessary to proceed by a first approximation, by assuming a suitable thickness.

Example.

Live load = 224 lbs./ft.²

Span = 6′.

To find the most economical effective depth, the slab being freely supported.—As a first assumption, assume a 4 inch slab. Then the total load = 224 + 50 = 274 lbs./ft.²

From diagram, plate XLIX, B = 14,800 in.-lbs.

Using diagram, plate LII, and getting over as far to the right as possible, while working on the straighter portion of the curves, it is found that a 3¾ inch effective depth of slab is most economical. If the steel is to have a cover of ½ inch, this will represent a total depth of slab of 4½ inches.

Therefore, total load will equal 224 + 56 = 280 lbs./ft.² and B = 15,200 inch-lbs

2. **To find the reinforcement per foot width of slab.**—Having found the bending moment and selected the effective depth of slab, the point on the diagram corresponding to these values is found, and the reinforcement per foot width may be read off at the bottom of the diagram.

Curves are also drawn showing the spacing of rods of various sizes required for a given amount of reinforcement. Therefore, by tracing this area of steel vertically to meet one of these lines, the size of rod and its spacing, as indicated by the scale on the right hand side of plate LII is read off. See also plate LII-A.

Example.

M = 17,700 inch-lbs.

One inch off the total depth of a slab to be allowed for the effective depth of slab.

From diagram—

Effective depth of slab = 4 inches (reading near the cusp).
∴ Total depth of slab = 5 inches.
Reinforcement = ·31 square inch.
= $\frac{5}{8}''$ rods at 11·8 inch centres,
or = $\frac{1}{2}''$ rods at 7·5 inch centres.
or = $\frac{3}{8}''$ rods at 4·2 inch centres.

If an effective depth other than the economical effective depth be used, say $4\frac{1}{2}$ inches, then from diagram—

Effective depth of slab = $4\frac{1}{2}$ inches.
∴ Total depth of slab = $5\frac{1}{2}$ inches.
Reinforcement = ·273 square inch.
= $\frac{5}{8}''$ inch rods at 13·3 inch centres,
or = $\frac{1}{2}''$ rods at 8·6 inch centres,
or = $\frac{3}{8}''$ rods at 4·8 inch centres.

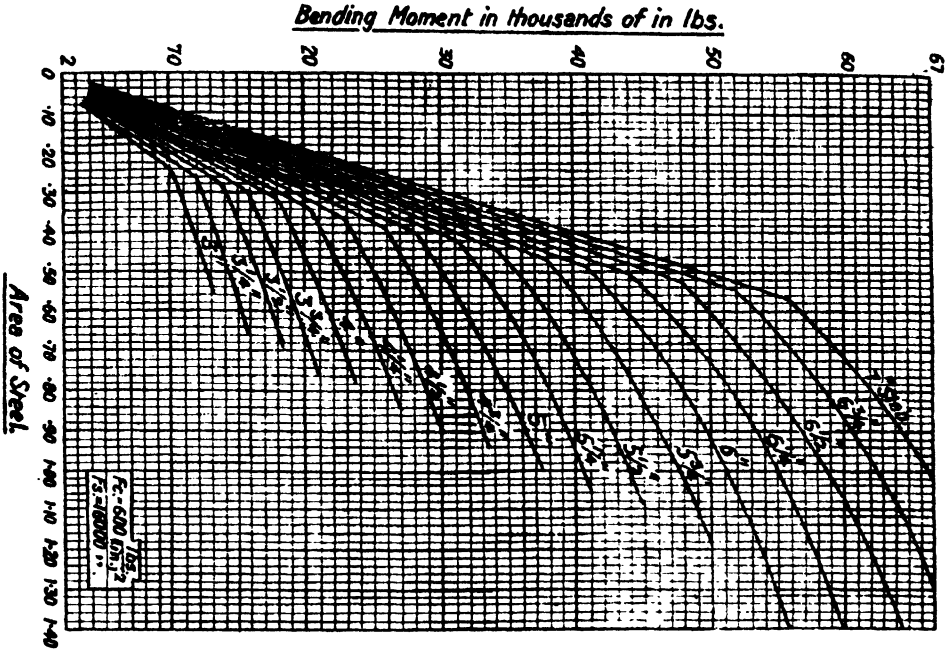
TABLE CXII.

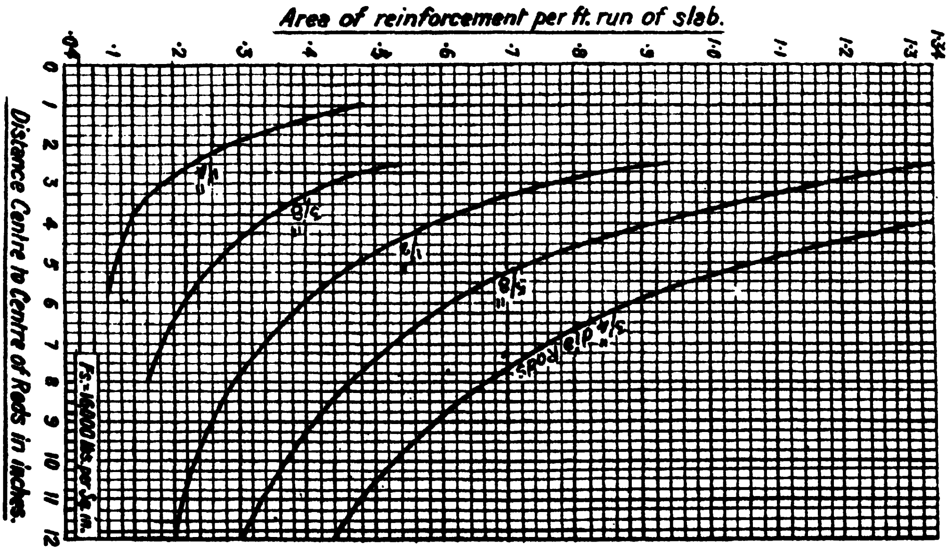
SLABS REINFORCED IN ONE DIRECTION (balanced design)

(Plate LII-A.)

Effective depth of slab in inches.	Maximum resistance to bending in inch-lbs.	Reinforcement for 10,000 inch-lbs. in square inches.
3	10 200	·24
$3\frac{1}{4}$	12,000	·22
$3\frac{1}{2}$	14,000	·21
$3\frac{3}{4}$	16,000	·19
4	18,200	·18
$4\frac{1}{4}$	20,600	·17
$4\frac{1}{2}$	23,000	·16
$4\frac{3}{4}$	25,700	·15
5	28,500	·14
$5\frac{1}{4}$	31,400	·136
$5\frac{1}{2}$	34,500	·13
$5\frac{3}{4}$	37,700	·124
6	41,000	·12
$6\frac{1}{4}$	44 500	·114
$6\frac{1}{2}$	48,200	·11
$6\frac{3}{4}$	52,000	·105
7	55 800	·10

Plate LII A.





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DESIGN OF RECTANGULAR BEAMS.

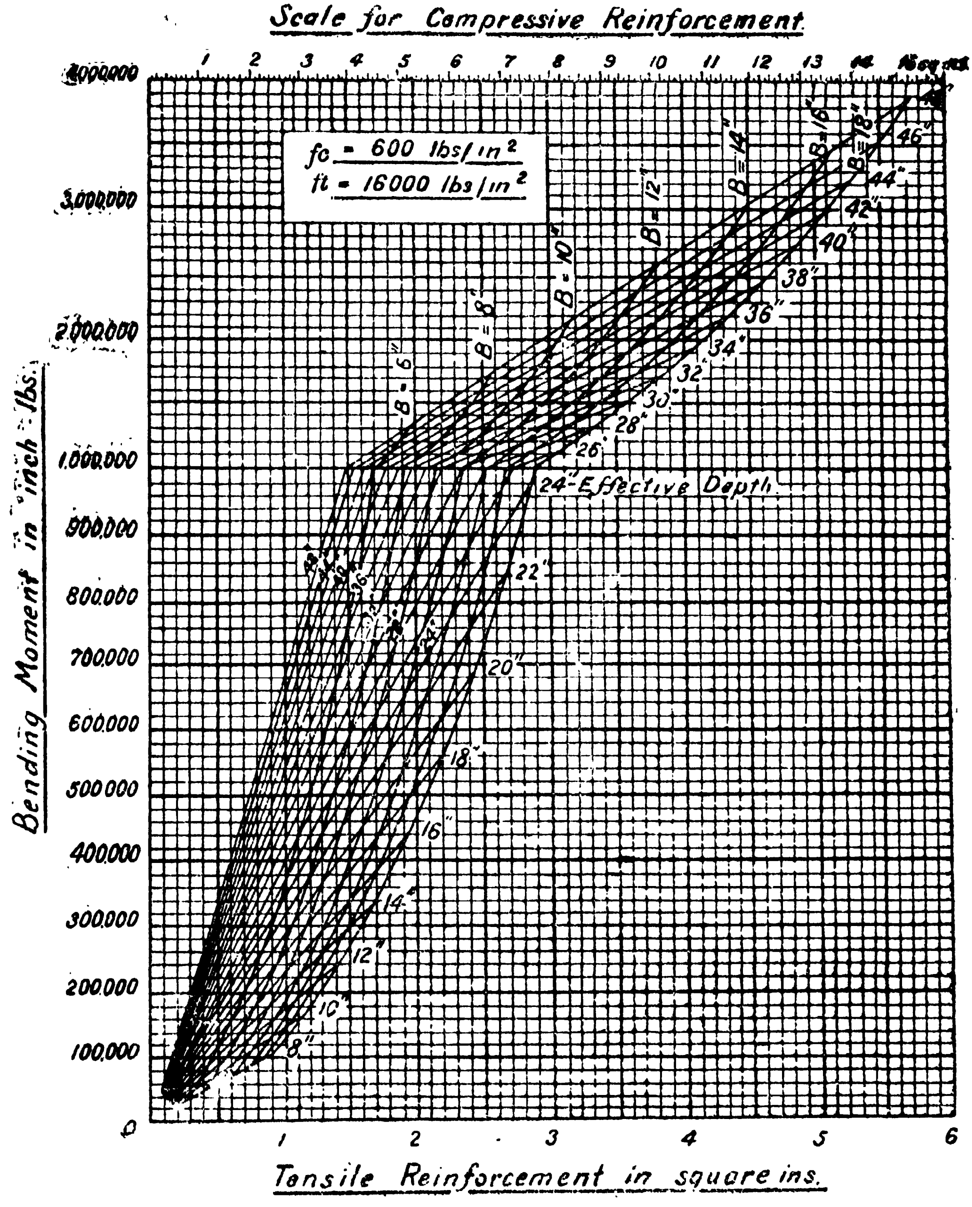
(Single reinforcement.)

The equations already given for the design of slabs are also true for rectangular beams.

Diagram below (plate LIII) can be used for the design of beams, in which $fc = 600$ lbs./in.^{2} and $ft = 16{,}000$ lbs./in.^{2} in the following manner :—

Having determined the bending moment on a beam, the horizontal line corresponding to this value is traced to intersection with the curves representing various

PLATE LIII.



effective depths. Having chosen some depth, the corresponding value for the tensile reinforcement can be found by tracing the above intersection to the scale at the bottom of the diagram. It will be found that, for given values of m and d, a corresponding value for b is obtained by either working on or interpolating a value between the curves, which have been drawn for values of b — 6, 8, 10, 12, 14, 16 and 18 inches. The value of b thus obtained will give the most economical breadth of beam to use.

The bending moment cannot, of course, be accurately determined until the size of the beam is known. In practice an allowance of 20 per cent. of the external bending moment can be made for that bending moment due to the weight of a rectangular beam. Values of b and d can then be found, and a second and more accurate determination of m and As can then be made.

Example.

M = 900,000 in. lbs. (say final, corresponding to chosen values of b and d).

ft. = 16,000 lbs./in.^{2}

fc = 600 lbs./in.^{2}

In the diagram the following series of values could be used :—

(1) d = 28 in., b = 12 in., and A_s = 2·27 square inches ; or

(2) d = 30 in., b = 11 in., and A_s = 2·12 square inches ; or

(3) d = 24 in., ; b = 17 in., and A_s = 2·64 square inches, etc.

Knowing the effective depth of the beam, the total depth of the beam can be settled when the amount of covering and the size and disposition of the reinforcement rods are known.

The following tables give results similar to the diagram, plate LIII.

(*See* next page.)

TABLE CXIII.

RECTANGULAR BEAMS (BALANCED DESIGN).

SHOWING REINFORCEMENT IN SQUARE INCHES.

B.M in inch-lbs	Effective depth of a beam in inches.							
	10″	12″	14″	16″	18″	20″	22″	24″
100,000	·710	·592	.507	·444	·395	·355	·323	·296
200,000	1·420	1·184	1·014	·888	·790	·710	·646	·592
300,000	2·130	1·776	1·521	1·332	1·185	1·065	·969	·888
400,000	2·840	2·368	2·028	1·776	1·580	1·420	1·292	1·184
500,000	3·550	2·960	2·535	2·220	1·975	1·775	1·615	1·480
600,000	4·260	3·552	3·042	2·664	2·370	2·130	1·938	1·776
700,000		4·144	3·549	3·108	2·765	2·485	2·261	2·072
800,000		4·736	4·056	3·552	3·160	2·840	2·584	2·368
900,000		5·328	4·563	3·996	3·555	3·195	2·907	2·664
1,000,000			5·070	4·440	3·950	3·550	3·230	2·960
2,000,000				8·880	7·900	7·100	6·460	5·920
3,000,000						10·650	9·690	8·880
4,000,000						14·20	12·92	11·840
5,000,000							16·15	14·800

Effective depth of a beam in inches—*concld.*

B.M. in inch-lbs.	26″	28″	30″	32″	34″	36″	38″	40″
100,000	·273	·254	·237	·222	·209	·197	·187	·178
200,000	·546	·508	·474	·444	·418	·394	·374	·356
300,000	·819	·762	·711	·666	·627	·591	·561	·534
400,000	1·092	1·016	·948	·888	·839	·788	·748	·712
500,000	1·365	1·270	1·185	1·110	1·045	·985	·935	·890
600,000	1·638	1·524	1·420	1·332	1·254	1·182	1·122	1·068
700,000	1·911	1·778	1·695	1·554	1·463	1·379	1·309	1·246
800,000	2·184	2·032	1·896	1·776	1·672	1·576	1·496	1·424
900,000	2·457	2·286	2·133	1·998	1·881	1·773	1·683	1·602
1,000,000	2·730	2·540	2·370	2·220	2·090	1·970	1·870	1·780
2,000,000	5·460	5·080	4·740	4·440	4·180	3·940	3·740	3·500
3,000,000	8·190	7·620	7·110	6·660	4·180	5·940	5·610	5·340
4,000,000	10·920	10·160	9·480	8·880	8·360	7·880	7·480	7·120
5 000,000	13·650	12·700	11·850	11·10	10·450	9·850	9·350	8·900

TABLE CXIV.

RECTANGULAR BEAMS.

SHOWING MOMENTS OF RESISTANCE OF R. C. RECTANGULAR BEAMS UNDER GIVEN DEPTH AND BREADTH IN INCHES.

Effective depth of beam in inches.	6″	8″	10″	12″	14″
8 ...	36,480	48,640			
10 ...	57,000	76,000	95,000		
12 ...	82,080	109,440	136,800	164,160	
14 ...	111,720	148,960	186,200	223,440	260,680
16 ...	145,920	194,560	243,200	291,840	340,480
18 ...	184,680	246,240	307,800	369,360	430,920
20 ...	228,000	304,000	380,000	456,000	532,000
22 ...	278,730	367,840	459,800	557,460	646,570
24 ...	328,320	437,760	547,200	656,640	766,080
26 ...	385,320	453,760	642,200	770,640	899,080
28 ...	446,880	595.840	744,800	893,760	1 042,720
30 ...	513,000	684,000	865 000	1,026,000	1,197,000
32 ...	583,680	778,240	972,800	1,167,360	1,361,920
34 ...	664,620	886,160	1,107,700	1,329,240	1,550,780
36 ...	738,720	984,960	1,231,200	1,477,440	1,723,680
38 ...	823,080	1,097,440	1,371,810	1,646,160	1,920,520
40 ...	912,000	1,216,000	1,530,000	1,824,000	2,128,000

Effective depth of beam in inches.	16″	18″	20″	22″	24″
8 ...					
10 ...					
12 ...					
14 ...					
16 ...	389,120				
18 ...	492,480	554,040			
20 ...	608,000	684,000	760,000		
22 ...	735,680	836,190	919,600	1,014,410	
24 ...	875,520	984,960	1,094,400	1,203,840	1,313,280
26 ...	907,520	1,155,960	1,284,400	1,292,840	1,541,280
8 ...	1,191,680	1,340,640	1,489,600	1,638,560	1,787,520
:0 ...	1,368,000	1,539,000	1,710,000	1,881,000	2,052,000
32 ...	1,556,480	1,751,040	1,945,600	2,140,160	2,334,720
34 ...	1,772,320	1,993,860	2,215,400	2,436,940	2,658,480
36 ...	1,969,920	2,216,160	2,462,400	2,708,640	2,954,880
38 ...	2,194,880	2,469,240	2,743,620	3,017,960	3,292,320
40 ...	2,432,000	2,736,000	3,040,000	3,344,000	3,648,000

TABLE CXV

SLABS AND RECTANGULAR BEAMS.

n=15.

SHOWING DEPTH OF NEUTRAL AXIS BELOW UPPER SKIN AND LEVERAGE IN INCHES FOR GIVEN DEPTHS OF SLABS AND RECTANGULAR BEAMS.

Effective depth in inches. d	Depth of neutral axis below upper skin. kd	Leverage in inches. jd
3	1·08	2·64
3½	1·26	3·08
4	1·44	3·42
4½	1·62	3·86
5	1·80	4·40
5½	1·98	4·84
6	2·16	5·28
6½	2·34	5·72
7	2·52	6·16
8	2·88	7·04
10	3·60	8·80
12	4·32	10·56
14	5·04	12·32
16	5·76	14·08
18	6·48	15·84
20	7·20	17·60
22	7·92	19·36
24	8·64	21·12
26	9·36	22·88
28	10·08	24·64
30	10·80	26·40
32	11·52	28·16
34	12·24	29·92
36	12·96	31·68
38	13·68	33·44
40	14·40	35·20
42	15·12	36·96

Rectangular beams, for working stresses of 600 and 16,000 lbs./inch ^{2} in concrete and steel respectively, can be easily designed from the following formula :

$M_R = 95{\cdot}04\ b.\ d^2$

where R = resistance moment.

b = breadth.

d = effective depth.

Assuming a suitable thickness for b, d can be found from the equation, and the area of the reinforcement can be got from the formula—

$A_s = \cdot 0068\ b\ d.$

The value of kd = 0·36d.

Value of leverage arm = 0·88d.

For other values of working stresses for steel and concrete, as well as for a different modular ratio the following tables are useful.

TABLE CXVI

Constants for Rectangular Beams and Slabs balanced design.

n=15

Resistance moment M_R = Constant × b d^2

Working Strength of Steel, Lb. per sq. inch. ft	Working Strength of Concrete, Lb. per sq. inch. fc	Ratio Depth of Neutral Axis to Depth of Steel. k	Ratio of Moment Arm to Depth of Steel (1—k/3) j	Ratio Area of Steel to Beam Above Steel. p	Constants for Beams and slabs.
16000	600	0·358	0·881	0·0067	95·0
	750	0·414	0·862	0·0097	133·5
	900	0·458	0·847	0·0129	174·5
18000	600	0·333	0·889	0·0056	88·9
	750	0·385	0·872	0·0080	126·2
	900	0·429	0·857	0·0107	165·4
20000	600	0·311	0·896	0·0047	83·5
	750	0·359	0·880	0·0067	118·8
	900	0·403	0·866	0·0091	157·0

Constants for Rectangular Beams and Slabs balanced design.

n= 12

Resistance moment M_R = Constant × b d^2

Working Strength of Steel, Lb. per sq. inch. ft.	Working Strength of Concrete, Lb. per sq. inch. fc	Ratio Depth of Neutral Axis to Depth of Steel. k	Ratio of Moment Arm to Depth of Steel (1 — k/3) j	Ratio Area of Steel to Beam Above Steel. p	Constant. For Beams and Slabs. R
16000	750	0·360	0·880	0·0085	118·8
	900	0·403	0·866	0·0113	157·0
18000	750	0·333	0·889	0·0070	113·1
	900	0·375	0·875	0·0094	148·8
20000	750	0·310	0·897	0·0058	104·1
	900	0·351	0·883	0·0079	138·3

Live Loads on Cross-drainage works.

The live loads on cross-drainage works are now prescribed for the whole of India by the Indian Road Congress.

The Indian Road Congress specifications lay down two types of loading both applicable to a carriageway width of 10 feet viz.

(1) Indian Road Congress standard loading and (2) Indian Road Congress Heavy Loading.

For all National highways and trails and for all Provincial highways and Major District roads Indian Road Congress heavy loading has been prescribed :—

TABLE CXVII

Loading type.	Bending moments		Shear
	Distributed load per lineal foot of traffic in Tons.	Knife edge load Tons.	Traffic edge load Tons.
I. R. C. Standard ..	0·34	6	9
I. R. C. Heavy ...	0·58	7	10

Proviso.

In the case of the standard loading on computing Bending moments, for loaded lengths of 20 feet and under, the distributed load shall never be less than 6·8 Tons per lane of traffic, and in the case heavy loading not less than 11·6 Tons per lane of traffic.

For all portions of the bridge accessible to pedestrians and animals only, the loading shall be 84 lbs. per square foot.

Impact factor.

The I. R. C. specifications lay down that the increment of stress in the members of any span due to speed is to be taken as the appropriate standard live-cost at the position giving the greatest stress in the member multiplied by the factor $I = \frac{1}{2} \times \frac{65}{45 + \frac{L(n+1)}{2}}$ with a maximum value of 0·50. Here

L is the loaded length of the span giving maximum stress in the member considered and n is the number of traffic lanes.

Note.—up to 14 feet with .. .. .. 1 lane of traffic.

above 14 feet up to 23 feet width .. .. 2 lanes of traffic.

above 23 feet up to 33 feet width .. .. 3 lanes of traffic.

above 33 feet up to 43 feet width .. .. 4 lanes of traffic and so on.

Loading on foot-paths.—84 lbs. per square foot without impact.

EXAMPLE

Simply supported slab.

Take a span of 10 feet and assume a total thickness of slab 10½ inches, with effective depth 9 inches. Then effective span is 10·75 feet. Dead load bending moments assuming a wearing coat of 3 inches thick plain cement concrete, at 140 pounds per cubic foot are as below :—

Weight of one foot width of 10½ inches slab ... 126 pounds.

Weight of a three inch thick cement concrete wearing coat ... ... 35 pounds.

Total ... 161 pounds

$$\text{Bending moments due to dead load} = \frac{161 \times 10{\cdot}75 \times 10{\cdot}75 \times 12}{8}$$

=28,200 inch pounds.

Live loads.

0·34 ton per linear foot of each traffic lane, plus a knife edge load of 6 tons for computing bending moments, or of 9 tons for computing shears, with the limitation that for computing bending moments, the total distributed load on loaded lengths of 20 feet and under shall never be less than 6.8 tons per lane of traffic over the whole loaded length.

Impact factor for a 10 feet span from the formula is 0·54 ; but 50 per cent. the limiting maximum is to be used.

Therefore bending moments per foot width of slab for live loads are as below :—

$$\text{Due to distributed load} = \frac{{\cdot}68 \times 2240 \times 10{\cdot}75 \times 12}{8}$$

= 24500 inch-pounds.

$$\text{Due to knife edge load} = \frac{{\cdot}6 \times 2240 \times 10{\cdot}75 \times 12}{4}$$

= 43400 inch-pounds.

Total B. M. = 67900 inch-pounds.

Adding 50 per cent. for impact, the total bending moments for live loads = 101800 inch pounds.

Adding dead load bending moment, the final total bending moment amounts to 130,000 inch-pounds.

Referring to Table it will be seen that a slab of total thickness 10½ inches is safe for a total bending moment of 133,000 inch-pounds.

Now test this slab for shear and bond stresses.

Shear

This will be a maximum at the supports.

Due to Dead load.

(*i*) Slab weight $= 10 \cdot 75 \times \frac{10 \cdot 5}{12} \times 144 \ldots$ ... = 1,356 pounds.

(*ii*) Wearing coat weight $= 10 \cdot 75 \times \frac{3}{12} \times 140$ ... = 377 pounds.

Total ... = 1,733 pounds.

Reaction on one support due to above weights $= \frac{1,733}{2}$ = 867 pounds.

Due to Live load distributed

$$\text{Reaction on one support} = \frac{\cdot 34 \times 10 \cdot 75 \times 2,240 \times 1 \cdot 5}{10 \times 2} = 615 \text{ pounds.}$$

Knife edge load for computing shears is to be taken as 9 tons, distributed on a width of 10 feet, which is equal to ·9 ton or 2,016 pounds on one foot width.

Adding 50 per cent. for impact, this equals 3,024 pounds : therefore adding up, total shear amounts to 867 + 615 + 3,024 = 4,506 pounds.

$$\text{Now} \quad v = \frac{V}{bjd}$$

$$j = 0 \cdot 857$$

$$v = \frac{4,506}{12 \times \cdot 857 \times 9.} = 48 \cdot 6$$

against an allowable stress of 75 pounds, which is safe.

Bond Stress.

$$\text{Bond stress } u = \frac{V}{jd\Sigma o}$$

Where $\Sigma 0$ = Sum of the perimeters of the bars in the tensile reinforcement.

$$\text{Hence } u = \frac{V \times b}{bjd \times \Sigma 0}$$

$$= v \times \frac{b}{o \times \frac{b}{\text{spacing of bars}}}$$

Where o = perimeter of one bar

$$\text{Hence } u = v \times \frac{\text{spacing of bars}}{\text{perimeter of one bar}}$$

$$= \frac{48 \cdot 6 \times 5 \cdot 5}{2 \cdot 356} = 113 \text{ lbs.}$$

u should not exceed twice the appropriate permissible bond stress which is 100 pounds and as 113 pounds is less than twice 100 pounds, the slab is safe for bond stress too.

TABLE CXVIII

Resistance Moments of Reinforced Concrete Slabs.

Unit stress in concrete	fc = 750 pounds per square inch
Unit stress in steel	ft. = 18,000 ,, ,, ,, ,,
Co-efficient	R = 137
Percentage of steel	p = ·0089
Moment of Resistanco	= Rbd^2 where
effective depth	d = total depth, t minus 1½ inches.
breadth	b = twelve inches
Area of steel	As = pbd.

Slab thickness in inches	Effective depth in inches	Moment of Resistance in inch pounds MR.	Steel required in square inches As	Main Steel Bars proposed	As supplied.	Distribution steel Bars proposed.	Weight of slab per square foot in pounds.
1	2	3	4	5	6	7	8
7	5½	49,400	0·59	⅝ in. diameter at 6 in. centres.	0·60	⅜ in. diameter at 10½ in. centres.	84
7½	6	59,200	0·64	⅝ in. diameter at 5½ in. centres.	0·67	⅜ in. diameter at 9½ in. centres.	90
8	6½	69,500	0·7	⅝ in diameter at 5 in centres.	0·74	⅜ in diameter at 9 in centres.	96
8½	7	80,600	0·75	⅝ in. diameter at 5 in. centres.	0·74	⅜ in. diameter at 9 in. centres.	102
9	7½	92,500	0·8	⅝ in. diameter at 4½ in. centres.	0·82	⅜ in. diameter at 8 in. centres.	108
9½	8	1,05,300	0·86	⅝ in. diameter at 4 in. centres.	0·92*	⅜ in. diameter at 7 in .centres.	114
10	8½	1,18,000	0·91	⅝ in. diameter at 4 in. centres.	0·92	⅜ in. diameter at 7 in centres.	120
10½	9	1,33,000	0·96	¾ in. diameter at 5½ in. centres.	0·96	½ in. diameter at 12 in. centres.	126
11	9½	1,48,000	1·01	¾ in diameter at 5 in centres. .	1·06	½ in. diameter at 11 in. centres.	132
11½	10	1,64,400	1·07	¾ in. diameter at 5 in. centres.	1·06	½ in. diameter at 11 in. centres.	138
12	10½	1,81,000	1·12	¾ in. diameter at 4½ in. centres.	1·18	½ in. diameter at 10 in. centres.	144
12½	11	1,99,000	1·17	¾ in diameter at 4½ in. centres.	1·18	½ in. diameter at 10 in. centres.	150
13	11½	2,16,000	1·22	¾ in diameter at 4 in. centres.	1·32	½ in. diameter in 8½ in. centres.	156
13½	12	2,37,000	1·28	¾ in diameter at 4 in. centres.	1·32	½, in. diameter at 8½ in. centres.	162
14	12½	2,56,000	1·33	¾ in diameter at 4 in. centres.	1·32	½ in. diameter at 8½, in. centres.	168
14½	13	2,78,000	1·39	⅞ in. diameter at 5 in. centres.	1·44	½ in. diameter at 8 in centres.	174
15	13½	2,98,000	1·44	⅞ in diameter at 5 in. centres.	1·44	½ in. diameter at 8 in. centres.	180

* *Vide* proceedings of the India Road Congress, 1939.

TABLE CXIX

TAB

Design of simply supported slabs for spans 4 *feet to* 18 *feet for Indian Roads Congress*

Span in feet	Assume thickness of slab in inches.	Effective span in feet.	Dead Load bending moment in inch pounds.	Live load bending moment including impact in inch pounds.	Total bending moment in inch pounds.
4 ..	7	4·5	3,620	42,600	46,220
5 ..	7½	5·5	5,700	53,150	58,850
6 ..	8½	6·6	8,900	64,000	72,800
7 ..	9	7·6	12,500	73,406	85,900
8 ..	9½	8·7	17,000	83,000	1,00,000
9 ..	10	9·7	22,800	92,400	1,15,200
10 ..	10½	10·75	28,200	1,00,000	1,30,000
11 ..	11	11·8	36,400	1,13,100	1,49,500
12 ..	11½	12·9	45,000	1,23,400	1,68,400
13 ..	12	13·9	57,000	1,33,300	1,90,300
14 ..	13	15	66,000	1,42,700	2,08,700
15 ..	13½	16	78,500	1,52,100	2,30,600
16 ..	14	17	90,000	1,60,000	2,50,000
17 ..	14½	18·1	1,10,000	1,67,600	2,77,600
18 ..	15	19·1	1,17,000	1,74,500	2,91,500

Vide Proceedings of the Indian

LE CXIX

Standard Loading and wearing coat of three inches thick cement concrete.

Shear Stresses in Pounds.					Bond stress in lbs. per square inch.
Shear due to dead load.	Shear due to distributed live load including impact.	Shear due to knife edge load including impact	Total shear.	Shear in lbs. per square inch.	
270	258	3,024	3,552	63	192
352	319	3,024	3,695	60	168
460	380	3,024	3,864	53	135
545	438	3,024	4,007	52	118
672	490	3,024	4,186	51	104
783	555	3,024	4,362	50	102
867	615	3,024	4,506	49	113
1,027	678	3,024	4,729	48	101
1,157	740	3,024	4,921	48	101
1,300	795	3,024	5,119	47	90
1,430	850	3,024	5,374	45	76
1,630	910	3,024	5,564	45	76
1,750	950	3,024	5,724	45	76
1,890	1,010	3,024	5,924	44	80
2,060	1,060	3,024	6,144	44	80

Road Congress, 1939

DESIGN OF T BEAMS

(Single reinforcement.)

T beams are by far the most common form of reinforced concrete construction. in designing them as regards their resistance in tension and compression, four main factors have to be considered :—

(1) The total depth of the slab, t.

(2) The effective breadth of the slab, b, i.e., the width of the slab which may be considered to act with the beam proper.

(3) The effective depth of the beam, d.

(4) The reinforcement required.

The amount of the floor slab which may be taken as acting with the web is usually limited as stated previously viz. :—

b does not exceed one-third the effective span of the beams.

b does not exceed the distance between centre to centre of the ribs of the T beams.

b does not exceed 12 times the depth of the slab plus the breadth of the rib, Of these, that which gives the least result, should be fixed as the breadth of T flange, b.

The following equations are applicable :—

$$Kd = \frac{\frac{b.\,t^2}{2} + 15\,A_s\,d}{b\quad t + 15\,A_s} \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

$$Jd = d - \frac{t}{2} + \frac{t^2}{(2\,kd - t)} \quad \ldots \quad \ldots \quad (2)$$

$$M_r = f_t.\,A_s.\,Jd \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

$$\frac{Kd}{d} = \frac{15\,f_c}{f_t + 15\,f_c} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

The value of t will first have been settled in designing the slab. The following table CXX gives the properties of tee-beams. It covers a range of sizes that will meet the requirements of all ordinary work.

For compressive or double reinforcement refer to any standard work. As far as possible, compressive reinforcement should be avoided.

