CIVIL ENGINEERING DRAWINGS SPECIFICATIONS AND QUANTITIES

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BY

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PUBLISHER'S NOTE

It has been the editor's endeavour to bring up to date this new edition of the late Mr. Rodger's book, which was originally published with the title *Engineering Drawings, Specifications and Quantities*, by ensuring that the information in it is in accordance with current practice. This has entailed considerable revision, particularly in Chapter III, which it is hoped will now be found to accord with the standard conditions agreed between the Institution of Civil Engineers, the Association of Consulting Engineers and the Federation of Civil Engineering Contractors. These agreed conditions were not in existence when the first edition was published.

With regard to specifications generally, a considerable number of British Standards have been issued since the first edition, and Chapters IV and V have been revised in accordance with these new or amended Standards.

Although a paper on quantities does not now form part of the Associate Membership examination of the Institution of Civil Engineers, yet it is felt that the retention of the worked examples in this book would be of great value to the student.

The editor was invited to undertake the preparation of this new edition by Mr. Rodger's widow. Having had over thirty years' practice in engineering construction and administration, he has revised the book with the practical standpoint constantly in mind. Experience both as a resident engineer and contractor's agent has included the building of reinforced concrete and timber jetties and wharves, silos, roads, sewerage works and aerodromes, also tube railway tunnels, concrete bridges, etc. From 1940-45, he served in the Royal Engineers, and from 1943 was engaged on the War Office Staff in port construction work, including schemes and plant for emergency repairs overseas and the famous " Mulberry " Harbours.

On demobilization he was appointed to the Staff of the Building Research Station of the Department of Scientific and Industrial Research.

Sincere thanks are due to Mr. C. Roland Woods, M.B.E., of Gray's Inn, barrister-at-law, Mr. A. MacNiven Brown, A.M.I.Mech.E., A.F.R.Ae.S., and Mr. W. D. Cutler, for their valuable help, and to many engineers, firms and organisations, especially the British Standards Institution, who have kindly allowed quotations to be made from their specifications and other publications.

PREFACE TO FIRST EDITION

Until the subject of this book was introduced as a compulsory section of the Associate Membership Examination of the Institution of Civil Engineers, the essentials of Drawings, Specifications, and Quantities were, as a general rule, picked up by the young engineer in the course of his daily duties, and his knowledge of the subject was governed, to a large extent, by the amount and class of work that was done in his place of business. With the introduction of the examination, it became necessary for him to devote some time to the study of the subject, and a sound working knowledge of it is really essential in the education of every engineer.

In the following pages, I have endeavoured to present the principles governing the preparation of Contract and Working Drawings, Specifications, and Quantities, illustrating throughout with typical examples.

A chapter on Contracts has been included, embodying the principal legal rights and obligations, and this is followed by a chapter giving a typical set of Conditions of Contract, with explanatory notes where necessary.

Specification Clauses, with explanatory notes, have been embodied in Chapters IV and V for the more common materials of construction as well as for the workmanship in connection therewith and in connection with many of the more common classes of construction, such as roads, reinforced concrete, etc.

It is inevitable, in a chapter devoted to the specification of materials, that reference must be largely made to the British Standard Specifications, and acknowledgment must be made to the British Standards Institution for their kind permission to include the excerpts from their Specifications given in Chapter V.

In the chapter on Quantities, examples from a number of papers set at the Associate Membership Examinations of the Institution of Civil Engineers have been completely worked out. These examples were chosen to cover as many sections of work as possible and the recommendations of the Committee of the Institution of Civil Engineers on Engineering Quantities have been adhered to in each case. For permission to include these examples and the further examples given for practice, and also for permission to include the excerpts given in this chapter from the Report of the above Committee, thanks are due to the Institution of Civil Engineers.

Whilst it is impracticable, if not impossible, to embody Specification Clauses for every material and class of work to be found in Engineering Contracts, it is hoped that those given and the worked examples of the Quantities will form sufficient guide to enable any others to be dealt with, and that the book will be of use, not only to those engineers who intend to sit for the examination of the Institution of Civil Engineers but to other engineers in the routine work of their offices.

My grateful thanks are due to the many friends who assisted me in the preparation of the book, amongst whom I must specially mention Mr. W. Abbott, Ph.D., M.I.Mech.E., for much helpful advice, Mr. A. H. Berman, B.Sc., barrister-at-law, for reading over and advising on the chapter on Contracts, Mr. H. J. Reed, one of my students, for assistance in the preparation of the drawings, and Mr. R. Brown, M.A. (Edin.), B.Litt. (Oxon), for reading the proofs.

I must also thank the many engineers throughout the country who were so good as to let me have copies of their Specifications and other particulars which were most helpful in the preparation of the book.

J. Marshall Rodger.

The Municipal College,
Portsmouth.
May 1934.

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CHAPTER I

PRELIMINARY AND DRAWINGS

In any Engineering Contract, before the work can be commenced, there is invariably a large amount of preliminary work of great importance to be carried out, consisting in the collection of data relative to the site, survey and levelling work, and often the taking of borings to determine the engineering possibilities of the proposed works. Then there is the preparation of drawings and specifications, and the taking out, multiplying and scheduling of the quantities.

As an example, let us consider a scheme for the erection of a proposed new bridge across a tidal river, and the various steps to be taken before the specification and the schedule of quantities can be prepared.

The first step is to decide tentatively upon the site, and this will depend upon the following factors :—

(*a*) The line of the proposed road or railway upon which the bridge is to be erected.

If this is not in a thickly populated district, there may be a fairly large limit within which it may be laid, but if the district be congested, the line allows of little or no variation, and all other considerations may have to be waived in deciding upon the proposal.

(*b*) The possibility of arranging suitable approaches.

These depend to a large extent upon the height of the bridge, and this depends largely upon the tidal range and upon whether or not the river is navigable. For a navigable river with a large tidal range, the headroom required is considerable and, unless the surrounding country and river banks are high over the river, this necessitates very long approaches to obviate too steep gradients.

(*c*) The nature of the subsoil for foundations.

It would be wise at this stage to consult a specialist in Soil Mechanics, who would by laboratory and field tests, be able to give reliable information as to the suitability of the subsoil for foundations and also advice as to the most suitable type of foundation. From his report, also, could be decided whether intermediate piers should be erected, or the bridge be of a single span ; but this depends on other conditions in addition, as instanced in the next paragraph.

(*d*) The ordinary tidal range and all information available as to the highest and lowest recorded tides, the prevailing winds, the frequency of storms, the speed of the river during ebb and flow of tides, and the maximum recorded speeds of the river at exceptionally high tides.

Tide gauge readings may be available from which much of this information may be got but, if not, these would require to be taken over an extended period in order to get the required information. In addition, the speed of the river would have to be measured over a whole range of the tide at both spring and neap tides, and, if possible during floods, so that an estimate could be formed of what might be expected in this direction.

Upon these factors depends to a large extent the design of any piers to be built in the river or whether piers should be built at all, as it should be observed that the introduction of an obstruction in a tidal river may introduce currents and eddies and also lead to silting, and these points must be taken into consideration in the proposed design.

(*e*) The contour of the river bottom, and whether this is fairly constant or varies due to scour or silting.

This would be determined by taking soundings periodically along lines ranged at intervals across the river and extending to some distance above and below the proposed site.

(*f*) The necessity or otherwise of arranging training walls in the river approaches to the bridge.

These might be advisable in some instances to direct the flow of the river, depending upon the line of this, and on the material forming the banks.

(*g*) The largest type of vessel that uses the river.

Allowance must also be made for future requirements in this respect.

(*h*) The class of traffic that is going to use the bridge, and the volume thereof.

If for a Railway, a standard load, allowing for probable developments, is always worked to. If for a road bridge, the recommendations of the Ministry of Transport should be followed. Upon the volume of traffic, also, will depend the width of the bridge and the allowance of width for roadway, trams, footpaths, etc.

It should be noted that, while it is practically always possible to erect a bridge in any position, the selection of the best site within a given area may lead to a considerable reduction in the cost.

To decide upon the line or route of the proposed road or railway it will be necessary to make a complete survey of the river for some distance around the proposed site. This may be done by making the complete survey or, as is more usual, by bringing up to date the existing Ordnance Maps of the district by surveying in and plotting all alterations and additions.

In addition to this survey, levels must be taken and sections plotted. These will include a longitudinal section along the proposed route, together with cross sections at intervals where the contour of the ground changes, and sections across the river showing the contour of same.

This plan (with the sections), on which the site of the proposed works is shown, forms the first of the necessary drawings for the Contract.

With regard to scale, it is an advantage if the sizes of the drawings can be standardized as is done in other branches of Engineering, keeping them within double elephant size (40 in. by 27 in.) or imperial size (30 in. by 22 in.). When such large drawings are not required, half or quarter sheets may be used, making them 27 in. by 20 in. and 20 in. by 13½ in. in the case of a standard double elephant sheet, and 22 in. by 15 in. and 15 in. by 11in. in the case of a standard imperial sheet. In cases where larger size drawings are necessary or desirable, as is often the case in Civil Engineering Contracts, a larger standard may be adopted, such as 72 in. by 40 in., 60 in. by 40 in., or 53 in. by 30 in., from which half and quarter sheets may be prepared and used. The advantages accruing from this standardization are that

(1) All drawings may be kept in standard sized drawers flat, (some of the drawers being divided into two and some into four for the smaller sized drawings), thus being more readily found and kept cleaner than under the old system of making them any length and storing them rolled up, in addition to taking up less room ; and

(2) Tracing papers and cloths, and photoprint papers are made in standard widths of 40 in. and 30 in., and are therefore economical of use with the sheets in question.

In many cases it is not practicable to use these standard sheets and in these cases the drawings may be made on rolls of drawing paper mounted on linen or on rolls of cartridge paper and cut off to the required lengths.

On the plan referred to above, the scale may be the 25-in. Ordnance Scale, or any larger scale that may be conveniently got on the paper. The advantage of using the Ordnance Scale is that the plan may be traced direct from an Ordnance Map brought up to date. The sections may be plotted to the same horizontal scale as the plan, but to an enlarged vertical scale of not less than 40 ft. to an inch.

On the same drawing, or on another sheet, if found advisable, will be shown the sections of the borings plotted from the journals indicating the nature of the substrata, the positions where the borings are taken being shown on the plan. These may be to a scale of about $\frac{1}{8}$ in. to a foot.

The next drawing will be one showing the general arrangement of the whole bridge with approaches and foundations, and on this drawing may also be shown a plan and sections. In works of this description it is usual to show elevations and plans half in outside elevation or plan and half in sectional elevation or plan, the fundamental idea being to show clearly the construction of the work. The scale of such a drawing may be from $\frac{1}{16}$ in. to a foot to $\frac{1}{8}$ in. to a foot, or if possible $\frac{1}{4}$ in. to a foot.

The number of detail drawings required depends wholly upon the magnitude and variety of detail of the work. For the bridge in question there would be at least one sheet of details for the approaches, one for the abutments, one for the piers, and one or more for the superstructure. The scale for these would usually be $\frac{3}{4}$ in. to the foot for the larger details, up to 3 in. to the foot for the smaller details.

It should be remembered in preparing the drawings that the more explicit these are, the less chance is there of disputes arising about the nature of the work, or of claims coming in from the Contractor for extras on account of work not shown on the drawings.

On the other hand, in Civil Engineering work, it is generally impracticable to make a detail drawing of every item as is done in some classes of Engineering work, and the drawings must be read in conjunction with the specification.

The best guide to the drawings required for any work is for the designer to go over the completed drawings from the Contractor's point of view and consider if he could make and erect the work completely from these drawings and the specification without reference to an outside source. If he could, the drawings are sufficient. If not, then the drawings necessary to remedy the omissions are still required.

[1] Parliamentary Plans

Many schemes, especially when they include the compulsory acquisition of property as for a Railway, or the acquisition of a monopoly such as Electricity or Gas Supply, or mean the levying of a special rate as for Town and Land Improvements, require Parliamentary sanction before they can be proceeded with, and in this connection certain drawings and estimates are required.

The schemes are promoted by means of Private Bills of which there are two classes ; the first class in general consisting of those seeking for powers to perform certain Public Services and to charge or levy rates for same, and the second class, in which Engineers are more generally interested, requiring powers to perform Public Works such as making, maintaining, varying, extending, or enlarging any Bridge, Dock, Railway, Waterwork, etc., and the form in which the Bill and the Drawings, Estimates, etc., are to be prepared and presented must comply with the Standing Orders of the House of Parliament before whose Examiner and Committee they are to come.

The Plans to be deposited must be to a scale of not less than 4 in. =1 mile, with an enlarged plan of buildings and lands such as yards, courtyards, etc., adjoining and within the boundary walls of the building and gardens, to a scale of not less than 1 in. = 400 ft. Sections must be drawn to the same horizontal scale as the plan, and to a vertical scale of not less than 1 in. =100 ft.

Limits of Deviation, within certain prescribed limits may be shown on the drawings, and the promoters may apply for powers to vary the lines of the work within these limits, but alternative lines or works are not permitted.

A book of Reference containing the names of all persons (Owners, Lessees, and Tenants) interested in lands and houses which may be taken or used compulsorily, or upon which the

[1] The particulars regarding Parliamentary Plans have been abstracted from the Standing Orders of the House of Commons by permission of the Controller of H.M. Stationery Office.

imposition of any improvement charges may be liable, has to be prepared and presented with the Drawings.

Where work is proposed on a cut, canal, reservoir, aqueduct, or navigation, the Plan must describe the brooks and streams to be directly diverted into such works for supplying them with water.

Plans for Railway Works must show on them the distances in miles and furlongs from one of the termini, together with a memorandum of the radius of every curve not longer than 1 mile in furlongs and chains. Tunnels shall be shown in dotted lines.

Where a diversion, widening, or narrowing of a public Carriage Road, Navigable River, Canal, or Railway is intended, the course of the diversion, and the extent of the widening or narrowing are to be marked on the Plan, as well as the proposed diverted course of any public footpath.

When a Railway is intended to form a junction with an existing or authorized line of Railway, the course of this existing or authorized line is to be shown on the Plan for a distance of 800 yd. on either side of the proposed junction, on the same scale as the General Plan.

All tidal waters to be coloured blue.

Sections shall show the surface of the ground marked on the Plan, the intended level of the proposed Work, the height of every embankment and the depth of every cutting, and a datum horizontal line referred to some fixed point near some portion of such Work, and, in the case of a Canal, Cut, Navigation, Public Carriage Road, or Railway, near either of the termini ; the height of such point above or below an Ordnance Bench Mark in the vicinity, and the level of such Bench Mark above Ordnance Datum, being stated.

In Bills for improving the Navigation of a River a Section shall be shown specifying the levels of both banks of such River, and any alterations intended shall be shown in feet and inches or decimal parts of a foot.

The line of a Railway marked on the Section is to correspond with the upper surface of the Rails, and the distances on the datum line are to be marked in miles and furlongs to correspond with those on the plan ; the vertical distances from the datum line to the line of the Railway to be marked in feet and inches or decimal parts of a foot, at the commencement and termination of such Railway, and at each change of gradient, and the gradient also to be marked between every two consecutive vertical measures.

At every public carriageway, navigable river, canal, or railway crossing, the height of the Railway over, or depth under, the surface thereof, and the height and span of every arch of all bridges and viaducts by which the Railways will be carried over the same, are to be marked in figures at every crossing ; and all Road or Railway level crossings are to be so described on the Section, with a note as to whether or not the level will be unaltered.

Any intended alteration in the water level of any canal, or in the level or gradient of any public carriage road or railway, which will be crossed by the line of Railway, to be stated on the Section and numbered ; and Cross Sections, referenced to the numbers, on a horizontal scale of not less than 1 in. = 330 ft. and a vertical scale of not less than 1 in. = 40 ft., to be added, showing the existing surface of such road, canal, or railway, and the intended surface thereof when altered ; and the greatest present and intended gradient of the portion proposed to be altered, to be marked on in figures. At any level crossing of a public carriage road, a Cross Section extending 200 yd. on each side of the Railway centre line also to be added.

Where the extreme height of any embankment or the extreme depth of any cutting exceeds 5 ft., the extreme height over or depth under the surface of the ground to be marked in figures on the Section, and where any bridge or viaduct of more than three arches shall intervene in an embankment or any tunnel in a cutting, the extreme height or depth to be marked in figures on each of the parts into which such embankment or cutting shall be divided by such bridge, viaduct, or tunnel.

Tunnelling and Viaducts must be marked on the Section.

When a Railway is intended to form a junction with an existing or authorized line of Railway, the gradient of such existing or authorized line is to be shown on the Section to the same scale as the general Section, for a distance of 800 yd. on either side of the point of junction.

A point of importance to Engineers is the date on which plans must be ready, and it should be noted that the first copies of the plans, sections, and books of reference must be deposited with certain specified authorities by the 20th November immediately preceding the Application for the Bill. As numerous copies are required, they are usually lithographed and bound for convenience. The actual depositing of the plans, etc., is usually attended to by the Solicitors for the Scheme and the Parliamentary Agents who attend to the passage of the Bill through Committee.

Estimates for Parliamentary Works must be submitted in the following form, or as nearly to this form as is possible :—

ESTIMATE FOR PERMANENT WORK

	£ s. d.
Purchase of land and easements - - - - -	
Buildings (specifying generally their nature) - - -	
Reservoirs, filter beds, etc. - - - - - -	
Tunnels, embankments, dams, etc. - - - - -	
Trunk mains and main sewers - - - - -	
Other mains, pipes, sewers, and sewage disposal works -	
Other works grouped with regard to the probable life of the works - - - - - - - - -	

The form for Works connected with a Railway, Tramway, Canal, Dock, or Harbour Bill is also prescribed and varies somewhat from the above, but full particulars relating to everything connected with the promotion of these Bills may be found in the Standing Orders of the House of Commons or that of the House of Lords, published by His Majesty's Stationery Office.

In drawings for Mechanical Engineering Works, such as Machines, Motor Cars, Aeroplanes, etc., the method of procedure is rather different from that detailed above.

The first drawings required here are arrangement drawings showing a general arrangement of the whole scheme in plan, side, and front or end elevation. These drawings will also, if necessary, show sectional plan and elevations, and all overall dimensions.

Then come the arrangement drawings of the different assemblies making up the whole work, also usually consisting of half outside and half sectional plan, and half outside and half sectional elevations, dimensioned up to show all overall sizes, and showing the positions of all component parts which should have reference numbers marked on the general arrangement drawing for convenience in locating and identifying individual part drawings when required.

Finally there are the detail drawings of the component parts, each of which is usually drawn on an individual sheet numbered to correspond with the reference number above referred to on the general arrangement drawings.

It is usual in Engineering Drawings to place the Drawing Number, Date, and the Firm's Name in the bottom right-hand corner of the Drawing, and sometimes this is repeated in the top left-hand corner to facilitate search for Drawings when required.

To illustrate the method adopted, let us consider the drawings required for a Motor Car Chassis complete.

First there will be a plan and elevation of the complete arrangement of the chassis, showing frame, engine, clutch, gear box, transmission, back axle, front axle, dash, petrol tank, springs, radiator, brake gear, and wheels, and giving overall dimensions, the whole being on a 30-in. by 22-in. sheet, and to a scale of say 1½ in. or 2 in. to the foot.

Next come the arrangement drawings for the different assemblies, comprising :—

(i) Arrangement of Engine and Clutch complete, comprising half outside and half sectional plan, half outside and half sectional side elevation, half outside and half sectional front elevation, and possibly half outside and half sectional rear elevation, all on a 30-in. by 22-in. sheet and to a scale of, say, 3 in. to the foot.

(ii) Arrangement of Gear Box, comprising the same selection of views as specified above for the Engine, and to the same scale or, if it can be got in, to half full size.

(iii) Arrangement of Transmission and Back Axle, again including views as above and to the same scale as the Engine Arrangement.

(iv) Arrangement of Chassis Frame, showing Dash, Petrol Tank, Spring Brackets and Shackles, Step Irons, Brake Rods, etc., with drawings showing plan, side and front elevation, and to a scale of probably 1½ in. or 3 in. to the foot.

(v) Arrangement of Front Axle assembled complete to a scale of 3 in. to the foot.

On all these drawings, overall dimensions will be given and dimensions locating the position of all components.

Finally there will be the drawings of all the component parts, each of which will have a drawing to itself, full size if possible, otherwise as large as can be conveniently got on to a standard sheet (either 30 in. by 22 in., 22 in. by 15 in., or 15 in. by 11 in.), and on which will be shown every dimension necessary for making the part. The scale or scales of all drawings should be clearly marked.

The standard method of projection of the views should be First Angle Projection, in which each view is so placed that it represents the object looked at from the side remote from the view as shown in Fig. 1. In the case of flanges and parts which

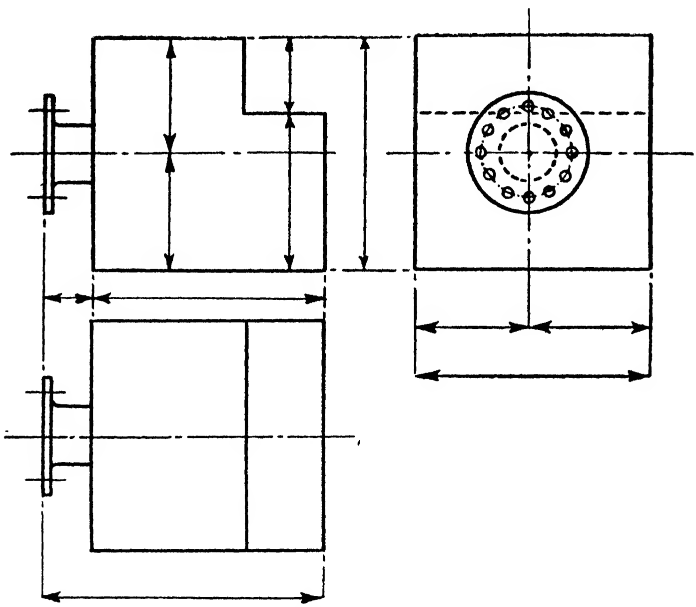


FIG. 1.—First Angle Projection.

it is desirable to show adjacent to their position on the general elevation, Third Angle Projection is commonly used, and in this case the direction of the view should be indicated by an arrow as shown in Fig. 2.

The dimensions should be inserted slightly above the dimension line which should be thinner than the main lines of the drawing proper and should stand normal to that line when read from the base or from the right-hand side of the drawing, vulgar fractions having their dividing line parallel to the dimension line. (See Fig. 3.) It should be noted that decimals in the dimensions indicate a greater degree of accuracy than fractions. All parts should be clearly dimensioned and when

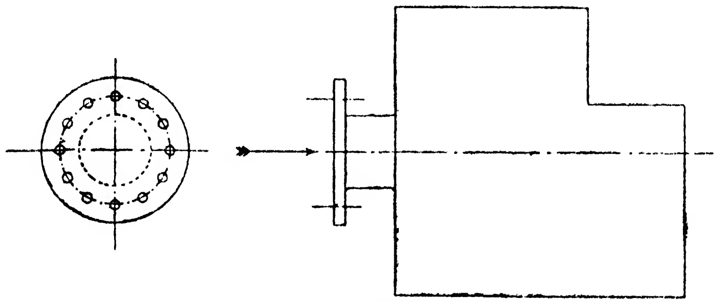


FIG. 2.—Third Angle Projection.

possible the dimensions taken out clear of the main lines of the part as shown in Fig. 3.

In some Drawing Offices, the dimensions of rounded fillets and small unimportant details are left to the Works. This practice is dangerous and should not be followed. The best method is to put in every dimension necessary for the complete manufacture of the part, leaving nothing whatsoever to be measured or guessed or left to the discretion of the Shops, and then there can be no question of mistakes or of parts fouling due to insufficient clearances.

If different types of hatching are used to indicate different materials, a key diagram should be given on the drawing, and also a key to the various symbols used for indicating the finish of the various parts, i.e. if rough machined, finish machined, ground, lapped or polished. When parts are to be heat-treated, hardened, annealed or tempered, a note should appear under the part stating clearly the various temperatures to be used.

Tapers should be clearly indicated, preferably as the alteration in diameter or thickness per unit length, although they are commonly given as 1 in 10, or 1 in 100, or 1 in some given number, on the diameter or on the thickness, and this should be clearly and fully stated so that the mechanic has no calculations to make.

Detail drawings should also be marked with the name of the

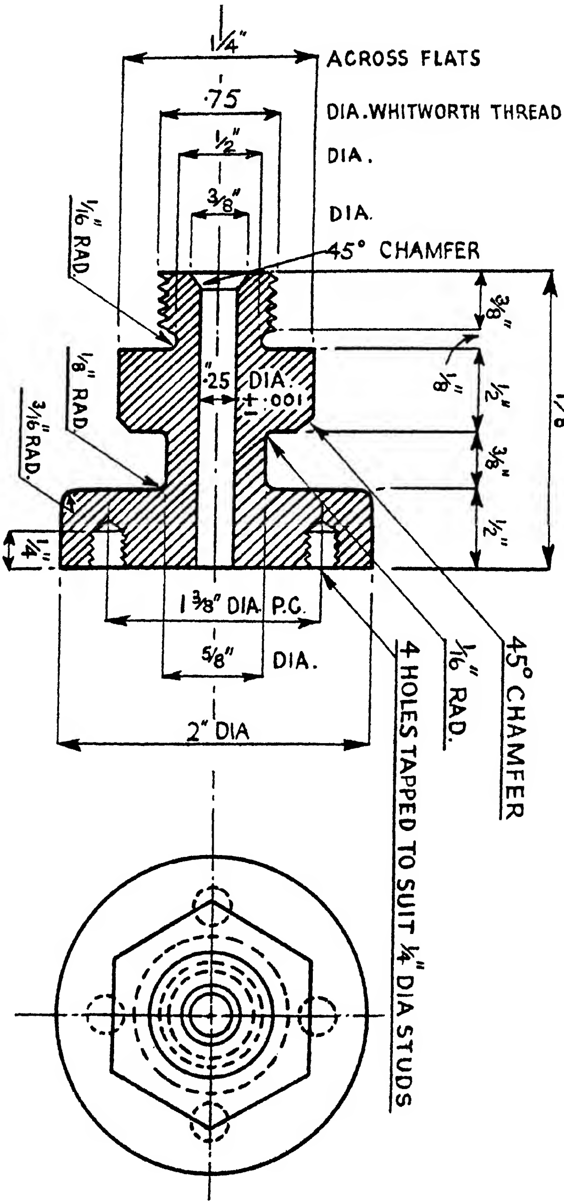


FIG. 3.—Showing dimensions clear of drawing and method of setting out sizes and tolerances.

material from which the part is to be made, i.e. Mild Steel Plate, Malleable Steel Casting, Brass, etc., and the number of Bolts and Nuts, Washers, Rivets, etc., required to attach the part to its main assembly.

In Works where the parts are manufactured from bar stock it is also usual to mark on the drawing the size of bar from which the part is to be made, especially where the work is repetition, so that when large quantities of material are required for a particular job the amount of material can be quickly arrived at by referring to the drawing. In addition, quantity sheets are prepared for each Assembly giving the number and description of each part and the quantity and description of material from which it is made. It should be noted in this connection that for a part made of say 1½-in. diameter steel, it is better to specify and order a number of bars of standard lengths to complete the requirements of the job.

In addition, if the Drawings are numbered with an initial letter corresponding to the assembly to which they belong (thus an Engine Drawing might be numbered E.746, and a Gear Box Drawing G.638, and so on) and the parts bear the same numbers as the Drawings, it makes every part easy to locate. In the event of orders being received for spare parts, when numbered thus they are easily dealt with.

In repetition work, when the design of a part is altered and the alteration does not affect the interchangeability of the part, the drawing is usually altered and given the same number as the old drawing, but with a new Issue Number, and a note put on the drawing giving the date of the alteration and particulars. If the change in design affects interchangeability, a new drawing with a new number should be issued, and a note made of the serial number of the machine on which the first of the new design is fitted.

The Drawings in Works Drawing Offices are usually done only in pencil, after which they are traced. Blue prints are then taken from the tracings and issued to the works, the original drawing and tracing being kept in the Drawing Office for reference and to be used when further prints are required.

To sum up with regard to drawings, these should, when read in conjunction with the Specification, be sufficient to enable the Contractor or the Works as the case may be, to execute the whole of the work without any dubiety as to what is required.

In checking a drawing to see if it is correct and complete, assuming that the design of the part is all right and that it functions properly if it is a working part, the points to be watched by the checker are these :—

(*a*) Is it possible and practical to make the part ?

(*b*) Is it possible and practical to fit it in position in its assembly ?

(*c*) When fitted in position will it foul any other part, either stationary or moving ? All doubtful clearances must be checked.

(*d*) Are the bolt, stud or rivet holes the same size and at the same centres as those of the part to which it is to be fitted ?

(*e*) Do the detail dimensions add up to the same figures as the overall dimensions ?

(*f*) Can the part be made from the information and dimensions given without leaving anything to the discretion of the Shops ?

(*g*) Is the part sufficiently strong or too strong for its purpose ? In other words, the stresses in it must be checked. In work where weight is a vital consideration, as in an aeroplane engine it is essential that the parts should be stressed up to the maximum allowable safe stress, so that it may be as light as possible consistent with its having the requisite strength.

(*h*) Is the material of which the part is to be made correctly specified ?

(*i*) Is the " Number Off " per engine correctly specified, and are they to the right hand ?

(*j*) Is the quantity of material from which the part is to be made correct, and are all Bolts, Nuts, Studs, Rivets, Washers, Split Pins, etc., for connecting it to the assembly correctly specified ?

If the drawing passes these tests, it can be passed as correct and complete.

Note.—The recommendations given in this section for the preparation of drawings conform to the recommendations issued by the British Standards Institution for Engineering Drawing Office Practice, British Standard No. 308/1943.

CHAPTER II

CONTRACTS

Incorporated in the Specification for any Works, there is usually a set of Conditions upon which the Contract is entered into and agreed upon by the Parties to the Contract, and it is advisable that the Engineer should know what constitutes a Contract, and the rights and liabilities arising therefrom. In addition, he should know his own legal rights and responsibilities towards his employers and third parties.

For instance, in the preparation of designs, specifications, and estimates for submission to public bodies, failure to exercise proper skill involves liability for damages arising from such failure. Failure in obtaining the necessary powers from public authorities to execute works, or in giving proper notices to the competent authorities when so required by law may again involve the Engineer in damages.

In general, an Engineer is bound to carry out his work with the skill requisite to a man in his position, and failure to do this in all instances renders him liable to an action for damages arising from his failure.

He is presumed to know the conditions under which a Contract is usually carried out but, obviously, cannot be expected to combine his duties with those of a Lawyer.

The drafting of the conditions into legal form is a matter for a lawyer, as is the elucidation of any complexity in the construction of any legal document, and the Engineer is entitled to the services of his employer's lawyer in these matters. If he acted in such matters on his own initiative, he would probably be presumed to have represented himself qualified to do so, and render himself subject to the consequent liabilities in the event of the Contract being unskilfully drawn. It should be noted that a knowledge of the conditions is the Engineer's responsibility, and the lawyer is only necessary to draft these into legal form.

A Contract may be defined as an agreement between two or more parties whereby, in consideration of one party doing, or refraining from doing, something, the other party is bound to do, or to refrain from doing, something as specified.

In other words a Contract is an agreement which is enforceable at law.

There are certain essential facts constituting a Contract, and these may be summarized as follows :—

(1) A communication between the parties to the Contract.

This must consist of a definite offer on the one hand and an unqualified acceptance on the other to complete the Contract. The whole must reduce to these essentials, however complicated the clauses or however protracted the correspondence.

(2) Capacity to contract legally.

In general all persons over twenty-one years of age are able to contract, but there are limitations. For instance, a corporation or a company may have limited powers stipulated in its charter and any contract entered into beyond these limits is void. Another case of a person having only limited capacity to contract is that of an undischarged bankrupt.

(3) Consideration.

That is, something in return for, or in consideration of, the offer of the one party to the other. This is required by law which assumes that people, on the whole, do not do things gratuitously. Consideration is required in all contracts not under seal, and may consist of conferring a benefit, a sum of money (the usual one in Engineering Contracts), an interest, or a concession on the one party, or exercising a forbearance or some such act by the other.

(4) Legality or Possibility of the subject-matter of the Contract.

Obviously the law will not enforce an agreement which is unlawful in any of its terms, or which calls for the performance of an illegal act. In addition the contract must be capable of performance when it is made, otherwise it will again be void for lack of sufficient consideration.

(5) Absence of Mistake, Misrepresentation, and Fraud.

Mistakes, to cancel a contract, must be of fact. If one party enters into a contract, that party cannot escape the effects thereof if it turns out contrary to his expectations. For instance, a man might contract to buy certain shares in the expectation that the market was rising. If his expectation was not realised, and prices fell, he could not repudiate his contract on the ground that he was mistaken in his expectations.

If any one or more of the above five elements is wanting, the so-called agreement or contract will be :—

(*a*) Unenforceable. That is, valid in itself but incapable of being proved in a Court of Law.

(*b*) Voidable. That is, one or other of the parties will be able to confirm or repudiate it at will.

(*c*) Void. That is, without legal effect.

Contracts are of three descriptions, viz.:—

(1) Contracts of Record. This is an obligation resulting from the judgment of a Court of Law.

(2) Contracts in sealed writing or under seal, generally referred to as speciality contracts or deeds. These are the formal contracts of the English Law. They may be used in any transaction of the nature of a contract but are, in practice, confined to cases where sealing is essential by law, such as conveyances of land, legal mortgages, contracts by corporations, etc.

(3) Simple Contracts. These are made either (*a*) by word of mouth, when they are termed oral ; or (*b*) in writing without seal ; both being frequently referred to as " parol " contracts ; and they include all contracts not included in the other two classes.

Simple Contracts are the type most frequently met with by Engineers.

If the terms of a Contract are clearly stated, the Contract is said to be " express ", but if they are to be implied from the conduct of the parties, the Contract is said to be " implied ".

It is perhaps advisable now to consider in more detail the principal elements in a contract, namely, the offer and the acceptance.

As already stated, the offer must be definite, but it may be made to a definite party, as is the usual case in Engineering Contracts, or to persons generally, as is the case when a reward is offered for the finding and return of a lost article. By some person returning the article to the offerer and thereby fulfilling the conditions stated by him, the contract will be completed and the reward become due.

All the terms of an offer must in every case be brought to the notice of the other party, and no attempt must be made to embody terms which will bind the acceptor and dispense with a communication of acceptance. Thus a clause in the offer stating that, if no reply is received within a certain time, the offerer will assume that it has been accepted and proceed with the work, is invalid, and the contract would still be uncompleted if a communication of acceptance was not received by the offerer.

The acceptance must be unconditional and must be communicated to the person making the offer.

If an offer is made by telegraph this is held to be an indication that a quick reply is expected and delay in acceptance may render the contract uncompleted.

If an offer is made by post, the post is considered primarily to be the Agent of the offerer, i.e. of the party to the contract first making use of the post, and the offer is of no effect until it reaches the other party. On the other hand an acceptance of the offer is complete the moment the letter containing the same is posted whether or not it ever reaches its destination. If the offerer withdraws his offer by a communication, however sent, it has no avail if the acceptor has already posted his acceptance, although until then it may be withdrawn at any time and in any way, on so giving notice to the other party.

Whilst writing is not essential to most contracts, it is always advisable in cases of difficulty or complication. So long as a contract can be proved it is enforceable in a Court of Law unless it belongs to the class of contract for which writing is essential, a class which, in general, does not affect Engineers, with the exception of contracts which cannot be completed within a year.

When in writing, and applying to matter of the value of £5 and upwards, the contracts must carry a 6*d.* stamp, which may be an ordinary postage stamp, cancelled by the signatures to the contract, or a stamp embossed on the contract at Somerset House within fourteen days of signing the contract. An unstamped contract will not be accepted in a Court of Law, but it is possible to have an overdue contract stamped at Somerset House on payment of a fine.

The existence of a document in writing does not dispense with the consideration in a simple contract, and the consideration must be " valuable ". That is, it must be some return for a promise made to show that the promise was not gratuitous. The simplest illustration is the payment of a sum of money for the performance of some work.

It should be noted that it is not essential that the consideration should be adequate in point of actual value, as the law has no means of deciding upon this matter. It is necessary that the consideration should be of some value, however small, and that it come from the party to whom the promise is made. In addition the consideration must be something definite, enforceable at law if necessary, and it must be lawful.

All agreements entered into to defraud third parties are void as being illegal.

An agreement may also be null and void if it is opposed to public policy or is made void by statute law. For example the Truck Act forbids the payment of wages to workmen otherwise than in money.

Under the heading of Public Policy come contracts in " Restraint of Trade ". The main rules regarding these may be summed up as follows :—

(1) A restraint is not void unless it extends further than is necessary for the reasonable protection of the party for whose protection it has been agreed to, or is injurious to the public interest of this country or is agreed to, even though under seal, without a consideration of some legal value.

(2) A restraint, if valid, is enforceable by injunction notwithstanding a stipulation for payment of liquidated damages in case of a breach and the defendant's willingness to pay such damages.

(3) An agreement in restraint of trade, if bad, is only not enforceable by law, and is not contrary to law.

(4) An agreement against the disclosure of trade secrets is not within the rules as to restraint of trade, and may be unlimited.

(5) A restraint of trade may be partly good and partly bad, and must be confined exclusively to the particular occupation or business in which the promisor was employed.

(6) The restraint must in any event be limited to a competing business, and is avoided by wrongful dismissal of the covenantee.

Under the heading of " Public Policy " comes also a contract of importance to Engineers, namely that which stipulates for the payment of penalties. Under certain conditions this is held to be opposed to public policy. Sometimes the parties to a contract agree as to the sum of money that is to be paid in case there is a breach of it, and give to the sum agreed upon, the name of " liquidated damages ". In general the law considers these cases very carefully and grants relief where it is clear that the sum is in the nature of a penalty and not a measure of the damage involved through non-compliance with the contract. The underlying idea is that Courts exist for the imposition of penalties and such action in a clause is usurping the functions of a Court.

When the interpretation of a contract is found necessary, words must be construed in their ordinary sense, and the construction must be liberal, favourable, and reasonable. The context must be considered as a whole, and the words of the contract must be construed most strongly against the Contractor.

There now remains only the Discharge of the Contract, and this happens when the contract entered into between the two parties is terminated and the rights and liabilities arising therefrom are extinguished.

A contract may be discharged in any of the following ways :—

(1) By Agreement. That is by agreement between the parties to the contract to terminate it, either by substituting a new contract ; by one party waiving his rights ; or by one party releasing the other from his obligations. In the latter case it must be made for sufficient consideration.

(2) By Performance. That is, by complete fulfilment of the terms of the contract in every respect.

(3) By Breach. In this case, there is a right of action for damages (or in some cases for an injunction or specific performance). Since the main object in awarding damages is to place the injured party as far as possible in his original position the measure of damages is the amount of loss sustained through the breach of the contract.

(4) By Lapse of Time. An action on a simple contract must be commenced within six years of the time when the cause of action arose.

(5) By Impossibility. Where this has arisen since the making of the contract.

Note that an injunction *forbids* a person or persons to do certain things. Refusal to obey renders the person in default liable to be committed for contempt of court. When the form of judgment *orders* a person to do a certain thing, which order must be obeyed under the same pains and penalties as an injunction, it is called one of " specific performance ".

As this chapter can, of necessity, only give a brief outline of the legal aspect of a Contract, it is strongly urged that competent legal advice be taken before drawing up a contract of any importance.

CHAPTER III

CONDITIONS OF CONTRACT

From the preceding chapter it is evident that a Contract is a very binding agreement not to be entered into without due consideration, and the Conditions under which it is entered into require careful thought on the part of the Engineer, so that he may cover all possible contingencies and provide for them.

The drawing up of the Conditions and of the Specification must be done in such definite and decisive language that as little doubt as possible could be thrown upon what its meaning was if it ever came before a Court of Law.

It is also essential that foresight should be used, for it is necessary for the Engineer to anticipate the various things and conditions that are likely to occur, and it is his province to protect in every way possible the interests of his Employer.

The Conditions on which the work is to be carried out, termed the " Conditions of Contract ", should not be mixed up with the clauses of the Specification proper (lest contrary or contradictory conditions, which could be a fruitful source of litigation, were introduced), but usually form the first part of the Specification. Alternatively, many Engineers and Authorities have them printed separately and issue them as their Conditions for all their Contracts.

There have been published the following model sets of General Conditions of Contract for works of civil engineering construction, which should be used as a basis for the conditions of all civil engineering Contracts, as they have been agreed between the Professional Institutions concerned and the Federation of Civil Engineering Contractors.

(1) " General Conditions of Contract, and Forms of Tender, Agreement and Bond for Use in Connection with Works of Civil Engineering Construction," published by the Institution of Civil Engineers, December 1945, price 2*s*. 6*d*.

(2) " Forms of Agreement and General Conditions of Contract for Use in Connection with Works of Civil Engineering Construction," published by the Association of Consulting Engineers, May 1930, price 3*s*. 6*d*.

The Institution of Structural Engineers also published in 1944 a set of " General Conditions of Contract for Structural Engineering Works " (price 1*s*. 6*d*.).

The following typical set of Conditions is based on the above-mentioned documents, and covers most of the items to be met with in the usual run of Civil Engineering Contracts.

1. CONTRACT.—The first clause commonly describes the nature of the work to be done under the Contract and may be as follows :—

> The Contract to which this Specification refers is for the construction of the works necessary for the formation of .... (*here describe the nature of the work*) ....
>
> The whole of the works, hereinafter described, are to be included in one Contract which is to include every description of work, whether permanent or temporary, which may be necessary to carry out the work to the true intent and meaning of the Specification, and the whole of the work is to be executed in strict accordance with the following Specification and the accompanying drawings numbered .... to ...., and with any working drawings furnished or approved in writing by the Engineer as the work proceeds, and under this and the following Conditions.

2. DEFINITIONS.—To prevent a needless repetition of terms, it is usual next to insert a Clause describing the various parties concerned in the Contract, and any other terms that require definition, as follows :—

> In this Contract the following expressions shall have the meanings herein assigned to them, unless there is something in the subject or context repugnant to that construction :—
>
> The " Employer " shall mean .... of .... and shall include the Employer's legal personal representatives or successors.
>
> The " Engineer " shall mean .... or any person appointed by the Employer from time to time to act in that capacity.
>
> The " Engineer's Representative " shall mean any Resident Engineer, Clerk of Works, or Inspector appointed from time to time by the Employer or the Engineer to supervise on the site the actual construction of the work and whose authority shall be notified to the Contractor by the Engineer.
>
> The " Contractor " shall mean the person or persons, firm or firms, company or companies, whose tender for the work herein specified shall be accepted by the Employer and shall include his or their legal personal representatives or successors.

The " Works " shall mean all the Works herein described, as set forth in the Specification and Schedule of Quantities, or any of them, as explained or described or implied in or by the Drawings, and shall include all extra Works and variations, and be subject to all omissions ordered in accordance with the Specification.

The " Contract " shall mean the General Conditions, Specification, Drawings, Tender, Priced Bill of Quantities, Schedule of Rates and Prices, and the Contract Agreement.

" Drawings " shall mean the Drawings, Maps, Plans, Sections, and other delineations which accompany or are referred to in the Specification and/or the Schedule of Quantities and which have been signed by the Engineer and the Contractor, and such further Drawings as may be approved in writing by the Engineer in connection with the Works, whether such further Drawings indicate variations of the Works (whether by way of addition, alteration, or omission) or merely elaborate in greater detail the signed Drawings or the further Drawings supplied to the Contractor as aforesaid.

" Contract Price " shall mean the value calculated at the rates and prices set out in the Schedule of Quantities, or, where no appropriate rate is set out, at the rate or rates fixed in accordance with the Specification, of the whole of the work done and the materials supplied in relation to the Works, the extent of such work being ascertained and determined in the manner hereinafter described, subject to such additions or deductions as may be made under the provisions hereinafter contained. Where an item is included in the Schedule of Quantities, but no price is therein set out in respect thereof, no charge in respect thereof shall be payable or included in the Contract price.

" Contract Documents " shall include the Specification, Schedules of Quantities, and Rates and Prices, Drawings, Tender, Letter of Acceptance, and the Contract to follow hereon.

The " Site " shall mean the lands and/or other places on or under, into or through which work is to be executed or carried out under the Contract, and any other lands and/or places acquired or used by the Contractor in connection therewith.

" Constructional Plant " shall mean all appliances or things of whatsoever nature required in or about the execution, completion or maintenance of the Works or Temporary Works, but does not include materials or other things which will form part of the Permanent Works.

" Temporary Works " shall mean all temporary works of every kind required in or about the execution, completion, or maintenance of the Works.

" Month " shall mean Calendar month.

"Writing" shall include any manuscript, typewritten, or printed statement under or over signature or seal, as the case may be.

The marginal notes in these Conditions shall not affect the interpretation thereof.

Words importing the singular only include the plural and vice versa where the context requires.

3. SUB-LETTING.—A clause should always be inserted to guard against indiscriminate assignment or sub-letting of the Contract; a usual form for this is as follows:—

> The Contractor shall not assign the Contract or sub-let the same, nor shall he make any Sub-Contract with any person or persons for the execution of any portion of the Works without the consent in writing of the Employer, through the Engineer, being first obtained. If the Contractor, in the proposed execution of the Contract, requires or determines to employ Sub-Contractors, he shall intimate to the Employer, at the time when his Tender for the Contract is lodged, the name or names of such Sub-Contractors. The Contractor shall be responsible for the observance by the Sub-Contractors, if any, of the whole of the conditions of the Contract. This condition as to Sub-letting does not apply to the contracting for timber, iron, steel, cement, or other materials, nor to the execution of any part of the work on a piece-work basis.

4. ACCURACY OF SCHEDULE OF QUANTITIES NOT GUARANTEED.—It is usual for the Engineer to supply with the Specification a Schedule of Quantities, and although this is made up with the greatest care and accuracy, it is possible for errors to arise which, if unprovided for, might, should occasion arise, give the Contractor ground for claims, or form a loophole for evading work. To obviate this, the Contractor is made responsible for the accuracy of the Schedule, thus:—

> A Schedule of Quantities, in which all measurements are taken to the net sizes, has been prepared by the Engineer and accompanies this Specification for the convenience of tenderers, but its accuracy is not guaranteed by the Employer or the Engineer, and tenderers must satisfy themselves as to all quantities before tendering, and add anything which they may consider necessary to complete the work to the true intent and meaning of the Specification, the Conditions, and the Drawings. No allowance will be made on account of any errors or omissions, actual or alleged, which may have been made in the Schedule by the Engineer, and the Contractor whose tender is

accepted shall be wholly responsible for the accuracy of the quantities and of the detailed estimate based upon them which shall accompany the tender on the Schedule Form supplied under this stipulation.

5. CHARACTER OF SOIL. BORINGS.—For Works underground it is common to supply borings, showing the nature of the subsoil, to the Contractor, but the accuracy of these is not guaranteed and Contractors are permitted to make any further trial borings they require or consider necessary for the purposes of their tender.

The Contractor will be held to have satisfied himself by his own independent inquiries and observations as to the character of the soil or strata through and on which the excavations or embankments are to be made, piling to be driven, foundations to be built, or other work or works executed, and no claim for additional work or extras will be allowed on account of the character of subsoil or strata met with.

If at any time during the execution of the works the Engineer shall require the Contractor to make boreholes or to carry out exploratory excavations, such requirement shall be ordered in writing and shall be deemed to be an addition ordered under Clause ...... hereof unless a provisional sum in respect of such anticipated work shall have been included in the bill of quantities.

Borings have been taken by Messrs. .... in the positions shown on Sheet No. .... of the Contract Drawings, upon which are also shown sections of the bores plotted in accordance with the journals which may be examined at the office of the Engineer by the Tenderers, but the Employer, the Borers, or any one acting for them do not guarantee in any way the accuracy of the information shown thereon, and will not be liable for any claim that may be made against them on account of any inaccuracy in the information given, and tenderers must satisfy themselves as to their accuracy, take other bores if they think it necessary, and make any corrections which may be required before tendering.

6. DOCUMENTS MUTUALLY EXPLANATORY.—It is obvious that an Engineer might quite easily overlook some discrepancies in the Drawings, or between the Drawings and the Specification, and of these discrepancies a Contractor might seek to take advantage, hence the Engineer must protect himself and the Employer by providing against this contingency, which may be done thus :—

> The several documents forming the Contract are to be taken as mutually explanatory and in case of ambiguities or discrepancies the same shall be explained and adjusted by the Engineer, who shall thereupon issue to the Contractor instructions directing in what manner the work is to be carried out. Provided always that if, in the opinion of the Engineer, compliance with any such instructions shall involve the Contractor in any expense which by reason of any such ambiguity or discrepancy the Contractor did not and had reason not to anticipate, the Engineer shall certify and the Employer shall pay such additional sum as may be reasonable to cover such expense.

7. Deed of Contract.—It is often required that a Deed of Contract be prepared; for instance, as pointed out in Chapter II, some contracts require to be under seal. Also, as a general rule, a Corporation cannot bind itself except by a Contract under seal; but this rule is subject to many exceptions, and in matters of little import or great urgency the seal is often dispensed with. The clause requiring a Deed of Contract may be as follows:—

> A Deed of Contract covering all the clauses of this Specification, and containing all other usual and necessary clauses shall be executed between the Employer and the Contractor, along with his Sureties, at the expense of the Employer, the original Contract being deposited with the Employer, and, should the Contractor require a copy, the same will be furnished to him at his own expense.

8. Sureties.—If the Engineer or the Employer think it advisable that the Contractor provide a suitable guarantee for the satisfactory fulfilment of the Contract, a clause to that effect may be provided thus:—

> The Contractor shall at his own expense provide two good and sufficient sureties or obtain the guarantee of an insurance company (in either case to be approved by the Employer) to be jointly and severally bound together with him to the Employer in the sum provided in the tender for the due performance of the Contract.

9. Alterations, Additions, and Deductions.—In a Contract of any extent, events may occur which will necessitate additions, alterations, and/or deductions in the work. Unless the Engineer has power to order these under the Contract, the Contractor could refuse to carry them out, or could insist on another Contract being entered into for the execution of this

work, as any variations in the terms of a Contract are sufficient to nullify it unless provision is made for them. It may be made thus :—

The Employer, through the Engineer, reserves the right to alter the Drawings and make alterations, additions, and/or deductions in the work, and such alterations, additions, and/or deductions shall not vitiate the Contract and are to be valued by the Engineer from prices in the Schedule of Quantities and Schedule of Rates for similar work or proportionate to the prices for work therein which is similar or equivalent in his opinion, and the Engineer's measurement and valuation of such work as affecting the amount of the tender shall be accepted by the Contractor.

Provided that if the nature or amount of any omission or addition relative to the nature or amount of the whole of the contract work or to any part thereof shall be such that, in the opinion of the Engineer, the rate or price contained in the Contract for any item of the Work is by reason of such omission or addition rendered unreasonable or inapplicable, the Engineer shall fix such other rate or price as in the circumstances he shall think reasonable and proper.

Provided also that no increase of the Contract Price under Para. 1 of this Clause or variation of rate or price under Para. 2 of this Clause shall be made unless as soon after the date as is practicable and in the case of extra or additional work before the commencement of the work or as soon thereafter as is practicable, notice shall have been given in writing :—

(*a*) By the Contractor to the Engineer of his intention to claim extra payment or a varied rate ; or

(*b*) By the Engineer to the Contractor of his intention to vary a rate or price as the case may be.

Should the Engineer be of the opinion and decide that any alteration or addition be made, or any circumstance require an extension of the Contract time, the same may be granted by him, and his decision shall be accepted by the Contractor without appeal.

No addition, alleged or real, will be acknowledged and paid for without the production of an official order for the work, duly signed by the Engineer, and of a weekly detailed statement to the Engineer of all such additions, the items of which shall be distinguished by the reference number of the official order.