DESIGN OF SLABS

TABLES CXX—CXXII

TABLE

DESIGN

SAFE LOADS ON INTERMEDIATE SPANS, MOMENTS OF RESISTANCE AND AREAS OF RE-

Effective depth of slab. Inches.	Thickness of cover. Inches.	Total Thickness of slab. Inches.	Safe distributed loads in lbs. per running					
			Span in					
			4	5	6	7	8	9
3	1	4	641	410	285	209	160	127
3¼	1	4¼	753	482	335	246	188	149
3½	1	4½	873	559	389	285	218	172
3¾	1	4¾	1,002	641	445	327	250	198
4	1	5	1,140	730	507	372	285	225
4¼	1	5¼	1,287	824	572	420	322	254
4½	1	5½	1,443	924	643	472	361	283
4¾	1	5¾	1,608	1,029	715	525	402	319
5	1	6	1,782	1,140	792	583	445	352
5¼	1	6¼	1,965	1,257	873	641	491	388
5½	1	6½	2,156	1,380	958	704	539	426
5¾	1	6¾	2,357	1,508	1,047	781	589	465
6	1	7	2,566	1,642	1,140	833	641	507
6¼	1	7¼	2,784	1,782	1,237	909	696	546
6½	1	7½	3,011	1,927	1,338	980	753	595
6¾	1	7¾	3,248	2,078	1,443	1,060	812	641
7	1	8	3,493	2,235	1,552	1,140	873	690
7¼	1	8¼	3,746	2,398	1,665	1,223	936	740
7½	1	8½	4,009	2,566	1,782	1,309	1,002	792
7¾	1	8¾	4,281	2,740	1,903	1,398	1,070	847
8	1	9	4,562	2,920	2,028	1,490	1,140	901
8¼	1	9¼	4,851	3,105	2,156	1,584	1,213	958
8½	1	9½	5,150	3,296	2,289	1,682	1,287	1,017
8¾	1	9¾	5,457	3,493	2,425	1,782	1,364	1,078
9	1	10	5,775	3,696	2,566	1,886	1,443	1,141
9¼	1	10¼	6,099	3,903	2,710	1,991	1,525	1,205
9½	1	10½	6,433	4,117	2,859	2,100	1,608	1,271
9¾	1	10¾	6,776	4,336	3,011	2,212	1,694	1,338
10	1	11	7,128	4,562	3,168	2,327	1,782	1,408
10¼	1	11¼	7,489	4,793	3,328	2,445	1,872	1,479
10½	1	11½	7,858	5,029	3,493	2,568	1,965	1,552
10¾	1	11¾	8,237	5,272	3,661	2,690	2,090	1,627
11	1	12	8,625	5,509	3,833	2,816	2,156	1,704
11¼	1	12¼	9,021	5,774	4,009	2,946	2,255	1,782
11½	1	12½	9,427	6,033	4,190	3,078	2,357	1,862
11¾	1	12¾	9,841	6,298	4,374	3,213	2,460	1,944
12	1	13	10,264	6,569	4,562	3,352	2,562	2,027

CXX.

OF SLABS.

INFORCEMENT FOR SLABS 1 FOOT WIDE & CONTINUOUS OVER MORE THAN 3 SUPPORTS.

foot on intermediate spans for slabs—1 foot wide. feet. 10	11	12	13	14	15	Weight per Sq. ft. of slab. lbs.	Area of Tensile reinforcement. Sq. inches.	Resistance moment. Inch lbs.
102	85	71	..	..	..	50	·243	10,264
120	99	84	71	..	..	53	·263	12,046
140	115	97	82	71	..	56	·283	13,971
160	132	114	95	82	71	59	·304	16,038
182	151	127	109	93	81	62	·324	18,248
206	170	143	122	105	91	66	·344	20,600
231	191	160	137	118	103	69	·364	23,094
257	213	179	152	131	114	72	·385	25,732
285	225	198	169	146	127	75	·405	28,512
314	260	218	186	160	140	78	·425	31,434
345	285	239	204	176	153	81	·445	34,499
377	312	262	223	192	168	84	·466	37,707
410	339	285	243	208	182	87	·486	41,057
445	368	309	264	229	198	91	·506	44,550
482	398	335	285	246	214	94	·526	48,185
520	429	361	302	265	231	97	·547	51,963
559	462	388	331	285	248	100	·567	55,883
599	495	416	355	306	266	103	·587	59,946
641	529	445	379	327	285	106	·607	64,152
685	566	475	405	349	304	109	·628	68,500
730	603	507	432	372	324	112	·648	72,991
776	641	539	459	396	345	116	·668	77,624
824	681	572	487	420	366	119	·688	82,400
873	721	606	517	446	388	122	·709	87,318
924	764	642	547	471	411	125	·729	92,400
976	807	678	577	498	432	128	·749	97,582
1,029	851	715	609	525	457	131	·769	1,02,928
1,084	896	753	641	553	482	134	·790	1,08,417
1,149	942	792	675	582	507	137	·810	1,14,048
1,198	990	832	709	611	522	141	·830	1,19,822
1,251	1,039	873	744	644	559	144	·850	1,25,738
1,318	1,089	915	780	672	586	147	·871	1,31,797
1,380	1,140	958	816	704	613	150	·891	1,37,998
1,443	1,193	1,003	823	736	642	153	·911	1,44,342
1,508	1,246	1,047	892	769	670	156	·931	1,50,828
1,574	1,301	1,093	932	803	700	159	·952	1,57,457
1,642	1,357	1,140	972	838	730	162	·972	1,64,229

TABLE

DESIGN

SAFE LOADS ON END SPANS, MOMENTS OR RESISTANCE AND AREAS OF REINFORCE

Effective depth of slab. Inches.	Thickness of cover. Inches.	Total Thickness of slab. Inches.	Safe distributed loads in lbs. per running					
			Span in					
			4	5	6	7	8	9
3	1	4	535	342	238	175	134	106
3¼	1	4¼	627	401	279	205	157	124
3½	1	4½	728	466	323	238	182	144
3¾	1	4¾	835	535	371	273	209	165
4	1	5	950	608	422	310	238	188
4¼	1	5¼	1,073	687	477	350	268	212
4½	1	5½	1,205	771	536	393	301	238
4¾	1	5¾	1,340	858	596	438	335	265
5	1	6	1,485	950	660	485	371	293
5¼	1	6¼	1,637	1,048	728	535	409	323
5½	1	6½	1,797	1,150	799	587	449	355
5¾	1	6¾	1,964	1,257	873	641	491	388
6	1	7	2,138	1,368	950	698	535	422
6¼	1	7¼	2,320	1,485	1,031	758	580	458
6½	1	7½	2,570	1,606	1,115	840	627	496
6¾	1	7¾	2,706	1,732	1,203	884	677	535
7	1	8	2,911	1,863	1,294	950	728	575
7¼	1	8¼	3,122	1,998	1,388	1,019	780	617
7½	1	8½	3,341	2,138	1,485	1,091	835	660
7¾	1	8¾	3,568	2,283	1,586	1,165	892	705
8	1	9	3,802	2,433	1,690	1,241	950	751
8¼	1	9¼	4,043	2,587	1,797	1,320	1,011	799
8½	1	9½	4,292	2,746	1,907	1,401	1,073	848
8¾	1	9¾	4,548	2,911	2,021	1,485	1,137	898
9	1	10	4,811	3,079	2,138	1,571	1,203	950
9¼	1	10¼	5,082	3,253	2,259	1,659	1,271	1,004
9½	1	10½	5,361	3,431	2,383	1,750	1,340	1,059
9¾	1	10¾	5,647	3,614	2,510	1,844	1,412	1,115
10	1	11	5,940	3,802	2,640	1,939	1,485	1,173
10¼	1	11¼	6,241	3,994	2,774	2,038	1,560	1,233
10½	1	11½	6,549	4,171	2,911	2,138	1,637	1,294
10¾	1	11¾	6,864	4,393	3,051	2,241	1,716	1,356
11	1	12	7,187	4,600	3,194	2,347	1,797	1,420
11¼	1	12¼	7,518	4,811	3,341	2,455	1,879	1,485
11½	1	12½	7,856	5,028	3,491	2,565	1,964	1,552
11¾	1	12¾	8,201	5,248	3,645	2,678	2,050	1,620
12	1	13	8,554	5,474	3,802	2,793	2,138	1,690

CXXI.

OF SLABS.

MENT FOR SLABS 1 FOOT WIDE AND CONTINUOUS OVER THREE OR MORE SUPPORTS.

foot on end spans for slabs 1 foot wide including weight of slab.						Weight per Sq. ft. of slab.	Area of Tensile reinforcement.	Resistance moment.
feet.						Lbs.	Sq. inches.	Inch lbs.
10	11	12	13	14	15			
85	71	..	..	..	..	50	·243	10,264
100	83	70	59	..	..	53	·263	12,046
116	96	81	69	59	..	56	·283	13,971
134	110	93	79	68	59	59	·304	16,038
152	126	106	90	77	67	62	·324	18,248
172	142	119	101	87	76	66	·344	20,600
193	159	134	114	98	86	69	·364	23,049
214	177	149	127	109	95	72	·385	25,732
238	196	165	141	121	105	75	·405	28,512
262	216	182	155	134	116	78	·425	31,434
287	238	200	170	147	128	81	·445	34,499
314	260	218	186	160	140	84	·466	37,707
342	283	238	202	174	152	87	·486	41,057
371	307	258	220	189	165	91	·506	44,550
401	332	279	238	210	178	94	·526	48,185
433	358	301	256	221	192	97	·547	51,963
466	385	323	275	237	207	100	·567	55,883
499	413	347	295	255	222	103	·587	59,946
535	441	371	316	273	238	106	·607	64,152
571	472	396	338	291	254	109	·628	68,500
608	503	422	360	310	270	112	·648	72,991
647	535	449	383	330	287	116	·668	77,624
687	567	477	406	350	305	119	·688	82,400
728	601	505	430	371	323	122	·709	87,318
770	636	535	455	393	342	125	·729	92,379
813	672	565	481	415	361	128	·749	97,582
858	709	596	507	438	381	131	·769	1,02,928
903	747	627	535	461	401	134	·790	1,08,417
950	785	660	562	485	422	137	·810	11,4,048
998	825	693	591	509	444	141	·830	1,19,822
1,048	866	728	620	535	466	144	·850	1,25,738
1,098	908	763	650	560	488	147	·871	1,31,797
1,150	950	799	680	587	511	150	·891	1,37,998
1,203	994	835	712	614	535	153	·911	1,44,342
1,257	1,039	873	744	641	559	156	·931	1,50,828
1,312	1,084	911	776	669	583	159	·952	1,57,457
1,368	1,131	950	810	698	608	162	·972	1,64,229

TABLE

DESIGN

SAFE LOADS, MOMENTS OF RESISTANCE AND AREAS OF REINFOCEMENT.

Effective depth of slab. Inches.	Thickness of cover. Inches.	Total Thickness of slab. Inches.	Safe distributed load in lbs. per running					
			Span in					
			4	5	6	7	8	9
3	1	4	428	274	190	140	107	84
3¼	1	4¼	502	321	223	164	125	99
3½	1	4½	582	372	259	190	146	115
3¾	1	4¾	668	428	297	218	167	132
4	1	5	760	486	338	248	190	150
4¼	1	5¼	858	549	381	280	214	169
4½	1	5½	964	617	428	315	241	190
4¾	1	5¾	1,072	686	476	350	268	212
5	1	6	1,188	760	528	388	297	235
5¼	1	6¼	1,310	838	582	427	327	259
5½	1	6½	1,437	920	639	469	359	284
5¾	1	6¾	1,571	1,005	698	521	393	310
6	1	7	1,711	1,095	760	558	428	338
6¼	1	7¼	1,856	1,188	825	606	464	364
6½	1	7½	2,007	1,285	895	655	502	396
6¾	1	7¾	2,165	1,385	962	707	541	425
7	1	8	2,328	1,490	1,035	760	582	460
7¼	1	8¼	2,498	1,598	1,110	816	624	493
7½	1	8½	2,673	1,710	1,188	873	668	528
7¾	1	8¾	2,854	1,827	1,268	932	713	564
8	1	9	3,041	1,946	1,352	1,013	760	601
8¼	1	9¼	3,234	2,070	1,437	1,056	808	639
8½	1	9½	3,433	2,197	1,526	1,121	858	678
8¾	1	9¾	3,639	2,328	1,617	1,188	910	719
9	1	10	3,849	2,463	1,711	1,257	961	761
9¼	1	10¼	4,066	2,602	1,807	1,328	1,016	803
9½	1	10½	4,289	2,765	1,906	1,400	1,072	847
9¾	1	10¾	4,517	2,891	2,008	1,475	1,129	892
10	1	11	4,752	3,041	2,112	1,552	1,188	939
10¼	1	11¼	4,992	3,175	2,219	1,630	1,248	986
10½	1	11½	5,239	3,353	2,328	1,711	1,310	1,035
10¾	1	11¾	5,491	3,514	2,441	1,793	1,373	1,085
11	1	12	5,750	3,680	2,555	1,877	1,437	1,136
11¼	1	12¼	6,014	3,840	2,673	2,044	1,503	1,188
11½	1	12½	6,284	4,022	2,793	2,052	1,571	1,241
11¾	1	12¾	6,561	4,199	2,916	2,142	1,640	1,296
12	1	13	6,843	4,379	3,042	2,234	1,708	1,352

CXXII.

OF SLABS.

FOR SLABS 1 FOOT WIDE AND SIMPLY SUPPORTED.

foot for simply suppoited slabs 1 foot wide including weight of slab. feet.						Weight per Sq. ft. of slab. Lbs.	Area of Tensile reinforcement. Sq. inches.	Resistance moment. Inch lbs.
10	11	12	13	14	15			
68	56	36	..	..	..	50	·243	10,264
80	66	56	47	..	..	53	·263	12,046
93	77	65	55	47	..	56	·283	13,971
108	88	74	63	54	47	59	·304	16,038
122	100	84	72	62	54	62	·324	18,248
137	113	95	81	70	61	66	·344	20,600
154	127	107	91	79	69	69	·364	23,094
171	142	120	101	87	76	72	·385	25,732
190	157	132	113	97	84	75	·405	28,512
209	173	145	124	107	93	78	·425	31,434
230	190	160	136	117	102	81	·445	34,499
251	208	174	149	128	112	84	·466	37,707
273	226	190	162	139	122	87	·486	41,057
297	245	206	176	152	132	91	·506	44,550
321	265	223	190	164	143	94	·526	48,185
347	286	241	203	177	154	97	·547	51,963
372	308	259	220	190	165	100	·567	55,883
399	330	277	236	204	178	103	·587	59,946
428	353	297	253	218	190	106	·607	64,152
457	377	317	270	233	203	109	·628	68,500
486	402	338	288	248	216	112	·648	72,991
517	428	359	306	264	230	116	·668	77,624
549	454	381	325	280	244	119	·688	82,400
582	481	404	344	298	259	122	·709	87,318
615	519	428	364	314	274	125	·729	92,379
650	538	452	385	332	288	128	·749	97,582
686	567	476	406	350	305	131	·769	1,02,928
723	597	502	425	369	321	134	·790	1,08,417
760	528	528	450	388	338	137	·810	1,14,048
779	660	555	473	407	355	141	·830	1,19,822
838	693	582	496	429	371	144	·850	1,25,738
879	726	610	520	448	390	147	·871	1,31,797
920	760	639	544	469	409	150	·891	1,37,998
962	795	668	569	491	428	153	·911	1,44,342
1,005	831	698	595	513	447	156	·931	1,50,828
1,050	857	729	621	535	466	159	·952	1,57,457
1,095	905	760	648	558	486	162	·972	1,64,229

Example.—Design the floor slab in the end span of a continuous slab-floor with the following data :—

Super load = 150 lbs. per square foot.

Weight of paving 25 lbs. per square foot.

The loads per foot of span per 12″-inch width of slab are :—

(*i*) Super load $= 1 \times 1 \times 150 = 150$ lbs.

(*ii*) Weight of paving $= 1 \times 1 \times 25 = 25$ „

(*iii*) Weight of slab $= 1 \times 1 \times \frac{1}{2} \times 150 = 75$ „

(assumed thickness = 6″)

Total load ... 250 lbs.

$$\text{Bending moment} = \frac{wl^2}{10} = \frac{250 \times 10 \times 10 \times 12}{10}$$

$$= 30{,}000 \text{ inch lbs.}$$

From Table CXXI. The nearest Resistance moment to this is 31,434 inch lbs. for a slab of $5\frac{1}{4}$″ effective depth with a reinforcement of 0·424 square inch.

By direct ratio the actual reinforcement for a slab of $5\frac{1}{4}$″ effective depth will be

$$= \frac{30{,}000}{31{,}434} \times 0\cdot424 \text{ square inch.}$$

$$= 0\cdot405 \text{ square inch.}$$

From Table CXXXIII $\frac{5}{8}$″ bars spaced 9″ apart give 0·409 square inch per foot width of slab.

The design can be worked out also from the safe loads in the tables thus—

The total load per foot is 250 lbs.

From Table CXXI the nearest safe load for a 10′ span is 262 lbs. for a slab of $5\frac{1}{4}$″ effective depth with 0·424 square inch of reinforcement.

By direct ratio, the actual reinforcement for a slab of $5\frac{1}{4}$″ effective depth $= \frac{250}{262} \times 0\cdot424 = 0\cdot405$ square inch.

DESIGN OF RECTANGULAR BEAMS, T-BEAMS AND SLABS

TABLES CXXIII—CXXVI

TABLE

DESIGN OF

SAFE LOADS ON INTERMEDIATE SPANS, MOMENTS OF RESISTANCE AND AREAS OF MORE THAN

Effective depth of beam. Inches.	Thickness of cover. Inches.	Total depth of beam. Inches.	Safe distributed load in Lbs. per running foot on intermadiate spans for — Span in									
			6	7	8	9	10	11	12	13	14	15
6	1	7	95	70	53	42	34	28	24	20	17	15
6½	1	7½	111	82	63	49	40	33	28	24	20	18
7	1·25	8·25	129	95	73	57	46	38	32	28	24	21
7½	1·25	8·75	148	109	83	66	53	44	37	31	27	24
8	1·25	9·25	169	124	95	75	61	50	42	36	31	27
8½	1·25	9·75	190	140	107	85	69	57	48	40	35	30
9	1·25	10·25	214	157	120	95	77	64	53	45	39	34
9½	1·25	10·75	238	175	134	106	86	71	59	51	44	38
10	1·5	11·5	264	194	149	117	95	78	66	56	48	42
10½	1·5	12	291	214	166	129	105	86	73	62	53	48
11	1·5	12·5	319	235	180	142	115	95	80	68	59	51
11½	1·5	13	349	256	196	155	126	104	87	74	64	56
12	1·5	13·5	386	279	214	169	137	113	95	81	70	61
12½	1·5	14	413	303	232	183	148	123	103	88	76	66
13	1·5	14·5	446	328	253	198	160	133	111	95	82	71
13½	1·5	15	481	353	271	214	173	143	120	102	88	77
14	1·5	15·5	512	380	291	230	186	154	130	110	95	82
14½	1·5	16	555	408	312	246	200	165	138	118	102	89
15	1·5	16·5	594	437	334	264	214	177	148	126	109	95
15½	1·5	17	634	466	357	282	228	189	158	135	116	101
16	1·5	17·5	676	496	380	300	243	201	169	143	124	108
16½	1·5	18	719	528	404	319	259	214	180	153	132	116
17	2	19	763	561	429	339	274	227	191	162	140	122
17½	2	19·5	808	594	455	359	291	240	202	172	148	129
18	2	20	855	628	481	380	308	255	214	182	157	137
18½	2	20·5	903	664	510	401	325	269	226	192	166	144
19	2	21	953	700	536	423	343	283	238	202	175	152
19½	2	21·5	1,004	737	571	446	361	299	251	215	180	160
20	2	22	1,056	776	595	470	380	314	264	225	194	169
20½	2	22·5	1,109	815	624	493	399	330	277	236	204	177
21	2	23	1,164	855	664	517	419	346	291	248	214	186
21½	2	23·5	1,220	896	686	542	439	363	305	260	224	195
22	2	24	1,278	939	718	568	460	380	319	272	235	204
22½	2	24·5	1,336	982	748	594	481	397	334	285	245	214
23	2	25	1,397	1,026	785	621	503	415	349	298	256	223
23½	2	25·5	1,458	1,071	820	648	525	434	364	310	268	233
24	2	26	1,545	1,117	855	676	547	452	386	323	279	243
25	2	27	1,651	1,212	926	733	594	490	413	351	303	264
26	2	28	1,784	1,311	793	793	642	531	445	380	327	285
27	2	29	1,924	1,414	1,082	895	693	573	481	410	353	308
28	2	30	2,070	1,521	1,163	920	745	614	518	442	380	330
29	2	31	2,220	1,631	1,249	987	799	660	554	473	407	355
30	2	32	2,378	1,747	1,336	1,056	855	706	593	505	436	380

CXXIII.

RECTANGULAR BEAMS.

REINFORCEMENT FOR RECTANGULAR BEAMS 1 INCH WIDE AND CONTINUOUS OVER THREE SUPPORTS.

Rectangular Beams 1 inch wide including weight of Beams. Feet. 16	17	18	19	20	21	22	23	24	Weight per running foot of Beam. Lbs.	Area of tensile reinforcement. Sq. inches.	Resistance moment. Inch-lbs.
									7·29	0·0405	3,421
16									7·81	0·0439	4,015
18	16								8·60	0·0473	4,657
21	18	16							9.11	0·0506	5,346
24	21	19	17						9·63	0·0540	6,082
27	24	21	19	17					10·15	0·0574	6,867
30	27	24	21	19	17				10·68	0·0606	7,698
33	30	26	24	21	19	18			11·20	0·0641	8,577
37	33	29	26	24	21	19	18		11·98	0·0675	9,504
41	36	32	29	26	24	22	20	18	12·50	0·0708	10,478
45	40	35	32	29	26	24	22	20	13·02	0·0743	11,500
49	43	39	35	31	28	26	24	22	13·54	0·0776	12,569
53	47	42	38	34	31	28	26	24	14·06	0·0810	13,686
58	51	46	41	37	33	31	28	26	14·58	0·0844	14,850
63	55	49	44	40	36	33	30	28	15·10	0·0878	16,062
67	60	53	48	53	39	36	33	30	15·62	0·0911	17,321
72	64	57	52	46	42	38	35	32	16·14	0·0945	18,628
78	69	62	55	49	45	41	38	35	16·67	0·0979	19,982
83	74	66	60	53	48	44	40	37	17·19	0·1013	21,384
89	82	70	63	57	52	47	43	40	17·71	0·1046	22,833
95	84	75	67	61	55	50	46	42	18·23	0·1080	24,330
101	89	80	72	65	59	53	49	45	18·75	0·1114	25,874
107	95	84	76	69	62	57	52	48	19·80	0·1148	27,466
114	101	90	80	73	66	60	55	50	20·31	0·1181	29,106
120	106	95	85	77	70	64	58	53	20·83	0·1215	30,793
127	111	104	90	81	74	67	61	54	21·35	0·1249	32,527
134	118	106	95	86	78	71	65	59	21·88	0·1283	34,309
143	125	111	101	90	82	75	68	63	22·40	0·1316	36,139
149	131	117	106	95	85	78	72	66	22·92	0·1350	38,016
156	138	123	110	100	90	82	76	69	23·44	0·1384	39,940
164	145	129	116	105	95	86	79	73	23·96	0·1418	41,912
172	152	135	122	110	99	91	83	76	24·48	0·1451	43,932
179	159	142	127	115	105	95	87	80	25·00	0·1485	45,999
187	166	148	133	120	119	99	91	83	25·52	0·1519	48,114
196	174	155	139	126	114	104	95	87	26·04	0·1553	50,276
205	181	162	145	131	119	108	99	91	26·56	0·1586	52,486
214	189	169	152	137	124	113	103	95	27·09	0·1620	54,743
232	205	183	165	148	135	123	112	103	28·13	0·1688	59,400
253	222	198	178	161	145	132	121	111	29·17	0·1755	64,246
270	239	214	101	173	157	143	131	120	30·21	0·1823	69,283
290	251	230	206	186	169	154	141	129	31·25	0·1890	74,511
312	276	247	221	200	181	165	151	139	32·29	0·1958	79,929
334	296	256	239	214	194	178	162	148	33·33	0·2025	85,536

TABLE

DESIGN OF

SAFE LOADS ON END SPANS, MOMENTS OF RESISTANCE AND
WIDE AND CONTINUOUS OVER

Effective depth of beam. Inches.	Thickness of cover. Inches.	Total thickness of beam. Inches.	Safe distributed load in Lbs. per running foot on end spans for — Span in									
			6	7	8	9	10	11	12	13	14	15
6	1	7	79	58	44	35	28	23	20	17	14	..
6½	1	7·50	93	68	52	41	33	28	23	20	17	15
7	1·25	8·25	108	79	61	48	39	32	27	23	20	17
7½	1·25	8·75	124	91	70	55	41	37	31	26	23	20
8	1·25	9·25	141	103	79	62	51	42	35	30	26	22
8½	1·25	9·75	159	117	89	71	57	47	40	34	29	25
9	1·25	10·25	178	131	100	79	64	53	44	38	33	28
9½	1·25	10·75	198	146	112	88	71	59	50	42	36	32
10	1·5	10·5	220	162	124	98	79	65	55	47	40	35
10½	1·5	12	242	178	136	108	87	72	61	52	44	39
11	1·5	12·5	266	195	150	118	96	79	66	57	49	42
11½	1·5	13	291	214	164	129	105	86	73	62	53	46
12	1·5	13·5	322	233	178	141	114	94	79	67	58	51
12½	1·5	14	344	252	193	153	124	102	86	73	63	55
13	1·5	11·5	372	273	209	165	134	111	93	79	68	60
13½	1·5	15	401	294	225	178	144	119	100	85	74	64
14	1·5	15·5	431	287	212	192	155	128	108	92	79	69
14½	1·5	16	462	340	260	205	166	138	116	98	85	74
15	1·5	16·5	495	364	278	220	178	147	124	105	91	79
15½	1·5	17	528	388	297	235	190	157	132	112	97	84
16	1·5	17·5	563	414	317	250	203	167	141	120	103	90
16½	1·5	18	599	440	337	266	216	178	150	127	110	96
17	2	19	626	467	358	282	229	189	159	135	117	102
17½	2	19·5	674	495	379	299	242	200	168	143	124	108
18	2	20	713	524	401	317	257	212	178	152	131	114
18½	2	20·5	753	553	423	335	271	224	188	160	138	120
19	2	21	794	583	446	353	286	236	198	169	146	127
19½	2	21·5	836	615	470	372	301	249	209	179	150	134
20	2	22	880	646	496	391	317	262	220	187	162	141
20½	2	22·5	924	679	520	411	333	275	231	197	170	148
21	2	23	970	713	546	431	340	288	242	206	178	157
21½	2	23·5	1,017	747	572	452	366	302	254	217	188	163
22	2	24	1,065	782	599	473	383	317	266	226	196	170
22½	2	24·5	1,114	818	623	495	401	331	278	237	204	178
23	2	25	1,164	855	654	516	418	346	291	248	214	186
23½	2	25·5	1,215	893	684	540	437	361	304	259	223	194
24	2	26	1,267	931	713	563	456	377	322	270	232	203
25	2	27	1,375	1,010	773	611	495	409	344	293	252	220
26	2	28	1,486	1,093	837	661	535	442	372	317	273	240
27	2	29	1,604	1,178	902	713	577	477	401	342	294	256
28	2	30	1,725	1,267	970	766	621	513	432	368	317	275
29	2	31	1,820	1,359	1,041	822	666	550	462	394	340	296
30	2	32	1,979	1,454	1,114	880	713	589	494	421	363	317

CXXIV.

RECTANGULAR BEAMS.

AREAS OF REINFORCEMENT FOR RECTANGULAR BEAMS 1 INCH THREE OR MORE SUPPORTS.

continuous rectangular beams 1 inch wide including weight of Beam.

Feet. 16	17	18	19	20	21	22	23	24	Weight of beam per running ft. Lbs.	Area of tensile reinforcement. Sq. inches.	Resistance moment. Inch-lbs.
									7·29	0·0405	3,421
									7·81	0·0439	4,015
15									8·60	0·0473	4,657
17	15								9·11	0·0506	5,346
20	17	16							9·63	0·0540	6,082
22	20	18	16						10·15	0·0574	6,867
25	22	20	18	16					10·68	0·0604	7,698
28	25	22	20	18	16				11·20	0·0641	8,577
31	27	24	22	20	18	16			11·98	0·0675	9,504
34	30	27	24	22	20	18	16		12·50	0·0708	10,478
37	33	29	26	24	22	20	18	17	13·02	0·0743	11,500
41	36	32	29	26	24	22	20	18	13·54	0·0776	12,569
44	39	35	31	28	26	23	21	20	14·06	0·0810	13,686
48	43	38	34	31	28	25	23	21	14·58	0·0844	14,850
52	46	41	37	33	30	28	25	23	15·10	0·0878	16,062
56	50	44	40	36	33	30	27	25	15·62	0·0911	17,321
60	54	50	43	39	35	32	29	27	16·14	0·0945	18,628
65	58	51	46	42	38	34	31	29	16·67	0·0979	19,982
70	62	55	49	44	40	37	34	31	17·19	0·1013	21,384
74	66	59	53	47	43	39	36	33	17·71	0·1046	22,833
79	70	62	56	51	46	42	38	35	18·23	0·1080	24,330
84	75	66	60	54	49	44	41	37	18·75	0·1114	25,874
89	79	70	63	57	52	47	43	40	19·80	0·1148	27,466
95	84	75	67	61	55	50	46	42	20·31	0·1181	29,106
100	89	79	71	64	58	53	48	44	20·83	0·1215	30,793
106	94	84	75	68	61	56	51	47	21·35	0·1249	32,527
112	99	88	79	71	65	59	54	50	21·88	0·1283	34,309
118	104	93	83	75	68	62	57	52	22·40	0·1316	36,139
124	110	98	88	79	72	65	60	55	22·92	0·1350	38,016
130	115	103	92	83	75	69	63	58	23·44	0·1384	39,940
136	121	108	97	87	79	72	66	61	23·96	0·1418	41,912
143	127	113	101	91	83	76	69	63	24·48	0·1451	43,932
150	132	118	106	96	87	79	72	66	25·00	0·1485	45,999
156	139	124	111	100	91	83	76	70	25·52	0·1519	48,114
164	145	129	116	105	95	86	79	73	26·04	0·1553	50,276
171	151	135	121	109	99	90	83	76	26·56	0·1586	52,486
178	158	141	126	114	103	94	86	80	27·09	0·1620	54,743
193	171	152	137	124	112	103	93	86	28·13	0·1688	59,400
209	185	165	148	134	121	110	101	93	29·17	0·1755	64,246
225	200	178	160	144	131	119	109	100	30·21	0·1823	69,283
242	215	192	172	155	141	128	117	108	31·25	0·1890	74,511
260	230	206	184	166	151	138	126	116	32·29	0·1958	79,929
278	246	220	197	178	162	148	134	124	33·33	0·2025	85,536

TABLE

DESIGN OF

SAFE LOADS, MOMENTS OF RESISTANCE AND AREAS OF REINFORCEMENT

Effective depth of beam. Inches.	Thickness of cover. Inches.	Total Depth of beam. Inches.	Safe distributed load in Lbs. per running foot for simply supported. Span in									
			6	7	8	9	10	11	12	13	14	15
6	1	7	63	46	36	28	23	19	16	13	..	..
6½	1	7·50	74	55	42	33	27	22	18	16	14	
7	1·25	8·25	86	63	48	38	31	26	22	18	16	14
7½	1·25	8·75	99	73	56	44	36	29	25	21	18	16
8	1·25	9·25	113	83	63	50	40	33	28	24	21	18
8½	1·25	9·75	127	93	71	56	46	38	32	27	23	20
9	1·25	10·25	142	105	80	63	51	42	36	30	26	23
9½	1·25	10·75	159	117	89	70	57	47	40	34	29	25
10	1·5	11·5	176	129	99	78	63	52	44	37	32	28
10½	1·5	12	194	142	109	86	70	58	48	41	36	31
11	1·5	12·5	213	156	120	95	77	63	53	45	39	34
11½	1·5	13	238	171	131	103	84	69	58	50	43	37
12	1·5	13·5	257	186	142	113	91	75	63	54	46	40
12½	1·5	14	275	202	154	122	99	82	69	58	50	44
13	1·5	14·5	297	218	167	132	107	88	74	63	55	48
13½	1·5	15	321	236	180	142	115	95	80	68	59	51
14	1·5	15·5	345	253	194	153	124	102	86	74	63	55
14½	1·5	16	370	272	208	164	133	110	92	79	68	59
15	1·5	16·5	396	291	223	176	142	118	99	84	73	63
15½	1·5	17	423	311	238	188	152	126	106	90	78	68
16	1·5	17·5	450	331	253	200	162	134	113	96	82	72
16½	1·5	18	479	352	269	213	172	142	120	102	88	77
17	2	19	509	374	286	226	183	151	142	108	93	81
17½	2	19·5	539	396	303	239	194	160	135	115	99	86
18	2	20	570	419	321	253	205	170	142	121	105	91
18½	2	20·50	602	442	339	268	217	179	150	128	111	96
19	2	21	635	466	357	282	229	189	159	135	116	101
19½	2	21·5	669	492	380	297	241	199	167	143	120	107
20	2	22	704	517	397	313	253	209	176	150	129	113
20½	2	22·5	740	543	416	329	266	220	185	158	136	118
21	2	23	776	570	436	345	279	231	194	165	142	124
21½	2	23·5	813	598	458	361	293	242	203	173	149	130
22	2	24	852	626	479	378	307	253	213	181	156	136
22½	2	24·5	891	654	499	396	328	265	223	190	164	142
23	2	25	961	684	523	414	335	277	232	198	171	149
23½	2	25·5	972	714	547	432	360	289	243	207	178	155
24	2	26	1,030	745	570	450	365	301	257	216	186	162
25	2	27	1,100	808	618	489	396	327	275	234	202	176
26	2	28	1,189	874	669	529	428	354	297	253	218	190
27	2	29	1,283	942	722	570	462	382	320	273	235	205
28	2	30	1,379	1,014	776	613	497	410	346	294	253	220
29	2	31	1,480	1,087	832	658	533	440	370	315	272	237
30	2	32	1,583	1,165	891	704	570	471	395	337	290	253

CXXV.

RECTANGULAR BEAMS.