10. DAYWORK.—The execution of work on a daywork basis by the Contractor should be covered by a clause such as :—

The Engineer may, if in his opinion it is necessary or desirable, order that any additional or substantial work shall be executed on a daywork basis. The Contractor shall then be paid for such work under the conditions set out in the Daywork Schedule included in the Bill of Quantities and at the rate and prices affixed thereto by him in his tender, and failing the provision of a Daywork Schedule he shall be paid at the rates and prices and under the conditions contained in the " Schedule of Daywork carried out incidental to Contract Work " issued by the Federation of Civil Engineering Contractors current at the time when the order for such work is given.

The Contractor shall furnish to the Engineer such receipts or other vouchers as may be necessary to prove the amounts paid and before ordering materials shall submit to the Engineer quotations for the same for his approval.

In respect of all work executed on a daywork basis, the Contractor shall during the continuance of such work deliver each day to the Engineer's Representative an exact list in duplicate of the names, occupation and time of all workmen employed on such work and a statement also in duplicate showing the description and quantity of all materials and plant used thereon or therefor (other than plant which is included in the percentage addition in accordance with the Schedules hereinbefore referred to). One copy of each list and statement will, if correct or when agreed, be signed by the Engineer's Representative and returned to the Contractor. At the end of each month the Contractor shall deliver to the Engineer's Representative a priced statement of the labour, material and plant (except as aforesaid) used and the Contractor shall not be entitled to any payment unless such lists and statements have been fully and punctually rendered. Provided always that if the Engineer shall consider that for any reason the sending of such list or statement by the Contractor in accordance with the foregoing provision was impracticable, he shall nevertheless be entitled to authorise payment for such work either as daywork (on being satisfied as to the time employed and plant and materials used on such work) or at such value therefor as he shall consider fair and reasonable.

11. Contract Times.—Work executed under Contract is invariably required as soon as possible, and the Contractor is usually required to state in his tender the time within which he undertakes to complete the work. As delay usually means loss to the Employer, it is necessary to emphasize that the work is to be completed within the Contract times, which is done in the following clause. (Provision is made in Clauses Nos. 48 and 49 for eventualities should the Contractor delay the work or fail to complete within the time stipulated.)

The Works shall be commenced within fourteen days from the date upon which the Engineer shall give notice to the

Contractor that he can enter upon the site or any portions thereof for the purposes of the Works, and shall be carried on regularly and expeditiously till completed, and that within the Contract time, or such extended time as may be allowed.

12. ARRANGEMENT FOR CARRYING OUT WORK.—It is necessary that the Engineer shall know in what order the Contractor proposes to proceed with the work and that he shall have power to compel the Contractor to carry it out in the manner which best suits him, as events may occur that necessitate an alteration in the order of the work ; hence the following :—

> As soon as practicable after the acceptance of his tender, the Contractor shall, if required, submit to the Engineer for his approval a programme showing the order of procedure and method in which he proposes to carry out the Works and shall, whenever required by the Engineer, furnish for his information particulars in writing of the Contractor's arrangements for the carrying out of the Works and of the Constructional Plant and Temporary Works which the Contractor intends to supply, use or construct, as the case may be. The submission to and approval by the Engineer of such programme or the furnishing of such particulars, shall not relieve the Contractor of any of his duties or responsibilities under the Contract.
>
> The Engineer shall have the power of ordering the manner in which the Works are to be proceeded with, and the Contractor shall be bound to carry out the work according to such arrangements and according to any directions that the Engineer may give from time to time as the work proceeds, and such directions must be complied with without delay.
>
> Any such directions which may be given by the Engineer shall in no way take away the responsibility of the Contractor to carry out the work in a proper and efficient manner, and the Contractor will not be allowed to plead any acts or directions of the Engineer, the Inspector, or any person as authorizing him to depart from the terms of the Specification or as granting him an extension of the Contract time, unless he produces written authority from the Engineer to that effect.

13. NOTICES, ORDERS, ETC., TO BE IN WRITING.—To prevent disputes it is advisable that all notices, orders, etc., be given in writing, and this is provided for thus :—

> All notices, orders, directions, authorities, consent, declarations, certificates, extensions of time, or the like, which are to be or may be given under this Specification, shall be given in writing under the hand of the person authorized to give such

notice, order, direction, authority, consent, declaration, certificate, extension, or the like, and unless so given shall be invalid and of no effect.

All notices to be given to the Employer and all other notices to be given under these Conditions may be served personally upon the person or persons to whom they are to be given, or may be served by registered letter addressed to him or them at his or their registered office or last known place of business, and any notice given may at any time thereafter, with the consent in writing of the person served, be withdrawn in writing, when it will become inoperative and null as from the date on which it was given. Except where otherwise expressly herein provided, all notices to be given by the Employer shall be signed by the Engineer.

14. ENGINEER, RESIDENT ENGINEER, AND INSPECTOR.—The following clause defines the responsibilities of the Engineer, the Resident Engineer, and the Inspector :—

The whole of the Works shall be executed to the satisfaction of the Engineer, whose decision shall be final and conclusive on all points relative to the mode of carrying on the Works and to the nature and quantity of the materials and workmanship.

The Resident Engineer, with the assistance of his Inspectors, shall have the immediate charge of the Works under the Contract, and his directions on all points relative to the nature and quality of all materials used, and to the workmanship and the mode of carrying on the works in accordance with the Specification, are to be received and acted upon by the Contractor.

The Engineer shall from time to time in writing delegate to the Engineer's Representative such of the powers and authorities vested in the Engineer as may be necessary for the efficient execution of the Works and shall furnish to the Contractor a copy of all such written delegations of powers and authorities. Any written instruction or written approval given by the Engineer's Representative to the Contractor within the terms of such delegation (but not otherwise) shall bind the Contractor and the Employer as though it had been given by the Engineer. Provided always as follows :—

(*a*) Failure of the Engineer's Representative to disapprove any work or materials shall not prejudice the power of the Engineer thereafter to disapprove such work or materials and to order the pulling down, removal or breaking up thereof.

(*b*) If the Contractor shall be dissatisfied by reason of any decision of the Engineer's Representative he shall be entitled to refer the matter to the Engineer, who shall thereupon confirm, reverse or vary such decision.

The Contractor shall provide all labour, information, and assistance, and all poles, pegs, staging, ladders, and other necessary instruments and apparatus as required by the Engineer, the Resident Engineer, and/or the Inspector, for checking the work, measuring the same, ascertaining the quantities and qualities of materials supplied, and for the proper supervision, inspection, and testing of the work at every stage, or for any other purpose connected with the Contract.

15. RESIDENT ENGINEER'S OFFICE.—In a Contract of any size it is common to specify the Contractor's liability in respect of office accommodation for the Resident Engineer and his Staff in a clause such as the following :—

The Contractor shall construct and maintain for the sole use of the Resident Engineer and his Staff a substantial, well-lighted, weathertight office of timber, lined with flooring boards, the office being at least 12 ft. wide by 12 ft. long, and equipped with a Post Office telephone, a fireplace and chimney of brick, one drawing table 8 ft. long by 4 ft. wide with two large plan drawers having lock and key, and chairs and other furniture as approved by the Engineer. He shall also have an intelligent man in attendance to look after the office, and to assist the Engineer's staff and the Inspector in setting out work, etc., and shall provide and keep the office in coal fuel, fires, and lights, all at his own expense.

16. CONTRACTOR'S SUPERINTENDENCE, MANAGER, MEN, ETC.—It is advisable that the Engineer shall have some jurisdiction over the Contractor's men, and this can be provided for thus :—

At all times throughout the course of the Contract the Contractor shall personally superintend the Works, or be constantly represented by a fully qualified responsible Agent having prior experience in carrying out Works of a similar character to the Works under this Contract, and the appointment of such Agent shall be subject to the approval of the Engineer, and be intimated to the Engineer in writing by the Contractor.

The Contractor shall employ as many and such servants, workmen, and others as the Engineer shall think necessary to complete the Works within the Contract time, and shall, on the direction of the Engineer, forthwith cease to employ on the Works any servant, workman, or foreman who, in the opinion of the Engineer, is incompetent or negligent, or guilty of improper conduct, whether in relation to the Works or not, and shall not re-employ any such servant, workman, or foreman on or about the Works without the consent of the Engineer. Further, the Contractor shall be responsible for the proper behaviour of such servants, workmen, and others, and shall exercise a proper degree of control over them, and in particular and without prejudice to the said generality the Contractor shall be bound to prohibit and prevent such servants, workmen, and others from trespassing, poaching, or acting in any way detrimental or prejudicial to the interests of the community or of the proprietors or occupiers of lands and properties in the neighbourhood, and in the event of such servants, workmen, or others so trespassing, poaching, or acting, the Contractor shall be responsible therefor, and shall relieve the Employer of all consequent claims or actions for damages or injury or on any other ground whatsoever. The decision of the Engineer upon any matter arising under this Clause shall be final.

17. CONTRACTOR RESPONSIBLE FOR LINES AND LEVELS.—Although the Engineer or one of his Assistants may set out the works and give the levels, this is not in any way to relieve the Contractor of his responsibility to see that these are correct, but merely to satisfy the Engineer himself that everything is in order. The Contractor is held responsible in the following clause :—

The Contractor shall be solely responsible for the setting out of the Works and for the correctness of the positions, levels, dimensions, and alignment according to the Plans, and he shall find all necessary assistants, instruments, pegs, stakes, poles, and other materials requisite for this purpose. Should the Resident Engineer or the Inspector at any time set out Works, this shall be at the entire risk and responsibility of the Contractor and no error or alleged error in so setting out any Works, and no act, order, or direction of the Resident Engineer or of the Inspector shall be admitted as a plea for improper performance of the work, or used by the Contractor for any claim against the Employer. Any error in the work, at whatever time it may be discovered, shall forthwith be rectified by the Contractor at his own expense, unless the error is due to incorrect information supplied by the Engineer.

18. PLANT AND MATERIALS.—It is necessary that the Engineer shall have power to ensure that the Contractor uses plant adequate to the work to be executed. In addition he must provide for retaining the plant until the completion of the Contract in the event of the Contractor dying, or going bankrupt or insolvent, or for any reason whatever being unable to complete the Contract, or in the event of the Employer taking over or discontinuing the Contract for any of the reasons given in Clause No. 49. This may be done thus :—

The Contractor is to provide all plant, and any materials or things whatsoever in connection with the same, to the full extent found necessary or requisite, in the opinion of the Engineer, for the due and proper execution, performance, and completion of the whole of the Works contracted for, together with that required for any alterations or additional Works. Such plant will be modern in its kind, and of a character equal to the importance and extent of the Works, and expressly well adapted for its uses ; otherwise, upon notice in writing from the Engineer, it must be removed from the Works.

All materials and all machinery, plant and tools of every kind, which may be brought by the Contractor to the Works, or laid upon the ground set apart by the Employer for the use of the Contractor, and all houses, offices, and temporary erections of every description made or erected upon the Employer's property shall become the absolute property of the Employer, and shall be held as conveyed over to the Employer without any deed or conveyance or being mentioned in the Contract, and shall not be attachable by the diligence of creditors. The Contractor shall not remove any of the materials or plant or erections aforesaid from the Works or ground on any pretence whatever, without express sanction in writing from the Engineer, until the Engineer certifies the completion of the whole of the Works under the Contract, when the said plant and materials provided by the Contractor shall reinvest in and become the property of the Contractor who shall remove the same. If the Contractor fails to remove any of the said constructional plant, temporary Works, or unused materials within such reasonable times after the completion of the Works as may be allowed by the Engineer, then in any such case the Employer may sell the same and apply the proceeds (first) in payment of the costs, charges, and expenses thereby incurred, and (secondly) may pay the overplus (if any) to the Contractor but without prejudice to the other remedies provided by these Conditions.

Notwithstanding that the plant and materials and things aforesaid become the property of the Employer, the Contractor shall keep them in thorough working order and repair at his own expense, and the Employer shall not at any time be liable for the loss of, or injury to, any of the said plant or materials or things.

The operation of the last preceding clause shall not be deemed to imply any approval by the Engineer of the materials or other matters referred to therein, nor shall it prevent the rejection of any such materials at any time by the Engineer.

19. TESTING OF MATERIALS.—It is desirable that the Contractors' liability in respect of testing materials shall be clearly laid down in a clause such as :—

All materials and workmanship shall be of the respective kinds described in the Contract and in accordance with the Engineer's instructions and shall be subjected from time to time to such tests as the Engineer may direct at the place of manufacture or fabrication or on the Site or at all or any of such places. The Contractor shall provide such assistance, instruments, machines, labour and materials as are normally required for examining, measuring and testing the Works and the quality, weight or quantity of the materials used, and shall supply samples of materials before incorporation in the Works for testing as may be selected and required by the Engineer.

The cost of making any test shall be borne by the Contractor. Provided that where the test or sample ordered is clearly not intended or provided for in the Specification of Bill of Quantities, the cost thereof shall be paid to the Contractor by the Employer.

Provided also that if any test of materials is ordered by the Engineer to be carried out by an independent person at any place other than the Site or the place of manufacture or fabrication of the materials, the cost of making such test (but not the cost of the samples) shall be paid to the Contractor by the Employer, unless the test shall show the workmanship or materials to be not in accordance with the provisions of the Contract or the Engineer's instructions.

Unless otherwise specified the cost of any test required by the Engineer of finished or partially finished work under load, or to ascertain whether the design of such work is appropriate for the purposes which it was intended to fulfil, shall be borne wholly by the Employer.

20. SANITARY ACCOMMODATION.—Sanitary Accommodation must be provided to meet the requirements of the Local Sanitary Authorities, thus :—

The Contractor shall provide, maintain, and keep in a good sanitary condition, adequate sanitary accommodation for the use of all men engaged on the Works, and shall remove and clear away same on completion of the Works, all to the satisfaction of the Engineer and the Local Sanitary Authority. The Contractor shall make the necessary arrangements, subject to the approval of the Engineer, for the use of any land required. Adequate precautions shall be taken by the Contractor to prevent nuisance of any kind on the Works or on the lands adjoining.

21. MESSING HUTS.—Where the Works are at any distance from suitable messing arrangements, the Contractor may be made to provide same as follows :—

The Contractor shall provide, maintain in a clean, orderly, and efficient manner, and remove on completion of the Works all necessary mess-sheds, shelters, and cook-houses supplied with lighting and heating arrangements, tables, forms, etc., and other necessary furnishings, utensils, and fittings, and shall make the necessary arrangements, subject to the approval of the Engineer, for the use of any land required. All such accommodation shall be constructed and maintained to the satisfaction of the Engineer and of the Local Sanitary Authority.

22. WAGES OF WORKPEOPLE.—In order to obviate stoppages of work owing to wages disputes, and to ensure the employment of sufficient workmen accustomed to the respective classes of work being carried out, it is common to insert a clause, as follows :—

The Contractor shall be bound to pay to the workmen employed by him in the execution of the Contract, rates of wages or piece prices, and to observe hours of labour and conditions of employment, not less favourable than the standard recognized rates of wages or piece prices and hours of labour and conditions of employment (or, in the absence of such standard recognized rates of wages or piece prices and hours and conditions, those which in practice prevail amongst good employers) in the trade, in the district or places where the work is carried out.

Where there are no such wages or piece prices and hours recognized or prevailing in the district, those recognized or prevailing in the nearest district in which the general industrial circumstances are similar shall be adopted, and the conditions of employment generally accepted in the district in the trade concerned shall be taken into account in considering how far the terms of this Clause are being observed, and the Contractor shall be responsible for the observance of the provisions of this Clause by any Sub-Contractor.

The Contractor shall from time to time and at all times during the continuance of the Contract, display and keep displayed upon the Site and in every factory, workshop or place occupied or used by the Contractor in or about the execution of the Contract, in a position in which the same may easily be read by all persons in his employ, a clearly printed or written copy of this Clause.

The Contractor shall keep proper wages-books and time-sheets showing the wages paid and the hours worked by the workmen in his employment in and about the execution of the Contract ; and the Contractor shall be bound, whenever and wherever required, to produce such wages-books and time-sheets for the inspection of the Engineer or any other duly authorized person. In the event of the Contractor failing to observe the foregoing provisions regarding rates of wages, hours of labour, or conditions of employment, the Employer shall be entitled to call upon the Contractor to make payment to the workmen of the difference between the amount of wages paid to them and the amount which would have been payable if the foregoing conditions had been duly observed.

The wages, hours and conditions of employment above referred to, shall be those prescribed for the time being by the Civil Engineering Construction Conciliation Board for Great Britain, save that the rate of wages payable to any class of labour in respect of which the said Board does not prescribe a rate, shall be governed by the provisions of ....

23. SUNDAY AND NIGHT WORK.—If the Engineer desires to have power to require Sunday and night work at his discretion, he may use the following Clause :—

The Contractor shall not carry on any work at night or on Sundays, other than pumping from excavations, without the knowledge and consent of the Engineer ; but if, by reason of bad or treacherous ground, or if there be any other cause whatsoever which, in the judgment of the Engineer, requires it, the Contractor shall carry on the Works day and night without extra charge.

24. WEEKLY RETURN OF LABOUR.—To keep the Engineer informed as to the number of men being employed on the Contract, the following Clause is useful :—

The Contractor shall, if required by the Engineer, deliver to the Engineer or at his office, a return in such form and at such intervals as the Engineer may prescribe, showing in detail the numbers of the several classes of labour from time to time employed by the Contractor on the Site and such information respecting Constructional Plant as the Engineer may require.

25. INJURIES TO WORKMEN.—To indemnify the Employer against the consequences of accidents to Workmen, etc., the following Clause is inserted :—

The Employer shall not be liable for or in respect of any damages or compensation under the Fatal Accidents Act, 1846, the Employers' Liability Act, 1880, the Workmen's Compensation Acts, the National Insurance Acts, or any statutory re-enactment, extension, or modification of those Acts or any of them, or at Common Law, by or in consequence of any accident or injury to any workman or other person, whether in the employment of the Contractor or any Sub-Contractor or not, and the Contractor shall indemnify and keep indemnified the Employer against all such damages or compensation and against all actions, proceedings, costs, charges, and expenses, claims, and demands whatsoever in relation thereto.

The Contractor shall effect a policy of insurance against all liability to pay damages or compensation as aforesaid in respect of all workmen and other persons who may be employed on the Works with a company approved by the Employer and shall continue such insurance during the whole of the time that any persons are employed by him on the Works and shall, when required, produce to the Engineer such policy of insurance and the receipt for payment of the current premium.

Provided always that in respect of any persons employed by any Sub-Contractor, the Contractor's obligation to effect a policy of insurance as aforesaid under this clause, shall be satisfied if the Sub-Contractor shall have effected such a policy of insurance in respect of such persons, but the Contractor shall require the Sub-Contractor to produce to the Engineer when required such policy of insurance and the receipt for payment of the current premium.

26. Work Not To Interfere With Traffic.—Where there is a possibility of the work interfering with traffic, and possible claims from the Contractor for delays due to this, a Clause to cover these may be introduced thus :—

The Contractor is to carry out the work in such a way as not to interfere unnecessarily or improperly with the public convenience or the use or occupation of public roads and footpaths and/or properties whether in possession of the Employer or of other persons, and he shall save harmless and indemnify the Employer in respect of all claims, actions, or suits arising out of or in relation to any such matters.

27. Inferior Material And Workmanship.—The following Clause deals with the provisions made in the event of inferior materials or workmanship occurring on the Works :—

All material and workmanship which may, in the opinion of the Engineer, the Resident Engineer, or the Inspector, be inferior to that specified for the work will be condemned. All condemned material must be removed by the Contractor from the Works immediately after the order for its removal is given by the Engineer, the Resident Engineer, or the Inspector. All condemned workmanship must be rectified or replaced to the satisfaction of the Engineer, the Resident Engineer, or the Inspector.

The Engineer's decision as to the quality of all materials brought to, and made use of in the execution of, the Works, and as to all workmanship in executing the Contract, must be accepted by the Contractor, and that without appeal.

In the event of such removal and replacement of any part of the Works being necessary, the Employer reserves power in reinstatement to strengthen the structure by increasing the dimensions or by improving the quality of the materials, or by altering their character, and such strengthening of the structure shall, in the event of its being rendered necessary by reason of default by the Contractor, be carried out at his expense. Should the Contractor delay removal of unsatisfactory materials or work, or delay execution of necessary remedial work, the Employer may have such materials or work removed, or such remedial work executed, at the Contractor's expense.

The Engineer may order the masonry, steelwork, or other materials, or the Works to be opened up and cut out where he considers it necessary to test the workmanship and quality; and if the work be found satisfactory the cutting-out and replacing of the materials will be paid for by time account, but if unsatisfactory the Contractor shall bear the whole cost.

28. Damage to Contract Work.—Provision is made in the following Clause for the rectification and repair of any damage done to the Works whilst under erection :—

From the commencement to the completion of the Works, the Contractor shall take full responsibility for the care of the same and of the Temporary Works, and in case any damage, loss, or injury shall happen to the Works or to any part of the Works, or to any Temporary Works from whatever cause, the Contractor shall at his own cost repair and make good the same so that at completion the Works shall be in good order and condition and in conformity in every respect with the requirements of the Contract and the Engineer's instructions.

In the event of damage, loss or injury to the Works or any part thereof or to any Temporary Works occurring from any cause for which the Contractor is not responsible under this condition, the Contractor shall if, and to the extent, required by the Engineer, repair and make good the same as aforesaid at the cost of the Employer.

29. Power to Suspend Work.—As it is advisable for the Engineer to have power to suspend work at any time he thinks fit, e.g. bad weather, frost, etc., a Clause to this end is provided :—

The Contractor shall, on the written order of the Engineer, suspend the progress of the Works or any part thereof for such time or times and in such manner as the Engineer may consider necessary and shall during such suspension properly protect and secure the work so far as is necessary in the opinion of the Engineer. The extra cost (if any) incurred by the Contractor in giving effect to the Engineer's instructions under this Clause shall be borne and paid by the Employer unless such suspension is

(*a*) Otherwise provided for in the Contract ; or

(*b*) Necessary for the proper execution of the work or by reason of the weather conditions or by some default on the part of the Contractor ; or

(*c*) Necessary for the safety of the Works or any part thereof.

Provided that the Contractor shall not be entitled to recover any such extra cost unless he gives notice in writing of his intention to claim to the Engineer within twenty-eight days of the Engineer's order. The Engineer shall settle and determine the extra payment to be made to the Contractor in respect of such claim as the Engineer shall consider fair and reasonable.

30. COMPLIANCE WITH GENERAL, LOCAL, AND PRIVATE STATUTES AND BY-LAWS.—The following Clause puts on the Contractor the onus of complying with legal requirements : —

The Contractor shall, throughout the continuance of the Contract, and in respect of all matters arising out of the performance thereof, conform with all Regulations and By-laws of the Local or other Authorities which may be applicable to the Works, and shall not, in the performance of the Contract, in any manner endanger the safety or unlawfully interfere with the convenience of the public. The Employer will, when desired, afford all reasonable assistance to the Contractor in obtaining information as to special local conditions.

31. WATCHING, LIGHTING, AND FENCING.—The Contractor must take the responsibility for all watching, fencing, and lighting arrangements on the Contract, and this is provided for by the following Clause :—

The Contractor shall provide and carry out proper watching, lighting, and fencing arrangements to the satisfaction of the Engineer and/or any competent statutory or other authority for the protection of the Works and the safety and convenience of the public and others, and shall be held responsible for any accidents that may take place through defect or neglect in such arrangements.

32. PATENT RIGHTS AND ROYALTIES.—The Engineer must see that the Employer is indemnified against the use of Patents by the Contractor in the execution of the Works, and the Contractor is held responsible for this as follows :—

The prices stated in the Tender are to include the use of all patent rights and payment of all patent royalties (if any), and the Contractor shall deliver and hand over to the Employer the whole of the Works and all apparatus, appliances, materials, or things included in the Contract, free from all royalties or patent rights (real or alleged) whatsoever.

The Contractor shall indemnify the Employer against all demands, actions, and damages whatsoever brought against, or sustained by, the Employer, and shall also pay all costs and charges incurred by the Employer by reason or in consequence of the use upon or in connection with the Works of any patented article or process supplied or used under the Contract, and the Contractor shall pay all royalties on or licences for the use of patented articles or processes used in connection with the Works.

33. Insurance of Works.—In addition to the insurance against injuries of the workmen, already provided for, the Contractor should be made responsible for the complete insurance of the works and plant, which may be done as follows :—

The Contractor shall insure in the joint names of himself and the Employer, in an office to be approved by the Employer, the Works and all materials, plant, appliances, machinery, tools, erections, articles, or others which are upon, or may be brought upon, and all buildings and contents of buildings which are or which may be erected upon, the site or upon lands occupied by the Contractor in connection with the execution of the Works, in a sum to be fixed by the Employer, against explosions of boilers, all risk from fire or tempest, and all other risks ordinarily insured against in similar circumstances, and shall from time to time, as required by the Engineer, increase the amount of such insurance up to a maximum sum not exceeding the Contract price, and shall continue to keep such Works, materials, plant, appliances, machinery, tools, erections, articles, buildings, or others so insured until the completion of the Works. The Contractor shall deposit the policy or policies with the Engineer, or shall produce the policy or policies to the Engineer for inspection and from time to time furnish such evidence as the Employer may require that the Works and all materials, plant, appliances, machinery, tools, erections, articles, buildings, and other things required under this Clause to be insured are fully insured throughout the period of the Contract, and the Contractor shall pay all premiums becoming due on such policy or policies as they become due, and if he fail to increase the amount of such insurance within seven days after being required to do so by the Engineer, or fail to pay any premium within seven days after it becomes due, then the Employer may increase the amount of such insurance, or pay such premium and deduct the expense so incurred from the money payable under the certificate granted (next after such expense is incurred) under Clause.... hereof, or from any moneys due or to become due to the Contractor from the Employer. All money paid under any policy or policies of insurance shall be received by the Employer who shall pay the same to the Contractor on certificate by the Engineer that the Works, materials, plant, appliances, machinery, tools, erections, articles, buildings, or others damaged or destroyed have been replaced, repaired, or rebuilt. Such replacing, repairing, rebuilding, and completion shall be carried out in every way subject to these conditions, and the Specification and the Schedule of Quantities, and the only variation of such terms and conditions shall be that the Engineer, whose decision shall be final, may extend the time for completion of the Works for such period as he may, having regard to the circumstances of the case, think reasonable. If the Engineer does not so extend the time for completion, then the Works must be completed within the time fixed under these Conditions.

34. PRECAUTIONS IN CARRYING OUT THE WORKS.—It will be necessary for the Contractor to take precautions to avoid damage to other Works on the land, and this is provided for thus :—

In carrying out the Works every precaution shall be taken by the Contractor to avoid injury to, or improper interference in connection with the use of, any roads, streets, paths, railways, tramways, canals, sewers, streams, drains, watercourses, pipes, or cables, or any deviations of same, and he shall be held responsible for any injury thereto or any improper interference therewith which may be caused in the execution of the Works. The Contractor shall effectually secure and maintain the existing drainage and irrigation of adjoining lands, in as good a state and condition as before the commencement of the Works, and the Contractor shall thoroughly make good any such drainage or irrigation interfered with in the execution of the Works. The Contractor shall make his own arrangements with the Trustees, owners, or other bodies or persons, interested in such roads, streets, paths, railways, tramways, canals, sewers, streams, drains, irrigating or other watercourses, pipes, or cables, for any temporary or permanent stoppage or diversion of the same, and, in the case of private roads or streets, for the use of the same, or respecting the sufficiency of any repairs of the same required in consequence of the execution of the Works. Provided always that no arrangements respecting a permanent stoppage, diversion, or alteration shall be made without the prior concurrence of the Engineer, and the Employer shall, if he thinks fit, be at liberty to take the negotiations, or any such last-mentioned arrangement, out of the hands of the Contractor and to conduct them himself.

35. PROTECTION OF EXISTING BUILDINGS AND SERVICES.—The Contractor must also ensure the protection of all adjacent property, which is done thus :—

During the execution of the Works the sides of excavations shall be securely shored, timbered, and strutted, and where buildings are adjacent thereto, all necessary steps shall be taken to prevent damage. All conduits, water and gas mains, sewers, drains, lamp columns, service piping, telephone, telegraph, electric, or other cables, or any other apparatus connected therewith, together with all walls, buildings, or other structures or properties which may be disturbed or injured during the execution of the Works, shall be raised, lowered, slung, protected underpinned, restored, or made good. The Contractor shall take all risks arising from conduits, water and gas mains, sewers, drains, lamp columns, service piping, telephone, telegraph, electric or other cables, apparatus, walls, buildings, structures or properties, and will be responsible for the safety of these, and for any damage done to them through, or in consequence of, his operations ; and shall free the Employer from any expense to which he may be put through such damage, or from any claim made on him in consequence thereof. The Contractor will also take any precautions for the safety of pipes, ducts, wires, or cables, which the owners thereof, or their representatives, may require.

In the case of new foundations adjoining any existing building, structure, or thing, the excavations shall be taken out and the concrete, brickwork, or masonry be built in such short lengths as the Engineer will determine and direct ; below the level of the foundations of any existing building, structure, or thing, no excavations shall be commenced until the concrete, brickwork, or masonry of the preceding length has been carried up at least as high as the said existing foundations, and allowed to set properly.

Before beginning any portion of the work, the Contractor shall ascertain by open trenching the exact depth, level, position, and dimensions of the foundation of any existing building or structure in the immediate vicinity, and shall, at his own cost, take such precautions as may be required temporarily to support and protect them by timbering and otherwise, as herein specified.

The Contractor should also protect fences, trees, etc., as provided for thus :—

All walls, fences, paths, trees, shrubs, greens, and other surfaces, which require to be maintained, shall be protected and kept free by the Contractor from damage due to operations under the Contract, and, upon completion of the Works, the same shall be handed over by him in a clean and proper state, to the satisfaction of the Engineer.

36. Keeping Excavations Free from Water.—To ensure that subterranean water or flooding shall be dealt with, the following provision is made :—

The Contractor shall keep the whole of the excavations free from water howsoever arising, and shall provide all pumping, temporary drains, and cuts necessary for the purpose.

37. Extraordinary Traffic.—The Contractor's liability with regard to claims for damage or injury to highways or bridges should be clearly set out in a Clause such as the following :—

The Contractor shall be responsible for all claims in respect of damage or injury to highways and bridges, due to extraordinary traffic, and shall make good such damage to the satisfaction of the Authority concerned. The Employer shall reimburse the Contractor the cost and expenses (as certified by the Engineer) incurred from this cause provided that the Contractor shall, in the opinion of the Engineer, have taken all reasonable precautions to prevent such damage.

38. Additional Land Required, Surface Damage, etc. If any additional land is required by the Contractor beyond that allotted by the Employer, the Contractor is required to make his own arrangements for same, thus :—

The Contractor shall, as far as possible, confine his operations within the limits of the lands to be provided by the Employer, but, if this is insufficient for the purpose, he must arrange with the proprietors and tenants for what further ground he may require, and must pay all charges connected therewith. The general application of this Clause shall not be affected, though in certain other Clauses it may be specifically stated that the Contractor shall provide land for the purpose of the said Clauses. He shall erect and maintain suitable temporary fencing wherever necessary, and he shall pay for all surface and trespass damages, charges, and expenses caused by the erection of temporary buildings, or by the carting of bricks, cement, clay, gravel, earth, sand, ironwork, or other materials, or by his workmen, beyond the limits of the land to be provided by the Employer ; for all damage to the stock, crop, or other property thereon, and any damage arising out of the insufficiency or disrepair of temporary or other fencing, by the straying of cattle or otherwise. In the case of a dispute between him and the parties claiming compensation, or in the case of the claim being made directly against the Employer, the amount of compensation may, with the consent of the party claiming compensation, be fixed by the Engineer, or by a Land Valuer named by the Employer, whose decision on that point shall be final, and the Employer shall be entitled to deduct the amount of compensation, however fixed, from any sum that may be due to the Contractor, if not settled by the Contractor direct.

The Works shall be carried on in such a manner as to cause the least possible annoyance or inconvenience to the residents of the district in which the Works are situated. The Contractor shall, as far as possible, prevent trespass by his workmen, or those seeking employment, upon the adjoining land, and private roads or streets, and he shall pay all damage caused by such trespass.

39. TEMPORARY WORKS.—The Contractor is, of course, responsible for all temporary works, and this is provided for thus :—

The Contractor shall be responsible for all staging, cofferdams, and temporary works of every description being of proper design and sufficient strength, and in case of failure he shall be liable for any damage that may occur. He shall submit the designs of such temporary works to the Engineer or his approval and no staging, cofferdams, dams, or other temporary works shall be used, the design, material, workmanship, and position of which have not been approved by the Engineer ; but such approval shall not relieve the Contractor from any of his responsibilities. The Contractor will be allowed to make temporary roads only when authorized by the Engineer and sanctioned by proprietors and tenants, and he shall remove the same when the work is finished, and he shall restore the surface, and shall pay all surface and other damages. He must make all the necessary arrangements therefor, and the rates and prices in the Schedule of Quantities must cover all charges involved in making and removing these temporary roads.

40. OPENING UP FOR INSPECTION ; PERMANENT WORK NOT TO BE PUT IN BEFORE EXAMINATION OF FOUNDATIONS, ETC.—To ensure that the Engineer or his representatives shall have the opportunity to inspect foundations or other work that is to be covered in, the following Clause may be inserted :—

The Contractor shall afford full opportunity for the Engineer, the Resident Engineer, or the Inspector, to examine and measure any works which are to be covered up or put out of view, and to examine foundations before permanent work is placed thereon.

The Contractor shall give due notice to the Engineer whenever the said works or things are ready or about to be ready for examination, and the Engineer, the Resident Engineer, or the Inspector shall without unreasonable delay attend for the purpose of examining and/or measuring such works.

The Contractor shall uncover any part or parts of the works or make openings in or through the same as the Engineer may from time to time direct, and shall reinstate and make good such part or parts to the satisfaction of the Engineer. If any such part or parts have been covered up or put out of view after compliance with the requirements of the first paragraph of this Clause and are found to be executed in accordance with the contract or the instructions of the Engineer, the expense of uncovering, making openings in or through, reinstating and making good the same, shall be borne by the Employer, but in any other case all such expenses shall be borne by the Contractor.

41. ACCESS TO CONTRACTOR'S YARDS.—The following Clause is advisable where work is being prepared in the Contractor's own yards :—

The Engineer and any person authorized by him shall at all times have access to the Works and to the Site and to all workshops and places where work is being prepared or whence materials, manufactured articles and machinery are being obtained for the Works and the Contractor shall afford every facility for and every assistance in or in obtaining the right to such access.

42. SERVICES FOR CONTRACTOR'S PURPOSES.—Any water, light, power, telephones or other services required on the Contract should be arranged for and paid for by the Contractor, as provided in the following Clause :—

The Contractor shall make his own arrangements with the proper Authorities and, at his own cost, supply such water, heat, power, light, telephones or other services as he may require at every part of the work and at all times ; and he shall also bear the cost of openings, connections, meter hire, and all works necessitated by the providing of such supplies.

43. PRECAUTIONS TO PREVENT NUISANCE.—The Contractor should take precautions to prevent any nuisance to third parties as provided for thus :—

The Contractor shall take all possible precautions to prevent any nuisance or inconvenience to the owners, tenants, or occupiers of adjacent properties, and to the public generally, and shall at all times keep all roads, streets, paths, and pavements contiguous to the works in a safe, clean and passable state, and all or any damage to sewers, drains, gullies, drainage outlets, roads, streets, paths, and pavements, wheresoever and whatsoever, caused by the execution of the Works, or by traffic brought thereon by the Contractor, shall be made good by the Contractor at his own expense, to the satisfaction of the owners, the Public and/or Local and/or Highway Authorities. All waste or superfluous materials shall be cleared away by the Contractor.

44. POLLUTION OF STREAMS AND WATERWAYS.—Where there is a possibility of pollution of streams, etc., due to the execution of the Works, this should be guarded against by a Clause :—

The Contractor shall take all possible precautions to secure the efficient protection of all streams and waterways against pollution, and shall indemnify the Employer against any claim arising from any such pollution, during the execution of the Works or the period of maintenance referred to in Clause.... hereof.

45. MATERIALS AND THINGS ON OR IN THE SITE.—Where the site of the Works is likely to contain materials that will be useful to the Contractor in the execution of the Works, he should pay for these in the ordinary way, and this is provided for as follows :—

All the old building materials and all other materials and things of every description whatsoever, including all earth, stone, clay, gravel, sand, timber, growing crops, and the like, found, or being upon, or excavated from the site, shall remain the property of the Employer, and shall be dealt with as the Engineer may direct. All such materials belonging to the Employer shall be, subject to the approval of the Engineer, at the disposal of the Contractor at the prices inserted in the Schedule of Quantities under the heading " Credit Items ", so far only as use can be made of them for the purposes of the Contract ; and, failing such prices, at such prices as may be fixed by the Engineer. Any surplus excavations or materials not required by the Employer shall, at the direction of the Engineer, be removed from the site and disposed of by the Contractor at his own expense.

46. ARTICLES OF VALUE OR ANTIQUITY.—The following provision may be made for articles of value or antiquity found on the site :—

All fossils, coins, articles of value or antiquity, and structures and other remains of archæological interest discovered shall, as between Employer and the Contractor, be deemed to be the absolute property of the Employer, and the Contractor shall prevent his workmen or any other persons from removing or damaging any such article or thing and shall immediately upon discovery thereof, and before removal, acquaint the Engineer of such discovery and abide by his orders as to the disposal of the same.

47. OFFERING GRATUITIES, ETC.—The offer of gratuities to employees of the Employer is covered thus :—

If the Contractor shall be found to have offered or given any gratuity, bonus, discount, bribe, or loan of any sort to any Officer or Employee of the Employer, or to any member of the Engineer's staff, it shall be competent for the Employer forthwith to cancel his Contract, and to hold the Contractor liable for any loss or damage which the Employer may thereby sustain.

48. LIQUIDATED DAMAGES FOR DELAY.—As time is usually of the essence of the Contract, it is usual to bind the Contractor in a certain sum as liquidated damages for delay in completion. This is sometimes accompanied by provision for a similar bonus to be paid to the Contractor for completion before the stated date. The following is a suitable Clause covering liquidated damages.

In the event of failure by the Contractor to complete the Contract within the time stipulated, he shall be liable, and is to pay to the Employer, as ascertained and liquidated damages, the sum of . . . . pounds sterling for every day the work remains uncompleted after the date fixed for completion, or any extended time as fixed by the Engineer. The Employer may deduct the amount of such damages from any monies in his hands, due or which may become due to the Contractor.

49. BANKRUPTCY OF CONTRACTOR.—Provision must be made for carrying on the work in the event of the bankruptcy or death of the Contractor, which may be done as follows :—

If the Contractor shall become bankrupt or have a receiving order made against him or shall present his petition in bankruptcy or shall make an arrangement with or assignment in favour of his creditors, or shall agree to carry out the Contract under a committee of inspection of his creditors, or being a corporation shall commence to be wound up (other than a voluntary liquidation for the purposes of amalgamation or reconstruction), or if the Contractor shall assign or sub-let the Contract without the consent in writing of the Engineer first obtained, or shall have an execution levied on his goods, or if the Engineer shall certify in writing to the Employer that in his opinion the Contractor :—

(*a*) has abandoned the contract, or

(*b*) has failed to commence the Works or has suspended the progress of the Works for 14 days after receiving from the Engineer written notice to proceed, without any lawful excuse under these Conditions, or

(*c*) has failed to proceed with the Works with due diligence, or

(*d*) has failed to remove materials from the site or to pull down and replace work for 14 days after receiving from the Engineer written notice that the said materials or work were condemned and rejected by the Engineer under these Conditions, or

(*e*) has failed to give the Engineer proper facilities for inspecting the Works or any part thereof for 14 days after receiving from the Engineer written notice demanding the same, or

(*f*) has failed to submit any work or materials to proper tests after receiving from the Engineer written notice requiring the same, or

(*g*) is not executing the Works in accordance with the Contract, or is persistently or flagrantly neglecting to carry out his obligations under the Contract, or

(*h*) has to the detriment of good workmanship, or in defiance of the Engineer's instructions to the contrary, sub-let any part of the Contract ;

then the Employer may, at any time by notice in writing, summarily terminate the Contract without compensation to the Contractor. Such termination shall not prejudice or affect any right of action or remedy which shall have accrued or shall thereafter accrue to the Employer.

In the event of the Contract being determined by the Employer in terms of the foregoing Conditions, the following provisions shall take effect :—

(*a*) The Employer shall have full power and authority without the necessity of resorting to any legal proceedings to take the work out of the Contractor's hands, and in his option to carry on the Works himself or to employ and to pay other persons to carry on and complete the work, to make good defects, and to rectify any damage consequent thereon or incidental thereto, and to use or to allow such other persons to use such materials, plant, appliances, machinery, tools, erections, or other articles brought or made by the Contractor, as aforesaid, upon the site or upon land occupied by the Contractor, as may be then on the ground, and to supply others to complete the work, all at the expense of the Contractor.

(*b*) Neither the Contractor, his creditors, nor sureties, nor any party acting for or deriving right from any of them, shall be entitled to remove from the site of the work or from any land adjoining thereto, without the written authority of the Engineer, any materials, plant, appliances, machinery, tools, erections, or other articles, nor have any right or authority to interfere in any way with the execution or construction of the Works.

(*c*) In the event of the Employer at any time deciding not to use or to continue to use the said materials, plant, appliances, machinery, tools, erections, or other articles for the Contract, he may sell the same to the best advantage and retain the proceeds towards payment of any claim he may have against the Contractor.

(*d*) No right of action for work done under the Contract or for materials, plant, appliances, machinery, tools, erections, or other articles, of which the Employer may have taken possession, or which he may have sold, or in any other respect, shall arise until the Engineer has given notice to the Contractor that the Works have been satisfactorily completed, and until the Engineer has ascertained the cost of completion and the damages due for delay in completion (if any) and the advances which have been made to the Contractor, and certified the amount thereof. If upon this being done it appears from the certificate of the Engineer that such amount is less than the Contract price, then the Employer shall pay the balance to the Contractor within fourteen days after the issue of such certificate, and if it so appear that such amount is more than the Contract price, then the balance shall be a debt due from the Contractor to the Employer. The Employer shall be entitled to apply towards this debt the proceeds from the sale of any materials, plant, appliances, machinery, tools, erections, or other articles, in his hands. Any balance after satisfying said debt shall be paid to the Contractor.

50. FACILITIES FOR OTHER CONTRACTORS.—It is, of course, essential that any other Contractors employed on the Works shall be allowed full access thereto, as provided for thus :—

The Contractor shall, in accordance with the requirements of the Engineer, afford all reasonable facilities and accommodation for any other Contractors employed by the Employer, and their workmen, or for the workmen of the Employer, who may be employed in the execution on or near the site of any work not included in the Contract, or of any Contract which the Employer may enter into in connection with, or ancillary to, the Works, and in default he shall be liable to the Employer for any delay or expense incurred by reason of such default.

51. Tests on Completion.—An important Clause is that providing for the carrying out of tests on completion, and stipulating what is to happen in the event of failure, which is covered as follows :—

(*a*) If the Specification provides for tests on completion, the Engineer, when the Works in his opinion are sufficiently complete, shall give to the Contractor notice to carry out such tests on a day or days to be mutually agreed upon.

(*b*) Should the whole or any portion of the plant or Works fail under such tests to fulfil the Contractor's guarantees or the requirements laid down in the Specification, the Employer may call upon the Contractor at the latter's expense to remove such plant or Works and replace the same with other plant or Works which will fulfil the said guarantees and requirements to the satisfaction of the Engineer.

(*c*) Until such other plant or Works are installed and ready for work, the Employer may, if in the opinion of the Engineer it is necessary to do so, continue to use the original plant or Works in the manner most beneficial to himself without prejudice to any of his rights under the Contract.

(*d*) All such replaced plant or Works shall be maintained by the Contractor under Clause .... hereof for a period of .... Calendar Months from the time at which the said tests are completed to the satisfaction of the Engineer.

(*e*) The Engineer may, if he thinks fit, extend the time for completion of the Works for such period as he may, having regard to the circumstances of the case, think reasonable. If the Engineer does not so extend the time for completion, then the Works must be completed within the time fixed under these Conditions.

(*f*) The decision of the Engineer on the matters referred to him under the provisions of this Clause shall be final.

52. Certificates of Completion.—The date of completion of the Contract is a most important one, since on that depends the amount of liquidated damages to be paid by the Contractor if the works are not completed to time, so that it is advisable to fix this definitely, which is done by the issue of certificates of completion, as provided for in the following Clause :—

As soon as, in the opinion of the Engineer, the Works shall have been substantially completed and shall have satisfactorily passed any final test that may be prescribed by the Contract, the Engineer shall, on receiving a written undertaking by the Contractor to finish any outstanding work during the Period of

Maintenance, issue a Certificate of Completion in respect of the Works and the Period of Maintenance of the Works shall commence from the date of such certificate. Provided that the Engineer may give such a certificate with respect to any substantial part of the Works which has been both completed to the satisfaction of the Engineer and occupied or used by the Employer and when any such certificate is given in respect of a part of the Works, such part shall be considered as completed and the Period of Maintenance shall commence from the date of such certificate.

53. MAINTENANCE.—Maintenance of the Works after completion, which gives time to ascertain that everything is satisfactory under use, is provided for by the following Clause:—

The Contractor shall, for the period named in the Tender (in these conditions referred to as the Period of Maintenance) from the date of completion of the Works certified by the Engineer in accordance with Clause .... hereof (or, in the event of more than one certificate having been issued by the Engineer in accordance with that Clause, from the respective dates so certified) maintain the Works in such manner that at the expiration of the Period of Maintenance they shall be in as good and perfect order, repair and condition (fair wear and tear excepted) as that in which they were at the commencement of the Period of Maintenance and shall, at the expiration of such period, deliver up the Works in such order, repair and condition to the satisfaction of the Engineer. The Contractor shall at his own cost repair, rectify and make good to the satisfaction of the Engineer all defects, imperfections, shrinkages and other faults arising from or out of the use of materials or workmanship not in accordance with the Contract, or from the neglect or failure on the part of the Contractor to comply with any obligation on his part under the Contract which may appear, arise or become manifest and of which the Engineer shall give him written notice during the Period of Maintenance ; and if the Contractor shall fail to repair, rectify or make good as aforesaid, the Employer may execute the necessary work by his own workmen or by other contractors, and recover from the Contractor the cost thereof or deduct the same from any monies due or that become due to the Contractor. Provided always that :—

(*a*) If the Contractor shall be required to carry out any work of repair, rectification or making good which he is not expressly liable to do at his own cost under the provisions of this Clause, the value of such work shall be ascertained and paid to the Contractor as if it were additional work.

(*b*) The Contractor shall not (save in the course of carrying out any work under this Clause) be liable for any damage to the Works or for damage or injury to any person or property occurring during the Period of Maintenance and arising out of or in consequence of the execution of the Works which is not due to the use of materials or workmanship not in accordance with the Contract, nor to the neglect or failure on the part of the Contractor to comply with any obligation on his part under the Contract and the Employer shall indemnify the Contractor against all claims, demands, proceedings, costs, damages, charges and expenses whatsoever arising out of or in relation to any such last-named damage or injury.

54. CLEARING UP ON COMPLETION.—The site must be left clear on the completion of the Contract as specified in the following Clause :—

On the completion of the Works the Contractor shall clear away and remove from the site all constructional plant, surplus material, rubbish, and temporary works of every kind, and leave the whole of the site and Works clean and in a workmanlike condition to the satisfaction of the Engineer.

The measurements of work, payments to be made to the Contractor, and the methods of making same are made clear in the succeeding Clauses :—

55. MEASUREMENT.

The Engineer shall, except as otherwise stated, ascertain and determine by admeasurement the value in accordance with the Contract of work done. He shall when he requires any part or parts of the Works to be measured give notice to the Contractor who shall forthwith attend or send a qualified agent to assist the Engineer or the Engineer's Representative in making such measurement and shall furnish all particulars required by either of them. Should the Contractor not attend or neglect or omit to send such agent then the measurement made by the Engineer or approved by him shall be taken to be the correct measurement of the Work.

Bills of Quantities shall be deemed to have been prepared and measurements shall be made according to the procedure set forth in the Report of the Committee on Engineering Quantities of the Institution of Civil Engineers (1933) and any subsequent amendment or modification thereof notwithstanding any general or local custom, except where otherwise specifically described or prescribed in the Contract.

56. PROVISIONAL AND PRIME COST SUMS.

(1) Provisional sums set out in the Bill of Quantities are intended to cover the cost of such items of work included in the

Contract, as may not be specified in detail when the Contract is entered into. The amounts inserted in the Bill of Quantities against provisional sums shall be expended in whole or in part in accordance with the direction in writing of the Engineer. Where appropriate the prices in the Bill of Quantities shall be applied, otherwise only the actual cost to the Contractor of any work done or equipment supplied will be paid, to which will be added a sum calculated at the percentage rate stated in the priced Bill of Quantities to cover overhead charges and profits.

(2) Prime Cost items set out in the Bill of Quantities (the initials P.C. used in the Contract shall be deemed to mean Prime Cost) are intended to cover articles specified in the Contract and priced in the Bill of Quantities by the Engineer, but such items may be liable to change. The articles supplied shall be to the requirements of the Engineer and only the actual net cost to the Contractor will be paid under this item, together with the sum stated in the priced Bill of Quantities calculated as a percentage of the actual cost to cover overhead charges and profit.

(3) The sums set out in the Bill of Quantities in respect of provisional sum and prime cost items shall be deducted in ascertaining the amount of the Contract Price and the sum or sums ascertained in accordance with sub-clauses (1) and (2) of this Clause in respect of such items shall be added.

(4) All provisional and prime cost sums shall be taken as the net cost to be defrayed as a prime cost as the case may be after deducting trade discounts and all discount for cash over and above 2½ per cent.

(5) Where a contingency sum has been included in the Bill of Quantities, no claim by the Contractor for loss of overhead charges and profit will be admitted on the ground that it has not been expended in whole or in part. Any expenditure required under the contingency item shall be in accordance with instructions issued by the Engineer in writing and only so much of the sum as is ordered by him to be expended shall be paid to the Contractor.

(6) The Contractor shall when required by the Engineer, produce all quotations, invoices, vouchers and accounts or receipts in connection with expenditure in respect of provisional or prime cost items.

57. Nominated Sub-Contractors.

(1) All specialists, merchants, tradesmen and others executing any work or supplying any goods for which provisional or prime cost sums are included in the Bill of Quantities, who may have been or be nominated or selected or approved by the Employer or the Engineer, and all persons to whom by virtue of the provisions of the Bill of Quantities or Specification the

Contractor is required to sub-let any work, shall, in the execution of such work or the supply of such goods, be deemed to be Sub-Contractors employed by the Contractor and are hereinafter referred to as " nominated Sub-Contractors ", provided always that the Contractor shall not be required by the Employer or the Engineer or be deemed to be under any obligation to employ any nominated Sub-Contractor who shall decline to enter into a sub-contract with the Contractor containing the following provisions :—

(*a*) That in respect of the work or goods the subject of the sub-contract, the Sub-Contractor will undertake towards the Contractor the like obligations and liabilities as are imposed upon the Contractor towards the Employer by the terms of the Contract, and will save harmless and indemnify the Contractor from and against the same and from all claims, demands, proceedings, damages, costs, charges and expenses whatsoever arising out of or in connection therewith or arising out of or in connection with any failure to perform such obligations or to fulfil such liabilities, and

(*b*) That the Sub-Contractor will save harmless and indemnify the Contractor from and against any negligence by the Sub-Contractor, his agents, workmen and servants and from and against any misuse by him or them of any Constructional Plant, or Temporary Works provided by the Contractor for the purposes of the Contract and from all claims as aforesaid.

(2) Before issuing under Clause .... hereof any certificate which includes any payment in respect of work done or goods supplied by any nominated Sub-Contractor, the Engineer shall be entitled to demand from the Contractor reasonable proof that all payments (less retentions) included in previous certificates in respect of the work or goods of such nominated Sub-Contractors have been paid or discharged by the Contractor in default whereof the Contractor shall

(*a*) inform the Engineer in writing that he has reasonable cause for withholding or refusing to make such payment, and

(*b*) produce to the Engineer reasonable proof that he has so informed such Sub-Contractor in writing.