FOR SIMPLY SUPPORTED RECTANGULAR BEAMS 1 INCH WIDE.

rectangular beams 1 inch wide including weight of beam. Feet.									Weight per running ft. of beam. Lbs.	Area of tensile reinforcement. Sq. inches.	Resistance moment. Inch-lbs.
16	17	18	19	20	21	22	23	24			
									7·29	0·0405	3,421
									7·81	0·0439	4,015
									8·60	0·0473	4,657
14									9·11	0·0506	5,346
16	14								9·63	0·0540	6,082
18	16	14							10·15	0·0514	6,867
20	18	16	14						10·68	0·0606	7,698
22	20	18	16	14					11·20	0·0641	8,577
25	22	19	18	16	14				11·98	0·0675	9,504
27	24	22	19	18	16	14			12·50	0·0708	10,478
30	26	24	21	19	17	16	14		13·02	0·0743	11,500
33	29	26	23	21	19	17	16	14	13·54	0·0776	12,569
36	31	28	25	23	21	19	17	16	14·06	0·0810	13,636
39	34	30	27	25	22	20	19	17	14·58	0·0844	14,850
42	37	33	30	27	24	23	20	18	15·10	0·0878	16,062
45	40	36	32	29	26	24	22	20	15·62	0·0911	17,321
48	43	38	34	31	28	26	23	21	16·14	0·0945	18,628
52	46	41	37	33	30	27	25	23	16·67	0·0979	19,982
56	49	44	40	36	32	30	27	25	17·19	0·1013	21,384
59	53	47	42	38	34	31	29	26	17·71	0·1046	22,833
63	56	50	45	40	37	33	31	28	18·23	0·1080	24,330
67	60	53	48	43	39	36	32	30	18·75	0·1114	25,874
71	63	56	50	46	41	38	34	32	19·80	0·1140	27,466
76	67	60	54	48	44	40	37	34	20·31	0·1181	29,106
80	71	63	57	51	46	42	39	37	20·83	0·1215	30,793
85	75	67	60	54	49	45	41	38	21·35	0·1249	32,527
89	79	70	63	57	52	47	43	40	21·88	0·1283	34,309
95	83	74	67	60	55	50	45	42	22·40	0·1316	36,139
99	88	78	70	63	57	52	48	44	22·92	0·1350	38,016
104	92	82	74	66	60	55	50	46	23·44	0·1384	39,940
109	97	86	77	70	63	58	53	48	23·96	0·1418	41,912
114	101	90	81	73	66	60	55	51	24·48	0·1451	43,932
120	106	94	85	77	70	63	58	53	25·00	0·1485	45,999
125	111	99	89	82	73	66	60	56	25·52	0·1519	48,114
131	116	103	93	84	76	69	63	58	26·04	0·1553	50,276
137	121	108	97	87	79	72	66	61	26·56	0·1586	52,486
142	126	113	101	91	82	75	69	63	27·09	0·1620	54,743
154	137	122	110	99	90	82	74	69	28·13	0·1688	59,400
167	148	132	119	107	97	88	81	74	29·17	0·1755	64,246
180	160	142	128	115	105	95	87	80	30·21	0·1823	69,283
193	171	153	138	124	113	103	94	86	31·25	0·1890	74,511
208	184	164	147	133	120	110	101	96	32·29	0·1958	79,929
223	197	176	160	142	129	118	108	99	33·33	0·2025	85,536

TABLE

DESIGN OF

SAFE LOADS ON INTERMEDIATE SPANS, MOMENTS OF RESISTANCE

3″

Effective depth of T-Beam. Inches.	Safe distributed loads in lbs. per running								
	Span in								
	10	12	14	16	18	20	22	24	26
12	126	88	64	49	39	32			
13	143	99	73	56	44	36	30		
14	161	111	81	63	49	40	33	27	
15	178	124	91	69	55	44	37	31	25
16	195	135	99	76	60	49	40	34	29
17	213	148	108	83	66	53	44	37	31
18	230	160	117	90	71	57	47	40	34
19	248	172	126	97	76	62	51	43	37
20	265	184	135	103	82	66	55	46	39
21	283	196	145	110	87	71	58	49	42
22	301	209	155	117	93	75	62	52	44
23	318	221	162	124	98	79	66	55	47
24	336	233	171	131	104	84	69	58	50
25	354	246	181	138	109	88	73	61	52
26	371	258	189	145	114	93	77	64	55
27	389	270	198	152	120	97	80	67	57
28	407	282	207	159	125	102	84	70	60
29	425	295	217	166	131	106	88	74	63
30	443	308	226	173	137	111	91	77	65
31	461	320	235	180	142	115	95	80	68
32	478	332	244	187	147	119	99	83	71
33	497	345	253	192	153	124	103	86	73
34	514	357	261	201	158	128	106	89	76
35	539	374	271	211	166	135	111	93	80
36	549	381	280	214	169	137	114	95	81

CXXVI.

T-BEAMS.

AND AREAS OF REINFORCEMENT FOR T-BEAMS 1 INCH WIDE.

SLAB.

foot on intermediate spans of continuous T-beams.					Leverage Arm.	Resistance Moment.	Area of Tensile Reinforcement.
feet.							
28	30	32	34	36	Inches.	Inch-lbs.	Sq. Inches.
					10·76	12,650	·07344
					11·74	14,330	·07631
					12·17	16,060	·07896
					13·69	17,800	·0813
					14·67	19,500	·08312
					15·66	21,275	·08489
30					16·65	23,000	·08646
32	27				17·64	24,800	·08785
34	29				18·62	26,510	·089
37	31	28	24		19·63	28,310	·09078
38	33	29	26	23	20·62	30,075	·09116
40	35	31	27	24	21·62	31,820	·092
43	37	33	29	26	22·61	33,600	·09288
45	39	34	31	27	23·61	35,400	·09375
47	41	36	32	29	24·59	37,130	·09438
50	43	38	34	30	25·58	38,900	·095
52	45	40	35	31	26·58	40,660	·09561
54	47	41	37	33	27·58	42,480	·09623
56	49	43	38	34	28·58	44,325	·0969
59	51	45	40	35	29·57	46,100	·0975
61	53	47	41	37	30·57	47,800	·0977
63	55	48	43	38	31·57	49,700	·0983
65	57	50	44	39	32·57	51,400	·0986
68	60	53	47	42	33·56	53,200	·0990
70	61	54	47	42	34·56	54,900	·0990

TABLE

3½"

Effective depth of T-Beam. Inches.	Safe distributed loads in lbs. per running								
	Span in								
	10	12	14	16	18	20	22	24	26
12	132	92	68	52	42	33			
13	153	106	78	60	47	38	31		
14	172	119	88	67	53	43	35	30	
15	192	133	98	75	59	48	40	33	28
16	212	147	108	83	65	53	44	37	31
17	232	161	118	91	72	58	48	40	34
18	252	175	129	98	78	63	52	44	37
19	272	189	139	106	84	68	56	47	40
20	293	203	149	114	90	73	60	51	43
21	314	218	160	122	97	78	65	54	46
22	334	232	170	131	103	83	69	58	49
23	354	246	181	138	109	88	73	61	52
24	375	260	192	146	116	94	77	65	55
25	396	275	202	154	122	99	82	69	58
26	416	289	212	162	128	104	84	72	61
27	436	303	223	170	135	109	90	76	64
28	457	317	233	179	141	114	94	79	68
29	478	332	244	187	148	120	99	83	71
30	499	346	254	195	154	125	102	87	74
31	519	361	265	203	160	130	107	90	77
32	540	375	275	211	167	135	112	94	80
33	561	390	286	219	173	140	116	97	83
34	582	404	297	227	180	145	120	101	86
35	603	419	308	236	186	151	125	105	89
36	624	433	318	244	192	156	129	108	92

CXXVI-A.

SLAB.

foot on intermediate spans of continuous T-beams.					Leverage Arm.	Resistance Moment.	Area of Tensile Reinforcement.
feet.							
28	30	32	34	36	Inches.	Inch-lbs.	Sq. inches.
					10·65	13,250	·07774
					11·61	15,267	·08219
					12·56	17,200	·08568
					13·53	19,200	·08869
27					14·50	21,200	·09138
30	26				15·48	23,220	·09374
32	28	25			16·46	25,220	·09575
35	30	27	23		17·45	27,240	·09758
37	32	29	25	23	18·44	29,300	·0993
40	35	31	27	24	19·43	31,360	·10088
43	37	33	29	26	20·42	33,420	·1023
45	39	35	31	27	21·40	35,420	·10346
48	42	37	32	29	22·39	37,460	·10458
50	44	39	34	30	23·40	39,600	·10575
53	46	41	36	32	24·39	41,600	·1066
56	48	43	38	34	25·38	43,640	·10747
58	51	45	40	35	26·38	45,730	·10836
61	53	47	41	37	27·37	47,820	·10924
64	55	49	43	38	28·36	49,870	·1099
66	58	51	45	40	29·35	51,940	·1106
69	60	53	47	42	30·35	54,000	·11118
71	62	55	48	43	31·35	56,100	·11182
74	65	57	50	45	32·35	58,200	·11247
77	67	59	52	46	33·35	60,330	·11305
79	69	61	54	48	34·34	62,400	·11333

TABLE

4″

Effective depth of T-Beam. Inches.	Safe distributed loads in lbs. per running foot on intermediate spans of Span in								
	10	12	14	16	18	20	22	24	26
12	136	94	69	53	42	34	28		
13	158	110	81	62	49	39	33		
14	180	125	92	70	55	45	37	31	27
15	202	140	103	79	62	50	42	35	30
16	225	156	115	88	69	56	46	39	33
17	247	172	126	97	76	62	51	43	37
18	270	187	138	105	83	67	56	47	40
19	293	204	150	114	90	73	61	51	43
20	317	220	161	124	98	80	65	55	45
21	339	235	173	132	105	85	70	59	50
22	362	252	185	142	112	91	75	63	54
23	386	268	197	151	119	96	80	67	57
24	410	284	209	160	126	102	85	71	60
25	433	301	221	169	133	108	89	75	64
26	456	317	233	178	141	114	94	79	67
27	479	333	244	187	148	120	99	83	71
28	503	349	257	196	155	126	104	87	74
29	527	366	269	205	162	132	109	91	78
30	550	382	281	215	170	137	114	94	81
31	573	398	293	224	177	143	118	99	85
32	597	415	305	233	184	149	123	104	88
33	621	431	317	243	192	155	128	108	92
34	644	447	329	252	199	161	133	112	95
35	668	464	341	261	206	167	138	116	99
36	691	480	353	270	213	173	143	120	102

CXXVI-B.

SLAB.

continuous T-beams of 1 inch wide including weight of Beam.					Leverage Arm.	Resistance Moment.	Area of Tensile Reinforcement.
feet.							
28	30	32	34	36	Inches.	Inch-lbs.	Sq. inches.
					10·57	13,600	·08052
					11·50	15,800	·08588
					12·44	18,000	·09044
					13·39	20,230	·09445
29					14·35	22,500	·09792
32	27				15·32	24,750	·10096
34	30	26			16·27	27,000	·10369
37	32	29			17·27	29,330	·10616
40	35	31	27		18·26	31,670	·1084
43	38	33	29	26	19·23	33,920	·11023
46	40	35	31	28	20·22	36,250	·11203
49	43	38	33	30	21·22	38,600	·11371
52	45	40	35	32	22·21	40,960	·11528
55	48	42	37	34	23·20	43,330	·11675
58	51	44	39	35	24·18	45,600	·11787
61	53	47	41	37	25·16	47,900	·11902
64	56	49	43	39	26·17	50,300	·12016
67	58	51	45	41	27·17	52,700	·12121
70	61	54	47	42	28·16	55,000	·12208
73	64	56	50	44	29·15	57,340	·12295
76	66	58	52	46	30·14	59,720	·12384
79	69	61	54	48	31·14	62,130	·1247
82	72	63	56	50	32·13	64,450	·12538
85	74	65	58	52	33·12	66,800	·12606
88	77	67	60	53	34·11	69,130	·12667

TABLE

4½″

Effective depth of T-Beam.	Safe distributed load in lbs. per running foot on intermediate spans of continuous T-beams.								
	Span in								
Inches.	10	12	14	16	18	20	22	24	26
12							As for	Rectangular	Beams,
13	160	111	82	62	49	40	33	28	....
14	185	128	94	72	57	46	38	32	27
15	209	145	107	82	65	52	43	36	31
16	234	162	119	91	72	58	48	40	34
17	259	180	132	101	80	65	53	45	38
18	285	198	145	111	88	71	59	49	42
19	310	215	158	121	96	77	64	53	46
20	336	233	171	131	104	84	69	58	50
21	361	251	184	141	111	90	75	63	53
22	388	269	198	151	120	97	80	67	57
23	413	287	211	161	128	103	85	72	61
24	439	305	224	171	135	110	91	76	65
25	465	323	237	182	144	116	96	81	69
26	492	342	251	192	152	123	102	85	73
27	518	360	264	202	160	130	107	90	77
28	545	378	278	213	168	136	113	95	81
29	571	396	291	223	176	143	118	99	84
30	597	414	304	233	184	149	123	103	88
31	623	433	318	243	192	156	129	108	92
32	650	452	332	254	201	163	134	113	96
33	677	470	345	264	209	169	140	117	100
34	703	488	359	274	217	176	145	122	104
35	729	501	372	284	225	182	151	127	108
36	756	525	386	295	233	189	156	131	112

CXXVI-C.

SLAB.

1 inch wide including weight of Beam. feet.					Leverage Arm.	Resistance Moment.	Area of Tensile Reinforcement.
28	30	32	34	36	Inches.	Inch-lbs.	Sq. inches.
					....	....	....
vide Table CXXIII.					....	....	....
....	....	....	....	....	11·44	16,000	·08757
....	....	....	....	....	12·36	18,480	·09344
27	....	....	....	....	13·29	20,920	·0984
30	....	....	...	....	14·20	23,370	·10286
33	29	....	....	....	15·18	25,920	·10671
36	32	28	....	....	16·15	28,460	·11016
39	34	30	27	....	17·12	31,010	·11321
43	37	33	29	....	18·09	33,575	·116
46	40	35	31	28	19·06	36,148	·11853
49	43	38	33	30	20·05	38,760	·12082
53	46	40	36	32	21·03	41,340	·12286
56	49	43	38	34	22·01	43,900	·12468
59	52	45	40	35	23·00	46,550	·1265
63	55	48	42	38	23·99	49,190	·12815
66	58	51	45	40	24·98	51,834	·12969
69	61	53	47	42	25·98	54,517	·13115
73	63	56	49	44	26·95	57,077	·13237
76	66	58	52	46	27·93	59,658	·1335
79	69	61	54	48	28·93	62,350	·13468
83	72	63	56	50	29·93	65,045	·13518
86	75	66	58	52	30·93	67,680	·13674
90	78	69	61	54	31·93	70,285	·13758
93	81	71	63	56	32·92	72,937	·13847
96	84	74	65	58	33·91	75,600	·13932

TABLE

5"

Effective depth of T-Beam.	Safe distributed loads in lbs. per running foot on intermediate spans of continuous T-beams.								
	Spain in								
Inches.	10	12	14	16	18	20	22	24	26
12	}								
13							As for	Rectangula	r Beams,
14	186	129	95	73	57	46	38	32	..
15	213	148	108	83	66	53	44	37	31
16	240	167	122	94	74	60	50	42	35
17	267	186	136	104	82	67	55	46	3[illegible]
18	295	205	151	115	91	74	61	51	44
19	323	224	165	126	100	81	67	56	48
20	351	244	179	137	108	88	73	61	52
21	380	264	194	148	117	95	78	66	56
22	408	283	208	159	126	102	84	71	60
23	436	303	222	170	134	109	90	76	64
24	465	323	237	182	144	116	96	81	69
25	495	344	252	193	153	124	102	86	73
26	523	363	267	204	161	131	108	91	77
27	552	383	281	215	170	138	114	96	82
28	581	404	296	227	179	145	120	101	86
29	611	424	311	238	188	153	126	106	90
30	640	444	326	250	197	160	132	111	95
31	670	465	342	261	205	167	138	116	99
32	698	485	356	273	215	174	144	121	103
33	727	505	371	284	224	182	150	126	107
34	756	528	386	295	233	189	156	131	112
35	786	546	401	307	243	196	162	136	116
36	816	567	416	319	252	204	169	142	121

CXXVI-D.

SLAB.

1 inch wide including weight of Beam. feet. 28	30	32	34	36	Leverage Arm. Inches.	Resistance Moment. Inch-lbs.	Area of Tensile Reinforcement. Sq. inches.
					....	....	....
vide Table CXXIII.					....	....	....
....	....	....	....	....	12·32	18,620	·09446
....	....	....	....	....	13·21	21,280	·10065
31	....	....	....	....	14·14	24,000	·10612
34	30	....	....	....	15·08	26,740	·11082
38	33	....	....	....	16·03	29,546	·1152
41	36	31	....	....	16·97	32,300	·11898
45	39	34	31	....	17·94	35,130	·1224
48	42	37	33	29	18·91	37,960	·12548
52	45	40	35	31	19·88	40,812	·12831
56	48	42	38	34	20·85	43,600	·13089
59	52	45	40	36	21·83	46,540	·13326
63	55	48	43	38	22·82	49,480	·1355
67	58	51	45	40	23·80	52,290	·13732
70	61	54	48	42	24·78	55,170	·13915
74	64	57	50	45	25·77	58,120	·14093
78	68	60	53	47	26·77	61,060	·14255
82	71	62	55	49	27·76	64,000	·1441
85	74	65	58	52	28·75	66,960	·14558
89	77	68	60	54	29·73	69,830	·1468
93	81	71	63	56	30·71	72,690	·14794
96	84	74	65	58	31·70	75,640	·14913
100	87	77	68	61	32·70	78,610	·1502
104	91	80	71	63	33·70	81,621	·15133

TABLE

5½"

Effective Depth of T-Beam.	Safe distributed load in lbs. per running foot on intermediate spans of continuous T-Beams								
	Span in								
Inches.	10	12	14	16	18	20	22	24	26
12, 13, 14, 15							As for Rectangular Beams,		
16	243	169	124	95	75	61	50	42	36
17	272	189	139	106	84	68	56	47	40
18	302	210	154	118	93	76	62	52	45
19	333	231	170	130	103	83	69	58	49
20	363	252	185	142	112	91	75	63	54
21	394	274	201	154	122	98	81	68	58
22	425	295	217	166	131	106	88	74	63
23	456	317	233	178	141	114	94	79	67
24	488	339	249	190	150	122	101	85	72
25	519	360	265	203	160	130	107	90	77
26	550	382	281	215	170	138	114	96	81
27	582	404	297	227	180	146	120	101	86
28	614	426	313	240	189	153	127	107	91
29	645	448	329	252	199	161	133	112	95
30	677	470	345	264	209	169	140	117	100
31	709	493	362	277	219	177	146	123	105
32	742	515	387	290	229	185	153	129	110
33	774	538	395	302	239	194	160	134	114
34	807	560	412	315	249	202	167	140	117
35	838	582	428	327	259	210	173	145	124
36	870	604	444	340	268	217	180	151	129

CXXVI-E.

SLAB.

1 inch wide including weight of Beam. feet. 28	30	32	34	36	Leverage Arm. Inches.	Resistance Moment. Inch-Lbs.	Area of Tensile Reinforcement. Sq. inches.
					....	....	....
					....	....	....
vide Table CXXIII.					....	....	....
					....	....	....
31	....	....	....	....	14·09	24,290	·10774
35	30	....	....	....	15·00	27,250	·11357
39	34	....	....	....	15·93	30,250	·11867
42	37	32	....	....	16·87	33,260	·12324
46	40	35	31	....	17·82	36,350	·1275
50	44	38	34	30	18·77	39,400	·13123
54	47	41	37	33	19·73	42,500	·13464
58	51	44	39	35	20·71	45,640	·13773
62	54	48	42	38	21·68	48,760	·14058
66	58	51	45	40	22·65	51,900	·14325
70	61	54	48	42	23·62	55,050	·14566
74	65	57	50	45	24·61	58,250	·14794
78	68	60	53	47	25·59	61,400	·14994
82	72	63	56	50	26·57	64,500	·15175
86	75	66	58	52	27·56	67,720	·15358
90	79	69	61	55	28·55	70,950	·15533
95	82	72	64	57	29·54	74,200	·157
99	86	76	67	60	30·53	77,440	·15851
103	90	79	70	62	21·53	80,700	·16
107	93	82	72	65	32·51	83,850	·16122
111	97	85	75	67	33·48	87,000	·16242

TABLE

6"

Effective Depth of T-Beam.	Safe distributed load in lbs. per running foot on intermediate spans of continuous T-Beams								
	Span in								
Inches.	10	12	14	16	18	20	22	24	26
12, 13, 14, 15, •16							As	for Rectan gular	Beams,
17	274	191	140	107	85	69	57	48	41
18	306	213	156	120	95	77	63	53	45
19	339	235	173	132	105	85	70	59	50
20	372	258	190	145	115	93	77	65	55
21	405	281	207	158	125	101	84	70	60
22	439	305	224	171	135	110	91	76	65
23	472	328	241	184	146	118	97	82	70
24	506	351	258	198	156	126	104	88	75
25	540	374	275	211	167	135	112	94	80
26	574	399	293	224	177	143	119	100	85
27	608	422	310	238	188	152	126	106	90
28	643	446	328	251	198	161	133	111	95
29	677	470	346	265	209	169	140	118	100
30	712	495	363	278	220	178	147	124	105
31	746	518	381	291	230	186	154	129	110
32	780	542	398	305	241	195	161	135	115
33	816	566	416	319	252	204	168	142	121
34	851	591	434	332	263	213	176	148	126
35	886	615	452	346	273	221	183	154	131
36	921	640	470	356	284	230	190	160	136

CXXVI—F.

SLAB.

1 inch wide including weight of Beam. feet.					Leverage Arm.	Resistance Moment.	Area of Tensile Reinforcement.
28	30	32	34	36	Inches.	Inch-Lbs.	Sq. inches.
					....	....	....
					....	....	....
vide Table	CXXIII.				....	....	....
					....	....	....
					....	....	....
35	30	....	....	....	14·96	27,440	·11463
39	34	30	....	....	15·86	30,650	·12078
43	38	33	29	....	16·78	33,900	·12633
47	41	36	32	....	17·72	37,200	·1312
52	45	40	35	31	18·67	40,520	·13566
56	49	43	38	34	19·61	43,860	·13979
60	52	46	41	36	20·56	47,200	·14350
64	56	49	44	39	21·53	50,600	·14688
69	60	53	47	42	22·50	54,000	·15
73	64	56	50	44	23·47	57,410	·15289
78	68	59	53	47	24·44	60,820	·15554
82	71	63	56	50	25·41	64,270	·15805
86	75	66	59	52	26·40	67,750	·16038
91	79	70	62	55	27·39	71,250	·1626
95	83	73	64	57	28·36	74,600	·16439
100	87	76	67	60	29·34	78,040	·16624
104	91	80	71	63	30·34	81,580	·16805
108	95	83	74	66	31·33	85,100	·16978
113	98	86	77	68	32·32	88,620	·17138
117	102	90	80	71	33·31	92,150	·17292

TABLE

6½″

Effective Depth of T-Beam.	Safe distributed load in lbs. per running foot on intermediate spans of continuous T-Beams								
	Span in								
Inches.	10	12	14	16	18	20	22	24	26
12, 13, 14, 15, 16, 17, 18							As	for Rectan	gular Beams,
19	342	238	175	134	106	86	70	59	51
20	377	262	192	147	116	94	78	65	55
21	413	287	211	161	127	103	85	72	61
22	448	311	229	175	138	112	92	78	66
23	484	336	247	189	149	121	100	84	71
24	521	361	266	204	161	130	108	90	77
25	557	387	284	217	172	139	115	97	82
26	594	412	303	232	183	148	123	103	87
27	630	437	322	246	194	158	130	109	93
28	668	464	341	261	206	167	138	116	99
29	705	489	359	275	217	176	145	122	104
30	742	515	378	290	229	185	153	129	110
31	779	541	397	304	240	195	161	135	115
32	817	567	417	319	252	204	169	142	121
33	854	593	436	334	264	213	176	148	126
34	891	619	454	348	275	223	184	155	132
35	929	645	474	363	287	232	192	161	137
36	967	671	493	378	298	242	200	168	143

CXXVI-G.

SLAB.

1 inch wide including weight of Beam.					Leverage Arm.	Resistance Moment.	Area of Tensile Reinforcement.
feet.							
28	30	32	34	36	Inches.	Inch-Lbs.	Sq. inches.
					....	....	....
					....	....	....
					....	....	....
vide Table C	XXIII.				....	....	....
					....	....	....
					....	....	....
					....	....	....
44	38	33	30	....	16·74	34,250	·12791
48	42	37	33	29	17·64	37,730	·1337
53	46	40	36	32	18·57	41,300	·13896
57	50	44	39	35	19·51	44,830	·14361
62	54	47	42	37	20·46	48,475	·14808
66	58	51	45	40	21·40	52,070	·15209
71	62	54	48	43	22·35	55,700	·15575
76	66	58	51	46	23·32	59,370	·15912
80	70	61	54	49	24·29	63,050	·16223
85	76	65	58	51	25·27	66,800	·16312
90	78	69	61	54	26·24	70,460	·16783
95	82	72	64	57	27·21	74,200	·1704
99	86	76	67	60	28·19	77,920	·17283
104	91	80	71	63	29·18	81,700	·17503
109	95	83	74	66	30·16	85,420	·17708
114	99	87	77	69	31·13	89,100	·17889
118	103	91	80	72	32·12	92,860	·18069
123	107	94	84	74	33·11	96,670	·18248

TABLE

Effective Depth of T-Beam.	Safe distributed load in lbs. per running foot on intermediate spans of continuous T-Beams								
	Span in								
Inches	10	12	14	16	18	20	22	24	26
12, 13, 14, 15, 16, 17, 18, 19							As	for Rectan	gular Beams
20	380	264	194	148	117	95	78	66	56
21	417	289	213	163	129	104	86	72	62
22	455	316	232	178	141	114	94	79	67
23	493	843	252	193	152	123	102	86	73
24	532	369	271	208	164	133	110	92	79
25	571	397	291	223	176	143	118	99	84
26	610	424	811	238	188	153	126	106	90
27	649	450	331	253	200	162	134	113	96
28	689	478	351	269	212	172	142	119	102
29	728	506	372	284	225	182	150	126	103
30	768	533	392	300	237	192	159	133	114
31	808	561	412	316	249	202	167	140	119
32	848	589	433	331	262	212	175	147	125
33	888	617	453	347	274	222	183	154	131
34	929	645	474	363	287	232	192	161	137
35	970	674	495	379	299	242	200	168	143
36	1,009	701	515	394	311	252	208	175	149

CXXVI-H.

SLAB.

1 inch wide including weight of Beams.

feet.					Leverage Arm.	Resistance Moment.	Area of Tensile Reinforcement.
28	30	32	34	36	Inches.	Inch-Lbs.	Sq. inches.
					....	....	....
					....	....	....
					....	....	....
					....	....	....
vide Table CXXIII.					....	....	....
					....	....	....
					....	....	....
					....	....	....
48	42	37	33	29	17·6	37,960	·1348
53	46	41	36	32	18·5	41,700	·14091
58	51	44	39	35	19·43	45,550	·14654
63	55	48	43	38	20·36	49,340	·15147
68	59	52	46	41	21·30	53,180	·15604
73	63	56	49	44	22·25	57,130	·1605
78	68	60	53	47	23·21	61,040	·16437
83	72	63	56	50	24·14	64,875	·16797
88	76	67	60	53	25·12	68,870	·17136
93	81	71	63	56	26·09	72,840	·17449
98	85	75	66	59	27·06	76,800	·17739
103	90	79	70	62	28·03	80,800	·18015
108	94	83	73	65	29·00	84,800	·18276
113	99	87	77	68	29·98	88,820	·18518
118	103	91	80	72	30·96	92,870	·18749
124	108	95	84	75	31·95	97,000	·1897
129	112	98	87	78	32·93	1,00,900	·19149

TABLE

$7\frac{1}{2}''$

Effective Depth of T-Beam. Inches.	Safe distributed load in lbs. per running foot on intermediate spans of continuous T-Beams — Span in								
	10	12	14	16	18	20	22	24	26
12									
13									
14									
15									
16							As	for Rectan	gular Beams,
17									
18									
19									
20									
21	419	291	214	164	129	105	86	73	62
22	459	319	234	179	142	115	95	80	68
23	499	346	255	194	154	125	103	87	74
24	540	375	275	211	167	135	111	94	80
25	581	404	296	227	179	145	120	101	86
26	622	432	318	243	192	156	129	108	92
27	664	461	339	259	205	166	137	115	98
28	706	490	360	276	218	174	146	123	104
29	748	512	382	292	231	187	154	129	111
30	790	549	403	309	244	198	163	137	117
31	833	578	425	325	257	208	172	145	123
32	875	608	447	342	270	219	181	152	129
33	918	637	469	359	283	230	190	159	136
34	961	668	490	375	297	240	199	167	142
35	1,004	697	512	338	310	251	207	174	148
36	1,048	728	535	410	323	262	216	182	155

CXXVI-I.

SLAB.

1 inch wide including weight of Beams. feet.					Leverage Arm.	Resistance Moment.	Area of Tensile Reinforcement.
28	30	32	34	36	Inches.	Inch-lbs.	Sq. inches.
					....	....	....
					....	....	....
					....	....	....
					....	....	....
vide Table	CXXIII.				....	....	....
					....	....	....
					....	....	....
					....	....	....
					....	....	....
52	46	40	36	32	18·48	41,900	·14169
59	51	44	40	35	19·38	45,900	·14808
64	55	48	44	38	20·28	49,900	·15383
68	60	52	47	42	21·21	54,000	·15918
74	64	57	50	45	22·15	58,120	·164
79	69	61	54	48	23·09	62,250	·16847
85	74	65	57	51	24·04	66,450	·1728
90	78	69	61	54	24·99	70,620	·17664
95	83	73	65	58	25·94	74,800	·18022
101	88	77	68	61	26·91	79,050	·1836
106	92	81	72	64	27·88	83,300	·18671
112	97	85	76	67	28·85	87,550	·18967
117	102	90	79	71	29·82	91,850	·19246
123	107	94	83	74	30·80	96,150	·1951
128	111	98	87	77	31·77	1,09,400	·19756
134	116	102	91	81	32·75	1,04,800	·1999

TABLE

8″

Effective Depth of T-Beam.	Safe distributed load in lbs. per running foot on intermediate spans of continuous T-Beams								
	Span in								
Inches.	10	12	14	16	18	20	22	24	26
12	As for Rectangular Beams,								
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23	502	349	256	193	155	125	104	87	74
24	545	378	278	213	168	136	112	94	80
25	589	409	300	230	182	147	122	102	87
26	632	439	322	247	195	158	130	110	93
27	676	469	345	264	209	169	140	117	100
28	720	520	367	281	231	180	149	130	106
29	765	531	390	299	236	191	158	133	113
30	809	562	413	316	248	202	167	140	120
31	854	593	436	333	263	213	176	148	126
32	899	624	459	351	277	225	186	156	133
33	945	656	482	369	292	236	195	164	140
34	990	687	505	387	306	247	204	172	146
35	1,036	719	528	410	320	259	215	180	153
36	1,081	751	551	422	334	270	223	188	160

CXXVI-J.

SLAB.

1 inch wide including weight of Beams. feet.					Leverage Arm.	Resistance Moment.	Area of Tensile Reinforcement.
28	30	32	34	36	Inches.	Inch-lbs.	Sq. inches.
					....	....	....
					....	....	....
					....	....	....
					....	....	....
					....	....	....
vide Table CXXIII.					....	....	....
					....	....	....
					....	....	....
					....	....	....
					....	....	....
					....	....	....
64	56	49	43	39	20·24	50,200	·15497
69	60	53	47	42	21·14	54,470	·16104
75	65	57	50	45	22·08	58,900	·16675
81	70	62	55	49	23·00	63.200	·17176
86	74	66	58	52	23·94	67,600	·17642
92	80	70	62	58	24·89	72,030	·18088
98	85	75	66	59	25·83	76,500	·18511
103	90	79	70	62	26·78	80,940	·1889
109	95	83	74	66	27·73	85,400	·19248
115	100	88	72	69	28·70	89,930	·19584
120	105	92	82	73	29·68	94,500	·19805
126	110	97	86	76	30·65	99,000	·20192
132	115	101	90	80	31·62	1,03,600	·20476
138	120	105	93	83	32·59	1,08,100	·20739

TABLE

8½"

Effective Depth of T-Beam.	Safe distributed load in lbs. per running foot on intermediate spans of continuous T-Beams								
	Span in								
Inches.	10	12	14	16	18	20	22	24	26
12–23	As for Rectangular Beams,								
24	547	380	279	214	169	137	113	95	81
25	593	411	302	232	183	148	122	103	88
26	638	443	325	249	197	159	132	111	94
27	685	476	349	267	211	171	141	119	101
28	731	508	373	285	226	183	151	127	108
29	771	536	393	301	238	193	159	134	114
30	825	573	421	322	255	206	170	143	122
31	873	606	445	341	269	218	180	151	129
32	919	638	469	359	284	230	190	160	136
33	967	671	492	378	298	242	200	168	143
34	1,015	705	518	396	313	254	210	176	150
35	1,063	738	542	415	328	266	220	184	157
36	1,112	772	567	434	343	278	230	193	164

CXXVI-K.

SLAB.

1 inch wide including weight of Beam. feet.					Leverage Arm.	Resistance Moment.	Area of Tensile Reinforcement.
28	30	32	34	36	Inches.	Inch-lbs.	Sq. inches
					....	....	....
					....	....	....
					....	....	....
					....	....	....
					....	....	....
					....	....	....
vide Tabel	CXXIII.				....	....	....
					....	....	....
					....	....	....
					....	....	....
					....	....	....
					....	....	....
70	61	53	47	42	21·12	54,700	·16186
76	66	58	51	46	22·02	59,300	·16825
81	71	62	55	49	22·92	63,800	·17396
87	76	67	59	53	23·86	68,500	·17938
93	81	71	63	56	24·79	73,100	·18428
98	86	75	67	59	25·73	77,140	·18884
105	92	80	71	64	26·68	82,500	·19330
111	97	85	75	67	27·63	87,270	·19740
117	102	90	79	71	28·57	91,950	·20115
123	107	94	84	75	29·52	96,700	·20472
129	113	99	88	78	30·50	1,01,500	·20808
138	118	104	92	82	31·47	1,06,300	·21118
142	123	108	96	86	32·44	1,11,200	·21417

TABLE

9″

Effective Depth of T-Beam.	Safe distributed load in lbs. per running foot on intermediate spans of continuous T-Beams.								
	Span in								
Inches.	10	12	14	16	18	20	22	24	26
12									
13									
14									
15									
16									
17									
18									
19	As for Rectangular Beams,								
20									
21									
22									
23									
24									
25									
26	641	445	327	250	198	160	132	111	95
27	690	479	352	269	213	172	142	120	102
28	739	513	377	288	228	185	153	128	109
29	788	547	402	308	243	197	163	137	117
30	837	581	427	327	258	209	173	145	124
31	886	616	452	347	274	222	183	154	131
32	937	651	475	366	289	234	193	138	139
33	987	685	503	385	305	246	204	171	146
34	1,037	720	529	405	320	259	214	180	153
35	1,087	755	555	424	335	272	224	189	161
36	1,138	790	581	444	351	284	235	197	168

CXXVI-L.

SLAB.