The Employer shall be entitled to pay to such nominated Sub-Contractor direct upon the certificate of the Engineer all payments (less retentions) which the Contractor has failed to make to such nominated Sub-Contractor and to deduct by way of set-off the amount so paid by the Employer from any sums due or which become due from the Employer to the Contractor.

Provided always that where the Engineer has certified and the Employer has paid direct as aforesaid, the Engineer shall, in issuing any further certificate in favour of the Contractor, deduct from the amount thereof the amount so paid direct as aforesaid, but shall not withhold or delay the issue of the certificate itself when due to be issued under the terms of the Contract.

58. PAYMENTS TO CONTRACTOR.

The Contractor will be paid monthly on the certificate of the Engineer, the amount due to him on account, the estimated contract value of the permanent work, executed up to the end of the previous month, together with such amounts, if any, as the Engineer may consider proper on account of materials on the Site and any Temporary Works or Constructional Plant for which separate amounts are provided in the Bill of Quantities, subject to a retention of the percentage named in the tender, until the amount retained shall reach the sum of £.... One half of such sum shall become due to the Contractor when the Works have been substantially completed, and the other half at the end of the period of maintenance, on the Engineer's certificate to the effect that the Works have been maintained in a substantial and satisfactory manner, and that the Contractor has fully and satisfactorily implemented his Contract.

59. ARBITER.—A very important Clause is that appointing an Arbiter. In some Contracts a final certificate Clause, providing that the Engineer shall have the final say in everything, is inserted. This is a disputes prevention Clause, and puts the Contract outside the Arbitration Acts. To embody such a Clause, the Engineer must be a man of very strong character, personality, and position, prepared to give a decision that might prejudice his position with the Employer, if he is to act fairly between the Employer and the Contractor. By introducing an Arbitration Clause, any dispute is referred usually to an Arbiter appointed by some prominent Engineer such as the President of the Institution of Civil Engineers, but there are usually a number of points on which the decision of the Engineer is final, these being specially mentioned in the Conditions.

In the event of any dispute or difference arising between the Employer and the Contractor on any matter relating to the true intent and meaning of the memorandum of Agreement between the parties (exclusive of prices under alterations, additions, and deductions ; the progress and conduct of the work ; the character and quality of materials and workmanship ; and all other points in connection with which the Engineer's decision is to be given and accepted without appeal, where specially stipulated) the same shall be referred to the amicable decision of an Arbiter, to be appointed by the President for the time being of the Institution of Civil Engineers, London, and any such reference shall be deemed to be a submission to arbitration within the meaning of the Arbitration Acts 1889 to 1935 or to the Arbitration (Scotland) Act 1894 as the case may be, or any statutory re-enactment or amendment thereof for the time being in force. Such arbitrator shall have full power to open up, review and revise any decision, opinion, direction, certificate or valuation of the Engineer and neither party shall be limited in the proceedings before such arbitrator to the evidence or arguments put before the Engineer for the purpose of obtaining his decision above referred to. The award of the arbitrator shall be final and binding on all parties. Such reference, except as to the withholding by the Engineer of any certificate or the withholding of any portion of the retention money under Clause .... hereof to which the Contractor claims to be entitled or as to the exercise of the Engineer's power to give a Certificate under Clause .... hereof, shall not be opened until after the completion or alleged completion of the Works, unless with the written consent of the Employer and the Contractor. Provided always that the giving of a Certificate of Completion under Clause .... hereof shall not be a condition precedent to the opening of any such reference.

60. PROPERTY IN AND DISPOSAL OF DRAWINGS SUPPLIED TO THE CONTRACTOR.—It is usual to require the return of the Contract Documents on the completion of the Contract :—

The Drawings and Specification supplied to the Contractor shall remain the property of the Employer and, either on the completion of the Works or on the termination of the Contract, they shall be delivered up by the Contractor to the Engineer.

The following typical forms of Tender and Agreement have been agreed between the Institution of Civil Engineers and the Federation of Civil Engineering Contractors.

Short Description of Works :—

FORM OF TENDER

(NOTE : The Appendix forms part of the Tender).

To..

Gentlemen,

Having examined the Drawings, Conditions of Contract, Specification and Bill of Quantities for the construction of the above-named Works, we offer to construct, complete and maintain the whole of the said Works in conformity with the said Drawings, Conditions of Contract, Specification and Bill of Quantities for the sum of ....

....

.... £ ....

or such other sum as may be ascertained in accordance with the said Conditions.

We undertake to complete and deliver the whole of the Works comprised in the Contract within the time stated in the Appendix hereto.

If our tender is accepted we will, when required, provide two good and sufficient sureties or obtain the guarantee of a Bank or Insurance Company (to be approved in either case by you) to be jointly and severally bound with us in a sum equal to 10 per cent. of the above-named sum for the due performance of the Contract under the terms of a Bond in the form annexed to the General Conditions of Contract.

Unless and until a formal Agreement is prepared and executed this Tender, together with your written acceptance thereof, shall constitute a binding Contract between us.

We understand that you are not bound to accept the lowest or any tender you may receive.

APPENDIX.

	CLAUSE	
Amount of Bond (if any)		£..............................
Amount of Third Party Insurance		£..............................
*Time for Completion ..		..............................(years) (months) (weeks)
Amount of Liquidated Damages		£.............................. (per week)
Period of Maintenance ..		..............................(months) (weeks)
Percentage of Retention		..............................per cent.
Limit of Retention Money		£..............................
Minimum Amount of Interim Certificates ..		£..............................
Time within which payment to be made after Certificate		..............................days

We are, Gentlemen,

Yours faithfully,

Signature ....

Address ....

Date..

*If the time for Completion is not stated the Contractor is to fill it in.

FORM OF AGREEMENT

This Agreement made the .... day of ....

19 .... Between ....

of ....

in the County of .... (hereinafter called " the Employer ")

of the one part and ....

of ....

in the County of .... (hereinafter called " the Contractor ")

of the other part WHEREAS the Employer is desirous that certain Works should be constructed, viz. ....

.... and has accepted a Tender by the Contractor for the construction completion and maintenance of such Works NOW THIS AGREEMENT WITNESSETH as follows :—

1. In this Agreement words and expressions shall have the same meanings as are respectively assigned to them in the General Conditions of Contract hereinafter referred to.

2. The following documents shall be deemed to form and be read and construed as part of this Agreement, viz. :—

(a) The said Tender.

(b) The Drawings.

(c) The General Conditions of Contract.

(d) The Specification.

(e) The Bill of Quantities.

(f) The Schedule of Rates and Prices (if any).

3. In consideration of the payments to be made by the Employer to the Contractor as hereinafter mentioned the Contractor hereby covenants with the Employer to construct complete and maintain the Works in conformity in all respects with the provisions of the Contract.

4. The Employer hereby covenants to pay to the Contractor in consideration of the construction completion and maintenance of the Works the Contract Price at the times and in the manner prescribed by the Contract.

IN WITNESS whereof, etc.

CHAPTER IV

SPECIFICATIONS—WORKMANSHIP

A Specification is a detailed account of anything. In a commercial sense it means full particulars of certain goods required or work to be performed, as supplied to Contractors or others so that they may estimate their cost, or as supplied by Contractors stating fully the terms upon which they are willing to supply the goods or to do the work.

Thus, in a Specification for a Contract, full particulars are given of the materials to be used, their quality, the tests to which they must conform, their composition, and how they are to be used on the Works, and also describes in detail the work to be done under the Contract, and any information relative to the carrying out of the work.

The Clauses are generally drawn up under headings as in the case of the Conditions of Contract. In this chapter are given typical Specifications for the most common work required in Civil Engineering Contracts.

61. British Standard Codes of Practice.—In 1942 the work of codification of good practice in Building and Civil Engineering was co-ordinated by mutual agreement between the Professional Institutions engaged on this work and the Minister of Works and Planning, and a Codes of Practice Committee was established.

The late Sir Clement Hindley, K.C.I.E., M.I.C.E., was the first chairman. The functions of the Codes of Practice (which are produced by Committees of the Professional Institutions) are to set out the requirements which are professionally recognised as good practice in the execution of Building and Civil Engineering work, to deal with methods of design, and to prescribe the method of use of materials of constructions. These Codes of Practice are published for the Codes of Practice Committee by the British Standards Institution, and will, when the series is complete, cover practically every variety of work met with in Building and an important part of the field of Civil Engineering.

62. British Standards.—Also published by the British Standards Institution (and obtainable, as are the Codes of Practice, from that Institution, at 28 Victoria Street, London, S.W.1) is another very useful series of pamphlets known as "British Standards", which lay down standards of quality of materials, and also define dimensions and testing of fabricated components and appliances.

It will be seen that the above two series of publications are complementary and, used in conjunction with one another, will be found almost indispensable in drafting a specification.

63. Clearing Site.—The Contractor shall take down all buildings, walls, fences, and other obstructions, cut down all trees, hedges, and bushes, and clear the site of the Works at such time as and to the extent required by the Engineer, but not otherwise. The materials so taken down shall become the property of the Employer, and shall be stacked or employed on the Works as and where directed by the Engineer, or disposed of as specified.

All stumps of trees, bushes, and shrubs on the site of road formation, cuttings, ditches, drains, embankments, piling, trenching, foundations, etc., shall, unless otherwise directed, be grubbed up and removed to a place of deposit to be provided by the Contractor. The holes made in grubbing up shall be filled in and rammed solid with approved materials. Brushwood roots, and refuse of every description shall be burnt, or removed from the site of the Works to a place of deposit to be provided by the Contractor.

Existing buildings, walls, trees, gates, and fences, where so ordered by the Engineer, shall be taken down, and the materials arising therefrom shall be stacked as and where directed by the Engineer. If ordered by the Engineer, young trees shall be transplanted as directed by, and to the satisfaction of, the Employer.

All cellars, tanks, underground chambers, and cess-pits shall be properly cleared, filled in, and rammed solid with approved materials.

Where so ordered by the Engineer, turf shall be properly cut, stripped, and stacked ready for relaying.

Vegetable earth or other surface soil shall be excavated and deposited in separate heaps for re-use in soil cuttings, embankments, and verges, or for disposal as specified.

64. Excavations.—The excavations indicated on the Sections, with any further excavations which may be necessary, for the walls, anchorages, foundations, trenching, timbering, piling, and cuttings, or for the execution of any other part of the Works, are to be done as directed, and, if so required, at any part before the driving of piles is commenced. No excavation other than that indicated on the Contract Drawings or otherwise stipulated will be paid for.

The prices for all excavations are to include all expenses whether the materials be hard or soft, the formation of slopes, and the depositing, levelling, trimming, and finishing of embankments, and the filling in and making up of the site for the disposal of the surplus materials, which site or sites shall be pointed out by the Engineer within the Employer's property and within which the whole of the excavations shall be deposited.

The Contractor shall include in his tender the cost of all timber used in and drawn from the trenches or excavations, and also of all timber required by the Engineer to be left in.

The excavation of the retaining wall foundations and of all the anchor ties, concrete anchorage, drain and other trenches where so directed by the Engineer, shall be done in timbered vertical trenches, without slopes, from the present or new surface or formation level of the ground downwards, the area in plan of ground excavated being merely that necessary for the trench and timbering.

It should be noted in connection with the above Clause that the second paragraph will depend greatly upon the district in which the Works are being executed. In congested and thickly populated districts, there will usually be difficulty in disposing of surplus materials, and, in this case, the Contractor will be made responsible for the complete disposal. On the other hand, in some districts surplus material is in great demand for making up ground, etc., and can be disposed of at a gain. The paragraph will be drafted to suit the conditions.

65. Refilling.—The refilling of the excavations, unless where otherwise specified, shall be done with approved clean engine ashes, deposited, beaten down, and watered in layers not exceeding 9 in. in depth. Proper allowance is to be made for subsidence and shrinkage, and special care shall be taken in

punning underneath and around foundations and pipes to prevent subsidence and leakage, and also where the surface is to be paved. The Contractor shall at his own expense make up any subsidence that may occur, when directed by the Engineer, and that till the end of the period of maintenance.

The water for consolidating the filling in and banking shall be paid for by the Contractor.

66. EXCAVATION OF CUTTINGS AND FORMATION OF EMBANKMENTS.—The Contractor, in excavating the cuttings and forming the embankments, shall carry out the same in accordance with the Drawings, and shall adhere to the depths and heights figured thereon. Should any cutting be excavated beyond the depths shown on the Drawings, the excess excavation shall be made good by the Contractor at his own expense with broken stone or ashes as directed, unless the deviation has been ordered by the Engineer. Should the slopes of any cutting be excavated beyond the width shown in the Drawings, the excess excavation shall be made good by the Contractor who shall also, if called upon by the Engineer, provide satisfactory support for the replaced material, all at his own expense. In excavating the carriage-way, the last 3 in. at least in depth shall be left for execution by manual labour immediately prior to the rolling of the formation and application of the clinker and ashes. Proper templates and profiles of the cross-section of the road are to be made and set for the guidance of the workmen at such intervals as the Engineer may direct. Unless otherwise ordered by the Engineer, all excavated materials shall be used to form the embankments. The Contractor shall, in tipping the embankments, make due allowance in the height and width of same for consolidation and shrinkage. When the Contractor has ascertained the nature of any soil to be used for making the embankments he will be held responsible that the filling is so carried out and the slopes so determined that on completion of the Contract the levels, widths, and dimensions of the finished surfaces of the road and side slopes shall correspond to the levels shown on the Drawings. The embankments shall be well consolidated by depositing in layers, rolling, or otherwise as the tipping proceeds and kept free from lodgment of water. Materials used in the embankments and obtained from cuttings or borrow cuttings will be paid for as excavation only, but

materials ordered to be and obtained from borrow cuttings shall be measured in the finished embankments. Before tipping any such borrowed material, the Contractor must give one week's notice to the Engineer of his intention to do so, stating the location where he proposes to use it, and material from borrow cuttings and material from ordinary excavation must not be tipped together without the written consent of the Engineer. The measurement of cuttings shall be calculated from the original ground surface (or, where the surface soil has already been stripped, from the new surface thus formed), to the lines and levels of the formations of carriageway and footpaths, verges, and side slopes. Embankments to be measured shall be measured on the same basis.

Any material which is in the opinion of the Engineer unfit to form embankments, shall be removed from the Works and deposited elsewhere by the Contractor at his own expense.

Any difference in the amount of soil, etc., stripped where directed and the amount of soil, etc., re-used as specified, will be taken as being included in the ordinary excavation, and shall be disposed of as specified.

67. STONES AND BOULDERS.—Except where specially permitted by the Engineer the Contractor shall not deposit in the embankments stones or boulders obtained from the excavations, but shall dispose of these otherwise as directed. No accumulation of stones and boulders will be permitted at the toe of embankments, which must be dressed and finished true to the lines and levels shown on the Drawings, and as specified in the preceding Clause.

Where ordered, these stones shall be employed on the Works for stone filling to drains, and the boulders shall be broken up for use in the carriageway bottoming, or otherwise as directed.

68. EMBANKMENTS OVER CULVERTS, BRIDGES, AND DRAINS. In carrying the embankments up to, or over, any bridge, culvert, or pipe drain, care shall be taken by the Contractor to have the embankment brought up equally on both sides and on top of such bridge, culvert, or pipe drain, the earth being carefully rammed in 1-ft. layers, or in case of rock embankments carefully packed, for such distance on each side as the Engineer may direct. The cost of these Works shall be included in the

Schedule rate of the excavation from which the bank is formed. Should any injury or derangement arise to any such bridge, culvert, or pipe drain, from want of such precautions or from any other cause which, in the opinion of the Engineer, is within the Contractor's control, the latter shall at his own expense, rebuild the bridge, culvert, or pipe drain, or make good the damage done, to the satisfaction of the Engineer.

69. Benching.—When benchings are required they shall be executed by the Contractor in such situations only and of such forms and extent as the Engineer may direct.

70. Trimming Side Slopes.—The side slopes of the cuttings and embankments shall be trimmed regular and true, to such inclinations as the Engineer shall direct, and if, from any circumstances, the Engineer shall deem it necessary to widen any cutting or to flatten its slopes after they have been trimmed, the Contractor shall perform this work and be paid only for the actual extra quantity of earth removed, at the Schedule price per cubic yard of cutting, without extra payment for the additional trimming, or for shifting men, tools, or plant, to and from this work.

71. Soiling and Sowing Side Slopes.—The side slopes and berms of cuttings and embankments, after trimming, shall, where ordered by the Engineer, be soiled at an even depth of 4 in. and, at the proper season, sown with grass seed as specified, in the proportion of 1 lb. of seed to 60 sq. yd. The sowing is to be repeated in case of failure without extra charge until a good growth is established. The Contractor shall provide and lay at the foot of the slopes in cuttings where these slopes are soiled, one row of turf as a toe for the soiling. Where from storms, trespassing, or any other cause, the soil requires replacing and fresh sowing, this shall be done by the Contractor without extra charge. Turf, when available, may be used with the consent of the Engineer as a substitute for the sowing of grass seed.

72. Shaping Formation.—The formation is to be properly shaped and regulated to an even and uniform surface, parallel to the required finished surface of the road, and properly consolidated by rolling with a roller not less than 6 tons in weight.

73. CURVES.—Where the lay-out is curved on plan, the bottoms of the cuttings and the tops of the embankments shall have such super-elevation as the Engineer shall direct.

74. SUBSIDENCES.—The Contractor shall, at his own cost, make up all subsidences in the embankments, whether arising from the nature of the material in the embankments, from the nature of the ground upon which the embankment rests, or from any cause whatsoever. Should any subsidences take place or depressions appear in the road surface or in the drainage system after it has been formed, they shall be remedied and made good by the Contractor at his own expense.

75. SLIPS.—The Contractor shall, at his own expense, keep the whole of the excavations at all times free from water, and construct such temporary watercourses and drains as may be necessary to preserve the slopes of cuttings from injury during the time the Works are in progress, and should any slip of earth take place during the continuance of the Contract or during the period of maintenance, the Contractor shall, at his own expense, carry away such earth or make good such slip, in a manner satisfactory to the Engineer.

76. SCARIFYING EXISTING CARRIAGEWAY AND MAKING GOOD.—Where the new carriageway abuts on or includes an existing carriageway, and the Engineer so directs, the surface of the latter shall be scarified, adjusted, and formed to suitable levels, lines, and cambers, to receive the new surfacing which shall be shaped to conform with existing and the new cambers. All material used in raising the formation shall be approved material.

77. STREAMS, WATERCOURSES, AND DITCHES.—Excavations carried out in the diversion, enlargement, deepening, or regularization of streams, watercourses, or ditches, shall be performed as directed by the Engineer. The rate for excavation shall include the necessary trimming of slopes and grading of bed, disposal of the excavated materials, and all pumping, timbering works, and requisites necessary for dealing with the flow of water.

78. FILLING OLD WATERCOURSES.—Where watercourses have to be diverted on the line of embankments, their original bed shall be carefully filled in with earth, in 1-ft. layers, and

rammed solid before the banking is proceeded with. The embankments shall be carried forward in such a manner as may be approved by the Engineer, and to such heights as will give the proper level when consolidated. If specially ordered by the Engineer, hardcore shall be used for refilling instead of earth.

79. OPEN DITCHES.—Open ditches for drainage purposes shall be cut where and of such sections as shall be ordered by the Engineer. The sides shall be dressed fair throughout, and the bottom graded, as directed by the Engineer.

80. FOUNDATIONS TO BE PROPERLY FINISHED AND APPROVED.—The bottom of all foundations and tracks shall be accurately excavated to the form of the permanent work and be truly levelled and thoroughly cleaned and, before building is begun, all loose or soft material of every kind shall be entirely removed. Concreting or pipe-laying shall not be commenced until the bottom has been expressly inspected and approved by or on behalf of the Engineer, in regard to the workmanship as well as to the character and stability of the strata, and, where necessary, investigation shall be made as to the under-strata by sinking pits and boring as provided in Clause 5 hereof.

81. EXCAVATIONS TO BE KEPT DRY.—All excavations shall be kept entirely dry and free from water and sewage until, in the opinion of the Engineer, any masonry, concrete, or other works therein are sufficiently set. The sides of the excavations shall be properly shored up and all slips which may arise shall be removed by the Contractor at his sole expense and made good in a manner satisfactory to the Engineer.

82. EXCAVATIONS FOR CONCRETE.—Excavations intended to receive concrete shall be made to the exact size ordered, and should the required dimensions be exceeded, or the sides cave in, the concrete shall be retained with boards and the vacant space afterwards filled in and rammed solid, without extra charge ; or if instructed by the Engineer, the whole vacant space shall be filled with concrete.

83. FILLING TO FOUNDATIONS, MANHOLES, TRENCHES, ETC. When the concrete, masonry, brickwork, or other foundation is sufficiently advanced, the necessary filling shall be carried out with selected materials, spread in 9-in. layers. Each layer

shall be rammed solid before the next is added. All surplus materials shall be removed and disposed of as the Engineer shall direct.

84. Rock Cutting in Formation.—Where rock is met with in the general excavations for the carriageway, it is to be cut out to a depth of 9 in. and not more than 12 in. below the intended finished levels of the permanent surface. In addition due provision shall be made for the proper bedding of the kerb. Where rock is met with in the excavation for the remainder of the roadway, it is to be cut out to a depth of not less than 4 in. below the intended finished level of the work. Irregularities under the carriageway shall be levelled up to the level of the underside of the carriageway foundation with whinstone shivers thoroughly consolidated or with 1 : 3 : 6 concrete the coarse aggregate of which shall be whinstone chippings graded from 1-in. or $\frac{3}{4}$-in. to $\frac{3}{8}$-in. gauges.

85. Trimming Sides of Rock Cuttings.—The sides of all cuttings through rock shall be examined by the Contractor and cleared of all loose or insecure fragments, blocks, or pockets which may at any time be likely to cause injury or damage through falling on the verges or footways.

86. Definition and Classification of Rock.—Should a difference of opinion arise between the Contractor and the Resident Engineer or the Inspector as to whether any material found in the trench or other excavation should be measured as rock, or as to the kind of rock, the matter shall be referred to the Engineer for his opinion before the trench is filled in, and his decision shall be final. Shale, coal, or boulder clay will not be considered or paid for as rock.

" Solid rock " shall comprise rock in solid beds or masses in its original position which may best be removed by blasting, and boulders or detached rock measuring 1 cu. yd. or over. " Loose rock " shall comprise all detached masses of rock or stone of more than 1 cu. ft., and less than 1 cu. yd., and all other rock which can be properly removed by pick and bar and without blasting, although steam shovel or blasting may be resorted to on favourable occasions to facilitate the work.

In trenches no allowance will be made for boulders less than 3 cu. ft. in size. Above that size they will be measured and paid for as " solid rock ".

87. Blasting.—Blasting shall not be done without the previous consent of the Engineer, and shall be restricted to the hours which the Engineer may prescribe. Such consent shall in no way relieve the Contractor of any of his liabilities included under this Contract.

In the event of such permission being granted the Contractor shall only use small charges of explosive, properly covered and loaded, at any one time, and then only in such a manner as not to be a nuisance or danger to residents or property in the district, and he shall provide and cause to be used at all times when firing is to take place, sufficient and efficient screens, shields, matting, and take any other preventive measures necessary to intercept debris, stones, earth, or other matter liable to be scattered or blown outside the trenches or excavations. He shall also give warning to all residents in the locality of the times he proposes to fire shots, and shall provide watchmen with red flags at sufficient distances in each direction to warn pedestrians and approaching traffic that such operations are being carried on.

If, in the opinion of the Engineer, blasting would be dangerous to persons or adjacent structures, or is being carried on in a reckless manner, or in the event of any complaints regarding the blasting operations being received by the Engineer, he may withdraw any consent he has given, and the rock shall be excavated by other means, and no extra claim will be allowed the Contractor by reason of such withdrawal.

All blasting operations shall be carried out in such a manner as not to cause damage or interference with sewers, gas, water, or other mains and services.

The Contractor shall, in the event of blasting operations being sanctioned by the Engineer, provide a properly secured isolated explosive store, in accordance with statutory requirements, and obtain all necessary licences ; and all blasting operations shall only be carried out under the direction of an experienced operator.

In no circumstances whatever will any blasting be permitted in, or under, or in the vicinity of, Railways, Canals, Bridges, or Culverts, or in the vicinity of buildings, etc.

88. Shoring, Timbering, and Supporting Buildings.—Before commencing any excavations for new sewers, drains, or

other works in the proximity of or under any buildings, bridges, walls, etc., the Contractor shall substantially shore up, support, strut, and timber the walls of such buildings, etc., where liable to be affected by the work.

All timbering, supporting, and shoring shall be carried out in such a manner as to cause the minimum possible amount of damage to the walls of such buildings, etc., and all damage shall be made good on the completion of the works by the Contractor at his own expense to the satisfaction of the Engineer and the owners of the affected properties.

89. Underpinning.—After the shoring, strutting, timbering, supporting, etc., to buildings, etc., as specified in Clause 98 above is completed, the Contractor shall underpin such portions of the walls of buildings, etc., as the Engineer may direct. The excavations for this shall be carried out as rapidly as possible in short lengths not exceeding 6 ft. or such less length as the Engineer may direct, and each length of underpinning shall be completed before any other adjacent length is commenced.

At all times during the progress of excavation, and whilst the existing walls are being underpinned, the Contractor shall so timber and support the excavations that the sides are solidly supported, and ashes, sand, or other solid matter are not drawn from the surrounding unexcavated ground, especially that which is supporting footings of buildings, etc.

After the excavation has been completed to the necessary depths, the Portland cement concrete bed or foundation shall be formed to the thicknesses, dimensions, and positions as directed by the Engineer, and in such a manner that a true and even surface is formed to receive the first course of brickwork of the underpinning walls.

After the concrete foundations have thoroughly set, the brickwork underpinning shall be carried up in even courses, laid in English bond, special care being taken to ensure that the last course is tightly driven and well bedded in cement under the lowest course of the existing footings. Steel wedges shall be inserted where ordered by the Engineer between the underpinning and the existing foundations.

Each course shall be carefully gauged and laid in horizontal courses, and the footings of the underpinning wall stepped, where necessary, on concrete foundations to suit.

For the purpose of properly bonding in the separate portions of underpinning with the subsequent work, proper toothings shall be left, and these shall be protected from mortar which might drop on them.

All cavities behind the underpinning shall be grouted up solid with 4 : 1 Portland cement grout under pressure, the Contractor to provide all the necessary plant and apparatus of approved pattern, and all labour, materials, and attendance on plant.

Items with respect to underpinning, where given in the Bill of Quantities, are provisional only, and only such underpinning work as is actually executed will be measured up and paid for at the rates set against the various detailed quantities set forth in such items.

90. Excavation for Fireclay and Concrete Pipes, and Concrete and Brick Sewers.—Except where headings are specified or permitted or otherwise ordered, the ground shall be excavated for sewers, drains, and the like, in open trench, to the lines and depths indicated on the Drawings, or such other lines and depths as the Engineer may direct. Any trench which may have been excavated to a greater depth than necessary shall be filled in to the required level with concrete 1 : 3 : 6 as specified at the Contractor's expense. All trenches shall be of sufficient width and at the bottom shall have at least 6 in. clearance between the outside of the barrel of the pipe to be laid, and the face of the excavation or timber sheeting, and roomy joint holes shall be provided. Special care shall be taken to provide a solid, even bed for the barrel of the pipe and, where a concrete bed is not specified, the floor of the trench shall be properly shaped to receive the sockets and barrels of the pipes.

In the case of concrete and brick sewers, the bottoms of trenches, so far as practicable, shall be carefully shaped to the exact contour of the underside of the brick or concrete base (proper templates being provided by the Contractor if necessary for this purpose), and the bottom longitudinally levelled up true to enable the sewer to be constructed to the proper gradient.

91. Rock Cutting in Trenches for Pipes.—Where rock is met with in the trenches it is to be cut out to a depth of 6 in.

below the intended level of the bottom of the pipes, and 6 in. of sand or fine ashes shall be filled in, and well beaten down to form a good firm bed for the pipe. Where required socket holes shall be cut in the rock.

Where pipes are to be left with open joints, such joints shall be surrounded with clean broken stones.

92. TIMBERING AND SUPPORTING TRENCHES.—The prices stated in the Schedule of Quantities for excavation (including excavation in trenches for sewers, drains, and manholes), shall include for the use of all timber and for all labour in placing and withdrawing the timber required for properly supporting and timbering the trenches, excavations, and headings in such a manner as to ensure the safety of the men and to protect the work, tramways, railways, canals, bridges, roadways, etc., buildings, and other properties in the vicinity thereof from damage.

In all cases where the ground is of an unstable character, or where the Engineer considers it necessary, the trenches, excavations, and headings shall be close-timbered from top to bottom, as the Contractor will be held responsible for any accident, subsidence, or damage caused by defective or insufficient timbering, careless workmanship, or any other cause whatever.

In bad ground, or where the Engineer considers it necessary, runners not less than 2½ in. thick shall be used.

Should, however, the ground be of such a nature that for the safety of men and to protect the work, roadways, etc., buildings, and other properties in the vicinity thereof, from damage, some means of supporting trenches, excavations, etc., is necessary, other than by the use of timber, as before specified, the Contractor shall substitute interlocking steel piling or other approved means for supporting trenches, excavations, etc.

Should the Engineer in any case direct that timber be left or specially placed and left in trenches, excavations, or headings, such timber will be allowed for at the prices stated in the Bill of Quantities, provided the necessity for leaving it in has not, in the opinion of the Engineer, arisen from carelessness or neglect on the part of the Contractor.

93. HEADINGS.—Where heading work is specified or permitted or otherwise ordered, only men of special experience shall be employed in the work, and the headings shall be

driven of sufficient size and in such a manner as to enable the sewers to be properly constructed. The sides and roof shall be carefully timbered and supported, and the headings (unless otherwise sanctioned) driven through from shaft to shaft before any portion of brickwork is commenced or pipes laid. The shafts are to be placed at such distances apart as the Engineer may direct, and shall be of sufficient length to enable the line of heading to be set out with accuracy. When a length not exceeding 5 ft. of brick sewer has been completed, the centres struck, and the timbers withdrawn, the space between the outside of brickwork and the sides and top of heading shall be solidly packed with boulders, broken bricks, or coarse material, well rammed in. The next length of brickwork is then to be added and the filling in repeated in a similar manner until the work is completed. The filling in around pipes to be carefully performed after the specified tests have been successfully carried out. Fine materials only shall be used for filling over and around pipes. Where the spaces in headings over and around pipes, brickwork, etc., are to be filled with concrete, this shall be solidly packed and rammed so as to fill completely all interstices.

94. Sight Rails and Boning Rods.—The Contractor shall fix over the centre of each manhole or lamphole where a change of direction or gradient occurs and at any other points to be decided by the Engineer, a strong sight rail not less than 6 in. deep with the top edge planed true and straight. This shall be supported by a stout wooden post or stump at each end, and its top edge accurately fixed to a definite height (in even feet) above the level of the invert of the sewer to be constructed. The centre line of the sewer shall be denoted on each sight rail both back and front by a single vertical line drawn thereon, and the rail on one side of the centre line painted red, and on the other side white. Where any length of sewer exceeds 50 yd., and has a flatter gradient than 1 in 50, three sight rails shall be fixed on each length and worked one with the other. The boning rods used are to be accurately made to the various lengths required in even feet, the lower end being provided with a shoe of sufficient projection to rest on the centre of the invert of the last pipe laid.

95. Laying and Jointing of Salt Glazed Ware and Fireclay Pipes.—Salt glazed ware or fireclay spigot and socket

pipes, as specified, shall be thoroughly bedded on the solid ground throughout the length between joint holes, laid to true invert, straight lines, and falls, each pipe being separately boned between sightrails. The spigot of each pipe shall be placed home in the socket of the one previously laid. The pipe shall then be adjusted and fixed in its correct position but it shall not be jointed until the earth has been partly refilled over the portion of the pipe between joint holes. A ring of rope yarn dipped in liquid mortar shall next be inserted in the socket of the pipe previously laid and driven home with a wooden caulking tool and wooden mallet ; such yarn, when in position, shall not occupy more than one-fourth of the total depth of the socket. (Or, alternatively, the sockets shall be caulked as tight as a stoneware pipe admits with tarred yarn, the depth of yarn after caulking to be ½ in. in 4-in. and 6-in. diameter pipes, and 1 in. in pipes of larger diameter.) The socket shall then be completely filled with cement mortar (two parts of sand to one part of cement) as specified, and a fillet of the same worked around the outside. The fillet shall be bevelled off at an angle of forty-five degrees to the barrel of the pipe.

Special care shall be taken that any excess of cement, etc., is neatly cleaned off while each joint is being made. Any earth, cement, or other material shall be thoroughly cleaned out of the pipes by drawing a closely fitting wad through them as the work proceeds. A properly fitting plug is to be well secured to the end of the last laid pipe, and is only to be removed when pipe-laying is proceeding. The refilling of trenches shall not be done until the joints of the pipes are thoroughly set and have been inspected and approved, and the finest of the excavated soil shall be used immediately under and around the pipes.

No pipes shall be laid until a distance of at least ten yards along the trench has been prepared and bottomed to receive the pipes, unless in special circumstances of which the Engineer shall be the judge. No greater length of trench is to be opened at one time than the pipe-layer can keep pace with, and the filling in of the trench shall be proceeded to completion immediately after inspection and approval as provided for in Clause 98.

The trench and joint holes shall be kept free from water until the pipes are laid and the joints thoroughly set.

The Contractor shall exercise every possible care to prevent the accumulation of sand, silt, or any deposit during the construction of the drains, and will be held responsible for any damage or expense arising from such causes or any costs or charges in connection with the removal of any such accumulation.

Where directed by the Engineer, spigot and socket fireclay pipes shall be laid open-jointed with a ½-in. space between the spigot and the back of the socket, and covered with clean broken stones of a size not exceeding 4 in. cube and of approved quality to a height of 1 ft. above the top of the pipe, and/or the joints packed and surrounded with clean broken stones of similar size and quality, as directed by the Engineer.

On completion all drains are to be flushed from end to end with clean water and left perfectly clear.

96. Laying and Jointing of Cast Iron Pipes and Specials.—Concrete blocks (two to each pipe) shall be lowered into the trenches, placed in position and firmly bedded on trench bottom to the correct line, levels, and spacings, but should the nature of the trench bottom render it necessary, in the opinion of the Engineer, then the blocks shall be laid on a 3-in. layer of broken slag laid, spread, and consolidated over the bottom of trench (which is to be further excavated to receive same).

The first or leading pipe shall be lowered, set true to line, level, and gradient on the concrete blocks by means of steel packing plates and timber wedges and then firmly fixed and strutted in position. The remainder of the pipes shall then be lowered and set true to line, levels, and gradients in a similar manner and the spigots and sockets properly fitted to the full depth of each socket.

When each consecutive pipe has been properly set, the jointing of the pipes shall be commenced and completed as hereafter specified, and the work of concreting, puddling, etc., shall then be carried out.

The wedges shall be of oak or other hard wood and of sufficient and proper size to enable the pipes to be properly centred and securely held in position on the steel packing plates.

The steel packing plates for supporting the cast iron pipes upon concrete blocks shall be of such sizes and variety of thickness to support the pipes and enable them to be properly laid to the necessary levels and gradients.

The Contractor shall supply and deliver sufficient steel plates and timber wedges to enable the work to be efficiently executed.

The cast iron pipes shall be jointed with spun yarn and pig lead in the following manner :—

The spun yarn shall be formed into strands and inserted as such in the jointing space and well and truly caulked home with a properly formed yarning iron. Unless otherwise specified, the joint shall then be run in one pouring with molten pig lead, after proper pipe joint clip or puddle band has been fixed ; the joint shall then be set up with proper sized caulking irons and hammers. Each length of pipe must be kept open until it has been inspected by the Engineer or his representative. In the event of the joint not being well and truly run at one pouring, the lead shall be burnt or cut out and the joint remade as described above.

The weights of lead and yarn per joint, for pipes up to and including 48-in. diameter, shall be in accordance with the following schedule :—

Nominal Internal Diameter of Pipe	Lead per Joint	Yarn per Joint	Nominal Internal Diameter of Pipe	Lead per Joint	Yarn per Joint
in.	lb.	lb.	in.	lb.	lb.
3	4·50	·25	27	46·75	2·94
4	5·50	·38	30	58·25	3·22
6	8·00	·44	33	65·75	3·63
9	13·50	·69	36	71·50	4·13
12	17·00	1·06	39	76·75	4·44
15	23·00	1·50	42	82·00	4·72
18	31·50	2·07	45	91·25	5·40
21	36·25	2·38	48	103·00	5·75
24	41·25	2·66			

Alternatively, the joints may be cold caulked with a fibrous lead.

97. **Bends.**—At all changes of direction where a manhole or lamphole is not provided, proper bends shall be inserted, the joints corresponding to those of the other pipes forming part of the same length ; such bends to be extra value on straight pipe sewers of the same size and description.

98. Water Test.—The Contractor shall include in his prices for testing all pipe sewers in the following manner :—He shall first have the pipes cleared of any earth or material that may be lying on them, and shall cause all hand-holes to be cleared out so as to enable a thorough examination of the joints to be made whilst the pipes are under pressure ; the lower end of the first pipe of the new length to be tested, together with all junction eyes, lamphole eyes, and other openings, shall then be closed by means of air bags or expanding stoppers, and, in the socket of the last pipe laid at the upper end of the length under test, a stoneware quarter bend shall be temporarily inserted with the socket pointing upwards, one 2-ft. length of pipe shall be added and fixed vertically from the socket of the bend, the joints being made in such a manner as to be absolutely watertight. The whole length shall then be filled with water, and after allowing a short time for absorption to take place, more water added until it stands not less than 2 ft. above the invert of sewer at the highest point in the length. For ten minutes no more water shall be added, or the sewer in any way interfered with ; if at the end of this time the water shall not have dropped in level more than 1 in. in the vertical pipe, the test will be regarded as satisfactorily withstood. Should, however, the water-level drop more than 1 in. in the ten minutes, the whole length of pipe shall be carefully examined, any leakages located and marked, and the pipes emptied. Such joints and pipes as were proved defective or incapable of withstanding the test shall be cut out, replaced, relaid, or otherwise made good to the satisfaction of the Engineer, and the test re-applied as many times as may be necessary until the entire length is proved to be watertight.

In carrying out the water test, care should be taken that no length of pipe (unless surrounded with concrete) is at any part subjected to a greater pressure than that due to a head of 8 ft. of water applied internally.

99. Manholes.—Manholes in brickwork and cement mortar (2 : 1) neatly pointed and key-drawn on the inner face and flushed full on the outer face, having concrete foundations, shall be built in the positions shown on the Plans and in accordance with the detail Drawings.

Glazed ware half-channel pipes and junctions of the required dimensions and radii shall be laid and bedded in cement mortar on the concrete (1 : 3 : 6) foundation to the same line and fall as the pipes, unless otherwise directed ; both sides of the channel shall be benched up in concrete 1 in. deep, to the level of the top of the pipes, finished smooth, and formed to a slope of not less than 1 in 12 to the channel.

The ends of all pipes shall be neatly built in and finished with cement mortar (2 : 1). Where the diameter of the pipe is 9 in. or more, a 4½-in. ring arch shall be turned over the end for the full thickness of the brickwork.

Where the depth of the invert exceeds 3 ft. below the surface of the ground, step-irons shall be built in the brickwork every fourth course, with such additional hand-irons as may be necessary for safety.

The manhole cover or frame shall be bedded in cement mortar (2 : 1), and the covers left flush with the surface of the ground or carriageway surfacing.

The Contractor shall provide two manhole keys for removing covers as directed by the Engineer.

Should there be any settlement or subsidence of the ground against the manhole between the times of the construction and of the completion of the Works, the surface level of the manhole frames shall be readjusted to the finished level of the surface, and the surface reinstated to the satisfaction of the Engineer.

The excavations shall be taken out to the dimensions required and after the brickwork has been built the space between the brickwork and the face of the excavation shall be carefully and solidly packed as directed by the Engineer.

The manholes when completed shall be thoroughly watertight.

100. Concrete Culverts Faced with Brickwork.—The foundations, walls, and roof of brick-faced culverts shall consist of concrete (1 : 2 : 4), and the invert, walls, and roof shall be faced with special facing brick as specified. The concrete in the walls is to be carried up in courses equal in depth to four courses of brickwork in single-faced walls, and two courses in double-faced walls, each starting from the bottom of a header course, and well rammed and packed behind the brickwork. Joints in courses shall be formed against vertical temporary boards, and left with a rough uneven

surface for bonding. If any concrete during the progress of the work has been allowed to set hard, the surface shall be channelled, thoroughly washed and scrubbed with a hard brush, and spread over with a ½-in. layer of cement mortar before another layer is added.

101. CONCRETE WORK.—Portland cement concrete shall be composed of Portland cement, fine aggregate and coarse aggregate.

Intimation must be given to the Inspector before the mixing of concrete is begun, as no concrete which has not been mixed under his supervision will be allowed to be placed in the work. Proper measures for gauging the quantities by volume of the aggregates for the concrete, such as wooden boxes of dimensions to be approved by the Engineer, shall be provided and constantly used, but the proportion of cement shall be determined by weight, it being understood that 1 cu. ft. of cement weighs 90 lb. The Contractor shall ascertain by experiment that the proportion of mortar is sufficient to fill all the interstices in the coarse aggregate as specified in Clause 147, and he shall, at his own expense, increase the amount of fine aggregate and reduce the quantity of stone or gravel in order to effect this, with the total volume remaining the same.

A set of sieves of the sizes required for use in conjunction with B.S. 882 shall be provided by the Contractor.

The cement, and fine and coarse aggregates shall be well mixed in a machine approved by the Engineer, or, if specially permitted by him, on a large and substantially close-boarded platform by turning over the ingredients at least three times in a dry state and three times during the process of wetting by water sprinkled through a rose in such quantity as will bring the mass to the required consistency. Machines shall preferably be of the rotary batch-mixing type. The mixing drum shall be turned a sufficient number of times to mix the material dry before water is added, and turning shall be continued until the Engineer is satisfied that a thoroughly homogeneous and uniform concrete is obtained and, in any case, not less than 1½ minutes. The drum shall be completely emptied after mixing each batch. The concrete shall be discharged on to a watertight platform, or into watertight containers for removal and deposit in its intended position.

Great care shall be exercised in the gauging of the water used in mixing, as it is essential that the concrete shall not be sloppy. The water supply to the mixer shall be adjusted until the resultant concrete flows sluggishly out of the mixer (or, alternatively, until it gives the required slump test, see Clauses 104 (6) and 146). The consistency shall be checked from time to time during the progress of the work.

In concrete which the Contractor has been permitted to mix by hand the quantities of fine and coarse aggregate shall be reduced by 10 per cent. to allow for the less efficient mixing.

The concrete shall be placed in its position in the work as soon as possible after mixing, and not more than twenty minutes shall be allowed between the times of first wetting and of placing in position, nor shall any remixing be allowed. The intimate and homogeneous character of the mixture of mortar and stone shall be preserved during transport, handling, and laying.

Tests.—When directed by the Engineer, the Contractor shall make several 6-in. cubes in moulds provided by the Contractor. Wherever practicable, concrete for these test cubes shall be taken immediately after it has been deposited in the work. When this is impracticable, samples shall be taken as the concrete is being delivered at the point of deposit. A sufficient number of samples shall be taken so that the test cubes made from them will be representative of the concrete in the portion of the structure selected for test. The Contractor shall send the cubes carriage paid to a testing laboratory selected by the Engineer, where three cubes of each set will be tested when twenty-eight days old, and the remaining one when ninety days old. The Contractor shall place an identification mark on each cube, and keep a record of date of casting and proportions, and shall notify such information to the testing laboratory when forwarding the cubes. The minimum results of each cube should be not less than the following :—

Nominal Mix	Minimum Cube Strength Requirements at 28 days. lb. per sq. in.
1 : 1 : 2	2,925
1 : 1·2 : 2·4	2,775
1 : 1·5 : 3	2,550
1 : 2 : 4	2,250

If concrete has been used in the works, and the tests of same have proved deficient according to the foregoing table, such concrete shall not be fully loaded for a period to be fixed by the Engineer, and to prevent a recurrence of defective tests, either a slight addition to the percentage of cement shall be made or other aggregate shall be used, at the option of the Engineer, but at the Contractor's expense.

Placing.—The concrete shall be wheeled or lowered into place in steel barrows or skips or by metal chutes, not dropped from a height, nor thrown directly on pipes, and shall be deposited in 6-in. courses or as directed ; each course and the whole mass being made thoroughly homogeneous by probing and ramming with steel bars and rammers. The upper surface of flat work shall be levelled off with a wooden screed unless otherwise ordered. Special care shall be taken that all reinforcement shall be properly surrounded with concrete without displacing the reinforcement, and that concrete placed against shuttering to form an exposed surface shall be thoroughly worked with small spades and tamping tools to produce a perfectly smooth finish without after-rendering, unless otherwise ordered by the Engineer.

As concrete is deposited it is to be well rammed or speared until it has been made to penetrate and fill all the spaces between and around the steel bars (where reinforcement is used), and properly and completely surround them throughout their entire length in such a manner as to ensure its being a solid mass entirely free from voids.

It is imperative that the work be done quickly as well as efficiently, and an adequate number of hands must therefore be employed to ensure this.

Alternatively, consolidation may be effected by the use of a mechanical vibrator. This method is strongly recommended and has the following advantages over manual tamping or ramming: firstly, the concrete is more thoroughly consolidated and forced into contact with the reinforcement, thus ensuring a better surface and decreasing the risk of honeycombing ; secondly, these results can be obtained with a concrete made with a low cement-water ratio and therefore having a higher strength than is obtained with a wetter mix containing the same proportion of cement to aggregates ; and lastly, the vibrated concrete is less permeable to water than concrete tamped in the ordinary manner.

When once deposited and rammed the concrete is not to be interfered with or shaken.

When placing the concrete the fine material must be carefully worked against the moulds so that the faces of the concrete shall be left perfectly smooth and free from honeycombing upon withdrawal of the moulds. Any defect in this respect must be dealt with by the Contractor as specified below.

All concrete work shall, so far as is possible, be carried on continuously, so that the whole structure shall form one solid mass, but, where joints are unavoidable, they shall be formed as specified below. When fresh concrete is to be deposited on concrete already in position, the hardened surfaces shall be thoroughly cleaned, roughened with picks, brushed with steel wire brushes, washed, and spread over with a ½-in. layer of cement mortar (2 : 1), as specified in Clause 153, before concreting begins.

Any unfinished course of concrete work which may have been allowed to set for more than two hours shall be channelled on top, formed vertical at the ends against temporary boards, and left with a rough and uneven surface within, but shall be carefully levelled on the outer edges by placing a temporary straight-edge on the soft concrete, and, before building any course above or against another which has already set, the surface to be built upon or against shall be washed and scrubbed with a hard brush and spread over with a ½-in. layer of cement mortar before another is added.

All joints in slabs and walls generally are to be formed by inserting temporary vertical boards against which the concrete can be deposited and properly rammed.

The concrete in arch slabs is to be deposited continuously across the span from abutment to abutment and in as great widths as possible at right angles to the span. Joints, if required, are to be made vertically and across the span from abutment to abutment between and parallel to the main reinforcing bars.

The concrete in deck slabs is to be deposited continuously from parapet to parapet and in as great widths as possible. Joints, if permitted, are to be made vertically between and parallel to the main reinforcing bars ; where a joint is made the longitudinal reinforcement shall be duplicated for a distance of 3 ft. on each side of the joint.

The positions generally at which joints may be made will be indicated by the Engineer or his representative.

Except in the case where special permission is granted by the Engineer, no concrete shall be deposited in water, but in such case the concrete shall be lowered in boxes with opening bottoms, or in bags, or otherwise as the Engineer may direct. (See Clause 149.)

Where foundations have been piled or timbered, the greatest care shall be taken to envelop properly the heads of the piles and the timber framing with the concrete.

Building of abutments and walls shall not be commenced until the concrete of the foundations is properly set and thoroughly hard.

Protection from traffic, weather, and frost.—After being placed in position the concrete shall be adequately covered with canvas to protect it against the weather, and, except during frost, shall be kept well wetted until the concrete has firmly set. No walking, wheeling, or traffic of any description shall be allowed over the concrete before the engineer has given permission.

No concrete work shall be carried out when the temperature is below 36° F. on a falling thermometer, or below 34° F. on a rising thermometer, and no concrete shall be made from frozen materials. When depositing concrete at or near freezing temperatures, precautions shall be taken to ensure that the concrete shall have a temperature of at least 40° F. and that the temperature of the concrete shall be maintained above 32° F. until it has thoroughly hardened.

Any portion which in the opinion of the Engineer or of the Inspector has been damaged by frost shall be removed and replaced by the Contractor at his own expense.

Finish—Faulty Work.—All concrete shall be so deposited that when the moulds are removed it shall present a perfectly smooth and finished appearance. The Contractor shall be required, if so requested by the Engineer, to make good any portion of the work which does not conform to this Clause, by applying and rubbing into the faulty portion cement mortar 2 : 1) until the whole surface is perfectly smooth and presents a finished appearance, or by picking out in squares to a depth of at least 3 inches and refilling against boarding with fresh concrete as instructed by the Engineer.

The Contractor shall remove and reconstruct at his own expense any structural members or portions of the work which, in the opinion of the Engineer or of the Inspector, give evidence before or after removal of the moulds that the concrete was of a faulty quality at the time of deposition or was not properly deposited and sufficiently rammed in the moulds, or that any bars of the reinforcement have been omitted, incorrectly placed, or displaced, or which give evidence of any fault, defect, or injury from any cause whatsoever which may prejudicially affect the strength or durability of the construction.

Records of Concreting.—When required by the Engineer and for his information the following records of concreting shall be kept by and at the expense of the Contractor during the progress of the Works :—

(1) Maximum and minimum temperature throughout the day from noon to noon.

(2) State of atmosphere, whether :—

(*a*) Dry, medium, or moist.

(*b*) Gale, windy, or calm.

(*c*) Sunshine or cloudy.

(3) Position of portion of structure of work concreted each day shall be clearly marked on a set of Drawings, and preserved for reference.

(4) Gallons of water used per batch, with particulars of quantities of materials used per batch. (It will only be necessary to note any change in the amount of water and proportions. Any exceptional dryness or wetness of stone and sand shall be recorded, especially when test cubes are being cast.)

102. CENTERING AND SHUTTERING.—The centering and shuttering for concrete shall be adapted in every respect to the structure, and to the required finish of the work. It shall be made of sound timber of sufficient thickness, fixed in perfect alignment, and so supported and braced as to withstand any bulging, displacement, vibration, or movement of any kind. Wedges and clamps shall be used wherever practicable instead of nails, and provision made for cambering if and where required. All shuttering shall be thicknessed and close-jointed, and shuttering for exposed faces shall be planed on the face, tongued and grooved on the edges, and all nail and knot holes

shall be filled up flush with putty. All exposed vertical or horizontal sharp arrises in the concrete work shall be chamfered to a width of 2 in. or as may be directed by the Engineer. Immediately before the placing of the concrete, all dirt and wood chips shall be removed from the inside of the forms, and the forms shall be swilled down with water, which shall be allowed to escape through temporary openings left in the forms for the purpose, and shall be washed over with a suitable and non-staining composition to prevent adhesion of the concrete to the forms. Moulded shuttering shall be provided for circular work where the radius is less than 20 ft. All centering and shuttering shall be thoroughly cleaned and repaired if necessary before re-use.

The Engineer shall have the power to order without extra cost additional centering and shuttering if in his opinion the rate of progress is retarded by its absence.

No wiring will be permitted through parapets and exposed walls or beams for the purpose of tying the two sides of centering together.

The finish of exposed surfaces of parapets, piers, and beams shown on the Drawings is to be obtained by shaping the centering to form the reeding, mouldings, coves, and suchlike shown.