1 inch wide including weight of Beam. feet.					Leverage Arm.	Resistance Moment.	Area of tensile Reinforcement.
28	30	32	34	36	Inches.	Inch-lbs.	Sq. inches.
					....	....	....
					....	....	....
					....	....	....
					....	....	....
					....	....	....
					....	....	....
					....	....	....
vide Table CXXIII.					....	....	....
					....	....	....
					....	....	....
					....	....	....
					....	....	....
					....	....	....
					....	....	....
82	71	63	55	49	22·89	64,140	·17514
88	77	67	60	53	23·79	68,960	·18117
94	82	72	66	57	24·72	73,900	·1868[illegible]
100	87	77	68	61	25·64	78,760	·19202
107	93	82	72	64	26·58	83,700	·1968
113	98	87	77	68	27·53	88,650	·20125
119	104	91	81	72	28·47	93,700	·20572
126	110	96	85	76	29·42	98,700	·20969
132	104	101	90	80	30·36	1,03,700	·21342
139	121	106	94	84	31·32	1,08,700	·21693
145	126	111	98	88	32·29	1,13,800	·22032

Notes.—(1) The table is prepared for beams 1 inch wide. The resistance moment and the area of reinforcement in a beam of known width will be obtained by multiplying the corresponding figures in the table by the figure representing the known width.

2. The safe loads given in the table are for intermediate spans of continuous T-beams where the bending moment is $\frac{wl^2}{12}$. For end spans where the bending moment $=\frac{wl^2}{10}$ deduct $16\frac{2}{3}$ per cent. and for simply supported T-beams, where the bending moment *is* $\frac{wl^2}{8}$ deduct $33\frac{1}{3}$ per cent. from the tabulated safe loads. The resistance moments and the areas of reinforcement will, of course, be the same for all the three cases.

Example.—Design a T-beam in the end span of a warehouse floor with the following data :—

Span=25′ : spacing of beams 7′ centre to centre.
Thickness of slab=$4\frac{1}{2}$″ : live load 224 lbs. per sq. ft.
Now the load per foot run on the beam is as below :—

Live load=7 × 1 × 224	=1,568 lbs.
Weight of slab=56 × 7	=392 lbs.
Weight of beam=say 240	=240 lbs.
Total load	..2,200

$$\text{Bending moment} = \frac{wl^2}{10} = \frac{2200 \times 25 \times 25 \times 12}{10}$$
$$=16{,}50{,}000 \text{ inch lbs.}$$

The width b of the beam will be the least of the following :—

(*i*) $\frac{1}{4}$th of span =6·25 ft.
(*ii*) Spacing of beams=7 ft.
(*iii*) 12 times the slab thickness=4′-6″.

The width therefore=4′-6″=54″.
Hence Bending Moment per inch width

$$= \frac{1650000}{54}$$
$$=30{,}555 \text{ inch lbs.}$$

Referring to the table CXXVI-C under $4\frac{1}{2}$″ slab, the nearest resistance moment is 31,010 inch lbs.

Hence effective depth of beam=19″
Area of reinforcement=54 × ·113
=6·1 sq. inches.

From Table CXXXV, 8—1″ diameter bars give 6·28 sq. inches.
These will be arranged in two layers of 4 bars each.

Minimum breadth of rib=5 × 1 + 4 × 1=9″.
The over all depth $=19 + \frac{1}{2} + 1 + 1$
$=21\frac{1}{2}$
say 22″.

The foregoing tables for the design of slabs and rectangular and T-beams have been based on the equal strength ratio of steel. The various coefficients corresponding to such a ratio in slabs and rectangular beams are tabulated below :—

TABLE CXXVII.

COEFFICIENTS FOR THE DESIGN OF SLABS AND RECTANGULAR BEAMS.

n = 15 p = ratio of steel

ft	fc	k	j	Ratio of steel. p.	$\frac{Mr}{bd^2}$
16,000	500	0·319	0·894	0·00499	71·38
	550	0·339	0·887	0·00585	83·02
	600	0·360	0·880	0·00675	95·04
	650	0·379	0·874	0·00769	107·54

In the case of T-beams the equal strength ratio of steel varies with the ratio of the slab thickness to the depth of the beam and the data for the design of such beams are embodied in the following table :—

(*See next page 486*).

TABLE CXXVIII

Design of T-Beams.

Data based on equal strength ratio of steel.

n = 15 ft = 16,000

k = 0.36 fc = 600

$\frac{t}{d}$	Ratio of steel : p	j	$\frac{Mr}{bd^2}$
·1	0·00323	0·953	49·25
·11	0·00349	0·948	52·94
·12	0·00375	0·944	56·64
·13	0·00399	0·940	60·00
·14	0·00423	0·936	63·35
·15	0·00445	0·931	66·29
·16	0·00467	0·928	69·34
·17	0·00487	0·924	72·00
·18	0·00506	0·920	74·48
·19	0·00524	0·916	76·80
·20	0·00542	0·913	79·17
·21	0·00558	0·909	81·15
·22	0·00573	0·906	83·06
·23	0·00587	0·903	84·81
·24	0·00600	0·90	86·40
·25	0·00612	0·897	87·83
·26	0·00623	0·894	89·11
·27	0·00633	0·892	90·34
·28	0·00642	0·89	91·42
·29	0·00649	0·888	92·21
·30	0·00656	0·886	92·99
·31	0·00662	0·884	93·63
·32	0·00667	0·883	94·13
·33	0·00670	0·881	94·44
·34	0·00673	0·881	94·87
·35	0·00674	0·88	94·90
·36	0·00675	0·88	95·04

All the foregoing tables give the minimum depth for slabs and beams. If less depth be provided, the concrete will be stressed to more than its working strength. If, on the other hand, greater depth be adopted, the steel can be proportionately reduced. The latter practice, especially in the case of T-beams, is generally advantageous and leads to economy.

Taking the case of a secondary beam of a workshop floor, with the following data,

Span = 25′; spacing of beams = 9′
Slab thickness = 5″; B. M. at centre = 10,42,000 inch lbs.
b is the least of the following :—

$$\tfrac{1}{4} \times 25 = 6 \cdot 25 \text{ ft.}$$
$$1 \times 9 = 9 \text{ ft.}$$
$$12 \cdot \times 5/12 = 5 \text{ ft.}$$
$$\text{hence } b = 5' = 60''.$$
$$\text{beniding moment per inch width} = \frac{1042000}{60} = 17{,}367$$

Referring to table CXXVI-D, under 5″ slab, it will be seen that the depth corresponding to R = 17,367 lies between 12″ and 13″, *i.e.*, nearly $\frac{1}{24}$th of the span.

The area of steel required will be about 5·67 sq. inches. Greater depth will in this case be more suitable and steel can be considerably reduced (see example under Table CXXX).

The following tables CXXIX and CXXX give the data corresponding to varying ratios of steel for slabs and rectangular and T-beams :—

(*See next page 488-489*).

TABLE CXXIX.

Data for the design of slabs and rectangular Beams.

n = 15

Ratio of Steel.	k	j	Max. Stresses in Steel and Max. $\frac{M_R}{bd^2}$ corresponding to f_c = 600 lbs. per sq. inch.		Max. Stresses in Concrete and Max. $\frac{M_R}{bd^2}$ corresponding to f_t = 16,000 lbs. per sq. inch.		Safe $\frac{M_R}{bd^2}$
			f_t	$\frac{M_R}{bd^2}$	f_c	$\frac{M_R}{bd^2}$	
0 ·001	0 ·158	0 ·947	47,950	44 ·88	200	15 ·06	15 ·06
0 ·0012	0 ·169	0 ·944	44,250	47 ·85	216	17 ·23	17 ·23
0 ·0014	0 ·181	0 ·940	40,700	51 ·06	235	20 ·08	20 ·08
0 ·0016	0 ·192	0 ·936	37,850	53 ·91	253	22 ·82	22 ·82
0 ·0018	0 ·207	0 ·931	34,500	57 ·81	270	25 ·44	25 ·44
0 ·002	0 ·217	0 ·928	32,450	60 ·42	296	29 ·80	29 ·80
0 ·0022	0 ·222	0 ·926	31,600	61 ·65	304	31 ·25	31 ·25
0 ·0024	0 ·231	0 ·923	30,000	63 ·96	320	34 ·11	34 ·11
0 ·0026	0 ·240	0 ·920	28,550	66 ·24	336	37 ·09	37 ·09
0 ·0028	0 ·248	0 ·917	27,400	68 ·25	350	39 ·80	39 ·80
0 ·003	0 ·258	0 ·914	25,950	70 ·71	370	43 ·62	43 ·62
0 ·0032	0 ·263	0 ·912	25,300	72 ·00	379	45 ·56	45 ·56
0 ·0034	0 ·271	0 ·910	24,300	73 ·98	395	48 ·83	48 ·83
0 ·0036	0 ·277	0 ·908	23,450	75 ·45	410	51 ·56	51 ·56
0 ·0038	0 ·284	0 ·905	22,750	77 ·10	422	54 ·23	54 ·23
0 ·004	0 ·292	0 ·903	21,800	79 ·11	440	58 ·01	58 ·01
0 ·0042	0 ·298	0 ·901	21,200	80 ·55	450	60 ·04	60 ·04
0 ·0044	0 ·303	0 ·899	20,700	81 ·72	465	63 ·30	63 ·30
0 ·0046	0 ·309	0 ·897	20,150	83 ·16	480	66 ·50	66 ·50
0 ·0048	0 ·314	0 ·895	19,650	84 ·30	490	68 ·80	68 ·80
0 ·005	0 ·320	0 ·893	19,100	85 ·74	500	71 ·40	71 ·40
0 ·0052	0 ·325	0 ·892	18,700	87 ·00	510	73 ·90	73 ·90
0 ·0054	0 ·330	0 ·890	18,300	88 ·11	520	76 ·40	76 ·40
0 ·0056	0 ·334	0 ·889	17,950	89 ·07	540	80 ·10	80 ·10
0 ·0058	0 ·339	0 ·887	17,550	90 ·21	550	83 ·02	83 ·02
0 ·006	0 ·344	0 ·885	17,150	91 ·32	560	85 ·20	85 ·20
0 ·0062	0 ·348	0 ·884	16,850	92 ·31	570	87 ·70	87 ·70
0 ·0064	0 ·353	0 ·882	16,500	93 ·39	580	90 ·60	90 ·60
0 ·0066	0 ·357	0 ·881	16,200	94 ·35	590	92 ·80	92 ·80
0 ·0675	0 ·360	0 ·880	16,000	95 ·04	600	95 ·04	95 ·04
0 ·0068	0 ·361	0 ·880	15,900	95 ·14	602	95 ·62	95 ·14
0 ·007	0 ·365	0 ·878	15,700	96 ·49	612	98 ·32	96 ·49
0 ·0072	0 ·369	0 ·877	15,400	98 ·12	620	101 ·02	98 ·12

TABLE CXXIX—*contd.*

Ratio of Steel.	k	j	Max. Stresses in Steel and Max. $\frac{M_R}{bd^2}$ corresponding to $f_c = 600$ lbs. per sq. inch.		Max. Stresses in Concrete and Max. $\frac{M_R}{bd^2}$ corresponding to $f_t = 16,000$ lbs. per sq. inch.		Safe $\frac{M_R}{bd^2}$
			f_t	$\frac{M_R}{bd^2}$	f_c	$\frac{M_R}{bd^2}$	
0·0074	0·373	0·876	15,150	98·20	634	103·71	98·20
0·0076	0·377	0·875	14,900	99·08	644	106·40	99·08
0·0078	0·381	0·873	14,600	99·42	655	108·96	99·42
0·008	0·384	0·872	14,450	100·80	664	111·58	100·80
0·0082	0·388	0·871	14,200	101·42	675	114·27	101·42
0·0084	0·392	0·869	13,950	101·83	686	116·80	101·83
0·0086	0·395	0·868	13,800	103·01	696	119·44	103·01
0·0088	0·398	0·867	13,600	103·76	704	122·08	103·76
0·009	0·402	0·866	13,400	104·44	715	124·70	104·44
0·0092	0·405	0·865	13,200	105·04	725	127·38	105·04
0·0094	0·408	0·864	13,000	105·58	734	129·92	105·58
0·0096	0·411	0·863	12,900	106·88	743	132·56	106·88
0·0098	0·415	0·862	12,700	107·28	755	135·15	107·28
0·01	0·418	0·861	12,550	108·05	765	137·76	108·05
0·0102	0·421	0·860	12,400	108·73	774	140·35	108·73
0·0104	0·424	0·859	12,200	108·99	784	142·91	108·99
0·0106	0·427	0·858	12,100	110·04	794	145·50	110·04
0·0108	0·430	0·857	11,950	110·60	803	148·10	110·60
0·0110	0·433	0·856	11,800	111·11	813	150·66	111·11
0·0112	0·435	0·855	11,700	112·04	821	153·22	112·04
0·0114	0·438	0·854	11,500	112·45	832	155·78	122·45
0·0116	0·441	0·853	11,400	112·80	842	158·32	112·80
0·0118	0·443	0·852	11,300	113·60	848	160·80	113·60
0·012	0·446	0·851	11,200	114·37	858	163·36	114·37

Example.—Find the stresses in steel and concrete and the resistance moment of a rectangular beam 12″ × 20″ reinforced at the bottom by four $\frac{5}{8}$″ diar. bars.

From Table CXXXV the area of the four bars = 1·227 sq. inch

$$\therefore \text{Steel ratio} = \frac{1 \cdot 227}{12 \times 20} = 0 \cdot 0051.$$

$$\text{From Table CXXIX for } p = 0 \cdot 005, \quad \frac{M_R}{bd^2} = 71 \cdot 40$$

$$\text{and for } p = 0 \cdot 0052, \quad \frac{M_R}{bd^2} = 73 \cdot 90$$

$$\text{hence for } p = 0 \cdot 0051, \quad \frac{M_R}{bd^2} = 72 \cdot 65.$$

$$\therefore M_R = 72 \cdot 65 \times bd^2$$
$$= 72 \cdot 65 \times 12 \times 20 \times 20$$
$$= 348{,}720 \text{ inch-lbs.}$$

The stress in steel = 16,000 lbs. per sq. inch.

Do. in concrete = 505 lbs. per sq. inch.

TABLE

Data for the design

n =

$\frac{t}{d}$	Ratio of steel = 0·00125						
	k	j	Max. Stresses in Steel and Max. $\frac{M_R}{bd^2}$ corresponding to f_c = 600 lbs. per sq. inch.		Max. Stresses in Concrete and Max. $\frac{M_r}{bd^2}$ corresponding to f_t = 16,000 lbs. per sq. inch.		Safe $\frac{M_R}{bd^2}$
			f_t	$\frac{M_R}{bd^2}$	f_c	$\frac{M_R}{bd^2}$	
·1	0·200	0·956	36,000	43·02	267	19·12	19·12
·11	0·193	0·952	37,650	45·42	255	19·04	19·04
·12	0·187	0·948	39,150	46·39	245	18·96	18·96
·13	0·183	0·946	40,200	47·53	239	18·92	18·92
·14	0·180	0·945	41,000	48·49	234	18·90	18·90
·15	0·178	0·943	41,550	48·97	231	18·86	18·83
·16	0·177	0·942	42,000	49·46	229	18·84	18·84
·17	0·176	0·941	42,150	49·60	229	18·83	18·83
·18	Neutral axis above the underside of slab for greater values of $\frac{t}{d}$						
·19							
·20							
·21							

CXXX.

of T-Beams.

15

$\frac{t}{d}$	k	j	Max. Stresses in Steel and Max. $\frac{M_R}{bd^2}$ corresponding to f_c = 600 lbs. per sq. inch. ft	$\frac{M_R}{bd^2}$	Max. Stresses in Concrete and Max. $\frac{M_R}{bd^2}$ corresponding to f_t = 16,000 lbs. per sq. inch. fc	$\frac{M_R}{bd^2}$	Safe $\frac{M_R}{bd^2}$
	Ratio of steel = 0·00175						
·1	0·247	0·954	27,500	44·90	350	26·71	26·71
·11	0·237	0·950	29,150	48·72	330	26·60	26·60
·12	0·228	0·947	30,600	50·70	314	26·52	26·52
·13	0·222	0·944	31,600	52·20	304	26·43	26·43
·14	0·217	0·941	32,450	53·44	295	26·35	26·35
·15	0·213	0·939	33,350	54·79	290	26·29	26·29
·16	0·210	0·936	33,900	55·53	280	26·21	26·21
·17	0·207	0·935	34,500	56·44	278	26·18	26·18
·18	0·206	0·933	34,700	56·65	277	26·12	26·12
·19	0·205	0·932	34,900	56·91	275	26·10	26·10
·20	0·205	0·932	34,900	56·91	275	26·10	26·10
·21							
·22	Neutral axis above the underside of slab for greater values of $\frac{t}{d}$						
·23							
·24							
·25							

TABLE

n=

$\frac{t}{d}$	Ratio of steel = 0·00225						
	k	j	Max. Stresses in Steel and Max. $\frac{M_R}{bd^2}$ corresponding to f_c = 600 lbs. per sq. inch.		Max. Stresses in Concrete and Max. $\frac{M_R}{bd^2}$ corresponding to f_t = 16,000 lbs. per sq. inch.		Safe $\frac{M_R}{bd^2}$
			f_t	$\frac{M_R}{bd^2}$	f_c	$\frac{M_R}{bd^2}$	
·1	0·290	0·953	21,800	46·75	435	34·31	34·31
·11	0·277	0·950	23,450	50·12	410	34·20	34·20
·12	0·266	0·946	24,900	52·06	386	34·06	34·06
·13	0·258	0·942	25,950	55·11	370	33·91	33·91
·14	0·251	0·939	26,900	56·55	357	33·80	33·80
·15	0·245	0·936	27,800	58·54	345	33·70	33·70
·16	0·240	0·933	28,550	60·07	336	33·59	33·59
·17	0·236	0·931	29,250	61·25	328	33·52	33·52
·18	0·234	0·929	29,550	61·79	325	33·44	33·44
·19	0·231	0·927	30,000	62·57	320	33·37	33·37
·20	0·230	0·926	30,150	63·82	318	33·34	33·34
·21	0·229	0·925	30.300	63·06	316	33·30	33·30
·22	0·228	0·924	30,450	63·32	314	33·26	33·26
·23	Neutral axis above the underside of slab for greater values of $\frac{t}{d}$						
·24							
·25							
·26							
·27							
·28							

CXXX—*contd.*

15

$\frac{t}{d}$	k	j	Ratio of steel = 0·00275. Max. Stresses in Steel and Max. $\frac{M_R}{bd^2}$ corresponding to f_c = 600 lbs. per sq. inch. f_t	$\frac{M_R}{bd^2}$	Max. Stresses in Concrete and Max. $\frac{M_R}{bd^2}$ corresponding to f_t = 16,000 lbs. per sq. inch. f_c	$\frac{M_R}{bd^2}$	Safe $\frac{M_R}{bd^2}$
·1	0·327	0·953	18,500	48·51	518	41·93	41·93
·11	0·313	0·949	19,800	51·68	485	41·76	41·73
·12	0·300	0·945	21,000	54·66	458	41·58	41·58
·13	0·290	0·941	22,050	58·23	435	41·40	41·40
·14	0·282	0·938	23,000	59·32	418	41·27	41·27
·15	0·274	0·934	23,900	61·37	402	41·10	41·10
·16	0·268	0·931	24,700	63·23	390	40·96	40·96
·17	0·263	0·928	25,300	64·54	380	40·83	40·83
·18	0·260	0·926	25,650	65·32	374	40·74	40·74
·19	0·256	0·924	26,200	66·57	366	40·66	40·66
·20	0·254	0·922	26,550	67·30	362	40·57	40·57
·21	0·252	0·920	26,800	68·26	358	40·48	40·48
·22	0·250	0·919	27,050	68·36	355	40·44	40·44
·23	0·250	0·918	27,150	68·40	353	40·39	40·39
·24	0·249	0·917	27,150	68·46	353	40·35	40·35
·25	Neutral axis above the underside of slab for greater values of $\frac{t}{d}$						
·26							
·27							
·28							
·29							
·30							

TABLE

n=

$\frac{t}{d}$	Ratio of steel = 0·00325.						
	k	j	Max. Stresses in Steel and Max. $\frac{M_R}{bd^2}$ corresponding to f_c = 600 lbs. per sq. inch.		Max. Stresses in Concrete and Max. $\frac{M_R}{bd^2}$ corresponding to f_t = 16,000 lbs. per sq. inch.		Safe
			f_t	$\frac{M_R}{bd^2}$	f_c	$\frac{M_R}{bd^2}$	$\frac{M_R}{bd^2}$
·1	0·361	0·953	15,900	49·20	603	49·56	49·20
·11	0·345	0·948	17,050	52·53	562	49·30	49·30
·12	0·331	0·944	18,200	55·85	527	49·09	49·09
·13	0·320	0·941	19,100	58·42	502	48·93	48·93
·14	0·310	0·937	20,050	61·05	478	48·72	48·72
·15	0·302	0·933	20,850	63·24	460	48·51	48·51
·16	0·295	0·930	21,500	64·99	446	48·36	48·30
·17	0·289	0·927	22,150	63·74	433	48·32	48·32
·18	0·284	0·924	22,750	68·33	422	48·05	48·05
·19	0·280	0·921	23,150	69·30	414	47·89	47·89
·20	0·276	0·919	23,600	70·48	406	47·79	47·79
·21	0·273	0·917	24,000	71·53	399	47·70	47·70
·22	0·271	0·915	24,300	72·26	395	47·58	47·58
·23	0·270	0·913	24,400	72·42	394	47·48	47·48
·24	0·268	0·912	24,700	73·21	389	47·42	47·42
·25	0·268	0·911	24,700	73·30	389	47·37	47·37
·26	0·267	0·911	24,800	73·44	387	47·37	47·37
·27							
·28	Neutral axis above the underside of slab for greater value of $\frac{t}{d}$						
·29							
·30							

CXXX—*contd.*

15

$\frac{t}{d}$	Ratio of steel = 0·00375.						
	k	j	Max. Stresses in Steel and Max. $\frac{M_R}{bd^2}$ corresponding to f_c = 600 lbs. per sq. inch.		Max. Stresses in Concrete and Max. $\frac{M_R}{bd^2}$ corresponding to f_t = 16,000 lbs. per sq. inch.		Safe]
			f_t	$\frac{M_R}{bd^2}$	f_c	$\frac{M_R}{bd^2}$	$\frac{M_R}{bd^2}$
·1	0·392	0·952	14,000	49·97	686	57·12	49·97
·11	0·375	0·948	15,050	53·49	640	56·88	53·49
·12	0·360	0·944	16,000	56·64	600	56·64	56·64
·13	0·347	0·940	16,900	59·57	557	56·40	56·40
·14	0·337	0·936	17,700	62·13	542	56·16	56·16
·15	0·327	0·932	18,500	64·66	518	55·92	55·92
·16	0·319	0·929	19,150	66·70	500	55·74	55·74
·17	0·312	0·926	19,950	69·10	482	55·56	55·56
·18	0·307	0·922	20,350	70·35	471	55·32	55·32
·19	0·302	0·920	20,850	71·95	461	55·20	55·20
·20	0·297	0·917	21,300	73·25	450	55·02	55·02
·21	0·294	0·914	21,600	74·03	445	54·84	54·84
·22	0·291	0·912	21,900	74·88	438	54·72	54·72
·23	0·289	0·910	22,150	75·58	433	54·60	54·60
·24	0·287	0·909	22,400	76·35	430	54·54	54·54
·25	0·286	0·907	22,450	76·35	427	54·42	54·42
·26	0·285	0·906	22,550	76·62	425	54·36	54·36
·27	0·285	0·906	22,550	76·62	425	54·36	54·36
·28	0·284	0·905	22,750	77·20	422	54·30	54·30
·29	Neutral axis above the underside of slab for greater values of $\frac{t}{d}$						
·30							
·31							
·32							
·33							

TABLE

$\frac{t}{d}$	Ratio of steel = 0·00425.						
	k	j	Max. stresses in steel and Max. M_R/bd^2 corresponding to f_c = 600 lbs. per sq. inch.		Max. stresses in concrete and Max. M_R/bd^2 corresponding to f_t = 16,000 lbs. per sq. inch.		Safe
			f_t	$\frac{M_R}{bd^2}$	f_c	$\frac{M_R}{bd^2}$	$\frac{M_R}{bd^2}$
·1	0·420	0·952	12,450	50·37	770	64·74	50·37
·11	0·407	0·948	13,150	52·97	731	64·46	52·97
·12	0·386	0·944	13,300	57·37	670	64·19	57·37
·13	0·373	0·940	15,150	60·52	634	63·92	60·52
·14	0·361	0·936	15,950	63·46	603	63·65	63·46
·15	0·357	0·932	16,200	64·16	590	63·38	63·38
·16	0·342	0·928	17,300	68·22	555	63·10	63·10
·17	0·334	0·925	17,950	70·54	534	62·90	62·90
·18	0·328	0·921	18,450	72·24	520	62·63	62·63
·19	0·322	0·918	18,950	73·94	507	62·42	62·42
·20	0·317	0·915	19,350	75·25	495	62·22	62·22
·21	0·313	0·913	19,800	76·84	485	62·08	62·08
·22	0·310	0·910	20,020	77·54	478	61·88	61·88
·23	0·307	0·908	20,350	78·54	471	61·74	61·74
·24	0·305	0·906	20,550	79·14	468	61·61	61·61
·25	0·303	0·904	20,700	79·54	463	61·47	61·47
·26	0·301	0·903	20,900	80·20	459	61·40	61·40
·27	0·300	0·902	21,000	80·50	458	61·34	61 34
·28	0·299	0·901	21,050	80·60	455	61·27	61·27
·29	0·299	0·900	21,050	80·60	455	61·20	61·20
·30	Neutral axis above the underside of slab for greater values of $\frac{t}{d}$						
·31							
·32							
·33							
·34							
·35							
·36							

CXXX—*contd.*

$\frac{t}{d}$	Ratio of steel=0.00475. k	j	Max. stresses in steel and Max. M_R/bd^2 corresponding to f =60 lbs. f_t	$\frac{M_R}{bd^2}$	Max. stresses in concrete and Max. M_R/bd^2 corresponding to f_t=16,000 lbs. sq. inch. f_c	$\frac{M_R}{bd^2}$	Safe $\frac{M_R}{bd^2}$
·1	0·445	0·952	11,250	50·86	854	72·35	50·86
·11	0·426	0·948	12,150	54·71	790	72·05	54·71
·12	0·410	0·943	12,950	58·02	741	71·67	58·02
·13	0·396	0·939	13,750	61·33	699	71·36	61·33
·14	0·384	0·935	14,450	64·17	664	71·06	64·17
·15	0·373	0·931	15,150	66·99	634	70·76	66·99
·16	0·364	0·927	15,750	69·38	610	70·45	69·38
·17	0·355	0·924	16,350	71·78	586	70·22	70·22
·18	0·350	0·920	16,700	72·99	574	69·92	69·92
·19	0·342	0·917	17,300	75·36	555	69·69	69·69
·20	0·336	0·914	17,800	77·27	539	69·46	69·46
·21	0·332	0·911	18,150	78·53	530	69·24	69·24
·22	0·328	0·909	18,450	79·67	520	69·08	69·08
·23	0·324	0·906	18,800	80·91	510	68·86	68·86
·24	0·321	0·904	19,000	81·60	505	68·70	68·70
·25	0·319	0·902	19,150	82·03	500	68·55	68·55
·26	0·317	0·900	19,350	82·72	492	68·40	68·40
·27	0·315	0·899	19,500	83·47	490	68·32	68·32
·28	0·314	0·897	19,650	83·74	488	68·17	68·17
·29	0·314	0·897	19,650	83·74	488	68·17	68·17
·30	0·313	0·896	19,800	84·28	485	68·10	68·10
·31	0·313	0·896	19,800	84·28	485	68·10	68·10
·32	Neutral axis above the under side of slab for greater values of $\frac{t}{d}$						
·33							
·34							
·35							
·36							

TABLE

$\frac{t}{d}$	Ratio of steel = 0·00525.						
	k	j	Max. Stresses in Steel and max. $\frac{M_R}{bd^2}$ corresponding to $f_c = 600$ lbs. per sq. inch.		Max. Stresses in Concrete and max. $\frac{M_R}{bd^2}$ corresponding to $f_t = 16,000$ lbs. per sq. inch.		Safe
			f_t	$\frac{M_R}{bd^2}$	f_c	$\frac{M_R}{bd^2}$	$\frac{M_R}{bd^2}$
·1	0·468	0·952	10,250	51·22	938	79·97	51.22
·11	0·450	0·948	11,000	54·75	872	79·63	54.75
·12	0·433	0·943	11,800	58·43	814	79·21	58.43
·13	0·418	0·939	12,550	61·89	765	78·88	61.89
·14	0·405	0·935	13,250	65·04	725	78·54	65.04
·15	0·393	0·931	13,920	67·93	690	78·20	67.93
·16	0·384	0·927	14,450	70·33	664	77·78	70.33
·17	0·375	0·923	15,050	72·94	639	77·53	72.94
·18	0·367	0·920	15,580	75·35	617	77·28	75.35
·19	0·360	0·916	16,000	76·94	600	76·94	76.94
·20	0·354	0·913	16,450	78·87	584	76·70	76.70
·21	0·349	0·910	16,750	80·02	572	76·44	76.44
·22	0·345	0·907	17,050	81·17	562	76·19	76.19
·23	0·341	0·905	17,350	82·54	553	76·02	76.02
·24	0·337	0·902	17,700	83·84	542	75·77	75.77
·25	0·335	0·900	17,850	84·34	537	75·60	75.60
·26	0·332	0·898	18,150	85·57	530	75·43	75.43
·27	0·330	0·896	18,300	86·10	525	75·26	75.26
·28	0·329	0·895	18,400	86·45	522	75·18	75.18
·29	0·328	0·893	18,450	86·52	520	75·01	75.01
·30	0·327	0·892	18,500	86·62	518	74·93	74.93
·31	0·326	0·892	18,650	87·26	515	74·93	74.93
·32	0·326	0·892	18,660	87·26	515	74·93	74.93
·33	Neutral axis	above the un	derside of slab f	or greater val	ues of $\frac{t}{d}$		
·34							
·35							
·36							

CXXX—*contd.*

$\frac{t}{d}$	Ratio of steel = 0·00575. k	j	Max. Stresses in Steel and max. $\frac{M_R}{bd^2}$ corresponding to f_c = 600 lbs. per sq. inch. f_t	$\frac{M_R}{bd^2}$	Max. Stresses in Concrete and max. $\frac{M_R}{bd^2}$ corresponding to f_t = 16,000 lbs. per sq. inch. f_c	$\frac{M_R}{bd^2}$	Safe $\frac{M_R}{bd^2}$
·1	0·490	0·952	9,100	51·45	1,024	87·58	51·45
·11	0·470	0·947	10,150	55·27	946	87·12	55·27
·12	0·453	0·943	10,900	59·10	882	86·76	59·10
·13	0·438	0·939	11,550	62·38	832	86·39	62·38
·14	0·425	0·935	12,200	65·60	787	86·02	65·60
·15	0·413	0·931	12,800	68·57	749	85·65	68·57
·16	0·403	0·927	13,350	71·17	718	85·28	71·17
·17	0·393	0·923	13,900	73·77	690	84·92	73·77
·18	0·385	0·919	14,400	76·10	667	84·55	76·10
·19	0·377	0·916	14,900	76·76	644	84·27	78·76
·20	0·371	0·912	15,300	80·80	628	83·90	80·80
·21	0·366	0·909	15,600	81·54	614	83·63	81·54
·22	0·361	0·906	15,950	83·10	602	83·35	83·10
·23	0·356	0·903	16,300	84·64	590	83·80	83·80
·24	0·353	0·900	16,550	85·63	582	82·80	82·80
·25	0·349	0·898	16,750	86·50	572	82·60	82·60
·26	0·346	0·896	17,000	87·58	565	82·40	82·40
·27	0·344	0·894	17,150	88·17	560	82·20	82·20
·28	0·342	0·892	17,300	88·74	555	82·10	82·10
·29	0·341	0·891	17,350	88·90	553	82·00	82·60
·30	0·340	0·889	17,450	89·20	550	81·80	81·80
·31	0·339	0·889	17,550	89·73	547	81·80	81·80
·32	0·338	0·888	17,650	90·12	544	81·70	81·70
·33	0·338	0·888	17,650	90·12	544	81·70	81·70
·34	Neutral axis	above the un	derside of slab f	or greater val	ues of $\frac{t}{d}$		
·35							
·36							

TABLE

$\frac{t}{d}$	Ratio of steel = 0·00625.						
	k	j	Max. Stresses in Steel and Max. $\frac{M_R}{bd^2}$ corresponding to f_c = 600 lbs. per sq. inch.		Max. Stresses in Concrete and Max. $\frac{M_R}{bd^2}$ corresponding to f_t = 16,000 lbs. per sq. inch.		Safe
			f_t	$\frac{M_R}{bd^2}$	f_c	$\frac{M_R}{bd^2}$	$\frac{M_R}{bd^2}$
·1	0·509	0·952	8,700	51·66	1,106	95·20	51·66
·11	0·489	0·947	9,400	55·63	1,020	94·70	55·63
·12	0·472	0·943	10,100	59·53	952	94·30	59·53
·13	0·457	0·939	10,700	62·80	896	93·60	62·80
·14	0·443	0·934	11,300	65·96	848	93·40	65·96
·15	0·431	0·930	11,900	69·16	806	93·00	69·16
·16	0·420	0·926	12,450	72·07	771	92·60	72·07
·17	0·410	0·922	12,950	74·64	739	92·20	74·64
·18	0·402	0·919	13,400	76·97	715	91·90	76·97
·19	0·394	0·915	13,850	79·22	693	91·50	79·22
·20	0·390	0·912	14,100	81·50	682	91·20	81·50
·21	0·381	0·908	14,650	83·16	655	90·80	83.16
·22	0·376	0·905	14,950	84·56	642	90·50	84·56
·23	0·371	0·902	15,300	86·25	628	90·20	86·25
·24	0·367	0·899	15,600	87·67	617	89·90	87·67
·25	0·364	0·897	15,750	88·30	610	89·70	88·30
·26	0·361	0·894	15,950	89·17	603	89·40	89·17
·27	0·358	0·892	16,150	90·07	594	89·20	89·20
·28	0·356	0·890	16,300	90·68	589	89·00	89·00
·29	0·354	0·889	16,450	91·42	584	88·90	88·90
·30	0·352	0·887	16,550	91·75	579	88·70	88·70
·31	0·351	0·886	16,600	91.93	577	88·60	88·60
·32	0·350	0·885	16,700	92·36	574	88·50	88·50
·33	0·350	0·884	16,720	92·37	574	88·40	88·40
·34	0·349	0·884	16,750	92·58	572	88.40	88·40
·35	Neutral axis	above the un	derside of slab f	or greater val	ues of $\frac{t}{d}$		
·36							

CXXX—*contd.*

$\frac{t}{d}$	Ratio of steel = 0·00675. k	j	Max. Stresses in Steel and Max. $\frac{M_R}{bd^2}$ corresponding to f_c [illegible]00 lbs. t_f	$\frac{M_R}{bd^2}$	Max. Stresses in Concrete and Max. $\frac{M_R}{bd^2}$ corresponding to ft = 16,000 lbs. per sq. inch f_c	$\frac{M_R}{bd^2}$	Safe $\frac{M_R}{bd^2}$
·1	0·528	0·952	3,050	51·72	1,192	102·82	51·72
·11	0·508	0·947	8,700	55·70	1,101	102·20	55·70
·12	0·490	0·943	9,400	59·69	1,024	101·84	59·69
·13	0·474	0·938	10,000	63·03	960	101·30	63·03
·14	0·460	0·934	10,750	66·70	907	100·97	66·70
·15	0·447	0·930	11,150	69·98	861	100·44	69·98
·16	0·436	0·926	11,650	72·83	824	100·01	72·83
·17	0·426	0·922	12,150	75·62	790	99·58	75.62
·18	0·418	0·918	12,750	77.78	765	99·14	77.78
·19	0·410	0·915	12,950	79·99	741	98·82	79·99
·20	0·402	0·911	13,400	82·40	715	98·39	82·40
·21	0·396	0·908	13,700	84·28	699	98·06	84·28
·22	0·390	0·904	14,100	86·04	682	97·63	86·04
·23	0·385	0·901	14,400	87·55	667	97·31	87·55
·24	0·381	0·898	14,650	88·83	655	96·98	88·83
·25	0·377	0·896	14,900	90·13	644	96·77	90·13
·26	0·374	0·893	15,100	90·73	637	96·44	90.73
·27	0·371	0·891	15,300	92·24	628	96·23	92·24
·28	0·368	0.889	15,500	93·00	619	96·02	93·00
·29	0·366	0·887	15,600	93·40	614	95·80	93·40
·30	0·364	0·885	15,750	94·08	610	95·58	94·08
·31	0·363	0·884	15,850	94·60	607	95·47	94·60
·32	0·362	0·882	15,900	94·69	605	95·27	94·69
·33	0·361	0·881	15,950	94·90	602	95·15	94·90
·34	0·361	0·881	15,950	94·90	602	95·15	94·90
·35	0·360	0·880	16,000	95·04	600	95·04	95·04
·36	0·360	0·880	16,000	95·04	600	95·04	95·04
	Neutral axis above the underside of slab for greater values of $\frac{t}{d}$						

TABLE CXXX—*concld.*

$\frac{t}{d}$	Ratio of steel 0.00725.						
	k	j	Max. Stresses in Steel and Max. $\frac{M_R}{bd^2}$ corresponding to f_c=600 lbs. per sq. inch.		Max. Stresses in Concrete and Max. $\frac{M_R}{bd^2}$ corresponding to f_t=16,000 lbs. per sq. inch.		Safe
			f_t	$\frac{M_R}{bd^2}$	f_c	$\frac{M_R}{bd^2}$	$\frac{M_R}{bd^2}$
·1	0·545	0·952	7,500	51·76	1,278	110·43	51·76
·11	0·525	0·947	8,150	55·95	1,178	109·85	55·95
·12	0·507	0·943	8,750	59·82	1,096	109·39	59·82
·13	0·491	0·938	9,350	63·53	1,028	108·81	63·53
·14	0·478	0·934	9,850	66·70	976	108·34	66·70
·15	0·464	0·930	10,400	70·12	922	107·88	70·12
·16	0·452	0·926	10,950	73·50	878	107·42	73·50
·17	0·442	0·922	11,350	75·86	845	106·45	75·86
·18	0·433	0·918	11,800	78·57	814	106·49	78·57
·19	0·424	0·914	12,250	81·18	784	106·02	81·18
·20	0·417	0·911	12,600	83·22	762	105·68	83·22
·21	0·410	0·907	12,950	85·15	741	105·21	85·15
·22	0·404	0·904	13,300	87·18	722	104·86	87·18
·23	0·399	0·901	13,550	88·50	707	104·52	88·50
·24	0·395	0·898	13,800	89·95	696	104·17	89·85
·25	0·390	0·895	14,100	91·48	682	103·82	91·48
·26	0·386	0·892	14,300	92·47	670	103·47	92·47
·27	0·383	0·889	14,500	93·78	661	103·12	93·78
·28	0·381	0·887	14,650	94·20	655	102·89	94·20
·29	0·378	0·885	14,850	95·72	646	102·66	95·72
·30	0·376	0·883	14,950	95·72	642	102·43	95·72
·31	0·374	0·881	15,050	96·10	637	102·20	96·10
·32	0·373	0·880	15,150	96·65	634	102·08	96·65
·33	0·372	0·879	15,250	97·16	630	101·96	97·16
·34	0·370	0·878	15,300	97·38	628	101·85	97·38
·35	0·370	0·847	15,350	97·60	626	101·73	97·60
·36	0·370	0·877	15,350	97·60	626	101·73	97·60

Example 1.—Taking now the case of the workshop beam mentioned before, we have the span=25′, b=60″ slab thickness=5″.
M=10,42,000 inch-lbs.

Take d = 20″ (generally from $\frac{1}{12}$th to $\frac{1}{16}$th)

$$\text{then } \frac{M}{bd^2} = \frac{10,42,000}{60 \times 20 \times 20}$$
$$=43 \cdot 4$$
$$\frac{t}{d} = \frac{5}{20} = \cdot 25$$

From Table CXXX for $\frac{t}{d}$ =0·25, the minimum value of $\frac{M_R}{bd^2}$ =47·37 for a ratio of steel=0·00325, and for lower ratios of steel, the neutral axis is above the underside of the slab.

The beam can therefore be designed as a rectangular beam.

The nearest value of $\frac{MR}{bd^2}$ in Table CXXIX is 43·62 for a ratio of steel=0·003

Hence adopting this ratio

Area of steel=0·003 × 60 × 20
=3·6 sq. inches.

From Table XCVII-P 6—$\frac{7}{8}$″ diameter bars give 3·607 sq. inches. These will be arranged in two layers.

Example 2.—Taking the case of the main beam of the same workshop, with the following data—

Span = 18′, thickness of slab = 5″, M = 16,80,000 inch-lbs. b = $\frac{1}{4}$ of span = $\frac{18}{4}$ = 4·5 = 54″.

Then M per inch width = $\frac{16,80,000}{54}$ =31,112 inch-lbs.

From Table CXXVI-D under 5″ slab.

the nearest resistance moment to the above is 32,300 inch-lbs. for 19″ effective depth and a reinforcement of 0·11898 sq. inch per inch width

hence total reinforcement for 19″ depth = $\frac{16,80,000}{32,300}$ × ·11898
=6·19 sq. inches.

From Table CXXXV 14—$\frac{3}{4}$″ diameter bars in three layers, or 8—1″ diameter bars in two layers will respectively give 6·185 and 6·285 sq. inches.

If due to requirements of shear we increase the effective depth to 23″

$$\text{then } \frac{M}{bd^2} = \frac{16,80,000}{54 \times 23 \times 23}$$
$$= 58 \cdot 8$$
$$\frac{t}{d} = \frac{5}{23} = \cdot 2174.$$

Now from Table CXXX for ratio of steel = 0·00375, and $\frac{t}{d}$ = 0·2174,

$\frac{M_R}{bd^2}$ lies between 54·84 and 54·72.

Similarly for ratio of steel 0·00425 and $\frac{t}{d}$ = 0·2174

$\frac{M_R}{bd^2}$ lies between 62·08 and 61·88.

Hence for $\frac{M_R}{bd^2}$ =58·8 and $\frac{t}{d}$ = 0·2174, ratio of steel lies between 0·00375 and 0·00425, We have, for $p = 0{\cdot}00375$ and $\frac{t}{d} = 0{\cdot}21$, $\frac{M_R}{bd^2} = 54{\cdot}84$

and for $p = 0{\cdot}00375$ and $\frac{t}{d} = 0{\cdot}22$, $\frac{M_R}{bd^2} = 54{\cdot}72$

hence for $p = 0{\cdot}00375$ and $\frac{t}{d} = 0{\cdot}2174$, $\frac{M_R}{bd^2} = 54{\cdot}75$

Similarly for $p = 0{\cdot}00425$ and $\frac{t}{d} = 0{\cdot}2174$, $\frac{M_R}{bd^2} = 61{\cdot}93$

from which for $\frac{t}{d} = 0{\cdot}2174$ and $\frac{M_R}{bd^2} = 58{\cdot}8$ the ratio of steel $= 0{\cdot}00403$.

$\therefore$ area of tensile reinforcement $=$ p. bd.

$= {\cdot}00403 \times 54 \times 23.$

$= 5{\cdot}00$ sq. inches.

From Table XCVII-P 5—$1\frac{1}{8}''$ diameter bars will give 4·97 sq. inches or 8—$\frac{7}{8}''$ diameter bars will give 4·81 sq. inches.

TABLE CXXXI.

Design of rectangular and T-beams with compressive reinforcement.

(Resistance moments of one sq. inch of compression steel and additional steel required in tension for that moment.)

Effective depth of beam. Inches.	Distance from top surface of beam to centre of compression steel = 1½".		Distance from top surface of beam to centre of compression steel = 2".		Distance from top surface of beam to centre of compression steel = 2½".		Distance from top surface of beam to centre of compression steel = 3".		Effective depth of beam. Inches.
	Resistance moment of one sq. inch of compression steel. Inch-lbs.	Additional steel required in tension for moment in col. 2. Sq. Inch.	Resistance moment of one sq. inch of compression steel. Inch-lbs.	Additional steel required in tension to balance the moment in col. 4. Sq. inch.	Resistance moment of one sq. inch of compression steel. Inch-lbs.	Additional steel required in tension to balance the moment in col. 6. Sq. inch.	Resistance moment of one sq. inch of compression steel. Inch-lbs.	Additional steel required in tension to balance the moment in col. 8. Sq. Inch.	
1	2	3	4	5	6	7	8	9	10
6	11,150	0·164	2,489	0·0387	..	..	....	..	6
6½	15,077	0·188	5,492	0·0763	..	..	....	..	6½
7	18,700	0·2125	8,666	0·108	..	..	....	..	7
7½	22,400	0·233	12,000	0·136	3,100	0·0389	....	..	7½
8	26,150	0·251	15,400	0·161	6,100	0·0693	....	..	8
8½	30,000	0·268	18,900	0·182	9,200	0·096	....	..	8½
9	33,850	0·282	22,500	0·201	12,450	0·12	4,050	0·012	9
9½	37,750	0·295	26,150	0·218	15,800	0·141	6,700	0·0645	9½
10	41,650	0·306	29,850	0·231	19,250	0·161	9,800	0·0875	10
10½	45,600	0·316	33,600	0·247	22,750	0·178	13,000	0·108	10½
11	49,550	0·326	37,400	0·260	26,300	0·194	16,300	0·127	11
11½	53,550	0·335	41,250	0·271	29,950	0·208	19,650	0·145	11½
12	57,600	0·343	45,100	0·282	33,600	0·221	23,100	0·16	12
13	65,650	0·357	52,900	0·301	41,100	0·2445	30,150	0·1885	13
14	73,750	0·369	60,800	0·317	48,700	0·265	37,400	0·2125	14
15	81,900	0·379	68,750	0·331	56,400	0·285	44,800	0·233	15
16	90,100	0·389	76,750	0·343	64,200	0·297	52,300	0·2515	16
17	98,300	0·396	84,800	0·3535	72,050	0·310	59,950	0·267	17
18	1,06,500	0·403	92,900	0·363	79,950	0·322	67,650	0·282	18
19	1,14,750	0·410	1,01,050	0·371	87,950	0·333	75,450	0·295	19
20	1,23,050	0·415	1,09,200	0·379	95,950	0·343	83,300	0·306	20
21	1,31,300	0·420	1,17,400	0·386	1,04,000	0·352	91,200	0·317	21
22	1,39,600	0·426	1,25,600	0·395	1,12,100	0·359	99,150	0·326	22
23	1,47,900	0·430	1,33,800	0·398	1,20,200	0·366	1,07,150	0·335	23
24	1,56,200	0·434	1,42,000	0·4035	1,28,350	0·373	1,15,150	0·343	24
25	1,64,500	0·437	1,50,250	0·408	1,36,500	0·379	1,23,200	0·3495	25
26	1,72,800	0·441	1,58,500	0·413	1,44,700	0·385	1,31,300	0·357	26
27	1,81,150	0·444	1,66,800	0·417	1,52,850	0·390	1,39,400	0·363	27

TABLE CXXXI—*concld.*

Effective depth of beam. Inches.	Distance from top surface of beam to centre of compression steel = 1½". Resistance moment of one sq. inch of compression steel. Inch-lbs.	Additional steel required in tension to balace the moment in col. 2. Sq. inch.	Distance from top surface of beam to centre of compression steel = 2". Resistance moment of one sq. inch of compression steel. Inch-lbs.	Additional steel required in tension to balance the moment in col. 4. Sq. inch.	Distance from top surface of beam to centre of compression steel = 2½". Resistance moment of one sq. inch of compression steel. Inch-lbs.	Additional steel required in tension to balance the moment in col. 6. Sq. inch.	Distance from top surface of beam to centre of compression steel = 3". Resistance moment of one sq. inch of compression steel. Inch-lbs.	Additional steel required in tension to balance the moment in col. 8. Sq. inch.	Effective depth of beam. Inches.
1	2	3	4	5	6	7	8	9	10
28	1,89,475	0·447	1,75,050	0·421	1,61,050	0·395	1,47,500	0·369	28
29	1,97,800	0·450	1,83,350	0·4244	1,69,300	0·399	1,55,650	0·374	29
30	2,06,150	0·452	1,91,650	0·428	1,77,550	0·403	1,63,800	0·379	30
31	2,14,500	0·4544	1,99,950	0·431	1,85,750	0·407	1,71,950	0·384	31
32	2,22,850	0·4565	2,08,250	0·434	1,94,050	0·411	1,80,150	0·3885	32
33	2,31,200	0·4587	2,16,550	0·437	2,02,300	0·415	1,88,350	0·3925	33
34	2,39,550	0·4606	2,24,900	0·439	2,10,550	0·418	1,96,600	0·396	34
35	2,47,900	0·4625	2,33,200	0·442	2,18,850	0·421	2,04,800	0·400	35
36	2,56,250	0·4642	2,41,550	0·444	2,27,100	0·424	2,13,050	0·4035	36

Example 1.—Design a doubly reinforced rectangular beam to resist a bending moment of 8,50,000 inch-lbs. Distance from top surface of beam to centre of compression steel = 2½", b = 12", d = 24".

From Table CXXIII, the resistance moment of a 12" × 24" beam
=12 = 54,743 = 6,56,916 inch-lbs., or say = 6,56,900 inch-lbs.
and reinforcement area = 0·162 × 12 = 1·944 sq. inch.
∴ The bending moment to be balanced by the compression steel
= 8,50,000 — 6,56,900
= 1,93,100 inch-lbs.

From Table CXXXI, the compression steel required

$$= \frac{1,93,100}{1,28,350} = 1\cdot 50 \text{ sq. inches.}$$

Additional steel required in tension = 1·5 × ·373
= ·5595
Total steel required in tension = 1·944 + ·5595
= 2·5035 sq. inches.

From Table CXXXV 5—⅝" diameter bars giving 1·534 sq. inches and 6—¾" diameter bars giving 2·65 sq. inches will be suitable in compression and tension respectively.

Example 2.—Design a T-beam of 20′ span with the slab 5" thick, spacing of beams =10′; bending moment at centre = 21,85,000 inch-lbs. depth not to exceed 23". the least width b = 12 × 5=60".

As there will probably be two layers of tensile reinforcement bars, the effective depth = 23" — 3½" = 19½", or say = 20".

From Table CXXVID the resistance moment of a T-beam with b = 60″ and d = 20″ with a slab thickness of 5″

= 35,130 × 60
= 21,07,800 inch-lbs.

Reinforcement area at bottom = ·1224 × 60
= 7·344 sq. inches.

The moment to be balanced by the compression steel
= 21,85,000 — 21,07,800
= 77,200 inch-lbs.

The distance from top surface of beam to centre of compression steel = 2″.

Hence from Table CXXXI the area of compression steel

$= \frac{77,200}{1,09,200} = 0·71$ sq. inch.

The additional area in tension to balance 77,200 inch-lbs. from table
= 0·71 × 0·379
= 0·269 sq. inch.

Total area in tension = 7·344 + 0·269
= 7·613 sq. inches.

11—$\frac{15}{16}$″ diameter bars in two layers giving 7·593 sq. inches and 4—½″ diameter bars giving 0·785 sq. inch will be suitable in tension and compression respectively. (Table CXXXV.)

R. C. C. beams under slabs and continuous over three or more supports are to be designed as T-beams at centre and as rectangular beams over supports. As the dimensions at the support are more or less determined by those at the centre, it becomes necessary to adopt double reinforcement at the supports. The Table CXXXI is especially useful for such designs.

Example 3.—Taking the case of the secondary beam of workshop in example 1 under Table CXXX, the breadth of the rib = 12″. The effective depth at supports = 23″. The bending moment over support = 12,49,000 inch-lbs.

We have in this case a rectangular beam 12″ × 23″.

From Table CXXIII, the resistance moment of the above beam
= 50,276 × 12 = 6,03,312.
or say = 6,03,300 inch-lbs.

Reinforcement at top tensile = ·1553 × 12 = 1·8636 sq. inches.

The bending moment remaining = 12,49,000 — 6,03,300
= 6,45,700 inch-lbs.

The distance from bottom of beam to centre of compression steel = 2″.

Then from Table CXXXI, the area of compression steel

$= \frac{6,45,700}{1,33,800} = 4·82$ sq. inches.

Additional steel in tension = 4·82 × 0·398
= 1·918 sq. inches.

Total area of steel in tension = 1·8636 + 1·918
= 3·7816 sq. inches.

8—⅞″ bars giving 4·81 sq. inches in compression or 5—1⅛″ diameter bars giving 4·970 sq. inches in compression will be suitable. Similarly 4—1⅛″ diameter bars in tensin will be suitable.

TABLE

WEIGHT OF REINFORCED CONCRETE MEMBERS OF

Depth Inches.	Width															
	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
3	19	22	25	28	31	34	38	41	44	47	50	53	56	59	63	66
4	25	29	33	38	42	46	50	54	58	63	67	71	75	79	83	88
5	31	36	42	47	52	57	63	68	73	78	83	89	94	99	104	109
6	38	44	50	56	63	69	75	81	88	94	100	106	113	119	125	131
7	44	51	58	66	73	80	88	95	102	109	117	124	131	139	146	153
8	50	58	67	75	83	92	100	108	117	125	133	142	150	158	176	175
9	56	66	75	84	94	103	113	122	131	141	150	160	169	178	188	197
10	63	73	83	94	104	115	125	135	146	156	167	178	188	198	208	219
11	69	80	92	103	115	126	138	149	160	172	183	195	206	218	229	241
12	75	88	100	113	125	138	150	163	175	188	200	213	225	238	250	263
13	81	95	108	122	135	149	163	176	190	203	217	230	244	257	271	284
14	88	102	117	131	146	160	175	190	204	219	233	248	263	277	292	306
15	94	109	125	141	156	172	188	203	219	234	250	266	281	297	313	328
16	100	117	133	150	167	183	200	217	233	250	267	283	300	317	333	350
17	106	124	142	159	177	195	213	230	248	266	283	301	319	336	354	372
18	113	131	150	169	188	206	225	244	263	281	300	319	338	356	375	394
19	119	139	158	178	198	218	238	257	277	297	317	336	356	376	396	416
20	125	146	167	188	208	229	250	271	292	313	333	354	375	396	417	438
21	131	153	175	197	219	241	263	284	306	328	350	372	394	415	438	459
22	138	160	183	206	229	252	275	298	321	344	367	390	413	435	[illegible]	481
23	144	168	192	216	240	261	288	311	335	359	383	407	431	455	479	503
24	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525
25	156	182	208	234	260	286	313	339	365	391	417	443	469	495	521	547
26	163	190	217	244	271	298	325	352	379	406	433	460	488	515	542	569
27	169	197	225	253	281	309	338	366	394	422	450	478	506	534	563	591
28	175	204	233	263	292	321	350	379	408	438	467	496	525	554	584	613
29	181	211	242	272	302	332	363	393	423	453	483	514	544	574	604	634
30	188	219	250	281	313	344	375	407	438	469	500	531	563	594	625	656
31	194	226	258	291	323	355	388	420	452	484	517	549	581	614	646	678
32	200	233	267	300	833	367	400	433	467	500	533	567	600	633	667	700
33	206	241	275	309	344	378	413	447	481	516	550	584	619	653	688	722
34	213	248	283	319	354	390	425	460	496	531	567	602	638	673	709	744
35	219	255	292	328	365	401	438	474	510	547	583	620	656	693	729	766
36	225	263	300	338	375	413	450	488	525	563	600	638	675	713	750	788

CXXXII.

RECTANGULAR SECTION AND 1 FOOT LONG.

In inches.

22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	Depth in inches.
69	72	75	78	81	84	88	91	94	97	100	103	106	109	113	3
92	96	100	104	108	115	117	121	125	129	133	138	142	146	150	4
114	120	125	130	135	141	146	151	156	161	167	172	177	182	187	5
138	144	150	156	163	169	175	181	188	194	200	206	213	219	225	6
160	168	175	182	190	197	204	211	219	226	233	241	248	255	263	7
183	192	200	208	217	225	233	242	250	258	267	275	283	292	300	8
206	216	225	234	244	253	263	272	281	291	300	309	319	328	338	9
229	240	250	260	271	281	292	302	313	323	333	344	354	365	375	10
252	264	275	286	298	309	321	332	344	355	367	378	390	401	413	11
275	288	300	313	325	338	350	363	375	388	400	413	425	438	450	12
298	311	325	339	352	366	379	393	407	420	433	447	460	474	488	13
321	335	350	365	379	394	408	423	438	452	467	481	496	510	525	14
344	359	375	391	406	422	438	453	469	484	500	516	531	547	563	15
367	383	400	417	433	450	467	483	500	517	534	550	567	583	600	16
390	407	425	443	460	478	496	514	531	549	567	584	602	620	638	17
413	431	450	479	488	506	527	544	563	581	600	619	638	656	675	18
435	455	475	495	515	534	555	574	594	614	633	653	673	693	713	19
458	479	500	521	542	563	583	604	625	646	667	688	709	729	750	20
481	503	525	547	569	591	613	634	656	678	700	722	744	766	788	21
504	527	550	573	596	619	642	665	688	710	733	756	779	802	825	22
527	551	575	599	623	647	671	695	719	743	767	791	815	839	863	23
550	575	600	625	650	675	700	725	750	775	800	825	850	875	900	24
573	599	625	651	677	703	729	755	781	807	833	859	885	911	938	25
596	623	650	677	704	731	758	785	813	840	867	894	921	948	975	26
619	647	675	703	731	759	788	816	844	872	900	928	956	984	1,013	27
642	671	700	729	758	788	817	816	875	904	934	963	992	1,021	1,050	28
665	695	725	755	785	816	846	876	906	936	967	997	1,027	1,057	1,088	29
688	716	750	781	813	844	875	906	938	969	1,000	1,031	1,063	1,094	1,125	30
710	743	775	807	840	872	904	936	969	1,001	1,033	1,066	1,098	1,130	1,163	31
733	767	800	833	867	900	934	967	1,000	1,033	1,067	1,100	1,133	1,167	1,200	32
756	791	825	859	894	928	963	997	1,031	1,066	1,100	1,134	1,169	1,203	1,238	33
779	815	850	885	921	956	992	1,027	1,063	1,098	1,133	1,169	1,204	1,240	1,275	34
802	839	875	911	948	984	1,021	1,057	1,094	1,130	1,167	1,203	1,240	1,276	1,313	35
825	863	900	938	975	1,013	1,050	1,088	1,125	1,163	1,200	1,238	1,275	1,313	1,350	36

TABLE

Spacing of

(Perimeter and sectional areas of round bars of various diameters and the areas

Daimeter of bar. Inches.	Perimeter of bar. Inches.	Sectional area of bar. Sq. Inches.	Sectional areas in square inches of rein- Spacing in inches of 2	2½	3	3½	4	4½	5	5½	6	6½	7
¼	0·785	0·0491	0·295	0·236	0·196	0·169	0·147	0·131	0·118	0·107	0·098	0·091	0·084
5/16	0·982	0·067	0·460	0·368	0·307	0·263	0·230	0·204	0·184	0·167	0·153	0·142	0·131
⅜	1·178	0·1104	0·662	0·530	0·442	0.378	0 331	0·294	0·265	0·241	0·221	0·204	0·189
7/16	1·374	0·1503	0·902	0·721	0·601	0·512	0·451	0·401	0·361	0·328	0·301	0·277	0·25[illegible]
½	1·571	0·1963	1·179	0·943	0·786	0·674	0·589	0·524	0·471	0·430	0·393	0·363	0·337
9/16	1·767	0·2485	1·491	1·193	0·994	0·852	0·745	0·663	0·596	0·542	0·497	0·459	0·426
⅝	1·964	0·3068	1·841	1·473	1·227	1·052	0·920	0·818	0·736	0·669	0·614	0·566	0·526
11/16	2·160	0·3712	2·227	1·782	1·485	1·273	1·114	0·990	0·891	0·810	0·742	0·685	0·636
¾	2·356	0·4418	2·651	2·121	1·767	1·515	1·325	1·178	1·060	0·964	0·884	0·816	0·757
13/16	2·553	0·5185	3·110	2·489	2·074	1·778	1·555	1·383	1·244	1·131	1·037	0·956	0·889
⅞	2·749	0·6013	3·608	2·886	2·405	2·062	1·804	1·603	1·443	1·312	1·203	1·110	1·031
15/16	2·945	0·6903	4·142	3·313	2·761	2·367	2·071	1·841	1·657	1·506	1·381	1·274	1·183
1	3·142	0·7854	4·712	3·770	3·142	2·693	2·331	2·094	1·885	1·714	1·571	1·445	1·346
1 1/16	3·338	0·8866	..	4·256	3·564	3·040	2·660	2·364	2·128	1·934	1·773	1·637	1·520
1⅛	3·534	0·9040	..	4·771	3·976	3·480	2·982	2·651	2·386	2·169	1·988	1·835	1·704
1 3/16	3·731	1·1075	..	..	4·43	3·797	3·322	2·953	2·658	2·416	2·215	2·045	1·898
1¼	3·927	1·2272	..	..	..	4·207	3·682	3·272	2·945	2·677	2·454	2·266	2·104
1 5/16	4·123	1·3530	..	..	..	4·639	4·059	3·608	3·247	2·952	2·706	2·498	2·319
1⅜	4·320	1·4849	..	..	..	..	4·455	3·960	3·564	3·240	2·970	2·741	2·831
1 7/16	4·516	1·6230	..	..	..	..	4·869	4·328	3·895	3·541	3·246	2·996	2·782
1½	4·712	1·7671	..	..	..	..	..	..	4·241	3·855	3·534	3·262	3·029

CXXXIII.

round bars in slabs.

of reinforcement per foot width of Slab for various spacings of the bars.)

forcement per 12 inch width of slabs.										Diameter of bar
bars centre to centre.										Inches.
7½	8	8½	9	9½	10	10½	11	11½	12	
0·078	0·074	0·069	0·065	0·062	0·059	0·056	0·053	0·051	0·049	¼
0·123	0·115	0·108	0·102	0·097	0·092	0·088	0·084	0·08	0·077	5/16
0·177	0·166	0·156	0·147	0·139	0·132	0·126	0·120	0·115	0·110	⅜
0·240	0·225	0·212	0·200	0·190	0·180	0·173	0·164	0·157	0·150	7/16
0·314	0·295	0·277	0·262	0·248	0·236	0·224	0·214	0·205	0·196	½
0·398	0·373	0·351	0·331	0·314	0·298	0·284	0·271	0·259	0·248	9/16
0·491	0·460	0·433	0·409	0·387	0·368	0·351	0·335	0·320	0·307	⅝
0·594	0·557	0·524	0·495	0·469	0·445	0·424	0·405	0·387	0·371	11/16
0·707	0·663	0·624	0·589	0·558	0·530	0·505	0·482	0·461	0·442	¾
0·830	0·778	0·732	0·691	0·655	0·622	0·593	0·566	0·541	0·518	13/16
0·962	0·902	0·849	0·802	0·759	0·721	0·687	0·656	0·627	0·601	⅞
1·104	1·035	0·974	0·920	0·872	0·828	0·789	0·753	0·720	0·690	15/16
1·237	1·178	1·109	1·047	0·992	0·942	0·898	0·857	0·819	0·785	1
1·418	1·330	1·352	1·182	1·120	1·064	1·013	0·967	0·925	0·887	1 1/16
1·590	1·491	1·403	1·325	1·255	1·193	1·136	1·084	1·037	0·994	1⅛
1·772	1·661	1·563	1·477	1·394	1·329	1·266	1·208	1·156	1·107	1 3/16
1·963	1·841	1·732	1·636	1·550	1·473	1·402	1·339	1·280	1·227	1¼
2·165	2·029	1·910	1·804	1·709	1·624	1·546	1·476	1·412	1·353	1 5/16
2·376	2·227	2·096	1·980	1·876	1·782	1·697	1·620	1·549	1·485	1⅜
2·597	2·434	2·291	2·164	2·050	1·948	1·855	1·770	1·693	1·623	1 7/16
2·827	2·651	2·495	2.356	2·232	2·120	2·019	1·928	1·844	1·767	1½

TABLE

Spacing

Perimeter and sectional areas of square bars of various sizes and the area

Side of square bar.	Perimeter of bar.	Sectional area of bar.	Sectional areas in square inches of										
			Spacing in inches of										
Inches.	Inches.	Sq. Inches.	2	2½	3	3½	4	4½	5	5½	6	6½	7
¼	1·00	0·0625	0·375	0·30	0·25	0·214	0·187	0·167	0·15	0·136	0·125	0·115	0·107
5/16	1·25	0·0977	0·586	0·469	0·391	0·335	0·293	0·260	0·234	0·214	0·195	0·180	0·167
⅜	1·50	0·1406	0·844	0·675	0·562	0·482	0·422	0·375	0·337	0·307	0·281	0·260	0·241
7/16	1·75	0·1914	1·148	0·919	0·766	0·656	0·574	0·510	0·459	0·418	0·383	0·353	0·328
½	2·00	0·25	1·500	1·200	1·000	0·857	0·750	0·667	0·600	0·555	0·50	0·461	0·428
9/16	2·25	0·3164	1·898	1·519	1·266	1·084	0·949	0·844	0·759	0·690	0·633	0·584	0·541
⅝	2·50	0·3906	2·344	1·875	1·562	1·340	1·172	1·042	0·937	0·852	0·781	0·721	0·670
11/16	2·75	0·4727	2·836	2·269	1·891	1·621	1·418	1·260	1·134	1·031	0·945	0·973	0·810
¾	3·00	0·5625	3·375	2·700	2·250	1·928	1·687	1·500	1·350	1·227	1·125	1·038	0·964
13/16	3·25	0·6602	3·961	3·169	2·641	2·263	1·981	1·760	1·584	1·440	1·320	1·219	1·132
⅞	3·50	0·7656	4·594	3·675	3·062	2·625	2·297	2·042	1·837	1·670	1·531	1·413	1·312
15/16	3·75	0·8789	5·273	4·219	3·516	3·013	2·637	2·344	2·109	1·918	1·757	1·623	1·507
1	4·00	1·0000	6·00	4·800	4·000	3·428	3·000	2·667	2·400	2·182	2·000	1·846	1·714
1⅛	4·50	1·2656	7·594	6·075	5·062	4·339	3·797	3·375	3·037	2·761	2·531	2·336	2·170
1¼	5·00	1·5625	9·375	7·500	6·250	5·357	4·937	4·167	3·750	3·409	3·125	2·884	2·678
1⅜	5·50	1·8906	11·344	9·075	7·562	6·482	5·672	5·042	4·537	4·125	3·781	3·490	3·241
1½	6·00	2·250	13·500	10·400	9·000	7·714	6·750	6·000	5·400	4·909	4·500	4·154	3·855

CXXXIV.

of square bars in slabs.

of reinforcement per foot width of slabs for various spacings of bars.

reinforcement per 12 inch width of slab.										
bars centre to centre.										Side of bar. Inches
7½	8	8½	9	9½	10	10½	11	11½	12	
0·100	0·094	0·088	0·083	0·079	0·075	0·071	0·068	0·065	0·062	¼
0·156	0·146	0·138	0·130	0·123	0·117	0·112	0·107	0·102	0·098	5/16
0·225	0·211	0·198	0·187	0·178	0·169	0·161	0·153	0·147	0·141	⅜
0·306	0·287	0·270	0·255	0·242	0·230	0·219	0·209	0·200	0·191	7/16
0·400	0·375	0·353	0·333	0·316	0·300	0·286	0·273	0·261	0·250	½
0·506	0·475	0·447	0·422	0·400	0·380	0·362	0·345	0·330	0·316	9/16
0·625	0·586	0·551	0·521	0·488	0·469	0·446	0·426	0·408	0·391	⅝
0·756	0·709	0·667	0·630	0·597	0·567	0·540	0·516	0·493	0·473	11/16
0.900	0·844	0·794	0·750	0·710	0·675	0·643	0·614	0·587	0·562	¾
1·056	0·990	0·932	0·880	0·834	0·792	0·754	0·720	0·688	0·660	—
1·225	1·148	1·081	1·021	0·967	0·919	0·875	0·835	0·799	0·766	⅞
1·406	1·318	1·241	1·172	1·110	1·055	1·004	0·959	0·917	0·879	—
1·600	1·500	1·412	1·333	1·263	1·200	1·143	1·091	1·043	1·000	1
2·025	1·898	1·787	1·687	1·599	1·519	1·446	1·381	1·321	1·266	1⅛
2·500	2·344	2·206	2·083	1·974	1·875	1·786	1·704	1·630	1·562	1¼
3·025	2·836	2·669	2·521	2·388	2·269	2·161	2·062	1·973	1·891	1⅜
3·600	3·375	3·176	3·000	2·842	2·700	2·571	2·455	2·365	2·250	1½