No centering or shuttering shall be struck or removed without the permission of the Engineer, which permission shall in no case relieve the Contractor from responsibility for the stability of the work. The periods stated in the following table are minimum and based on the assumption that weather conditions are normal and that the work is not loaded in any way. If frost has occurred extra time at least equal to the period of the frost must be allowed.

Part of Structure.	*Minimum Period before Striking Centering.*
Abutments, Wing Walls, Spandrel Walls, and Parapet Walls – –	5 days.
Arch Soffit – – – – – –	28 days.
Deck Slab – – – – – –	9 days, plus 1 day for each extra foot of span above 6 ft.
Sides of Beam casings and pipe ducts	4 days.

103. PRE-CAST CONCRETE CONSTRUCTION.—It is of great importance that the dimensions of pre-cast beams and slabs as

given on detail working Drawings shall be exactly adhered to, and the projection of steel reinforcement from the beams and slabs shall be in strict accordance with detail Drawings and sketches.

All pre-cast concrete work shall be manufactured and matured in a properly equipped yard, to be provided and laid down by the Contractor at his own expense on a site near the Works or at some other suitable and approved site. The manufacture of the pre-cast concrete work shall be carried out under the strict supervision of the Inspector.

Pre-cast bearing blocks, impost courses, quoins, base courses, and copes shall, unless otherwise ordered, be composed of fine concrete (1 : 1½ : 3).

Pre-cast beams and slabs shall not be moved from the positions in which they were cast for at least ten days, and shall not be erected until they are at least fourteen days old, or for such longer periods as may be considered advisable after inspection. Where one concrete member bears on another concrete member the bearing surface shall be thickly coated with cement mortar (2 : 1) before the concrete member is placed on the bearing. All beams and slabs shall be placed in the correct positions and levels as shown on the detail working Drawings, with the steel reinforcement interlocking as required.

Timber bearers, wedges, and other supports temporarily supporting the pre-cast slabs shall not be removed in less than seven days after the slab joint has been cast.

Before any joints are made they must be finally examined to ensure that all the steel reinforcement specified is in position. The joint shall then be cleaned of all dust and other foreign matter, and scoured with water so as to moisten thoroughly the adjacent concrete immediately before concreting the joint. The concrete in joints between pre-cast beams and slabs shall be 1 : 1 : 2 mixture, of a medium consistency and not sloppy. The jointing concrete shall be well tamped into position and brought to the level of the adjacent concrete.

104. Reinforced Concrete.—In Reinforced Concrete Work it is particularly essential that the concrete should be of good quality, well mixed, properly placed and rammed, and that the reinforcement should be fitted accurately in the positions shown in the drawings and not displaced in ramming,

otherwise the strength of the job may be ruined. The following Specification is typical for this class of work :—

(1) *Composition of Concrete.*—The concrete shall be composed of Portland Cement, fine aggregate and coarse aggregate in the proportions specified, and water to give the required consistency.

(2) *Proportions.*—The proportions by volume of the concrete in the various parts of the work will be specified on the drawings and shall be accurately measured as follows :—

Concrete described as	Cement, lb.	Fine Aggregate, cu. ft.	Coarse Aggregate, cu. ft.
1 : 2 : 4	112	2½	5
1 : 1⅔ : 3⅓	112	2⅛	4¼
1 : 1½ : 3	112	1⅞	3¾
1 : 1 : 2	112	1¼	2½

The quantity of water used shall be the minimum consistent with practical workability and shall be varied as required to suit the moisture contents of the aggregate, and to produce concrete having the specified slump.

(3) *Strength.*—Concrete mixed in the proportions stated should have compressive strengths at twenty-eight days after placing not less than the following :—

Concrete described as	Strength, lb. per sq. in.
1 : 2 : 4	2,250
1 : 1⅔ : 3⅓	2,400
1 : 1½ : 3	2,550
1 : 1 : 2	2,925

(4) *Tests.*—The Contractor shall make, when required by the Engineer, 6-in. die square cubes of the concrete being used in the work. After maturing for twenty-eight days in the same conditions as the concrete in the work itself, these shall be tested by crushing at the expense of the Contractor and shall show results not less than those specified in the preceding paragraph.

(5) *Mixing.*—An approved mechanical batch mixer shall be used unless the quantity of concrete is small, when hand mixing will be permitted. The mixer and mixing platform shall

be suitably protected from the wind to prevent loss of cement. The aggregates and cement shall be first mixed dry, then, after the addition of water, mixing shall be carried on until the concrete is of even colour and consistency throughout.

When mixing ceases the mixer and all handling plant shall be thoroughly washed out.

(6) *Consistency.*—The consistency of the concrete shall be determined at all times by means of a slump test ; the slump for concrete in various members shall not exceed the following amounts :—

Footings –	– 3-in. slump
Columns –	– 4-in. ,,
Walls –	– 5-in. ,,
Floor Slabs	– 5-in. ,,
Beams –	– 5-in. ,,

The standard slump mould shall be a hollow truncated cone made of sheet metal with a flush seam. The cone shall be 12 in. high (open at top and bottom) and have an internal diameter of 8 in. across the bottom and 4 in. across the top. Side handles and foot plates may be attached as required. Any rivets must be countersunk and filed smooth on the inside. (See also Clause 146.)

The slump test shall be made immediately after mixing and at the point where the concrete is being delivered for placing in the work.

A test shall be made of the concrete first placed, and if this appears to be satisfactory, the Inspectors shall be instructed to see that it is maintained during the work. If the slump varies at any time from that selected as a result of this test the quantity of water added to the next mix shall be altered and the slump again measured, repeating the procedure on the next batch if necessary. The test shall then be applied several times daily to ensure that the required consistency is uniformly maintained.

(7) *Blinding.*—Where concrete has to be deposited in contact with the ground, a blinding layer of rough concrete not less than 1 in. thick, or as specified on the drawings, shall be laid on the ground surface.

(8) *Placing Concrete.*—The concrete shall be conveyed from the mixer to its position in the work as rapidly as possible, and in no case shall more than thirty minutes elapse between

mixing and placing. Concrete shall not be dropped from a height of more than 3 ft.

The concrete shall be well rammed into position around the reinforcement and shall be properly spaded against the forms to ensure a good surface free from honeycomb.

The placing of concrete shall as far as practicable be continuous.

Column forms shall be left open on one side for ramming the concrete and built up as the work proceeds.

The ribs and slabs of Tee-beams shall be concreted in one continuous operation.

Walls shall be concreted in horizontal layers about 9 in. thick. Granolithic finish to floor slabs shall be laid immediately after the slab concrete is placed.

(9) *Stoppages.*—Day's-work joints shall be made in the following positions :—

(*a*) Slabs and Beams—at the middle of the span.

(*b*) Columns and Piers—2 in. below the junction of column with beam or haunch.

(*c*) Walls—Vertical joints in sections staggered 1 ft. 6 in. over each other.

Joints shall be made at right angles to the main reinforcement. Before recommencing, the surface shall be thoroughly swilled with clean water and coated with cement mortar. Joints of long standing shall be hacked back to a clean surface, the dust removed with a wire brush, well swilled, and coated with neat cement mortar. Keyed joints shall be made when shown on the drawings.

(10) *Placing under Water.*—Where concrete must be placed under water, some approved method such as a tremie must be employed to minimize loss of cement and segregation of the materials. (Fig. 5, p. 131.)

(11) *Frosty Weather.*—No concrete shall be deposited when the temperature is below 36° F. on a falling thermometer, or below 34° F. on a rising thermometer, excepting when specially approved precautions have been taken to ensure protection of the concrete during setting.

When depositing concrete at or near freezing temperatures, precautions shall be taken to ensure that the concrete shall have a temperature of at least 40° F. and that the temperature of the concrete shall be maintained above 32° F. until it has thoroughly hardened. When necessary, concrete shall be heated before mixing. Dependence shall not be placed on salt or other chemicals for the prevention of freezing. No frozen materials or materials containing ice shall be used. All concrete damaged by frost shall be removed.

In frosty weather all newly placed concrete must be kept properly protected.

(12) *Curing.*—After being placed, concrete shall not be jarred, walked on, or otherwise disturbed during setting.

In hot weather and during high winds freshly placed concrete must be kept watered and protected by wet sand or other approved method for at least three days after placing.

(13) *Defective Work.*—Any concrete damaged during setting from any cause whatsoever shall be cut out and replaced by the Contractor at his own expense.

(14) *Piles.*—Piles should remain undisturbed for twenty-one days after casting when they may be carefully moved to the stacking ground. They may not be driven until six weeks after casting unless special cements are used.

(15) *Bending and Placing Reinforcements.*—The reinforcement shall be accurately bent cold to the shapes shown on the working Drawings, and all bends shall conform to the special details supplied.

The reinforcement shall be built up exactly as shown on the detail working Drawings, and supported so as to give the correct cover. All intersections of bars shall be wired firmly with tying wire supplied by the Contractor. Stirrups shall be wired to the main bars at two points on the bottom cross wires.

Fabrics must be waved up over supports exactly as shown in the Drawings.

(16) *Formwork.*—Formwork may be constructed of any suitable materials. It must be true to line and level, strong and well braced to carry the wet concrete without deformation or deflection, and with close joints to prevent loss of cement. For face-work the boards must be wrought and thicknessed and have shot edges.

The design of the formwork must be such that it can be struck in the following order : columns, beam, sides, slabs, and beam bottoms. To facilitate striking, bolted and wedged connections should be used in preference to nails.

The bottoms of beam forms of over 20-ft. span shall be given a small camber.

(17) *Cleaning.*—Immediately before concreting is commenced, all forms shall be thoroughly cleaned out and swilled with clean water.

All forms must be thoroughly cleaned before re-use.

(18) *Inclined Work.*—The upper surfaces of all concrete at a slope of more than 30° shall be shuttered.

(19) *Striking.*—The formwork shall be eased off carefully in order to allow the structure to take up its load gradually. After removal of the forms the props shall be replaced under the beams for a further period. The time interval between placing of concrete and striking formwork depends on the weather and time of year, and the responsibility for removing formwork must rest with the Contractor.

After the formwork is removed the concrete surface shall be cleaned down to a fair face, all unsightly projections removed, and all holes filled with cement mortar.

(20) *Cutting Holes.*—No tampering with the concrete whether by cutting holes or otherwise will be allowed without the sanction of the Engineer.

(21) *Completion of Work.*—On completion of the work all rubbish and surplus material shall be carted away from the Site, and the work handed over to the Employer in a clean condition.

The Contractor must maintain a competent foreman on the job to supervise and to receive instructions.

105. ONE-COURSE CONCRETE ROAD.—The following Specification for a one-course concrete road is suggested by the Cement and Concrete Association, and may be regarded as typical :—

SPECIFICATION FOR ONE-COURSE ROAD BY MECHANICAL COMPACTION

The concrete carriageway laid to the following specification shall have a finished thickness of not less than .... inches.

I—MATERIALS

(1) *General.*—All materials used upon the work shall comply with the requirements of the specification and shall be

the best of their respective kinds, and properly representative samples shall be submitted for the Engineer's approval.

(2) *Cement.*—The cement to be used for this work shall be of British manufacture and shall comply in all respects with British Standard No. 12/1940 for Ordinary Portland and Rapid Hardening Portland Cement, or any subsequent British Standard for Portland Cement that may be issued.

Suitable provision for storage of cement and for protection against atmospheric influences shall be made by the Contractor. Any bag which contains lumps of caked cement or of cement which has partially set shall be rejected.

Bulk Cement. The use of cement delivered in bulk will be permitted only after the Engineer has approved of :—

(*a*) The method of transport and containers used.

(*b*) The method of discharge and storage.

(3) *Aggregates.*—The aggregates, coarse and fine, shall comply in all respects with British Standard No. 882/1944 for "Coarse and fine aggregates from natural sources for concrete."

(4) *Water.*—Only fresh clean water from the water mains or from a source approved by the Engineer shall be used for mixing concrete or mortar.

(5) *Waterproof paper.*—The waterproof paper shall be of a brand approved by the Engineer and shall comply with British Standard No. 1521/1949.

(6) *Jointing material.*—The jointing material shall be premoulded and of a type and manufacture approved by the Engineer. It shall be not less than ½ in. thick and its width shall be equal to the depth of the slab, less ¾ in. It shall be of a non-extruding nature and capable of adjusting itself to changing widths of the expansion joint. After being compressed momentarily to 50 per cent. of its original thickness at 120° F. it shall recover to at least 80 per cent. of its original thickness in five minutes.

(7) *Joint sealer.*—This shall be either a bituminous filler poured hot or a proprietary material, approved by the Engineer, placed or ironed in position in accordance with the manufacturer's instructions. The sealing material shall be of a colour matching as closely as possible the colour of the concrete.

(8) *Reinforcement.*—The steel used for reinforcement shall comply with British Standard No. 785/1938.

The reinforcement shall consist of either mild steel rods or a proprietary brand approved by the Engineer. It shall be made up in mat form, and when placed in position shall be free from oil, excessive rust, or any coatings which might impair its bond with the concrete.

II—FORMATION

(9) *General.*—The lines and levels of the proposed road shall be as shown on the drawings, and shall be set out by the Contractor in accordance therewith.

The turf and top soil shall be removed to a depth of at least 3 in., and the ground then excavated or filled to the required levels.

(10) *Excavation.*—The excavation shall be carried out to the levels shown on the drawings, all tree roots and other obstructions being removed. All surplus spoil to be disposed of to the satisfaction of the Engineer.

(11) *Filling.*—Filling shall be done only after the top soil and sods have been removed. Suitable material, free from sods, etc., taken from the excavation may be used for filling at the discretion of the Engineer. The fill shall be placed and consolidated in layers not exceeding 9 in. in thickness of loose materials. Consolidation shall be effected by a suitable roller. The filling material shall have the correct water content to allow maximum compaction. If the material is too wet consolidation shall be deferred until, in the opinion of the Engineer, it has dried sufficiently.

(12) *Checking formation.*—Before any concrete is deposited the level of the formation shall be checked by means of a scratch template working off the side forms. Any irregularities shall be made good, and the formation protected against any further disturbance.

(13) *Sub-base.—Alternative A.* The prepared formation shall be covered with a consolidated thickness of 3 in. to 6 in. (depending on the nature of the sub-soil) of concrete which shall be mechanically compacted. This concrete shall be composed of one part of cement to fourteen parts of mixed aggregates by weight, and shall be brought to a tamped finish shaped to the contour of the finished concrete slab. It shall be given a

light spray of tar or bituminous emulsion to prevent adhesion with the slab concrete.

Alternative B. The proposed formation shall be covered evenly with a layer, of not less than 3 in. consolidated thickness, of hard burned clinker, sand, or other approved material. This sub-base shall be consolidated by a roller weighing not less than 6 tons to the required cambers and levels, and until a tight smooth surface has been obtained. This sub-base shall be covered with waterproof paper, or alternatively well watered, immediately before the concrete is placed on it. The waterproof paper shall be laid with an edge lap of at least 3 in. and an end lap of at least 6 in.

Alternative C. Where the existing formation is composed of a well drained material, e.g. gravel or sand, the clinker sub-base (of Alternative B) may be omitted. The formation shall be blinded with a suitable material and well consolidated. It shall be well wetted and covered with waterproof paper (as in Alternative B) before the concrete is deposited.

III—FORMS

(14) The forms used shall be of steel and shall be of a depth equal to or greater than the thickness of the slab. The use of timber forms may be permitted at the Engineer's discretion.

(15) Timber forms shall be free from warps and twists, their thickness shall be such as to secure rigidity and their tamping edge shall be true for level and line.

(16) Steel forms shall be of approved section and construction. They shall be perfectly straight, or suitably curved, have a broad base, and be of sufficient stiffness to withstand, without displacement or distortion, the passage of the vibrating plant working on them. They shall be provided with an efficient locking device to ensure continuity of line and level through joints and with steel pins to hold them in position.

(17) The forms shall be set true to line and level and shall be supported on thoroughly compacted material for their entire length. They shall be tested for level with a 10-ft. straight-edge before concreting commences and where a variation of more than $\frac{1}{8}$ in. is found the form shall be taken up and reset. Packing up the forms with pieces of slate, pebbles, etc., shall not be allowed. Bent or damaged forms shall not be used.

(18) All forms, timber and steel, shall be thoroughly cleaned and well greased or oiled before concrete is placed against them. They shall also be cleaned and oiled before being taken into storage.

(19) Forms shall not be removed from the road slab for 24 hours or such other time as the Engineer may permit.

IV—CROSS FALLS AND LONGITUDINAL FALLS

(20) The normal cross fall on the finished surface shall be not flatter than 1 in 48 or greater than 1 in 36. In exceptional places, e.g. at road junctions or where super elevation is introduced, a sharper fall than 1 in 36 may be permitted by the Engineer.

(21) The longitudinal fall in the channels shall in no place be flatter than 1 in 250.

V—CONCRETE

(22) *Mix.*—The concrete shall be composed of one part of cement to six parts of combined aggregates measured by dry weight. The coarse aggregate shall have a maximum particle size of 1½ in. The coarse and fine aggregates shall conform to the grading of Clause 4 of B.S. 882/1944.

OR

The concrete shall be so gauged as to give 520 lb. of cement to a cubic yard of finished concrete. The proportions of fine and coarse aggregate shall be determined by the Engineer so as to produce a dense concrete of satisfactory workability within the limits of the specified water-cement ratio. The cement and aggregates shall be gauged by the dry weight of these materials.

OR

The mix used shall be such as to produce a good workable concrete crushing strength; shall be not less than 3,000 lb. per sq. in. at the age of seven days.

(23) *Water content.*—The quantity of water used in the mix, including the free moisture contained in the aggregates, shall not exceed 6 gallons to a bag (112 lb.) of cement. The exact quantity of water to give workability with the particular type of vibrator being used shall be determined by the Engineer from trial mixes, and the amount of water to be added to the mix shall not be varied without the consent of the Engineer.

(24) *Mixing.*—The concrete shall be mixed either in

mixers of the portable type located near the work, or at a central mixing depot. In the case of a central mixing plant the arrangements for transporting the concrete from the mixer to the site shall be to the satisfaction of the Engineer.

All mixers shall be of an approved type and capacity, and shall comply with the requirements of British Standard No. 1305/1946 for batch type concrete mixers.

Mixing shall continue for at least one minute after all the ingredients, including water, have been placed in the drum, and until the concrete is thoroughly mixed and of obvious uniform consistency.

The mixing drum shall not be loaded beyond its rated capacity. All contents of the drum shall be discharged before any ingredients for the subsequent mix are placed in it.

The drum of the mixer shall be kept free from hardened concrete. The mixer, chutes, barrows and other equipment shall be cleaned of all caked concrete at the end of the day's work.

No mixing shall take place with frozen aggregates, and no mixing or concreting shall take place when the atmospheric temperature is below 36° F.

(25) *Transporting and placing concrete.*—The mixed concrete shall be transported to and placed in the site as rapidly as possible after it leaves the mixer, and in no case more than 20 minutes thereafter.

The concrete shall be spread uniformly over the sub-base, great care being taken to ensure that it is of uniform composition and that segregation does not take place. Spreading shall be continuous between joints.

The concrete shall be spread to such greater thickness than that specified so as to allow for consolidation, and to permit a uniform ridge of concrete being maintained ahead of the screed during the operation of vibration.

The concrete shall be spread by a mechanical spreader if such a machine is available.

(26) *Compacting.*—The concrete shall be consolidated and finished by means of a vibratory beam which shall be capable of compacting the concrete to its full depth. If the vibrator proves to be incapable of compacting the full thickness of the concrete, the compaction shall be effected in two layers of

concrete. When the concrete is thus vibrated in two layers the top layer shall be placed within 30 minutes of placing the bottom layer.

When mesh reinforcement is used the concrete shall be vibrated in layers, the surface of each finishing at the plane of the reinforcement.

Where a self-propelled vibrating machine is used it shall be fitted with a front screed for striking off the concrete at a sufficient height to allow for proper compaction.

(27) *Finishing.*—Two passes of the vibrator should suffice to give a dense close-knit sealed surface finish. After two passes the surface shall be checked and any major irregularities shall be corrected by another pass of the vibrator. Minor irregularities shall be made good by hand floating, using a wooden float. The use of mortar to make good the surface shall not be permitted.

(28) The surface shall be checked with a 10-ft. straight-edge and any irregularities exceeding $\frac{1}{8}$ in. shall be at once corrected.

The channels shall also be checked with a straight-edge and spirit level to ensure that at all points there is a true fall to the gullies. Any faults disclosed by this check shall be immediately made good.

All work on the concrete including finishing and making good shall be completed within 40 minutes of the mixing of the concrete.

VI—CURING

(29) *Preliminary.*—Immediately the surface has been finished it shall be covered with waterproof paper kept in close contact with the surface, or with wet hessian canvas kept just clear of the surface but overlapping the slab on both sides. This preliminary curing shall continue for 24 hours or until the concrete is sufficiently hard to be walked on without damage.

If the weather is frosty the hessian shall be dry, and the concrete fully protected against frost action.

(30) *Later curing.*—As soon as the canvas has been removed the surface shall be covered with 2 in. of sand or earth, or straw, which shall be kept wet for 9 days or such other period as the Engineer may determine.

(31) If waterproof paper is used for the preliminary curing its use may be continued throughout the whole 10 days.

Before the road is opened to traffic all curing material shall be removed, and the road shall be left clean and tidy.

VII—JOINTS

(32) *Expansion joints.*—Transverse expansion joints shall be formed at the positions shown on the Drawings and shall be at intervals of 40 ft.

The joints shall be ½ in. wide and extend to the full depth of the slab. They shall be filled with an approved pre-moulded filler of a resilient non-extruding nature. This filler shall extend to the underside of the slab and to within ¾ in., or less, of the surface of the slab. The joints shall be straight and vertical, and normal to the centre line of the road. Where the road is constructed in two or more widths the joints shall be continuous across the carriageway and shall not be staggered.

The arrises of the joint shall be rounded to ½ in. radius, and immediately thereafter the surface at the joint shall be checked with a 5-ft. straight-edge to ensure that there is absolute truth of level in both transverse and longitudinal directions. The top of the joint shall be cleaned out down to the top of the joint filler, and the cavity thus formed shall be filled with an approved sealing compound. Great care shall be taken that no stones or pebbles get into the joint.

Where required by the Engineer, the joints shall be provided with dowel bars which shall be 16 in. long, ½-in. or ¾-in. diameter and spaced at 12-in. centres. The dowel bars shall be bonded to the concrete for half their length, the other half being coated with bitumen, or treated in some other approved fashion, to prevent bonding. The free ends shall be provided with caps to permit ¾-in. end movement.

The dowel bars shall be securely held so that they will be truly horizontal and parallel to the centre line of the road. No difference in level or line shall be permitted. The bars shall be straight and free from all burrs and distortions. The joint filler shall have holes drilled in it to accommodate the dowel bars.

(33) *Dummy joints.*—Dummy joints shall be formed at 15-ft. to 20-ft. intervals, or midway between expansion joints; by inserting a strip of wood ¼ in. thick and 2 in. or 3 in. wide close to the surface (or bottom) of the slab in a vertical position.

Such strips shall be held so that they will not be disturbed from their position by subsequent compacting of the concrete.

Alternatively, the dummy joints shall be formed by cutting a groove $\frac{3}{8}$ in. wide and not less than 2 in. deep in the surface of the concrete before it has hardened. The arrises of such joints shall be rounded and the joint sealed as specified in the previous Clause.

Where the slab is reinforced near its surface, dummy joints shall be omitted.

(34) *Longitudinal joints.*—The carriageway shall be constructed in longitudinal strips, each of a width not exceeding 15 ft. The joints so formed between the strips shall be vertical butt joints or tongue and groove joints. All joints shall have their arrises rounded and the top of the joint shall be sealed as already specified.

Tongue and groove joints shall be formed by means of suitably shaped timbers fixed to the forms. The concrete shall be well punned or vibrated against the forms to prevent honeycombing.

(35) *Construction joints.*—Construction joints shall be avoided as far as possible, and shall be formed only when unavoidable. They shall be vertical butt joints with the arrises rounded and the top of the joint sealed as specified above. If the road slab is reinforced the reinforcement shall be carried through the joint and suitable formwork shall be provided to effect this.

VIII—GENERAL

(36) *Gullies and manholes.*—Gullies shall be set in the positions shown on the Drawings.

The gully covers and frames shall be set truly flush with, or a shade below, the level of the concrete in the channel. The concrete round the gully shall be slightly dished towards it and care shall be taken that there is no obstruction to the free flow of water into the gully.

All cast iron frames of gullies, manholes, etc., in the carriageway shall be separated from the concrete by a strip of felt or bituminous sheeting of not less than $\frac{1}{8}$ in. thickness.

(37) *Weather conditions.*—No concrete shall be deposited on a frozen sub-base. In frosty weather the sub-base ahead of the concreting shall be protected against frost.

Frozen aggregates shall not be used in concrete.

No mixing or placing of concrete shall be carried out when the atmospheric temperature is below 35° F.

During frosty weather the placed concrete shall be protected against damage by frost by being covered with straw, tarpaulins or other approved material.

Notwithstanding any precautions taken the Contractor shall be responsible for any damage caused by frost, and the Engineer shall have the power to reject such concrete.

(38) *Road junctions.*—At all junctions and intersections of roads other than those of concrete construction, two rows of stone setts shall be laid at the edge of the concrete. The setts shall be bedded on concrete at least 6 in. thick and grouted with cement grout, and they shall be laid so that their top edge is truly level with the finished concrete surface.

(39) *Traffic on finished surface.*—All traffic shall be kept off the finished surface for at least 14 days unless permission in writing is given by the Engineer for the road to be opened to traffic in a shorter period.

106. WATERBOUND MACADAM ROADWAY.—This type of road, although now almost entirely superseded, still forms the base of many bituminous macadam roads, etc. The foundation for such a roadway may be of concrete or reinforced concrete to the specification above, or may be hand set or rubble bottoming. The bottoming introduced originally by Macadam was 8 in. thick consisting of a layer of broken stone not larger than 3 in. diameter worked until it was set to a thickness of 4 in., and on this was superimposed another similar layer, again worked to a thickness of 4 in., the whole forming the bottoming.