TABLE

Reinforcement

Sectional areas in square inches of various

Diameter of bars.	Number of						
Inches.	1	2	3	4	5	6	7
¼	0·049	0·098	0·147	0·196	0·245	0·294	0·343
5/16	0·076	0·153	0·230	0·306	0·383	0·460	0·536
⅜	0·110	0·220	0·331	0·441	0·552	0·662	0·772
7/16	0·150	0·300	0·450	0 601	0·751	0·901	1·052
½	0·196	0·392	0·588	0·785	0·981	1·177	1·374
9/16	0·248	0·497	0·745	0·994	1·242	1·491	1·739
⅝	0·306	0·613	0·920	1·227	1·534	1·840	2·147
11/16	0·371	0·742	1·113	1·484	1·856	2·227	2·598
¾	0·441	0·883	1·325	1·767	2·209	2·650	3·092
13/16	0·518	1·037	1·555	2·074	2·592	3·111	3·629
⅞	0·601	1·202	1·802	2·405	3·006	3·607	4·209
15/16	0·690	1·380	2·070	2·761	3·451	4·141	4·832
1	0·785	1·570	2·356	3·141	3·927	4·712	5·497
1 1/16	0·886	1·772	2·659	3·545	4·432	5·318	6·204
1⅛	0·994	1·988	2·982	3·976	4·970	5·964	6·958
1 3/16	1·107	2·215	3·322	4·430	5·537	6·645	7·752
1¼	1·227	2·454	3·681	4·908	6·136	7·363	8·590
1 5/16	1·353	2·706	4·059	5·412	6·765	8·118	9·471
1⅜	1·484	2·969	4·454	5·939	7·424	8·909	10·394
1 7/16	1·623	3·246	4·869	6·492	8·115	9·738	11·361
1½	1·767	35·34	5·301	7·068	8·835	10·602	12·369
1 9/16	1·917	3·836	5·752	7·670	9·587	11·505	13·422
1⅝	2·073	4·147	6·221	8·295	10·369	12·443	14·517
1 11/16	2·236	4·473	6·709	8·946	11·182	13·419	15·655
1¾	2·405	4·810	7·215	9·621	12·026	14·431	16·837
1 13/16	2·580	5·160	7·740	10·320	12·901	15·481	18·061
1⅞	2·761	5·522	8·283	11·044	13·806	16·567	19·328
1 15/16	2·948	5·896	8·844	11·793	14·741	17·689	20·638
2	3·141	6·283	9·424	12·566	15·708	18·849	21·991

CXXXV.

in beams and columns.

groups of round bars of uniform size.

bars in group.							Diameter of bars.
8	9	10	11	12	13	14	Inches.
0·392	0·441	0·491	0·540	0·589	0 638	0·687	1/4
0·613	0·690	0·767	0·843	0·920	0·997	1·073	5/16
0·883	0·993	1·104	1·214	1·324	1 435	1·545	3/8
1.202	1·352	1·503	1·653	1·803	1·953	2·104	7/16
1·570	1·766	1·963	2·159	2·355	2·551	2·748	1/2
1·988	2·236	2·485	2·733	2·982	3·230	3·479	9/16
2·454	2·761	3·068	3·374	3·681	3·988	4·295	5/8
2·969	3·340	3·712	4·083	4·454	4·825	5·196	11/16
3·534	3·976	4·418	4·859	5.301	5·743	6·185	3/4
4·148	4·665	5·185	5·703	6·222	6·740	7·259	13/16
4·810	5·411	6·013	6·614	7·215	7·816	8·418	7/8
5·522	6·212	6·933	7·593	8·283	8·973	9·664	15/16
6·285	7·068	7·854	8·639	9·424	0·210	10·995	1
7·091	7·977	8·864	9·750	10·636	11·523	12·409	1 1/16
7·952	8·946	9·940	10·934	11·928	12·922	13·916	1 1/8
8·860	9·967	11·075	12·182	13·290	14·397	15·505	1 3/16
9·817	11·044	12·272	13·499	14·729	15·953	17·180	1 1/4
10·824	12·177	13·530	14·883	16·236	17 589	18·942	1 5/16
11·879	13·364	14·849	16·333	17·818	19·303	20·788	1 3/8
12·984	14·607	16·230	17·853	19·476	21·099	22·722	1 7/16
14·136	15·903	17·671	19·438	21·205	22·972	24·739	1 1/2
15·340	17·257	19·175	21·092	23·010	24·927	26·845	1 9/16
16·591	18·665	20·739	22·812	24·886	26·960	29·034	1 5/8
17·892	20·128	22·365	24·601	26·838	29·074	31·311	1 11/16
19·242	21·647	24·053	26·458	28·863	31·268	33·674	1 3/4
20·641	23·221	25·802	28·382	30·962	33·542	36·122	1 13/16
22·089	24·850	27·612	30·375	33·134	35·895	38·656	1 7/8
23·586	26·534	29·483	32·431	35·370	38·327	41·276	1 15/16
25·132	28·274	31·416	34·557	37·699	40·840	43·982	2

TABLE

Design of Reinforcement

Sectional area in square inches of various

Side of bar. Inches.	Number of bars						
	1	2	3	4	5	6	7
1/4	0·062	0·125	0·187	0·25	0·312	0·375	0·437
5/16	0·098	0·195	0·293	0·391	0·488	0·586	0·684
3/8	0·141	0·281	0·422	0·562	0·703	0·844	0·984
7/16	0·191	0·383	0·574	0·766	0·957	1·148	1·340
1/2	0·250	0·50	0·750	1·00	1·250	1·500	1·75
9/16	0·316	0·633	0·949	1·266	1·582	1·898	2·215
5/8	0·391	0·781	1·172	1·562	1·953	2·344	2·734
11/16	0·473	0·945	1·418	1·891	2·363	2·836	3·309
3/4	0·562	1·125	1·687	2·250	2·812	3·375	3·937
13/16	0·660	1·320	1·981	2·641	3·301	3·961	4·621
7/8	0·766	1·531	2·297	3·062	3·828	4·594	5·359
15/16	0·879	1·758	2·637	3·416	4·394	5·273	6·152
1	1·000	2·000	3·000	4·000	5·000	6·000	7·000
1 1/8	1·266	2·531	3·797	5·062	6·328	7·594	8·859
1 1/4	1·562	3·125	4·687	6·250	7·812	9·372	10.937
1 3/8	1·891	3·781	5·672	7·562	9·453	11·344	13·234
1 1/2	2·25	4·500	6·750	9·000	11·250	13·500	15 .50

CXXXVI.

in beams and Columns.

groups of square bars of uniform size.

..n group.							Side of bar Inches.
8	9	10	11	12	13	14	
0·500	0·562	0·625	0·687	0·750	0·812	0·875	$\frac{1}{4}$
0·782	0·879	0·977	1·075	1·172	1·270	1·368	$\frac{5}{16}$
1·125	1·265	1·406	1·547	1·687	1·828	1·968	$\frac{3}{8}$
1·531	1·723	1·914	2·105	2·297	2·488	2·680	$\frac{7}{16}$
2·00	2·250	2·500	2·750	3·000	3·250	3·500	$\frac{1}{2}$
2·531	2·848	3·164	3·480	3·797	4·113	4·430	$\frac{9}{16}$
3·125	3·515	3·906	4·297	4·687	5·078	5·468	$\frac{5}{8}$
3·782	4·254	4·727	5·200	5·672	6·145	6·618	$\frac{11}{16}$
4·500	5·062	5·625	6·187	6·75	7·312	7·875	$\frac{3}{4}$
5·282	5·942	6·602	7·262	7·922	8·583	9·243	$\frac{13}{16}$
6·125	6·890	7·656	8·422	9·187	9·953	10·518	$\frac{7}{8}$
7·031	7·910	8·789	9·668	10·547	11·426	12·305	$\frac{15}{16}$
8·000	9·000	10·000	11·000	12·000	13·000	14·000	1
10·125	11·490	12·656	13·921	15·187	16·453	17·718	$1\frac{1}{8}$
12·500	14·062	15·625	17·187	18·750	20·312	21·875	$1\frac{1}{4}$
15·125	17·015	18·906	20·797	22·687	24·578	26·468	$1\frac{3}{8}$
18·000	20·250	22·500	24·750	27·000	29·250	31·500	$1\frac{1}{2}$

WEB REINFORCEMENT.

The failure of a beam will be due to one of three causes :—

(1) Failure in direct compression.

(2) Failure in direct tension.

(3) Failure in diagonal tension, or what is commonly called a shear failure.

The maximum shearing strength of a beam having no web reinforcement should be taken 60 lbs. per square inch, calculated as average shearing stress on a cross section. Web reinforcement should be provided if the shearing stress exceeds 60 lbs. per square inch on the concrete, and the concrete should then be considered as taking no shearing stress at all.

In the designs of slabs shear is not taken into account, as the section of concrete is generally suffi·ient to take up the shear due to ordinary loading It is a good practice, however, to bend up alternate rods as they approach the point of support, to provide against shear and also any possible negative bending moments there.

1. **Shear reinforcement consisting of vertical stirrups.**—Let V represent the total shear on a section. Then intensity of shear (assumed uniform) $= \frac{V}{bjd} = v$ This is also (as proved by the theorem of the ellipse of stress) the intensity of the diagonal tensile stress at 45°.

Vertical stirrups will carry only the vertical component of this diagonal tension.

Assuming that each stirrup takes the same amount of stress, equal to P, if the stirrups are spaced s inches apart

$$P = v.b.s. \quad \ldots\ldots (1)$$

$$= \frac{V}{jd} s. \quad \ldots\ldots (2)$$

Also if As be the area of the vertical stirrups at any section, and a stress, f_t, of 16,000 lbs. per square inch is allowed,

$$P = 16{,}000 \text{ As} = \frac{V}{jd} s \quad \ldots\ldots (3)$$

The resistance to shear of stirrups is calculated from the equation below :—

$$\text{Resistance to shear} = V = \frac{f_t \times a_s \times jd}{\text{pitch or spacing of stirrups}}$$

The resistance to shear at any section of bent up bars may be calculated on the assumption, that the bent up bars form the tension members of one or more single systems of lattice girders, in which the concrete forms the inclined compression members. The shear resistance at any vertical section shall be taken as the sum of the vertical components of the inclined tension and compression forces cut by such section.

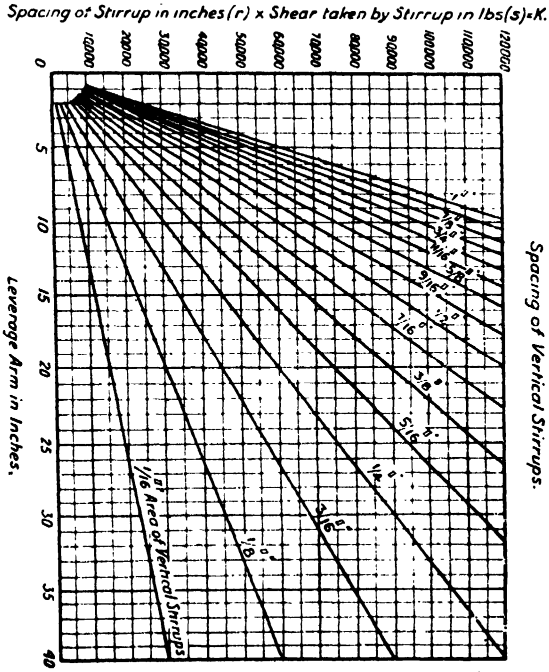
Spacing of first stirrup.

For a beam freely supported, the shear is a maximum at the ends and equal to $\frac{W}{2}$; and although in continuous beams the maximum shear will have other values, it will be sufficient to take this as the shear on all beams, supported at both ends, at the supports. When the shear stress is more than 60 lbs. per square inch, or shear reinforcement should be provided. Shear taken by the stirrups at end, S, will then be W/2 and spacing of the first stirrup $r = \frac{16,000\ A_s\ jd}{V}$ .... (4).
When an area of steel, A is bent up at an angle, the shear taken by the vertical stirrups becomes

$$V = (\frac{W}{2} - f_t.\ A_s \sin\phi) \text{ at the ends.}$$

s is then found as above.

Diagram, plate LIV, gives for corresponding values of the leverage arm and the area of shear reinforcement, the value of the spacing of the first stirrup × the shear taken by the stirrups at the end.



NOTE:- The working stress for steel in diagonal tension is taken 12,000 lbs. per square inch.

(Reduced from plate LIV.)

Example.

A T-beam of 24 inches total depth and 6 inches thickness of rib, supporting a 4-inch floor, carries a total load of 20,000 lbs. The shear reinforcement consists of vertical stirrups.

To find the area and spacing of the first stirrup. Effective depth of beam, d, may be taken as 22 inches. Also, for purposes of these calculations, the leverage arm, jd may be taken as, $= d - \frac{t}{2}$

$$\therefore \text{Leverage arm} = 22 - 4/2 = 20 \text{ inches, and } v = \frac{W}{2} = 10{,}000 \text{ lbs.}$$

Unit shear stress $= \frac{V}{jd.\ b} = \frac{10{,}000}{20 \times 6} = 84$ lbs., which is more than 60 lbs. per square inch allowed.

So the whole of the shear should be provided for by steel reinforcement.

Take stirrup $1 \times \frac{1}{8}$ inch, giving $\frac{1}{4}$ square inch in sectional area for two prongs.

From diagram for leverage arm 20″ and stirrup area $\frac{1}{4}$ square inch.

Spacing of first stirrup $\times$ v = 60,000 ....(K), for both the arms of the stirrup.

$$\therefore \text{Spacing of first stirrup} = \frac{K}{V} = \frac{60{,}000}{10{,}000} = 6''.$$

By expressing this in terms of the half span, $\frac{L}{2}$, the positions of the other stirrups can be found from table.

TABLE CXXXVII.

TABLE

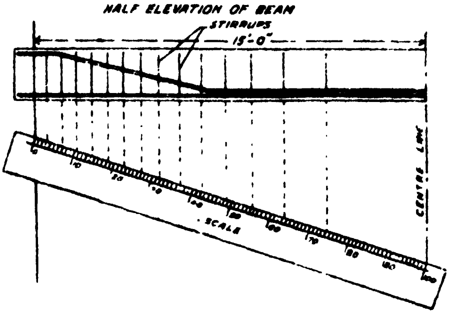
SHOWING POSITIONS OF STIRRUPS ON REINFORCED

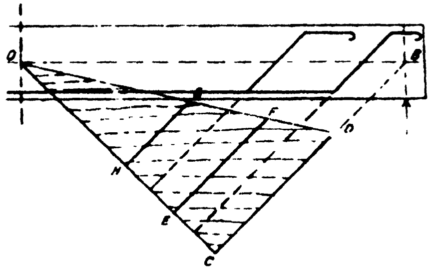
Distance from nearest support.	Number of stirrup from the nearest										
	1	2	3	4	5	6	7	8	9	10	11
$\frac{L}{2}\times$	·020	·041	·062	·084	·106	·128	·152	·175	·200	·225	·252
	·021	·043	·064	·088	·110	·134	·159	·184	·209	·236	·264
	·022	·045	·067	·092	·115	·140	·166	·192	·219	·247	·274
	·023	·047	·070	·096	·121	·147	·174	·200	·230	·260	·293
	·024	·049	·074	·100	·128	·155	·185	·211	·243	·271	·309
	·025	·051	·078	·106	·134	·163	·194	·225	·258	·293	·329
	·026	·054	·084	·112	·142	·173	·207	·239	·273	·311	·352
	·027	·058	·089	·118	·150	·184	·220	·254	·291	·332	·378
	·028	·062	·095	·125	·160	·196	·234	·272	·312	·360	·406
	·030	·066	·100	·134	·172	·210	·250	·292	·336	·393	·438
	·033	·070	·106	·144	·184	·225	·270	·317	·368	·423	·484
	·035	·074	·113	·154	·198	·245	·295	·347	·400	·463	·538
	·038	·078	·123	·167	·215	·265	·322	·382	·442	·516	·606
	·042	·086	·133	·184	·234	·293	·358	·432	·495	·589	·713
	·047	·095	·146	·200	·262	·325	·400	·474	·566	·700	—
	·051	·106	·163	·225	·293	·368	·452	·553	·684	—	
	·058	·116	·184	·252	·329	·423	·532	·665	—		
	·065	·134	·211	·293	·383	·492	·646	—			
	·075	·150	·241	·345	·459	·618	—				
	·090	·184	·293	·416	·599	—					
	·106	·225	·368	·553	—						

A convenient way of setting out these values is as follows :—

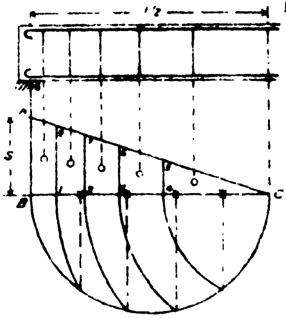
Take any scale divided into tenths, of such a length that it is equal to or greater than the half span, lay it across the drawing of the half elevation of the beam so that the zero end corresponds with the point of support and the other with the centre line of the beam. Then points corresponding to the proportionate distances of the half span can be at once marked off along the line of the scale, which, when projected upwards, will give the proper position of the stirrups. See plate LV.

Plate LV



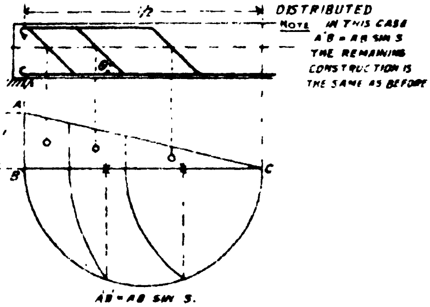


GRAPHICAL CONSTRUCTION TO LOCATE POSITIONS OF VERTICAL BARS, WHEN LOAD IS UNIFORMLY DISTRIBUTED.



NOTE—1 ABC REPRESENTS ONE HALF OF THE SHEARING FORCE DIAGRAM
2. DIVIDE BC INTO AS MANY PARTS AS THERE ARE STIRRUPS (IN THIS CASE FIVE)
3 DROP PERPENDICULARS FROM THE POINT OF DIVISION OF BC TO CUT A SEMI-CIRCLE DESCRIBED ON BC
4 WITH CENTRE C DESCRIBE ARCS PASSING THROUGH THE POINTS OF INTERSECTION ON THE SEMICIRCLE AND CUTTING LINE BC AT POINTS 1,2,3,4, THE LINES 1 2, 8-7, 3-6, AND 4 5 DRAWN PARALLEL TO AB DIVIDE TRIANGLE A B C INTO FIVE EQUAL PARTS
5 VERTICALS DRAWN TO THE BEAM THROUGH THE CENTRES OF GRAVITY OF THESE ARE AS GIVE POSITIONS OF STIRRUPS

GRAPHICAL CONSTRUCTION TO LOCATE POSITIONS OF DIAGONAL SHEAR BARS, WHEN LOAD IS UNIFORMLY DISTRIBUTED



NOTE IN THIS CASE A'B = AB SIN S THE REMAINING CONSTRUCTION IS THE SAME AS BEFORE

TO FIND THE CENTRE OF GRAVITY OF A TRAPEZIUM GRAPHICALLY

PRODUCE E, A DISTANCE EQUAL TO F, AND F IN THE OPPOSITE DIRECTION, A DISTANCE EQUAL TO E THE LINE JOINING THE EXTREMITIES CUTS THE LINE JOINING THE MIDDLE POINTS OF E AND F IN G, WHICH IS THE CENTRE OF GRAVITY

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G.P.Z.O. Poona. 1949.

CXXXVII.

CONCRETE BEAMS ON TWO SUPPORTS.

support to the centre of span.

12	13	14	15	16	17	18	19	20	21	22	23	24
·279	·307	·337	·368	·400	·434	·471	·510	·551	·600	·654	·717	800
·293	·323	·354	·389	·422	·457	·499	·540	·593	·649	·712	·785	
·309	·340	·375	·410	·447	·488	·533	·584	·641	·705	·781		
·324	·361	·399	·434	·470	·522	·575	·631	·700	·775			
·345	·383	·420	·462	·510	·562	·620	·690	·770				
·368	·408	·452	·500	·553	·613	·684	·776					
·394	·439	·485	·542	·603	·674	·769						
·420	·471	·520	·596	·666	·762							
·455	·515	·584	·657	·749								
·495	·570	·648	·749									
·553	·635	·742										
·619	·734											
·723												

2. **Shear reinforcement of inclined rods or stirrups.**—Inclined stirrups have the advantage over vertical stirrups in that the whole sectional area is effective in taking up diagonal tension. They are, however, not generally used owing to the danger of their being disturbed out of their proper position during construction.

The spacing at right angles to the line of rupture is r cos 45°

Hence

$P = v.\ b.\ r \cos 45°$ ....(5)

$= \frac{V}{jd}\ r \cos 45°$ ....(6)

Graphical method for finding the spacing of bent rods—

Referring to plate LV, calculate the total shearing stress at end ; we have from equations (1) and (2), $v = \frac{W}{2\ b.\ jd}$

Project the axis OB upon an axis OC at 45° inclination and mark off C D equal to s. Join OD. The ordinates between OD and OC will represent the shearing stresses along the beam.

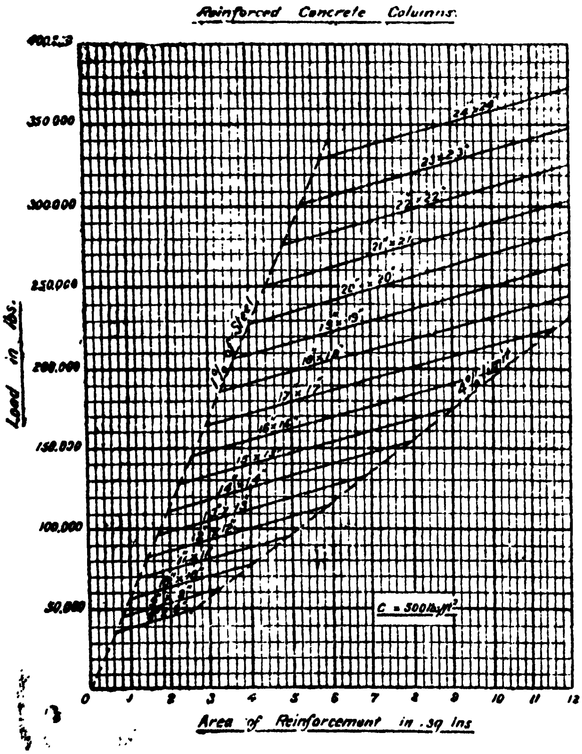
Next calculate the shearing force of the first rod, area A_s bent up.

$P_1 = ft.\ A_s \sin 45°$ ....(7)

or taking ft=16,000 lbs./inch ^{2}, $P_1 = 11\ 400\ A$ ....(8)

Then set off EF so that the area of the figure C D F E will equal this value of P_1 divided by the breadth of the beam. Through the centre of gravity of the figure CDFE draw a line at 45° and this should represent the position of the first rod bent up.

Next find an area EFGH which shall equal the shearing force taken by the second rod bent up divided by the breadth of the beam. The position of this rod will be represented by a line passing through the centre of gravity of E F G H, and so on.



(Reduced from plate LVII.)

Reinforced Concrete Columns.

General Clauses.

(1) *Longitudinal Reinforcement*.—The cross-sectional area of longitudinal reinforcement in a column, shall be not less than 0·8 per cent., nor more than 8·0 per cent. of the gross cross-sectional area of the column.

Columns with spiral (helical) reinforcemet, shall have at least six bars within and around the spiral. All other columns shall have one longitudinal bar near each angle point of the column.

At all joints in longitudinal reinforcement, the bars shall be overlapped for a length equal to twenty-four times the diameter of the upper bar, or a sufficient distance to develop the force in the bar by bond, whichever is the lesser, unless they are otherwise efficiently jointed by welding, screwing, or other means, in such a a manner as to develop the full force in the bar.

(2) *Transverse Reinforcement.*—(*i*) General—The volume of transverse reinforcement shall not be less than 0·4 per cent. of the gross volume of the column. Transverse reinforcement shll be so disposed, that every longitudinal bar is held against outward buckling, and shall have its ends anchored.

Where adequate restraint is afforded to the main longitudinal reinforcing bars by beams and slabs at points of junction with the columns, the transverse reinforcement may be modified.

(3) *Lateral Ties.*—The pitch of lateral ties shall not exceed twelve inches, and need not be less than six inches. Within these limits, the pitch shall not exceed the least lateral dimension of the column, or twelve times the diameter of any longitudinal bar.

Where the pitch is the maximum permitted, the diameter of a lateral tie shall be at least one-quarter of the largest longitudinal bar secured by it. Where a closer pitch is used, the diameter of the ties may be reduced, provided that the volume of lateral reinforcement is maintained.

(4) *Spiral (Helical) Reinforcement.*—Spiral reinforcement shall consist of evenly spaced spirals, and shall have its ends anchored.

The pitch of the spirals shall not be more than three inches or one-sixth of the diameter of the core, whichever is the lesser, and shall not be less than one inch or three times the diameter of the bar composing the spiral, whichever is the greater.

(5) *Axially-loaded Columns.*—(*i*) Short columns.

With Lateral Ties.—The axial load "P" on short columns reinforced with longitudinal bars and lateral ties, shall not be greater than the value obtained from equation.

$$P = fc\,Ac + ft\,As \quad \ldots \quad \ldots \quad \ldots(1)$$

where fc = permissible direct stress for concrete.

ft = permissible stress for longitudinal steel in direct compression.

Ac = cross-sectional area of concrete not includ ng any finishing material applied after the casting of the column,

and As = cross-sectional area of longitudinal steel.

With Spiral Reinforcement.—Where spiral reinforcement is used, the axial load "P" on the column shall not exceed the value given by equation (*1*) or equation (*2*) below, whichever is the greater.

$$P = fc\,Ak + ft\,A + 2{\cdot}0\,ftb\,A \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

where Ak = cross-sectional area of concrete in the core,

tb = permissible stress in tension in spiral reinforcement.

and Ab = equivalant area of spiral reinforcement (volume of spiral per unit length of the column).

In no case shall the sum of the loads contributed by the concrete in the core and by the spiral exceed 0·50 u. Ac where "u" is the crushing strength of the concrete required from the works test.

(*ii*) *Long Columns.*—The permissible working loads of axially loaded long columns shall not exceed the values calculated for short columns multiplied by the following buckling co-efficients.

TABLE CXXXVIII,

BUCKLING CO-EFFICIENTS FOR LONG COLUMNS.

Ratio of effective length to least lateral dimension of column.*	Ratio of effective length to least radius of gyration.*	Co-efficient.
15	50	1·0
18	60	0·9
21	70	0·8
24	80	0·7
27	90	0·6
30	100	0·5
33	110	0·4
36	120	0·3
39	130	0·2
42	140	0·1
45	150	0

*When in spirally reinforced concrete columns the permissible load is based on the core area, the least leteral dimension and radius of gyration of the column shall be taken to be the least lateral dimension and radius of gyration of the core of the column.

The least lateral dimension of the column may be used only when the cross-section of the column is symmetrical in form about each of two axes at right angles to each other and has no re-entrant angles.

The effective length to be assumed in determining the permissible working load shall be as follows :—

	Type of column.	Effective column length.
Columns of one storey.	Adequately restrained at both ends in position and direction.	0·75 of the column length.
	Adequately restrained at both ends in position but not in direction.	The column length.
	Adequately restrained at one end in position and direction and imperfectly restrained in both position and direction at the other end.	A value intermediate between the column length and twice that length, depending upon the efficiency of the imperfect restraint.

	Type of column.	Effective column length.
Columns continuing through two or more storeys.	Adequately restrained at both ends in position and direction.	0·75 of the column length.
	Adequately restrained at both ends in position and imperfectly restrained in direction at one or both ends.	A value intermediate between 0·75 and 1·00 of the column length depending upon the efficiency of the directional restraint.
	Adequately restrained at one end in position and direction and imperfectly restrained in both position and direction at the other end.	A value intermediate between, the column length and twice that length depending upon the efficiency of the imperfect restraint.

Note.—The effective length values given above are in respect of typical cases only. and embody the general principles which should be employed in assessing the appropriate value for any particular column.

Bending in column.—Bending moments in internal columns supporting an approximately symmetrical arrangement of beams need not be calculated.

Bending moments in external columns shall be provided for and unless more exact estimates are made, may be assumed to have the following values :—

	Frames of one bay.	Frames of two or more bays.
Moment at foot of upper column	$M_e \dfrac{K_u}{K_l + K_u + \dfrac{K_b}{2}}$	$M_e \dfrac{K_u}{K_l + K_u + K_b}$
Moment at head of lower column.*	$M_e \dfrac{K_l}{K_l + K_u + \dfrac{K_b}{2}}$	$M_e \dfrac{K_l}{K_l + K_u + K_b}$

*These expressions may be used for top storeys by putting $K_u = 0$ where M_e = bending moment at the end of the beam framing into the external column, assuming both ends of the beam encastered or fixed.

K_b = stiffness of beam,

K_l = stiffness of lower column,

K_u = stiffness of upper column.

In long columns the maximum stresses shall not exceed the permissible values for short columns multiplied by the co-efficients given in para. 5 (*ii*).

RECTANGULAR COLUMNS.

(Both ends fixed).

The first thing in the design of columns is the finding out of the total load the column has to carry. Having determined this load, the section of the column can be designed. All loads are supposed to act at right-angles to the plane of the cross section, the consideration of eccentric loading being left out.

A 1 : 2 : 4 mixture is supposed to carry a load of from 400 to 500 lbs. per square inch in comprssion. A 1 : 1½ : 3 mixture takes up to 583 lbs. and a 1 : 1 : 2 mixture takes up to 750 lbs. per square inch.

The I. R. C. specifications permit a stress of 13,500 lbs. per square in steel in axially loaded compressive members such as columns.

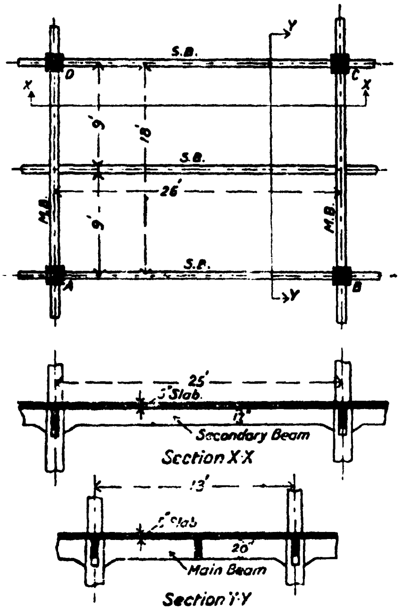
The amount of reinforcement, for short columns is found by the formula

$$W = fc\,(A + 14\,Ac),$$

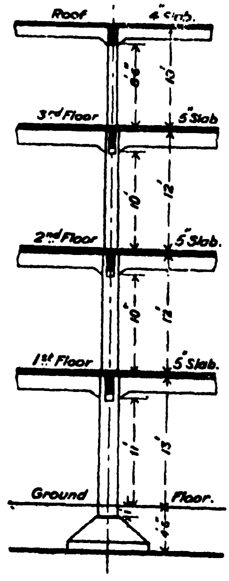
where A = effective area of concrete core
and Ac = cross sectional area of compression reinforcement, and a diagram to suit the case where fc = 500 lb. /inch ^{2} is given. Plate LVII.

The diagram is so drawn that a percentage of steel of at least 1·00 per cent. of effective concrete section, measured between the outer edges of the rods, will always be used. Distance pieces should be provided at intervals of about 5 feet so that the rods keep up their exact distances apart from one another.

For the internal details of pillar, see plate LX.



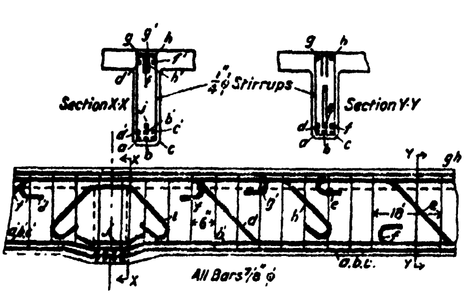
(Reduced from plate LVIII.)



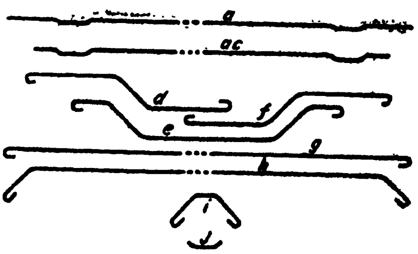
DESIGN OF PILLAR

(Reduced from plate LIX.)

DISPOSITION OF REINFORCEMENT BARS IN SECONDARY BEAMS.



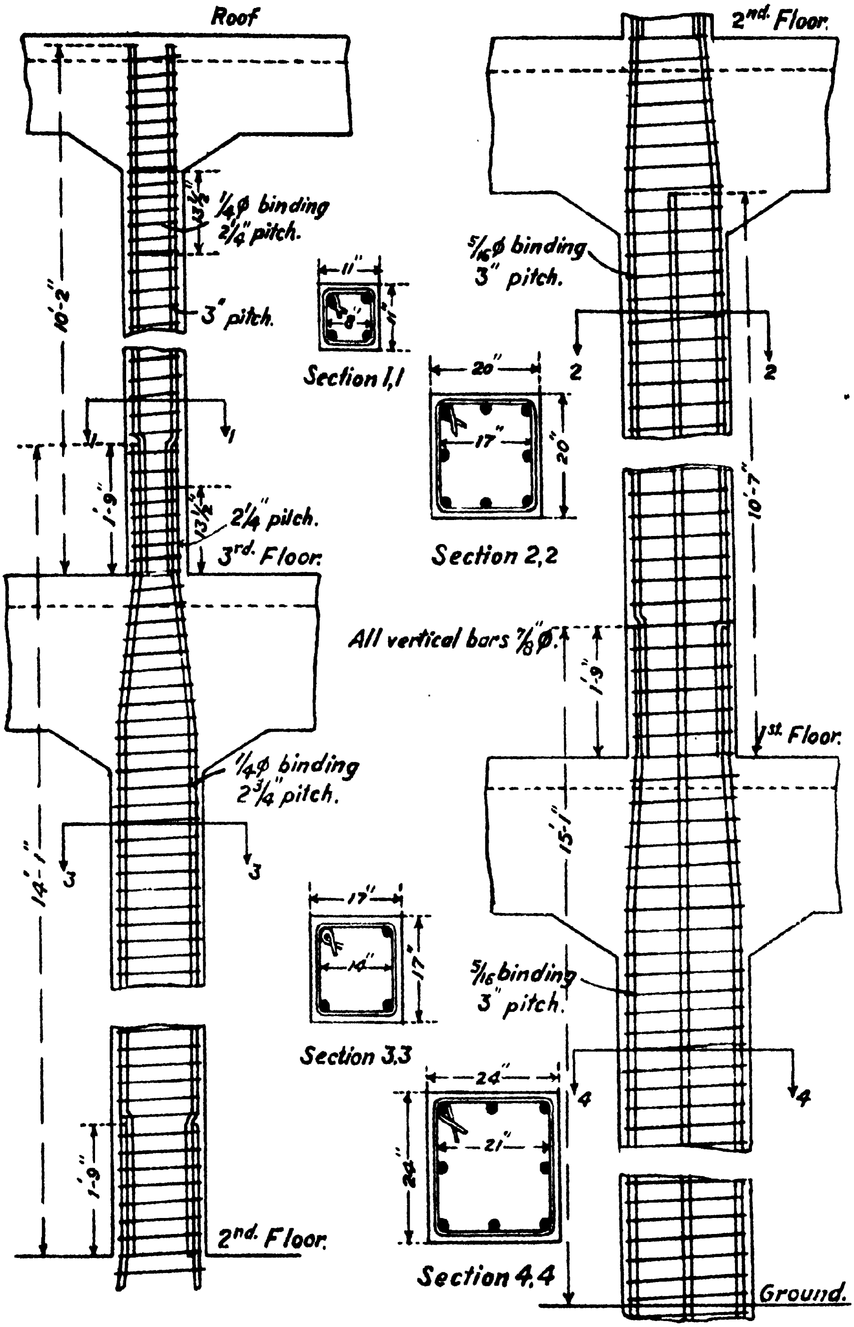
DETAILS OF SECONDARY BEAM REINFORCEMENT.



BAR BENDING DIAGRAM FOR SECONDARY BEAM.

(Reduced from plate LVI).

Plate LX



PILLAR DETAILS.

Note:— 1/2 φ means 1/2 inch round bar.

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Example.

Design a column to support a load of 250,000 lbs.
Permissible stress in concrete = 500 lbs. /in^2.
From diagram, plate LVII,

Column = 21 × 21 inches.
Ac = 4.4 square inches.
= say No. 8, ⅞ inch diameter rods.

TABLE CXXXIX.

SHOWING REINFORCEMENT IN STANCHIONS (UNHOOPED) IN SQUARE INCHES.

(Plate LVII.)

(Section of stanchions in inches.)

Load on stanchion in lbs.	8×8	10×10	12×12	14×14	16×16	18×18	20×20	22×22	24×24
20,000	0·51	1·0							
40,000	1·14		1·44						
60,000	4·00	1·43							
80,000	..	4·30		1·96					
100,000	..	..	4·00		2·56				
120,000	..	..	6·86	3·14					
140,000	..	..	..	6·00		3·24			
160,000	..	..	..	8·86	4·57				
180,000	..	..	..	..	7·43		4·0		
200,000	..	..	..	..	10·30	5·43			
220,000	..	..	..	..	..	8·30		4·84	
240,000	..	..	..	..	..	11·14	5·71		
260,000	..	..	..	..	..	14·00	8·57		
280,000	..	..	..	..	..	..	11·43	5·43	5·76
300,000	..	..	..	..	..	..	14·30	8·30	
320,000	..	..	..	..	..	..	17·14	11·14	
340,000	..	..	..	..	..	..	..	14·00	7·4
360,000	..	..	..	..	..	..	..	16·86	10·3
380,000	..	..	..	..	..	..	..	19·73	13·1
400,000	..	..	..	..	..	..	..	..	16·0
420,000	..	..	..	..	..	..	..	..	18·9
440,000	..	..	..	..	..	..	..	..	21·7
460,000	..	..	..	..	..	..	..	..	24·6

In rectangular columns, longer then 15 times its shortest side, the working stresses are reduced in proportions (k) as per table given below :—

TABLE CXL.

$\frac{L}{b}$	Values of (k)	
	Both ends fixed.	One end fixed.
16	0·91	0·84
18	0·88	0·79
20	0·85	0·75
22	0·83	0·71
24	0·81	0·67

An isolated pillar, supporting a roof truss, and receiving no lateral support from lintels, must be given a virtual length equal to twice the actual length.

Struts.—Struts are subject to all the rules applying to pillars and the combined stresses at any part should not exceed the permissible stresses for pillars of like ratios.

TABLE CXLI.

Condition of axis at ends.	Virtual length.
Both ends fixed in position and direction	v = l.
One end fixed in position and direction, and one end fixed in position, but not in direction	v = 1·4l.
Both ends fixed in position, but not in direction ...	v = 2l.
One end fixed in position and direction, and one end not fixed in position and direction	v = 4l.

FOUNDATIONS OF COLUMN.

(Plates LXI and LXII.)

To find area of base.—The base of a column is usually made square, the area required being found by dividing, the weight of the column and base *plus* the load supported, by the pressure per unit area that the soil can support safely.

If W = weight upon the footing.
R = safe unit pressure on the soil.
A = area of the footing base on plan.

Then $A = \frac{W}{R}$ ....(1).

To find the thickness, t—The minimum allowable thickness will be determined by the punching shear round the perimeter of the base of the column, but other considerations may require a greater thickness than this.

The force causing punching shear will equal the difference between the area of the slab and the area of the column, multiplied by the upward pressure intensity from the soil.

$\therefore$ if Vp = punching shear,
$Vp = R\,(l^2 - b^2)$ ....(2)

The sectional area exposed to punching shear will equal the perimeter of the column, multiplied by the depth of the slab.
$= 4\,b.\,t$

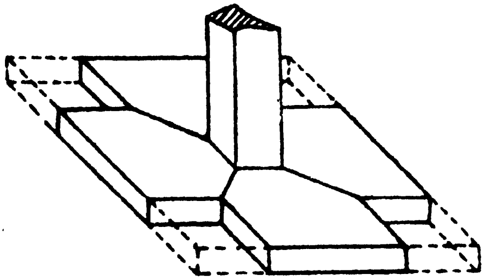
The safe resistance of concrete to punching shear is generally taken as 3 times that for shear producing diagonal tension.

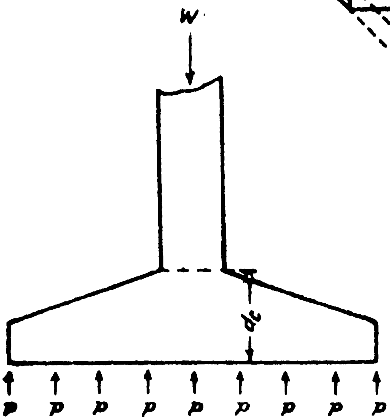
$\therefore$ if v = safe ordinary unit shear stress, the resistance to punching shear
$= 4\,b.\,t \times 3v$
$= 12\,v.\,b.\,t = Vp = R\,(l^2 - b^2)$

$\therefore t = \frac{R\,(l^2 - b^2)}{12\,b.\,v}$ ....(3)

Reinforcing foot slabs.

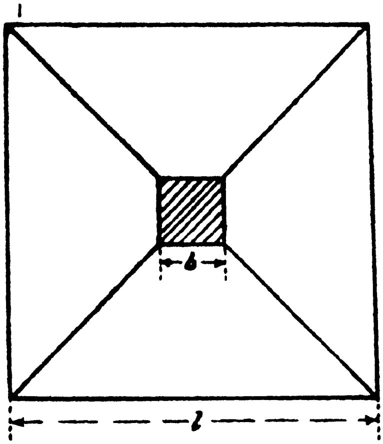
In the 2-way system of reinforcement, the bars are laid in two directions at right angles, parallel to the edges of the footing, and cover the whole area of the slab. The slab is designed on the assumption that it is composed of two main beams at





ELEVATION.

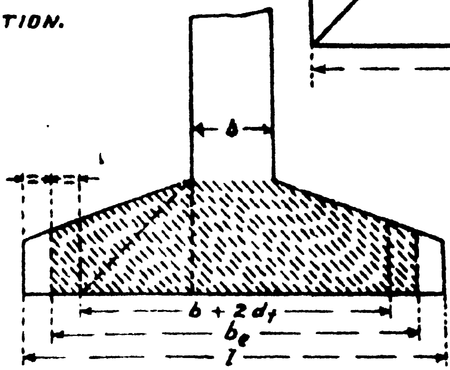
3



PLAN.

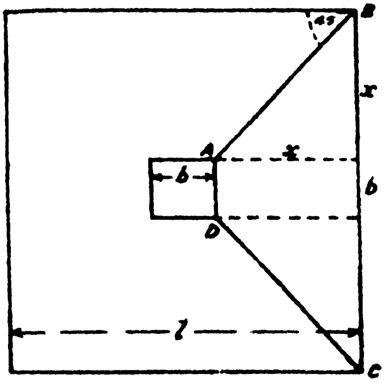
2

5



ELEVATION.

4



PLAN.

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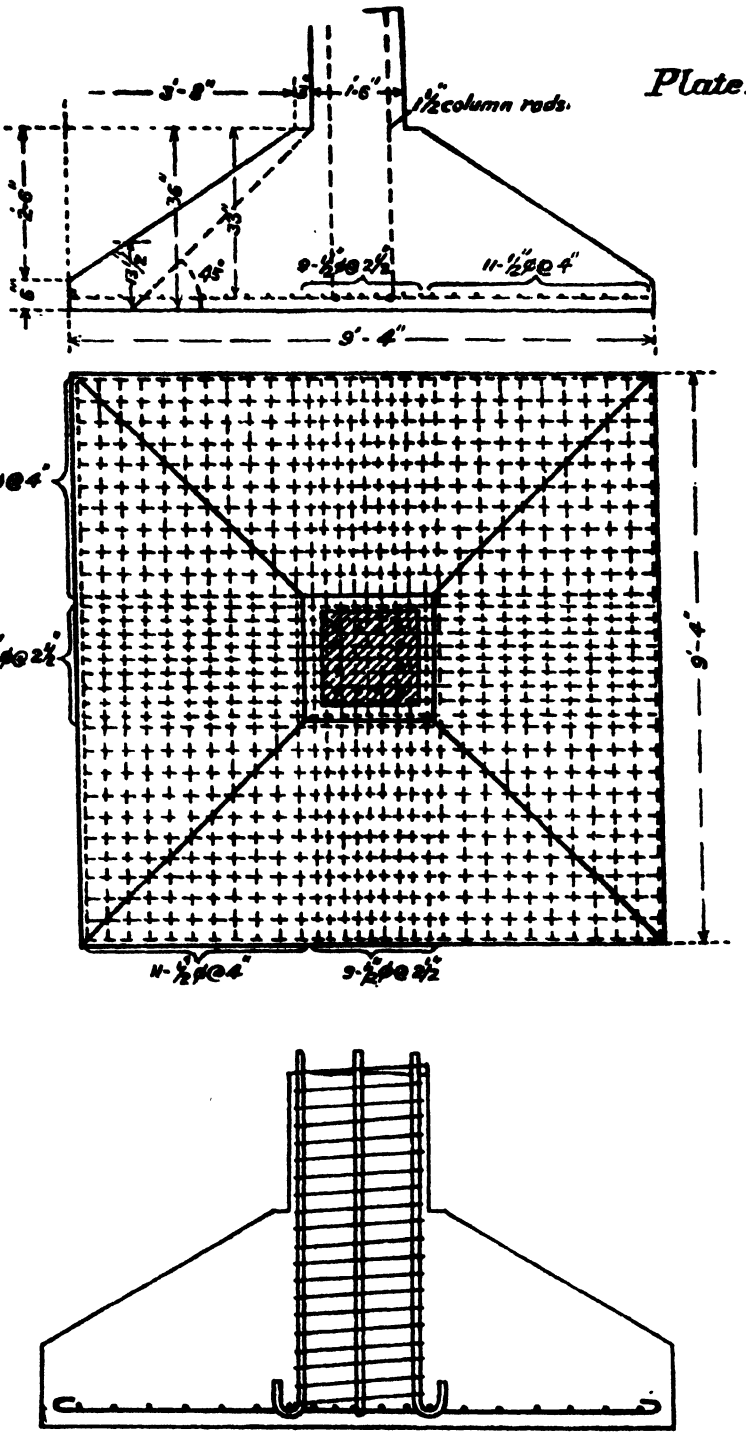
Plate LXII



FOOTING DETAIL.

To face page 5.

right angles as in plate LXI, the projecting part of each beam acting as a cantilever, of which the critical section is close to the face of the column.

Consider a square column of side b, on a square base of side l. Each cantilever is subject to a bending moment, at the critical section, due to the upward pressure of the soil on the area A B C D.

Let x = distance from the edge of column to the edge of slab. If R = unit pressure on soil,

then the bending moment about AD $= R\left\{\frac{bx^2}{2} + \frac{2x^3}{3}\right\}$....................(4)

$= \frac{Wl}{24} \times (l - \frac{b}{l})^2 (2 + \frac{b}{l}$ ....(5)

To find the bieadth of the catilever beams.—The reinforcing rods are spaced to cover the whole breadth of the slab, but the stress will be greatest in those immediately under the column, and considerably less in those nearest the edge of the slab.

As the cantilever must be calculated on the basis of equal stress in all the rods, it is necessary to take for the calculations, not the full breadth l, but some lesser breadth, such that the stress calculated from this assumed breadth will agree with the actual stress in the bar most heavily stressed.

Taking the angle of dispersion of the column load as 45°, it is the common practice to take the limits for the assumed breadth, at points half way between the edge of the slab and the point where the 45° line from the edge of the column strikes the base.

Thus if be = the assumed or equivalent breadth,

$be = \frac{1}{2} (l + b + 2t)$..............................(6).

This value for the breadth is used for calculating the reinforcement and the sectional area of steel, thus found, is that which must be contained within the limits of the breadth, be.

The remainder of the breadth is then provided with steel rods of the same size and at the same spacing as those within the equivalent breadth.

Shearing causing diagonal tension is usually tested at the section where the 45° cone of dispersion strikes the base.

Type example of design of base for a column.

Data :—

Weight on footing = 356,000 lbs.

Dimension of column = 18″ × 18″

Vertical reinforcement = 12,1½″ rods.

Stress in concrete in column = 583 lbs./in.² (assumed).

∴ Stress in rods = 15 × 583

= 8,745 lbs./in. ²

Assume a safe pressure on the soil of 2 tons per square foot.

Calculations.—To allow for the weight of the footing itself, allow 10 per cent. of the weight in the column.

In this example, allowance for the weight of footing = 35,600 lbs.

∴ Total load on the soil = 356,000 + 35,600 = 392,000 lbs. nearly.

(i) The required area of base $= \frac{392,000}{2 \times 2240} = 87 \cdot 5$ square feet.

∴ Length of the side of a square slab $= \sqrt{87 \cdot 5}$ ft.
$= 9 \cdot 35$ ft.
$= 9' - 4''$

(ii) The length of the side of column $= 18''$
$= 1 \cdot 5$ ft.

∴ If $Vp =$ the punching shear,

$$Vp = 2 \times 2240\ (9 \cdot 35^2 - 1 \cdot 5^2)$$
$$= 2 \times 2240 \times 10 \cdot 85 \times 7 \cdot 85.$$
$$= 381{,}500 \text{ lbs.}$$

If $t\delta =$ the depth of footing under the edge of column, the area resisting punching shear $= 4 \times 18 \times t\delta$ square inches.

The safe unit stress in concrete against punching shear $= 3 \times 60 = 180$ lbs./in^2.
∴ $4 \times 18 \times t\delta \times 180 = 381{,}500$.

Whence $t\delta = 29 \cdot 5'' = 30''$, say.

This depth must now be tested, to ensure that the vertical column rods are embedded in the footing for a sufficient length to develop the stress in the bars without exceeding the safe bond stress.

Sectional area of $1\frac{1}{2}''$ rod $= 1 \cdot 767$ square inches.

The perimeter of $1\frac{1}{2}''$ rod $= 4 \cdot 712''$

The unit stress in the rods $= 15 \times 583 = 8{,}745$ lbs./in^2.

The safe adhesive stress $= 100$ lbs./in^2.
∴ $t\delta. \times 4 \cdot 712 \times 100 = 1 \cdot 767 \times 8{,}745$.

Whence $t\delta = 32 \cdot 8''$.

Adding about 3 inches below the hook (to allow 1 inch for inequalities in the ground surface, upon which the concrete will be laid), the total depth will be taken as 36 inches and the effective depth for the slab rods will be 33 inches.

The shape of the base will be as in plate LXII.

A ledge 3 inches wide will be left round the base of the column, to facilitate the placing of the column centring. The footing will then be sloped off to a thickness of 6 inches, at the outer edges.

(iii) The equivalent breadth

$$= be = \tfrac{1}{2}\ (112 + 18 + \overline{2 \times 36}).$$
$$= 101''$$

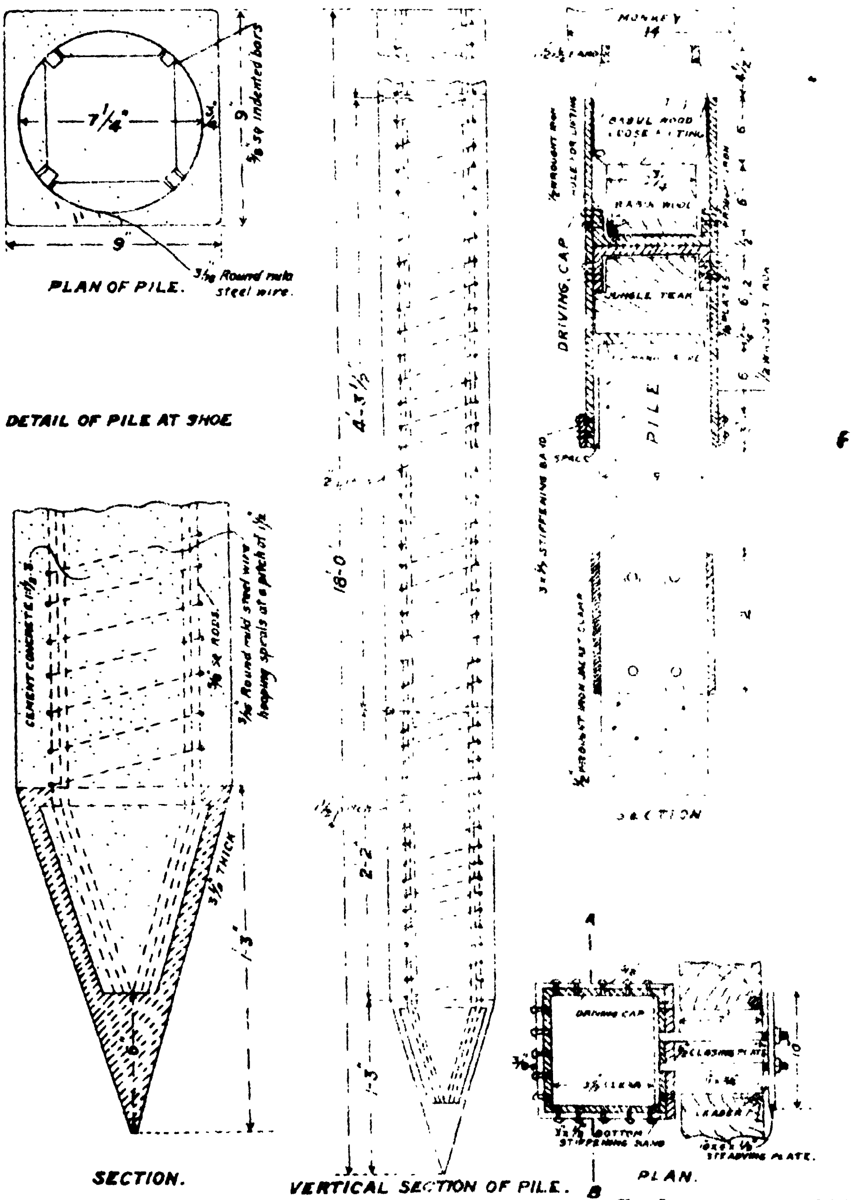
The bending moment on one cantilever at the critical section $= \frac{Wl}{24} \times (l - \frac{b}{l})^2 \times (2 + \frac{b}{l})$. (See *ante.*)

$= 2{,}766{,}000$ in-lbs. (neglecting the opposite bending moment due to the weight of the footing itself),
which requires a reinforcement of $5 \cdot 67$ square inches. The usual size of bar for footings is $\frac{1}{2}$ inch, with sectional area of $0 \cdot 196$ square inch.

∴ the number required in a breadth of 101 inches $= \frac{5 \cdot 67}{0 \cdot 196} = 29$.

Plate LXIII

CONCRETE PILES
USED IN THE
NEW SEA WALL
ON THE
KENNEDY SEA-FACE, BOMBAY.



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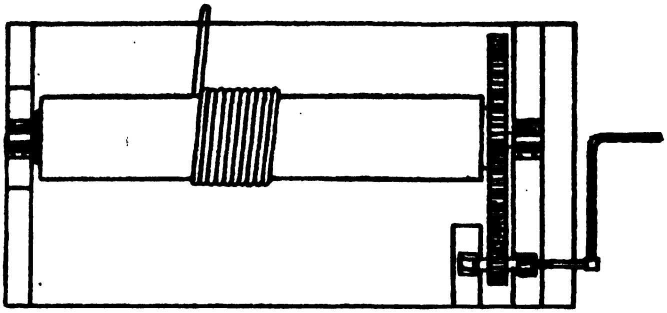
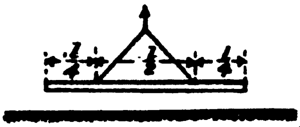
G. P. Z. O. 1949.

Plate LXIV

REINFORCED CONCRETE PILES.



METHOD OF WINDING HELICAL REINFORCEMENT FOR PILES



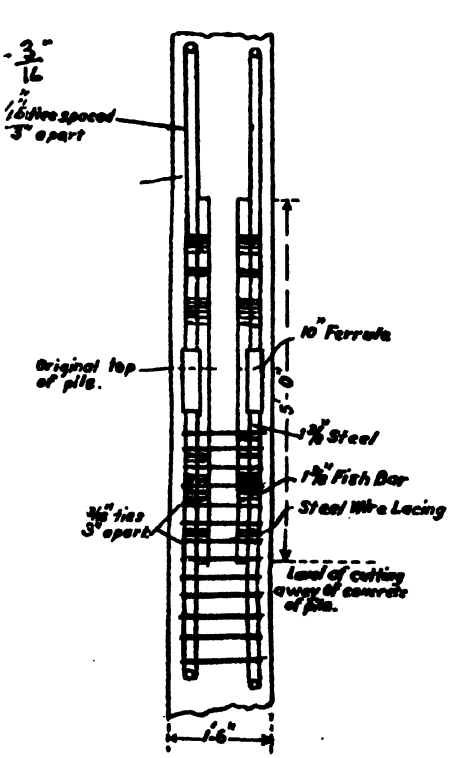
Supported Beam Span $\frac{1}{2}$

$B = \frac{wl^2}{32}$

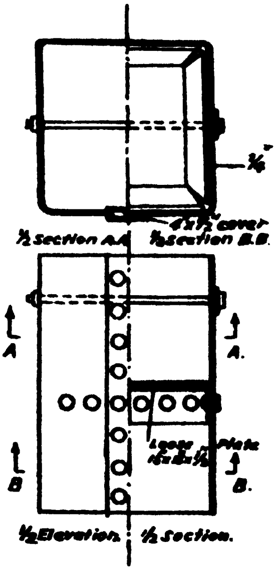
Cantilever Span $\frac{1}{4}$

$B = \frac{wl^2}{32}$

CORRECT METHOD OF LIFTING REINFORCED CONCRETE PILE.



METHOD OF LENGTHENING PILE.



MILD STEEL HELMET FOR DRIVING R.C. PILES

To face page 533

Nine rods will be grouped under the column at a spacing of 2½ inches, with 10 rods on each side at a spacing of 4″.

One extra rod at each end will cover the remaining 5½ inches, making 31 rods in all.

A similar set will be laid at right angles.

(iv) Test for shear causing diagonal tension.—

The 45° cone of dispersion strikes the base at a distance, from the centre, of 9″ + 36″ = 45″.

= 11″ from the edge.

Total depth at this point $= 6'' + 11/44 \times 30$

$= 13\frac{1}{2}''$.

Effective depth $= 10\frac{1}{2}''$.

Lever arm $= 10 \cdot 5 \times 0 \cdot 88$ nearly.

$= 9''$.

If S = shearing force, $S = \frac{2 \times 2240}{144} \times (112^2 - 90^2)$.

$\therefore S = \frac{2240}{72} \times 202 \times 22$.

$= 138{,}200$ lbs.

Total perimeter of the critical section $= 4 \times 90 = 360''$.

$\therefore$ Unit shear stress $= s = \frac{S}{\text{b.a.}} = \frac{138{,}200}{360 \times 9} = 42 \cdot 7$ lbs./in², which is less than the maximum safe value of 60 lbs./in². Had it been greater, it would have been necessary either to provide stirrups or to increase the depth of the footing. The ater is preferable, as stirrups are difficult to fix in footings.

(v) Finally, test for bond stress in the main reinforcing rods.

The shear at the critical section at the edge of column = ¼ of the punching shares.

$= \frac{381{,}500}{4} = 95{,}400$ lbs., nearly.

The number of ½ in. bars in the equivalent breadth, $be = 29$.

The perimeter of a ½ in. bar $= 1 \cdot 571$ in.

$\therefore$ The total perimeter, $29 \times 1 \cdot 571'' = 45 \cdot 6''$.

The lever arm $= 33 \times 0 \cdot 88$ nearly.

$= 29''$

$\therefore$ bond stress $\frac{95{,}400}{45 \cdot 6 \times 29}$

$= 72 \cdot 1$ lbs./in².

which is less than the safe allowable stress of 100 lbs. per square inch.

Had it been greater, it would have been necessary to diminish the diameter and increase the number of bars, so as to prov.de the requisite surface and cross sectional area.

The design shown in the sketch is, therefore, satisfactory.

REINFORCED CEMENT CONCRETE PILES.

(Plates LXIII and LXIV.)

1. **General.**—The use of reinforced concrete piles has many advantages over the use of timber or steel, the principal being the immunity from rot or rust.

In marine work particularly the condition of alternating wetting and drying causes rapid rotting of timber and rusting of steel and, in addition, the former material is liable to the attacks of marine borers.

On the other hand, if concrete piles are used, sometime must elapse between the decision to commence work and the driving of piles, as the later must be cured for at least a month before driving.

Concrete piles are much heavier than those of timber and the handling of long lengths require great care to avoid fracture.

2. **Manufacture.**—Piles are generally cast horizontally in a pile yard for transport to the site as required. This economizes in forms, and gives a more uniform composition to the pile than if it were cast vertically.

The bars are kept at the right distances apart by forked distance pieces of flat or round iron, placed at suitable intervals, and incorporated in the pile.

Piles are usually made of rich mixtures, the commonest being :—

1 : 1½ : 3
1 : 2 : 2
1 : 1 : 2

The ends are generally cast with a rather richer mixture than that used in the body of the pile.

The maximum size of coarse aggregate is limited to ½ inch, as compared with ¾ inch for ordinary reinforced concrete work.

Plate LXIII shows the method of attaching a pile shoe to the foot of the pile.

All piles should be well provided with lateral hoops throughout their length. The usual size of binding is 3/16 inch with a spacing of 2 inches to 3 inches for a length of 3 feet at each end of the pile, lengthening to 10 inches, at the centre.

3. **Form and size.**—The driving stresses being indeterminate, as they depend on the resistance of the ground to penetration, the sizes of the piles and the ratio of reinforcement generally follow empirical rules, rather than theoretical treatment as columns.

The usual forms of piles are :—

(*a*) Square, with one rod at each corner.
(*b*) Octagonal, with one rod at each angle.

The usual sizes of square piles are :—

12″ × 12″ up to 40′ long.
14″ × 14″ from 40′ to 50′.
16″ × 16″ above 50′.

The proportion of steel varies from 5 per cent. for long piles to 2½ per cent. for short piles.

The usual sizes of rods for square piles are :—

Up to 40′ long	1″, ⅞″, or ¾″
40′ to 50′ long	1⅛″
Above 50′	1¼″ to 1¾″

Above 50′, resistance to fracture, when lifted from the ground, is the deciding factor.

4. **Handling.**—To minimise lifting stresses, the pile should be hung at the quarter points, pipe holes being left at these points into which lifting bars can be inserted. See plate LXIV.

Great care should be taken to keep the sides vertical during transport. Should the diagonal become vertical, the moment of resistance of the compressive flange is reduced nearly by 36 per cent., and the danger of fracture is correspondingly increased.

5. **Driving.**—For driving piles, a cast iron or built up steel helmet of the type shown in plate LXIV should be used. The underside of the diaphragm should be lined with about 2 inches of planking, and the head should be packed with wooden billets, placed vertically, with a sufficient projection above the edge of the helmet to allow for brooming. An alternative arrangement is shown in plate LXIII.

The usual practice is to employ a heavy monkey, say 2 to 2½ tons, with a fall varying from 15 inches to 6 feet, according to the nature of soil. On the Kennedy Sea Face, Bombay, monkey of 30 cwts. was used. and the largest pile driven weighed about 1 ton. For a pile weighing 3 tons, monkey weighing 40 to 60 cwts. would be suitable.

6. **Lengthening piles.**—Owing to delay and trouble involved in lengthening a pile after driving, it is most important that trial piles, of timber, should be driven at various places over the site.

Should the driven piles require to be lengthened, the concrete at the heads should be hacked off until the rods are exposed for a length of at least 3 feet. Ferrules should be placed on the heads of the rods, new lengths butted on, and the joints stiffened by fish bars at least 3 feet to 5 feet long ; and the whole, well laced by steel wire.

The old surface of concrete must be well cleaned and brushed, the column shuttering erected, and the additional length cast and allowed to cure for at least one month before driving is continued.

If for any reason lengthening *in situ* is impossible, and the piles are cast to their full length, the weight to be handled can be reduced to manageable proportions by casting them hollow, by laying a line of stoneware drain pipes inside the lateral bindings. After being driven the hollow is filled up with concrete.

7. **Ready-made piles.**—Reinforced concrete piles can sometimes be purchased ready-made from specialist firms in this form of construction. Where the site is accessible to barges, it may be cheaper to obtain them in this way than to instal a pile manufacturing plant on the spot.

TABLE CXLII.

ROUND IRON RODS.

Diameter of rods in inches.	Round rods.		
	Circumference in inches.	Sectional area in sq. inches.	Wt. in lbs. per r. ft.
¼	0·785	0·049	0·167
⅜	1·178	0·110	0·376
½	1·571	0·196	0·668
⅝	1·964	0·307	1·043
¾	2·356	0·442	1·502
⅞	2·748	0·601	2·044
1	3·142	0·785	2·670
1⅛	3·534	0·994	3·380
1¼	3·927	1·227	4·172
1⅜	4·320	1·485	5·049
1½	4·712	1·767	6·008

$$\text{Spacing in 12-inch slab} = \frac{\text{Area of bar} \times 12}{\text{Area of steel required}}.$$

TABLE CXLIII.

SQUARE IRON RODS.

Side of square bar in inches.	Square rods		
	Perimeter in inches.	Sectional area in square inches.	Wt. in lbs. per r. ft.
¼	1·00	0·0625	0·213
⅜	1·50	0·1406	0·478
½	2·00	0·250	0·849
⅝	2·50	0·3906	1·328
¾	3·00	0·5625	1·912
⅞	3·50	0·7656	2·603
1	4·00	1·000	3·400
1⅛	4·50	1·266	4·303
1¼	5·00	1·5625	5·312
1⅜	5·50	1·8906	6·428
1½	6·00	2·250	7·650

$$\text{Spacing in a 12-inch slab} = \frac{\text{Area of bar} \times 12}{\text{Area of steel required.}}$$

REINFORCED CEMENT CONCRETE ROOFS AND FLOORS.

Specification No. 161.

1. **Cement.**—All cement used shall be Portland cement (British manufacture) of slow setting quality and shall be in accordance with the British standard specification revised from time to time.

The brand of cement shall be approved by the Executive Engineer, and shall be tested before it is used in the work.

2. **Sand.**—The sand shall be clean and gritty and composed of hard silicious grains. It shall be free from clay or any vegetable matter. All sand shall pass through a mesh ⅛th of an inch square. If there is any trace of earthy matter, the sand must be washed.

3. **Aggregate.**—The aggregate shall consist of shingle or broken stone, sound, hard and durable, so as to pass through a mesh of ¾ths of an inch, but not through a ¼″ mesh. The sizes shall be varied as far as possible.

All aggregate must be perfectly clean, being washed if necessary, and free from any sulphur. No limestone must be used.

4. **Reinforcement.**—All reinforcement shall be of steel which shall comply with the British standard specification. The ultimate tensile stress of mild steel must not be less than 28 tons per square inch. Any medium steel of British manufacture having an ultimate tensile stress greater than 72,000 lbs. per square inch shall have an efficient continuous mechanical bond with the concrete. The working tensile stress in each case must not exceed one-fourth of its ultimate resistance.

5. **Centering.**—The term "centering" shall include all forms, moulds, sheeting, shuttering, planks, poles, posts, shores, struts, ties and uprights and all other temporary supports to the concrete during the process of setting.

The centering shall be of such dimension and so constructed as to remain rigid during the laying, tamping and setting of the concrete. The joints must be tight so as to prevent leakage of the liquid cement. The centering must be arranged so that the portion below the slabs can be removed first, then the sides of beams, and finally that below the beams.

All faces which will come in contact with the concrete in beams must be planed and smoothed, while those for the soffit of slabs may be mud-plastered to a smooth and absolutely uniform surface.

6. **Placing of reinforcement.**—All bars must be accurately placed in the exact position shown on the drawing and care must be taken that they are not displaced during the process of packing the concrete around them. All stirrups must be tied to the bars with soft wire before concreting is commenced.

7. **Mixing of concrete.**—Unless otherwise stated in particular cases, the concrete shall be mixed in the proportion of four parts of aggregate, two parts of sand and one part of cement. The concrete must be thoroughly well mixed, at least three times in a dry state before water is added, and as far as possible the mixture shall always be brought to the same degree of wetness. A fairly wet mixture must be used particularly for beams. The concrete must be mixed on watertight platforms sufficiently large to allow of two heaps being mixed simultaneously.

8. **Placing of concrete.**—Before any concrete is put in position the centering must be well watered to prevent it sucking up too much moisture from the concrete. The concrete shall be placed in its final position in the work as soon as possible after mixing, and care must be taken to place it gently into position and not to drop it from a height. It must then be well tamped with light wooden rammers till the cement creams to the surface, care being taken to see that the steel reinforcement is thoroughly surrounded by the liquid concrete and that no voids or cavities are left.

The concrete shall be continually watered and kept damp for twenty days after placing in position.

9. **Stopping and recommencing work.**—As far as possible when concreting is once commenced it must be carried on without stoppage until the job is completed. If, however, a cessation is unavoidable, the break should be made in the centre of the span of beams or slabs and the joints should be at right angles to the direction of the span. On no account must a joint be made towards the end or at the end of a beam or a slab.

Wherever a stop has been made in lay'ng the concrete, the surface of the existing concrete must be carefully brushed with a stiff brush before recommencing work to remove loose particles and dust and a thick grout of neat cement must be poured over the edge before the new concrete is tamped against it.

10. **Striking centering.**—Under the ordinary circumstances the centering at the sides of beams and under the slabs may be removed after seven to ten days to enable the concrete to dry. The supports below the beams must be left in position for twenty days. No heavy loads should be allowed to come up on the work beyond the safe load which the work was designed to bear and that after four weeks. All centering shall be removed without shock or vibration.

11. **Finish of floors and roofs.**—The soffit of all slabs and soffit and sides of all beams shall be finished with *neeru* plaster and whitewash (2 coats). The upper surface of floors shall be finished off with a very wet mortar (1 part cement to 2 parts fine sand, sand to pass through 1/16″ mesh) immediately after the concreting has been done.

For rate abstracts see pp. 543 and 544.

For rate graphs see plate LXV.

REINFORCED BRICKWORK.

(Plates LXVI, LXVII AND LXVIII).

1. **Introduction.**—Reinforced brick work is in all essential features practically the same as reinforced concrete construction save that brickwork in cement mortar is substituted for cement concrete. The principles of reinforcement are similar and steel is used in various ways where necessary, as in reinforced concrete to give the requisite strength to the material. Floors, roofs, staircases, decking of bridges, etc., can all be constructed out of this material.

2. **Homogeneity of cement and brick work.**—At first sight it would seem that brickwork could not be a homogeneous mass in the sense that concrete is, and that the regular joints in the work would present planes of weakness along which failures would readily take place. On the contrary it has been proved by experiment that the steel and the masonry surrounding it act as one compact mass in almost exactly the same way as the concrete and the reinforcement in reinforced concrete work, provided ordinary precautions, as explained below, are taken in designing and carrying out the work.

3. **Advantages.**—over other systems commonly in use are :—

(*i*) Simplicity of construction.

(*ii*) Good, sound and permanent work involving very low repair charges.

(*iii*) Fire proof.

(*iv*) Neat and artistic appearance of the finished work, unlike that of jack arching or other systems in common use.

(*v*) Cool rooms.

(*vi*) Low cost. It is cheaper than any other form of *pakka* roofing.

4. **Reinforced brick slabs.**—For this purpose bricks of the size ordinarily used for building purposes are used. In Patna 10″ × 5″ × 3″ bricks, which is the ordinary size there, are used. Slabs, are, therefore, limited to certain definite depths, viz., 3″, 5″, 6″ or combinations of these, *i.e.*, 3″ slabs are made by laying bricks flat 5″ by laying bricks on edge, and 6″ by laying 2 courses one upon another in the ordinary manner. A flat course *plus* a brick on edge course can be made to make up 8″ slabs, 9″ or 10″ slabs are made of 3 courses flat, while 10″ slabs have also been constructed of bricks on end. Though very satisfactory from the point of view of strength and appearance of the finished work, slabs thicker than 6″ are generally too heavy and expensive for ordinary use. See plate LXVI.

Some top reinforcement is necessary to be given even where the ends are free to guard against the tendency, which is present in many cases, on account of the mortar from the slab sticking to the bearing on the wall, for the slab to act as partly fixed at the supports. The thickness of the joints in slabs varies from ⅜″ to ½″.

RATES FOR R.C.C. BEAMS & SLABS.

SLABS. From the plan or data given, ascertain the area of reinforcement per ft. run of the slab: and from this value as read on the left of the graph, trace to the curve for the thickness of slab. At the point of intersection with this curve trace vertically downwards and read off the rate at the bottom.

BEAMS From plan or data given, find the value of $\frac{As}{b_r d}$ where "As" = area of steel provided, "b_r" = breadth of rib and "d" = effective depth below slab. From this value as read on the left of the graph, trace to the curve nearest the value of b_r : d. At the point of intersection with this curve trace vertically down and read off the rate at the bottom.

Fig. 1. Approx Cost of Slabs per Sq. ft.

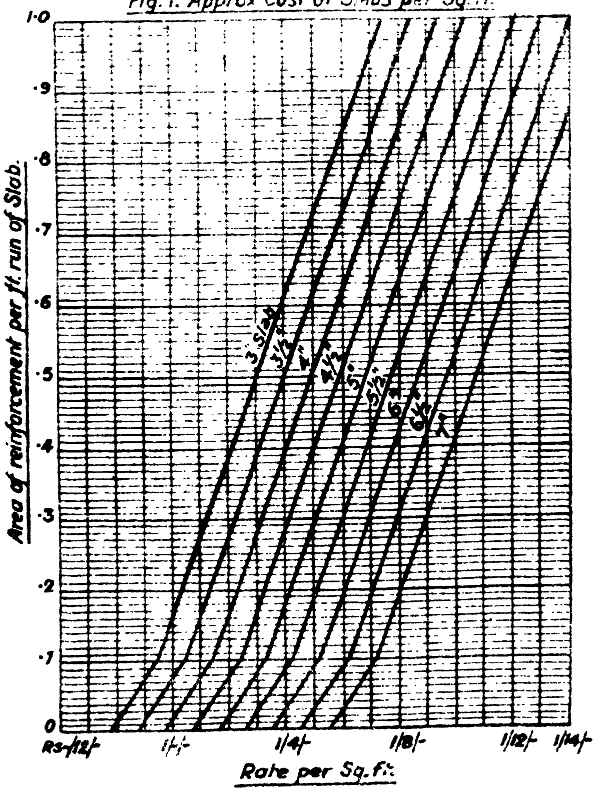


Fig. 2. Approx. Cost of Beams per C. ft.

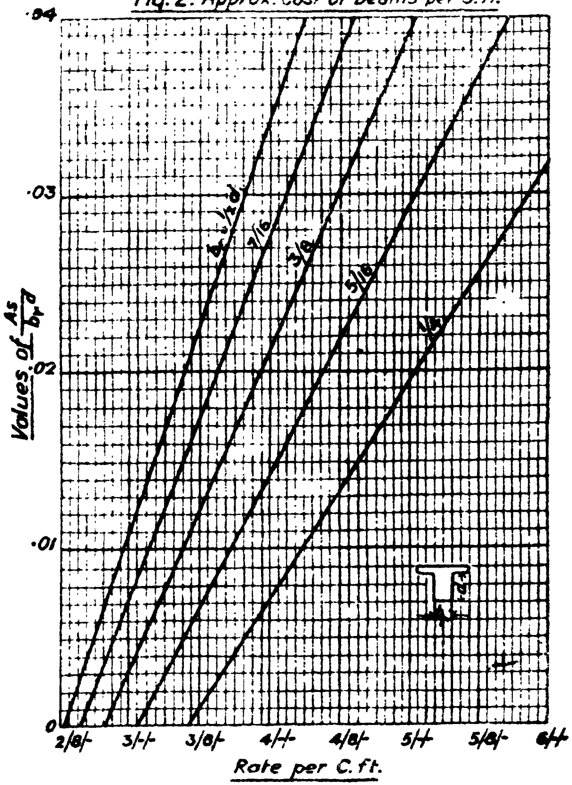


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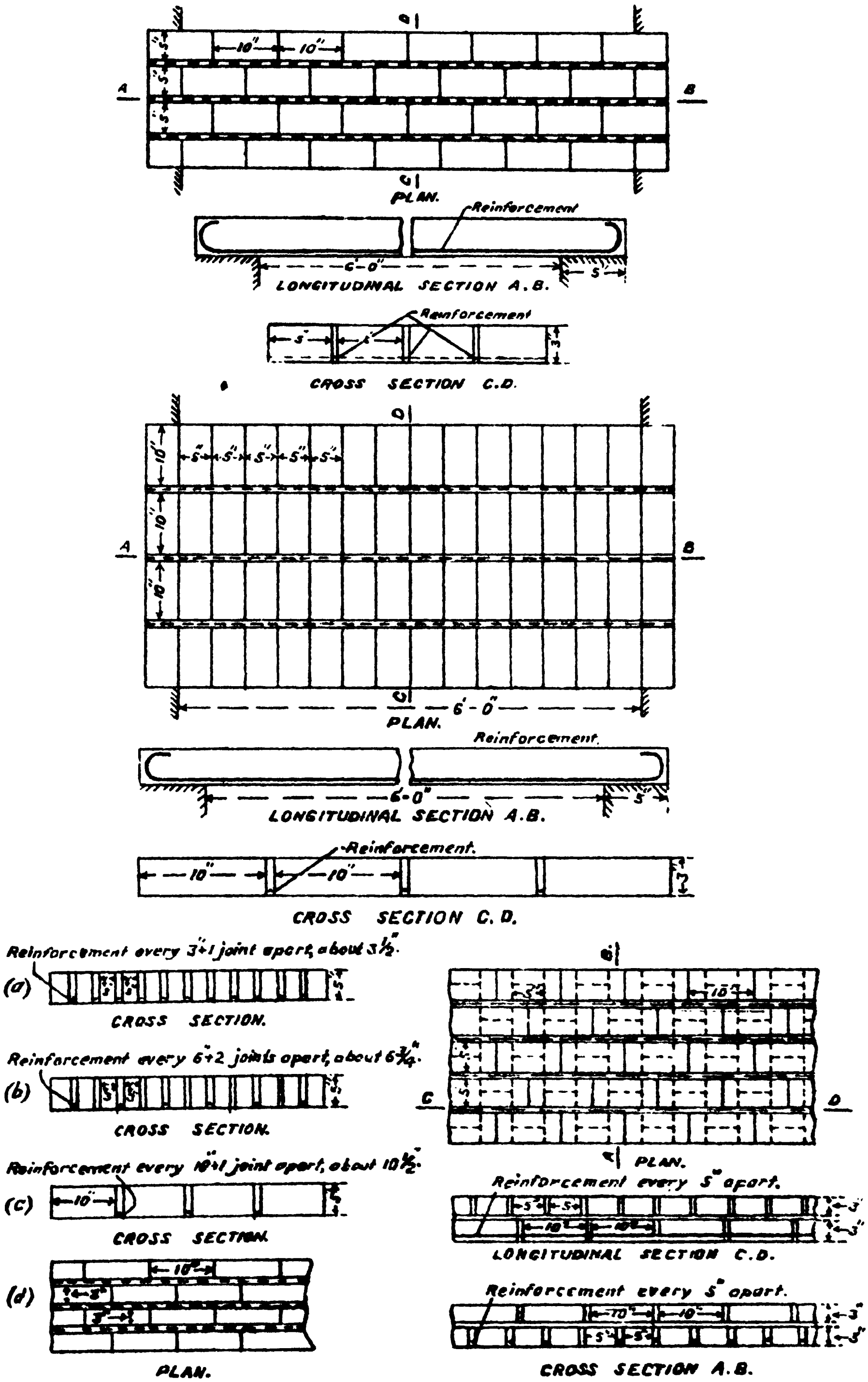
Plate LXVI.

ARRANGEMENTS OF REINFORCEMENTS IN SLABS 3", 5" & 6" THICK.



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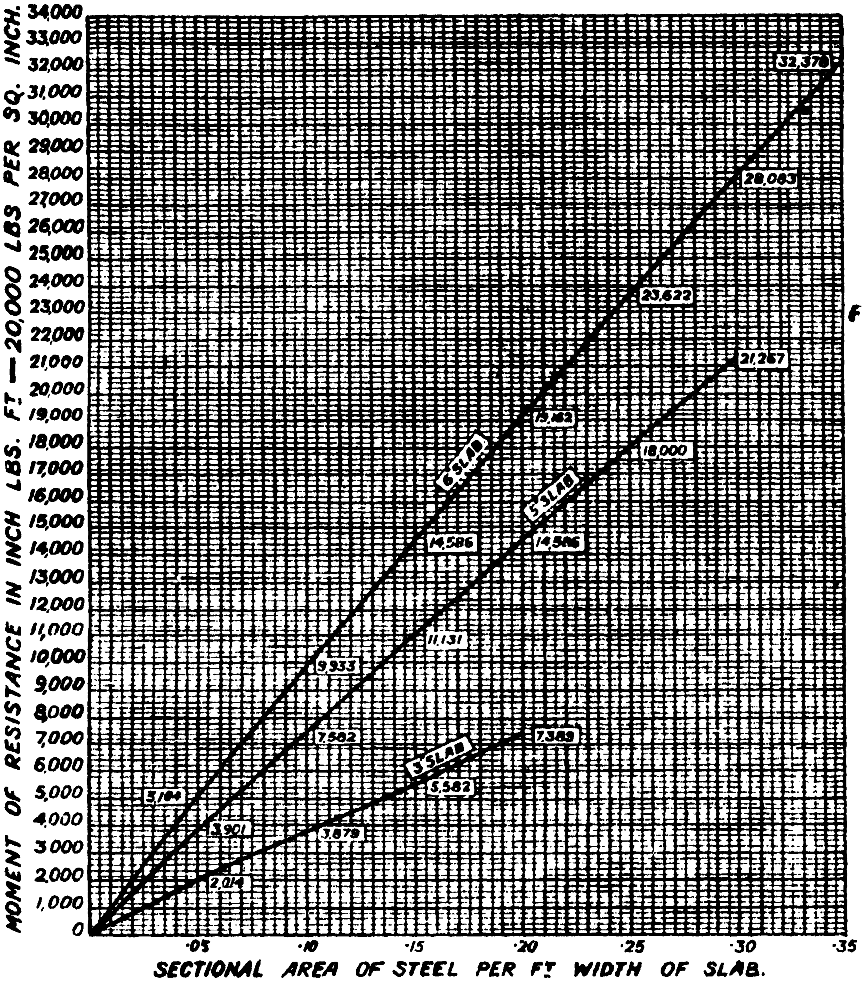
REINFORCED BRICKWORK

COMPARATIVE TABLE SHOWING MOMENT OF RESISTANCE IN INCH LBS. WITH FT.= 20,000 LBS. PER SQ. INCH FOR SLABS OF VARIOUS DEPTHS, AND AREA OF STEEL REQUIRED FOR EACH.

WORKING STRESS IN COMPRESSION = 350 LBS. PER SQ. INCH.



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R. B. slabs are usually finished with lime concrete terracing for roofs, and patent stone for floors. The terracing may be done after 21 days, but it is better to wait for a month. Patent stone should be done as soon after the R. B. slab is finished as possible, preferably before removing the centering, unless, perhaps, in the case of slabs continuous over beams, where it should be laid as soon after the removal of the centering as possible.

The underside is finished with ordinary lime plaster, which readily adheres to the surface of the bricks.

5. **Measurement conventions.**—In referring to the depths of slabs it is usual to give the thickness in terms of brick dimensions neglecting the depth of the horizontal mortar joints, *e.g.*, a 6″ slab is made up of 2 courses of bricks laid flat, each, therefore, 3″ deep *plus* a joint, and has an actual depth of 6″ *plus* one joint. A similar convention is used as regards the spacing of reinforcing rods; thus the distance apart specified indicates the brick intervals at which rods should be placed and does not take into consideration the thickness of the mortar joints.

6. For strengths of reinforced brick slabs of various depths see plate LXVII.

TABLE CXLIV.

WORKING STRESSES.

From experiment carried out at Patna, the following working stresses are considered suitable :—

Safe compressive stress for brick in slabs when the compression is limited to the thickness of one brick	350 to 400 lbs. per square inch.
Safe compressive stress for beams or when compression is not limited to one brick ...	250 lbs. per square inch.
Tensile working stress for steel for ordinary residences	20,000 lbs. per square inch.
Steel in R. B. beams and cantilevers ...	16,000 lbs. per square inch.
Ratio of modulus of elasticity for steel to that of brick	40 to 1.
Adhesion between steel and mortar ...	80 to 90 lbs. per square inch.
Shear in brickwork	60 lbs. per square inch.

SPECIFICATIONS FOR REINFORCED BRICKWORK.

Specification No. 162.

1. **Centering.**—The simplest type, and that which is most generally used, consists of a platform composed of planking or sheeting at the required level, supported on runners or beams and covered with a layer, about 1 inch thick, of earth well beaten flat and finished off with a thin sprinkling of fine sand.

The top surface of the centering should be given a camber as below to allow for initial settlement.

For slabs, 1/12″ for every foot of span, subject to a maximum of 1¼″.

For beams, about 1/18″ for every foot of span, subject to a maximum of 1½″.

It is essential that whatever centering be used, it shall possess,—

(1) Rigidity.

(2) Simplicity of construction for slackening and removal.

(3) A smooth surface on which to lay the slab. For typical kinds of centering, see plate LXVIII.

2. **Time for removal of centering.**—The following may be taken as a fair guide :—

(*a*) Ordinary slabs—from a minimum of about 5 days in summer to a maximum of about 10 days in winter.

(*b*) Specially heavy reinforced slabs—from 7 days to 15 days.

(*c*) Ordinary beams—from 10 to 15 days.

(*d*) Important beams carrying heavy loads—28 days.

3. **Removing centering.**—When the time comes to ease and remove the centering, great care shall be taken to see that no jarring of any kind occurs. All operations in connection with the removal of centering shall be gently performed. Every one connected with the work shall be impressed of this at the very outset, otherwise accidents may occur and in any case centering is needlessly damaged and destroyed.

4. **Bricks.**—Only the best bricks complying with the usual first class specifications shall be used in R.B. work. Hardness is a desirable quality, but brittleness is not, while anything approaching a smooth glaze on the surface, such as is observed on overburnt bricks, is also undesirable, as mortar will not adhere well to bricks with such a surface. Specimens of bricks intended to be used in R. B. work should be tested in tension and compression.

Tension tests may be carried out by carefully cutting briquettes (similar to cement briquettes used in testing cement and cement mortars) out of the bricks, and testing these in the ordinary manner in a cement testing machine. Bricks giving about 200 lbs. per square inch may be accepted with confidence. For compression tests whole 'frogless' bricks may be tested in a Buckton or other machine, or 2″ cubes may be cut out of bricks and tested. A breaking stress of about 1,200 lbs. per square inch or 77 tons per square foot or over, indicates sufficiently good bricks.

5. **Sand.**—Shall be coarse, clean, well graded, *i.e.*, there should be particles of all sizes from 3/16″ diam. to the very finest grains, and, if possible. sharp. Sharpness is not absolutely essential, if the grading is good and the sand otherwise sound. It shall be free from organic and vegetable matter, and shall also be as free from clay and mica as possible.

6. **Cement.**—The cement shall comply in every way with the specifications laid down for R. C. work. Both Katni and Bundi cement, used extensively in Patna, gave excellent results. It must be fresh—any cement which shows signs of staleness shall be rejected. Samples of all cements used shall be regularly tested.

7. **Mortar.**—The mortar used shall consist of cement and sand in proportions varying according to the quality of sand available. Throughout work at Patna, the proportions used were 1 cement to 3 sand by volume, mixed dry, with very

REINFORCED BRICKWORK TYPE DESIGNS.

Plate LXVIII

5" SLAB FOR AN 11' SPAN ROOF WITH 4" TERRACING, AND PARAPET ALL ROUND ABOVE SLAB

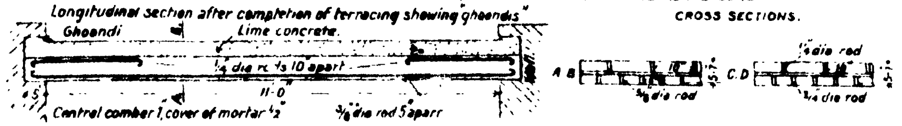

FIG 1.

COMBINED BRICK & CONCRETE T BEAM.

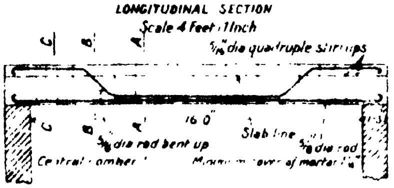

FIG 2.

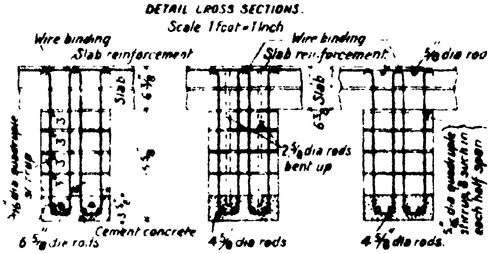

FIG. 3.

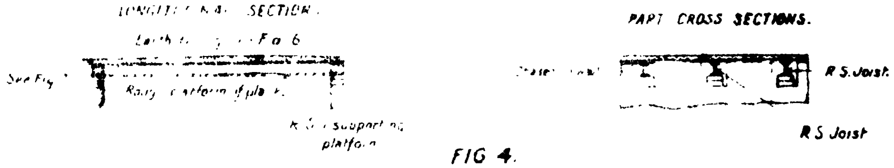

FIG 4.

CENTERINGS.

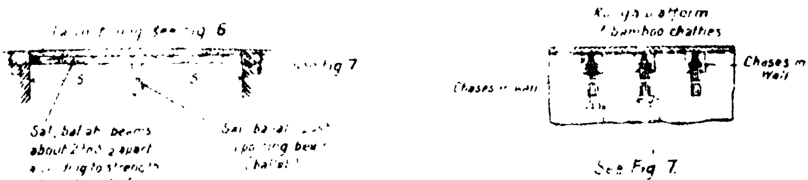

FIG 5

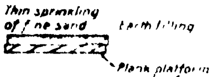

FIG 6.

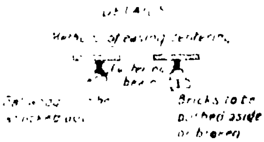

FIG 7

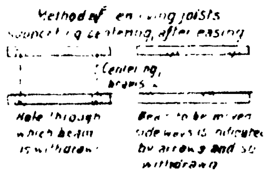

FIG 8

Note. Top surface of centering platform is finished with earth filling to correct slope for camber and topped off with a thin sprinkling of fine sand

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satisfactory results. Only enough water shall be added to make the mortar of such a consistency that is easily workable, leaves the trowel clean and can be readily packed round the reinforcement bars.

In fixing upon the proportion of cement to sand, the proportions which ensure that the following results are attained should be adopted :—

(1) Mortar briquettes made in the usual way should give a breaking tensile strength of 150 lbs. per square inch, when one week old, and not less than 350 lbs per square inch at six months.

(2) Short columns, built of single bricks one upon another set in the mortar, should have an ultimate breaking stress of not less than 1,200 lbs. per square inch after 28 days.

(3) Adhesion stress between bricks and mortar shall not be less than 25 lbs. per square inch. This can be tested by pulling apart bricks, set one upon another cross-wise, with mortar joint between them. For this test the bricks should be well soaked with water before the sample is made, and the sample, after being made, should be kept under water till the time of test.

(4) Bond stress between a round steel rod and mortar should be at least 400 lbs. per square inch of the embedded surface of the rod, after 28 days. It will usually be found that a mortar satisfying the tension test satisfies all other tests.

8 **Mixing of mortar at work site.** All mortar used in work shall first be throughly mixed dry and water shall be on no account be added except by the Masons employed on the work and then only in small quantities. Too great stress cannot be laid on this point. If these precautions be ignored, there is every likelihood that stale mortar will be used.

The most suitable method has been found to have the mortar mixed dry in some central position where this work can be easily supervised, and then have it distributed. If this method be adhered to, each mason need only add water in his iron pan and there is, therefore, no fear that the mortar will be partially set when used. Needless to say, this method can only be adopted when the sand is really dry. Only clean water should be used.

9. **Steel of reinforcement.**—Only the best mild steel shall be used as reinforcement. As far as possible, only steel of circular section should be used. Square sections may also be used but flats or angles should be avoided. If they have to be used, care should be taken to see that the bond stresses are kept very low.

In floor and roof slabs no section of greater diameter than ½" shall be used, and as far as possible, only small sections such as ¼" $\frac{5}{16}$" and ⅜" should be used. Sections in beams shall not be larger than 1" diameter for main reinforcement and ½" for shear reinforcement. Hoop iron, although unsuitable for slabs and beams, is suitable for reinforcing partition walls.

A little rust on the reinforcement is desirable, as it ensures good adhesion, but all loose and scaly rust shall be removed prior to use. Hoop iron with a bluish glazed surface shall not be used. If it has to be, then it should be immersed in water for a few days. This produces rusting and effectively destroys the glaze on the surface.

The ends of all rods shall be bent into semi-circular hooks of a diameter at least six times the diameter of the rod itself with a short length of straight rod beyond the bend.

As far as possible, overlapping shall be avoided by ordering rods of proper lengths, but where this cannot be done, and overlapping has to be resorted to, a lap of 50 diameters shall be given with proper hooks at the ends and the two rods shall be bound with wire along the lap. Welds are strictly prohibited.

10. **Workmanship, etc.**—(*a*) All bricks shall be soaked in water for at least six hours before being used.

(*b*) Bricks shall be properly arranged as they are laid. When possible, the arrangement should be shown in the drawings, but it may be laid down as a general principle, that joint should be broken wherever possible, as this gives increased strength.

(*c*) Before starting work all rods shall be prepared and bent to the correct lengths and shapes shown in the drawings and, where possible ,laid out *in situ*. If this is done, difficulties will be anticipated and cutting and overlapping reduced to a minimum.

(*d*) All joints shall be well filled, and all reinforcement well surrounded by mortar. This requires careful attention, as workmen, unless watched, are apt to scamp the work or grout the joints.

Care shall be taken that the bottom rods in slabs have a real cover of mortar under them and do not touch the centering.

Masons engaged on the work should squat on planks and not on the centering itself. P.anks should also be laid to prevent walking over newly finished work.

(e) All work shall be kept moist by means of wet straw, wet sand or merely sprinkling water, for the first and part of the next day after finishing. It shall then be profusely watered and kept wet until one or two days before the removal of centering. Water tables or " *kinaris* " might be made all round the slab to hold about ½" depth of water over it. A clear day should be allowed for dry setting before the centering is removed. The work should be kept wet or moist until it is about a month old.

(*f*) **Places to stop.**—As far as possible, each structure shall be finished in one operation and in one day, but there will be occasions when this is not possible, and in such cases the following hints may be of use :—

(*i*) Ordinary slabs supported on two sides may be left after finishing any layer of reinforcement.

(*ii*) Cross reinforced slabs, i.e., having reinforcement in two directions, may, if absolutely necessary, be left somewhere near the middle, i.e., when half the slab from one side is laid.

(*iii*) Beams may be left near the centre (section of least shear and maximum bending moment), but as far as possible these should be finished in one operation and as the size is seldom very large, this can nearly always be done.

(*iv*) Ordinary T beams with a continuous slab, in which all the shearing action has been provided for in the shape of stirrups, may be left after completing the rib portion, provided the stirrups project from the rib almost to the top of the slab. The slab should be built over the rib not later than two days after the completion of the rib. In all such cases the work on the remaining part of the structure should be resumed very early, the next day, if possible.

For rate abstract see page 545.

RATE ABSTRACT No. 131 (BOMBAY).

REINFORCED CEMENT CONCRETE BEAMS, SPAN 25′ 0″.

DISTANCE C TO C OF BEAM = 9′ 0″.

BEAM = $15\frac{1}{2}''$ × 31″, REINFORCED WITH 7 × $\frac{7}{8}''$ DIAMETER BARS AND $\frac{1}{4}''$ DIAMETER STIRRUPS, 18″ C TO C.

Cubic contents of beam, 25′ × $15\frac{1}{2}''$ × 28″ = 75·35 c.ft.

Materials for 75 c. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 75 c. ft.	Number or quantity.	Rate.	Per	Amount.
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
For concrete. Proportion (1 : 2 : 4).					*For concrete.*				
			c. ft.						
Gravel .. c. ft.	60		100		Masons .. No.	1½		Each	
Sand .. ,,	30		,,		Coolies .. ,,	7½		,,	
Cement .. ,,	15		c. ft.		Women ,,	7½		,,	
					Bhisties .. ,,	2		,,	
					Sundries	..		Lot	
**For centering.*			s. ft.		*For centering.*				
1¼″ deal planks sq. ft.	150		100		Maistry .. No.	1½		Each	
Props .. c. ft.	24		c. ft.		Carpenters .. ,,	7½		,,	
Stirrups, etc. ,,	4		,,		Coolies .. ,,	7½		,,	
Bolts .. lbs.	10		lb.		Sundries ..	..	..	..	
For reinforcement.					*For reinforcement.*				
Main bars .. lbs.	388		cwt.		Fitters .. No.	4		Each	
Stirrups .. ,,	18		,,		Coolies .. ,,	4		,,	
Wire .. ,,	6		lb.						
	Total materials ..					Total, labour ..			
						Total, materials ..			
						Total for 75 c. ft. ..			
						Cost per c. ft. ..			

*¼ Market rate is taken for these items on the assumption that the materials can be used 4 times and are then valueless.

RATE ABSTRACT No. 132 (BOMBAY)

REINFORCED CEMENT CONCRETE FLOOR SLAB 10′ 0″.

Full depth of floor slab 5½″ ; reinforcement ⅜″ diameter bars, 3⅞″ c to c.

Material for 100 sq. ft.	Number or quantity.	Rate.	Per	Amount.	Labour for 100 sq. ft.	Number or quantity.	Rate.	Per	Amount
		Rs. a.		Rs. a.			Rs. a.		Rs. a.
For concrete (1 : 2 : 4)			c. ft.		*For concrete.*				
¾″ to 1″ gravel c. ft.	37		100		Masons .. No.	1		Each	
Sand .. ,,	18½		,,		Coolies ,,	5		,,	
Cement ,,	9·25		c. ft.		Women .. ,,	5		,,	
					Bhisty (including watering for 20 days).	1½		,,	
					Sundries ..	..		Lot	
For centering.			sq. ft.		*For centering.*				
1½″ deal planking sq. ft.	100		100		Maistry .. No.	1		Each	
Joints jungle wood c. ft.	9		c. ft.		Carpenter ,,	5		,,	
					Coolies ,,	5		,,	
Props. do. ,,	15*		,,						
Nails .. lbs.	6		lb.						
Coir string bundle ..	1		bundle						
For reinforcement.					*For reinforcement.*				
⅜″ diam bars lbs.	144		cwt.		Fitters ..	1		,,	
¼″ do. (distribution)	10		,,		Coolies ..	1		,,	
Wire binding ,,	1		lb.						
	Total, materials ..					Total, labour ..			
						Total, materials ..			
						Total per 100 sq. ft.			

*¼ Market rate is taken for these items on the assumption that the materials can be used 4 times and are then valueless.

RATE ABSTRACT No. 133.

COST OF R. B. SLABS PER 100 SQUARE FEET (PATNA).

Materials.	Rate.	Unit.	3" Quantity.	3" Cost.	5" Quantity.	5" Cost.	6" Quantity.	6" Cost.	8" Quantity.	8" Cost.	9" Quantity.	9" Cost.
	Rs. a.			Rs.		Rs.		Rs.		Rs.		Rs.
1. Bricks		1000	270		470		550		700		830	
2. Cement		c. ft.	1·6		3		4.2		5.0		6 to 6·2	
3. Sand		100 c.ft.	5·0		9		13		15		19	
(a) Total, materials ..	..		..		..		..		..		..	
4. Labour—												
Head mason		Day	0·05		0·10		0·15		0·20		0·30	
Mason		,,	0·6		1·00		1·50		2·00		2·50	
Coolies—carriers ..		,,	1·2		1·80		2·70		3·50		4·50	
Coolies—mixers ..		,,	0·2		0·33		0·50		0·66		0·83	
Coolies—brick wetters ..		,,	0·2		0·33		0·50		0·66		0·83	
Bhistis		,,	0·5		0·75		1·00		1·00		1·00	
(b) Total, labour ..	..	..	..		..		..		..		..	
5. Centering erecting, dismantling, etc.	..	..	..		..		..		..		..	
6. Scraping cleaning, etc. ..	..	..	..		..		..		..		..	
7. Filling holes, etc. ..	..	..	..		..		..		..		..	
(c) Total, 5, 6 and 7 ..	..	..	..		..		..		..		..	
Total cost (a), (b) and (c).	..	..	..		..		..		..		..	

Notes.—(1) One bag cement—1·2 c. ft.

(2) Bricks = 10" × 5" × 3" each (no allowance for wastage is made in the above figures).

(3) Mortar 3 : 1 = 3·5 c. ft. mixed dry = 2·7 c. ft. mixed wet.

(4) The table omits the cost of reinforcement which varies with the conditions of span, loading, etc.

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INDEX

(For Vols. I and II)

(1) The following abbreviations have been used in the Index: T. for Table No.; Pl. for Plate No.; Spc. for Specification No.; R. Ab. for Rate Abstract No.; To face p. for To face page.
(2) The figures refer to pages.
(3) Pages 1 to 546 refer to Volume I and pages 547 to 1075 to Volume II.

C—*contd.* Pages

C—*contd.* Pages

F

G—*contd.* Pages

G—*concld.* Pages

H

H—contd. Pages

H—concld. Pages

I

W—*contd.* Pages

W—*contd.* Pages

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