Telford introduced hand-packed bottoming, and his specification for this was as follows :—

Upon the level bed prepared for the road materials a bottom course or layer of stone is to be set by hand in form of a close firm pavement. The stones set in the middle of the road are to be 7 in. in depth ; at 9 ft. from the centres, 5 in. ; and at 15 ft., 3 in. They are to be set on their broadest edges lengthwise across the road, and the breadth of the upper edge is not to exceed 4 in. in any case. All the irregularities of the upper part of the said pavement are to be broken off by the hammer, and all the interstices to be filled with stone chips firmly wedged or packed by hand with a light hammer, so that when the whole pavement is finished there shall be convexity of 4 in. in the breadth of 15 ft. from the centre.

The middle 18 ft. of pavement is to be coated with hard stones to the depth of 6 in. Four of these 6 in. to be first put on and worked in by carriages and horses, care being taken to rake in the ruts until the surface becomes firm and consolidated, after which the remaining 2 in. are to be put in.

The whole of this stone is to be broken into pieces as nearly cubical as possible, so that the largest piece in its longest dimensions may pass through a ring of 2½-in. inside diameter. The paved spaces on each side of the eighteen middle feet are to be coated with broken stones or well-cleaned strong gravel up to the footpath or other boundary of the road, so as to make the whole convexity of the road 6 in. from the centre to the sides of it, and the whole of the materials are to be covered with a binding of 1½ in. in depth of good gravel free from clay or earth.

107. ROAD BOTTOMING.—The formation to carriageway and foundation of kerbs shall be well cleaned and freed from mud and water, rolled with a roller not less than 6 tons in weight, consolidated, shaped, and regulated to the correct cross sections and approved by the Resident Engineer immediately before the foundation works are carried out.

Where specially directed by the Engineer approved hardcore, consisting of hard whinstone, freestone, slag, or broken bricks, shall be laid under the formation of the carriageway, rolled with a roller not less than 8 tons in weight, and consolidated to the correct cross section.

Hard-burnt coarse clinkers or ashes shall be evenly spread in one coat over the formation of the carriageway where directed by the Engineer, rolled with a roller not less than 8 tons in weight to a consolidated thickness of 3 in. and to the cross sections shown on the Drawings.

If any clay or mud works through to the surface of the clinker, the Contractor shall immediately cut out such affected areas to such depths as directed by the Engineer, and shall, at his own expense, replace the same with clinker as before specified, rolled and consolidated.

Where directed by the Engineer, the bottoming or foundation for the carriageway shall be of approved whinstone or approved steel slag, in blocks not less than 8 in. deep, set by hand on edge with the largest and flattest end downwards, which shall be as nearly as possible square.

The stone shall be laid in regular courses across the carriageway, breaking joint as much as possible, any irregularities on top shall be broken off with a hammer, and all interstices shall be wedged and filled up with whinstone or slag shivers, and rolled with a roller not less than 8 tons in weight, all depressions being made up with whinstone or other approved material. The whole surface shall thereafter be blinded with clean engine ashes and thoroughly rolled with a roller not less than 10 tons in weight until consolidated to the thickness and camber or curvature shown on the Drawings.

If any clay or mud works up through to the surface of the bottoming the Contractor shall immediately cut out such affected areas to such depths as directed by the Engineer, and replace the same at his own expense, with layers of ashes and bottoming, which material shall be rolled, consolidated, etc., as previously specified, and finished conformably to the adjacent surfaces of ashes and bottoming respectively. The bottoming must be inspected and approved by the Engineer both before rolling and before being blinded with ashes. The finished surface of the bottoming shall be even and smooth, free from potholes, ruts, undulations, irregularities, depressions, or loose material, true to cross sections, lines, and levels shown on Drawings, and ready in all respects to receive the surfacing coat.

108. Re-Surfacing.—These general directions are intended for use in cases where a new surface coating is to be laid with steam-rolled water-bound macadam on any road which has a proper foundation or sub-crust of adequate thickness.

(1) *Trial Trenches.*—Before laying the new surface the thickness of the old crust, including the foundation, should be ascertained by opening trial trenches at intervals averaging about 150 yards apart, extending from the side to the centre of the road, such trenches to be made alternately on opposite sides of the road. A careful record of the facts disclosed by these trenches should be kept with plans and sections for future reference.

If a proper foundation or sub-crust of adequate thickness does not exist, or if the road is weak at the haunches, the following steps should be taken.

In the case of heavily trafficked roads the haunches should be strengthened and the crust thickened either with stone of any kind suitable for bottoming work, broken to a gauge of from 3 in. to 4 in., or with hardcore, clinkers, or other suitable materials, according to the nature of the sub-soil. In some cases where the surface of the broken stone, after being steam-rolled, is sufficiently smooth for the purpose of traffic, it may be possible to allow the bottoming material to be used as the wearing surface of the road for a short period, not exceeding twelve months, if it is important for financial reasons to postpone for that period the laying down of the final surface coating in accordance with the other provisions contained in these general directions.

(2) *Total Thickness of Crust.*—Even when there exists a good natural foundation, the total thickness of the road crust, including the old and the new macadam, after consolidating by rolling, should not be less than 4 in. In the case of well-drained sub-soil, which cannot be materially softened by the infiltration of surface water, the total thickness, including the new consolidated surface coating, as well as the sub-crust and foundations, if any, should not under ordinary circumstances be less than 5 in. In the case of fairly hard clay or other yielding sub-soils, the total thickness including foundations should not be less than 9 in. In the case of soft, wet clay or bog or marshy sub-soil, foundations of a special character may be required.

(3) *Thickness of New Surface Coating.*—The thickness of the new surface coating of macadam when consolidated by rolling should be from 2 in. to 3 in. according to the traffic requirements. If it is desired that the new coating should have a greater thickness than 3 in. when consolidated, the stone should be applied in two coatings separately rolled.

(4) *Stones and Screenings.*—The road stone for the new surface coating should be stone of approved quality, broken as cubically as possible, and should contain about 70 per cent. of stone which should pass through a 2½-in. ring, but which will not pass through a 1¾-in. ring; about 20 per cent. which will pass through a 1¾-in. ring but not through a screen with rods ¾ in. apart. The screenings forming the residue from the above,

which will be obtained by the use of the ¾-in. rod screen, should be kept separate and used as a top dressing during rolling operations.

(5) *Spreading.*—The stone must be spread by careful men selected for their knowledge and experience of such work, as the suitability and evenness of wearing of the surface obtained by steam-rolled coatings greatly depends on judicious uniform spreading. The stones should be well mixed so as to obviate the possibility of having larger stones on some parts of the road and smaller stones on other parts.

Note.—One ton to cover 8 to 9 sq. yd. may be taken as an average quantity required to give a consolidated thickness of 3 in. When stones are spread in thick coatings, so that 1 ton covers less than 8 sq. yd., there is a greater liability to unequal consolidation, because stones are pushed in front of the roller until the roller surmounts them and thus a corrugated or wavy surface is formed.

(6) *Rolling.*—The rolling must be carried out by a roller of a weight of about 10 tons. This must be in charge of a skilled driver who has been specially trained for this purpose. The macadam should be consolidated by starting the work at the sides and gradually working towards the centre. No water or binding should be applied until dry rolling has been carried out to a sufficient extent to form a smooth hard surface with a correct cross-fall with the stones well knit together and showing their faces on the surface. Notice-boards warning the public that steam-rolling work is in progress should be placed at reasonable distances from each end of the work.

(7) *Binding.*—The binding material should be the best obtainable. It should be either of the same material as the new coating, or of granite, limestone, or slag chippings, or failing these suitable pit sand or gravel, and the largest stone in it should not exceed ¾ in. in its greatest dimension. The binding material is not to be applied until the stones have been tightly rolled as above described. It should then be spread, watered, and swept over the surface during the final rolling operations, working it from the channels towards the centre so as to fill the interstices or voids between the rolled stones. Care should be taken not to use more binding material or water than is absolutely necessary to ensure proper consolidation. The success of

waterbound steam-rolling so greatly depends on the quality and quantity of the binding material used that extreme care should be taken in its selection and application.

(8) *Re-rolling.*—In some cases it is advisable that a steam-rolled waterbound macadam surface should be lightly watered and re-rolled from a week to a fortnight after the first rolling.

109. SINGLE COURSE TARMACADAM ROAD.

(1) *General Description.*—The tarmacadam surface should consist of a suitable aggregate, and mineral filler, uniformly mixed with a tar or tar and bitumen filler, and should be laid upon a prepared base to a consolidated thickness of 3 in.

(2) *Aggregate.*—The aggregate shall be either :—

(*a*) Crushed igneous rock or limestone ; hard, durable, free from all foreign matter and substantially free from dust ; or, (*b*) best blast furnace or acid steel slag, free from all deleterious matter. The weight per cubic foot and stability of the slag shall be in accordance with B.S. 1047, and the total sulphur content and increase of weight of the slag due to the absorption of water shall not exceed 2·75 per cent. and 4 per cent. respectively when tested by the appropriate method described in B.S. 1047.

The grading of the aggregate, including any filler, when tested by method 1 of B.S. 812 shall be within the following limits :—

Sieve size (B.S. 410)	Percentage by weight passing.
2 in.	100
1½ ,,	95±5
1 ,,	65±15
½ ,,	40±10
¼ ,,	25±5
200 mesh	0 to 5

(3) *Mineral Filler.*—The mineral filler should be of igneous rock, dry limestone, Portland cement, or other approved filler, at least 50 per cent. of which should pass through the 200 B.S. mesh sieve, at least 90 per cent. shall pass the 52 B.S. mesh and none shall be retained on the 7 B.S. mesh sieves.

(4) *Binder.*—The binder shall be tar which shall comply with B.S. 76 of 1943, the type and viscosity of which shall be agreed between the Engineer and the Manufacturer.

Alternatively, the binder may consist of one of the following mixtures :—

(*a*) Tar to B.S. 76, types A and B, and asphaltic bitumen, or refined lake asphalt as defined in B.S. 594.

(*b*) Tar as above, and natural asphalt as defined in B.S. 595.

The quantity of binder used shall be not less than 8·4 nor more than 10·5 gallons per ton of dry aggregate at the mixing temperature.

(5) *Mixing.*—The aggregate shall be thoroughly dry and shall be heated to a temperature not exceeding 120° F. The binder shall be separately heated to a temperature not exceeding 220° F. and the aggregate and binder shall then be measured into the mixer and thoroughly and intimately mixed together for a minimum time of 1½ minutes, the filler being subsequently added and thoroughly mixed for at least another minute.

(6) *Transportation of Mixture.*—The surface mixture should be conveyed from the paving plant to the work in vehicles previously cleaned of all foreign materials, and protected, if necessary, against weather conditions.

(7) *Spreading and Laying of Mixture.*—The prepared base upon which the tar macadam is to be laid should be cleaned of all loose and foreign materials. The mixture should be laid only when the prepared base is dry and only when weather conditions are suitable. The mixed material should be evenly distributed in a uniformly loose layer of the correct depth.

All manholes, kerbs, etc., upon which the mixture is to abut, should be painted with a thin uniform coating of hot tar prior to the surface mixture being laid against them. The finished surface should in all cases be left slightly proud on manholes, lampholes, and other similar structures.

(8) *Consolidation of Surface.*—Whilst still hot, the surface should be thoroughly and uniformly consolidated by means of a roller of not less than 6 tons laden weight ; rolling should commence longitudinally at the sides and proceed to the centre of the pavement ; the wheels to overlap on successive trips in order to eliminate all roller marks.

Adjoining kerbs, manhole covers, etc., the surface coating should be thoroughly consolidated by means of heated punners.

(9) *Joints.*—The greatest care must be exercised in ensuring that a proper bond is obtained between the finish of one day's

work and the commencement of the next, all vertical faces to be painted with hot tar.

(10) *Application of Grit.*—The surface of the tarmacadam shall be blinded immediately after final rolling and before traffic is allowed on it, with grit not exceeding $\frac{1}{8}$ in. nominal size, which shall have been coated with a suitable matrix.

110. ASPHALT AND OTHER ROADS.—There are many British Standards dealing with road surfacing materials and their use, and it is recommended that the appropriate standard for each particular case be used as a basis for specification. The British Standards concerned are :—

B.S. 510, 511	Asphalt surfacing, cold process.
B.S. 348	Asphalt surfacing, hot process. Compressed natural rock.
B.S. 594	Asphalt surfacing, hot process. Fluxed lake and asphaltic bitumen.
B.S. 595	Asphalt surfacing, hot process. Fluxed natural and asphaltic bitumen.
B.S. 1152	Asphalt surfacing, hot process. Rolled.
B.S. 347, 433, 434	Asphalt macadam.
B.S. 596, 597	Asphalt mastic surfacing, hot process.
B.S. 63	Nomenclature and size of stone and chippings.
B.S. 618	Tar emulsion.
B.S. 802 (2 parts)	Tarmacadam.
B.S. 1242	Tarpaving.
B.S. 76	Tars for road purposes.

111. SETT PAVING.—With regard to the former, the shape of the setts to be adopted depends upon the class of traffic carried by the road. For roads with much horse traffic, such as occur in the neighbourhood of docks and railway sidings, long narrow setts are advisable in order to provide toe-holds for the horses, but where the loads drawn are lighter individually, or where most of it is motor traffic, square setts, $3\frac{3}{4}$ in. by $3\frac{3}{4}$ in. or 4 in. by 4 in. are commonly used. Setts over 5 in. to $6\frac{1}{2}$ in. deep are seldom used now. The setts, usually of granite or whinstone, are laid on a bed of sand about 1 in. to $1\frac{1}{2}$ in. thick, covering the concrete foundation. Each course shall be laid true to line, level and camber. After the setts are laid they are beaten down with a heavy rammer (50 lb. to 60 lb.) and the joints are filled with fine gravel or granite screenings, and afterwards grouted either with cement and sand grout or with a mixture of melted pitch and tar poured in hot.

112. Wood Block Paving.

(1) *Blocks.*—The timber from which the blocks are to be cut shall be carefully selected fourth Swedish close-grained yellow deals, bearing the shipper's mark, and which must be described in the current Timber Trades Journal List. The blocks shall be of uniform size and weight and uniformly cut. The timber shall, before being cut, be submitted to the Engineer or his Representative, and no blocks shall be sawn from timber of which the Engineer or his Representative has not signified his preliminary approval. Four samples sealed and marked with the Contractor's name and shipper's marks shall be left at the Engineer's office for his examination with the tender, and any blocks which may be brought on to the Works and which may be inferior to these samples may be rejected by him. The Engineer or his Representative shall have full power to reject any blocks, either at the cutting yard or at the creosoting works, and he shall also have power to reject any blocks after delivery on the site of the proposed Works, or at all or any of these places, whether they are creosoted or not, or which are not creosoted in a satisfactory manner, or to the extent of 10 lb. of creosote to the cubic foot of timber, or with a satisfactory quality of creosote. The blocks when cut shall be truly square and measure 3 in. wide by 4½ in. to 9 in. long by 3½ in. to 4½ in. deep. They should be manufactured on the "Firmosec" system with splines ⅛ in. to ½ in. thick as required by the Engineer. The annular rings shall be not less than 10 to the inch, nor shall more than 2 in. of sapwood appear in any block, and the percentage of such in bulk shall not exceed 15. They shall also be free from large, loose, or dead knots, shakes, or other defects, and shall not contain more than 5 per cent. of waney edges. Timber that has not been properly stored and has become dry will not be accepted. Care must be taken to prevent the blocks from becoming wet, as any in such a condition either from rain, bilge water, or other causes must not be creosoted.

Note.—In addition to the above wood, English oak, ash, elm, and beech have been used, as well as hard woods from abroad, including pitch pine, blue gum, and Australian jarrah, karri, tallow-wood, and black-butt. Of these, pitch pine and jarrah have been most successful. Jarrah weighs about 56 lb. per cu. ft., is very hard and dense in character, of good uniform quality, and entirely free from sapwood and knots. The chief objection which has been made to its use arises from the expansion and contraction of the blocks, especially the latter. It is not unusual, in the case of a road paved with jarrah wood, to find after a dry season that the blocks are loose, and, the joints being open, heavy rainfall penetrates to the foundation of the road, with injurious results both to the foundation and to the blocks. Experience has shown that soft woods, such as are commonly termed Baltic fir, Baltic red deal, Swedish yellow deal, Scotch fir, and such woods, are much the best for paving purposes. The timber is imported in the shape of 3-in. by 8-in. or 3-in. by 9-in. deals, and cut accurately into 5-in. lengths. The wood should be well selected before being creosoted, no blue sap or discoloured wood being allowed, and there should also be an absence of loose and dead knots as specified above.

(2) *Expansion Joint.*—The Contractor shall provide wood battens 1½ in. wide by the depth of the blocks, which shall be used in the channels against the kerb, and the blocks shall be paved up to it. After the paving has been grouted in, the battens shall be withdrawn and the space left shall be filled in with clay and gravel as directed.

(3) *Composition between Joints.*—Approved pitch or bitumen is to be heated and run in between the blocks to within ½ in. of the surface as directed.

(4) *Cement Groutings.*—The blocks are then to be grouted with cement grout until the joints are thoroughly filled. Alternatively the blocks may then be filled with bituminous granite well punned into the joints.

(5) *Protection for Forty-eight hours.*—After the completion of the grouting the work is to be protected for at least forty-eight hours before the road is thrown open to traffic.

(6) *Creosoting.*—Before laying the blocks are to be creosoted with creosote to the following specification :—

The creosote is to be of the description known as heavy oil of tar, obtained solely by distillation of coal tar, and consist of that portion of the distillation which comes over between the temperature of 350° F. and that of 760° F. The specific gravity shall be not less than 1·035 nor more than 1·065 at 60° F. and as nearly as possible 1·050.

The liquor must be free from any admixture with any oil or other substance not obtainable from such distillate ; it shall contain not less than 20 per cent. and not more than 30 per cent. of constituents that do not distil over at a temperature of 600° F. It must yield not less than 8 per cent. of tar acids, and must become completely fluid when raised to a temperature of 100° F.

113. RAILWAY PERMANENT WAY.—This consists of the formation and road bed, sleepers, rails, chairs, fishplates, and spikes.

(1) *Formation and Road Bed.*—Great care must be taken to see that the formation is properly drained, and slopes of 1 in 45 to 1 in 20 outwards from the centre should be given to

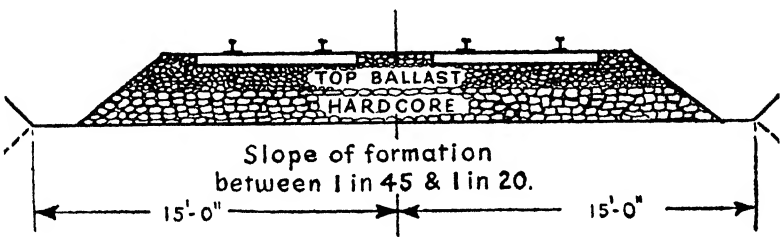


FIG. 4.—Typical Section of Railway Permanent Way.

the surface for this purpose. In cuttings, special attention must be given to drainage, beyond that afforded by the ballast. The usual practice is to cut a trench on both sides of the formation for carrying off the water. The trench may be left open, or an open jointed drain may be laid in the bottom of the trench and covered with rubble. The form of the trench depends largely on the nature of the ground.

The procedure to be adopted in making a road bed depends on the nature of the formation, i.e. whether it is of rock, clay, gravel, etc., and the character of the bed desired. On an average bottom for ordinary work it is usual to lay from 6 in. to 8 in. of rough broken stone, often known as " pitching ", before putting down the ballast.

The ballast may consist of 1½-in. to 2-in. cubes of broken stone or macadam, gravel, or clinkers, whichever is procured most readily in the district. In selecting ballast a material should be procured that will drain satisfactorily, and will not readily pulverize and escape as dust. The depth of ballast under the sleepers depends upon the local conditions, but a thickness of

6 in. gives good results and allows a latitude for repacking. It must be borne in mind that the life of the sleeper largely depends upon the quality of the road bed.

(2) *Sleepers.*—The pine timber usually used for sleepers on our home railways is brought principally from the countries bordering on the Baltic Sea, and for this reason is commonly known as Baltic red wood. Scots fir or larch sleepers are also used, the latter being particularly suitable for wet places. Pine sleepers not treated with creosote or other preserving agency have a short life, not exceeding three or four years on a damp bottom, but when the timber is carefully selected and well impregnated with creosote, sleepers of this description will last eight to ten years under the heaviest traffic and as long as twenty years on branch lines. It is general practice to lay the sleepers with the annual rings of the smallest diameter downwards. Spike holes should be bored right through the sleepers, about $\frac{1}{8}$ in. less than the diameter of the shank of the spike. For entrance and running roads 10-in. by 5-in. creosoted sleepers should be used, 8 ft. 6 in. being the usual length of these.

Steel sleepers of an inverted trough form are also used on a number of railways, the chairs being either an integral part of the sleeper or being welded to the sleeper. The weight of these sleepers, each 8 ft. in length, is from 140 to 145 lb. each, and they are made to approximately the following measurements when pressed : overall width $11\frac{1}{4}$ in., depth $2\frac{1}{2}$ in. to $3\frac{1}{2}$ in., the thickness of metal being $\frac{5}{16}$ in. or $\frac{3}{8}$ in.

Concrete is now being increasingly used for sleepers.

(3) *Rails.*—The most common type of rail in use in this country is the Bullhead, which is supported by a chair usually made of cast iron (although cast steel is occasionally used where greater strength is required).

(4) *Chairs.*—Main line chairs weigh from 46 to 66 lb. each and the rails are secured in position in the chairs by means of wedges termed keys, which are often made of oak, shaped to fit the chairs with which they are being used. Steel keys are in some ways more satisfactory than oak, and are now largely used. Most main line specifications demand that wood keys should be compressed and black-leaded.

(5) *Spikes.*—The most usual sleeper fastening for a Bullheaded rail chair is a plain cup-headed spike.

The rails and fishplates are to be to the British Standard Specification.

The following particulars of Standard Main Line Dimensions for 4 ft. 8½ in. gauge are useful :—

Rails :—75 to 100 lb. per yard.

Vertical flangeway clearance from top of rails :—1¾ in. to 2 in.

Travel of switch points at end :—3½ in. to 4½ in.

Tilt, or inclination of rail inwards, and cone of wheels :—1 in 20. (Sometimes 1 in 22 or 1 in 24.)

Crossing sleepers :—13 ft. to 15 ft. long, and 12 in. by 6 in. to 14 in. by 7 in. section, creosoted.

Pitch of sleepers (intermediate), centre to centre :—2 ft. 6 in. to 2 ft. 10 in.

Pitch of sleepers (joint), centre to centre :—1 ft. 7 in. to 2 ft. 6 in.

Minimum distance between two lines of way to allow trucks to clear :—4 ft.

Minimum depth of ballast below sleepers :—4 in.

Clearance between rail ends to allow for expansion when laid in temperatures from 75° F. to 40° F. :—¼ in. ; but for rails exceeding 45 ft. in length :—$\frac{5}{16}$ in.

Minimum width of wheel tread that will safely run over crossing :—3⅜ in.

On wagons for sidings, minimum width of tyres :—4½ in.

On engines and wagons for main line, minimum width of tyres :—5 in.

Wheel flanges should not exceed in depth :—1¼ in.

Back and back of wheels :—4 ft. 5⅝ in.

Thickness of wheel flanges :—1⅛ in.

Clearance between wheel flanges and rails :—$\frac{5}{16}$ in.

114. Reinforced Concrete Piles.—Reinforced concrete piles shall be composed of Portland cement as specified, or of an approved brand of high-alumina cement, and fine aggregate in the proportions ordered by the Engineer, reinforced with steel rods as shown on the Drawings.

(1) *Moulds.*—Piles shall be cast horizontally on specially constructed timber floors, the flooring timber being not less than 2 in. thick, planed on the top surface and edges, and properly clamped and supported at close intervals so as to be thoroughly rigid. The sides of the moulds shall consist of 2-in. boarding, planed on both sides and edges, and shall be properly clamped together and stayed to the floor.

The reinforcing steel shall be carefully and accurately set in the moulds and adequately supported so that it will not be deformed or displaced during the process of ramming the concrete.

(2) *Shoes.*—A shoe of pattern and weight approved by the Engineer shall be provided for each pile, and accurately centred in its axis.

(3) *Hydraulic Pipe.*—If ordered, a ½-in. diameter malleable iron pipe with screwed couplings extending from the shoe to about 4 ft. from the head shall be carried along the axis of each pipe, returning out through one side and terminated in a screwed connection for hydraulic pressure pipe.

(4) *Slinging Piles.*—When piles are being moved or turned they shall be carefully handled and supported on skids, and when lifted they shall be slung at the quarter points of their length, being protected by sacking or other efficient means where the slings go round them.

(5) *Driving.*—Piles made of Portland cement concrete shall not be driven before they have been matured for at least six weeks.

If made of high-alumina cement, piles may be driven four days after casting.

(6) *Driving Caps.*—During driving, the pileheads shall be protected by a properly fitting cap of cast-iron or steel plate conforming to a design to be submitted to, and approved by, the Engineer.

(7) *Set.*—Bearing piles shall be driven to a set of 1 in. for eight consecutive blows of a 2-ton hammer, having a free fall of 3 ft., or such other set as the Engineer shall determine for each particular case.

If piles are driven inaccurately and are more than 2 in. out of their proper position, such remedial work as is ordered by the Engineer shall be carried out by the Contractor at his own expense.

For the driving of the above or of timber piles, piling machines will be required which may be to the following specification :—

115. PILING MACHINES.—All the piling machines used shall be steam driven and of proper power and construction for the work. The rams for driving the main and guide piles shall be not less than 35 cwt., and the rams for driving the sheet piles

not less than 55 cwt. in weight. The weight in each case shall be regulated to suit the stratum or strata and the depth to which the pile or bay of piles is to be driven. The drop of the ram shall in no case exceed 6 ft., and in no case shall the Contractor use a dolly without the approval of the Engineer in writing. The above shall not prohibit the Contractor using an automatic pile hammer should he so desire, so long as the latter meets with the approval of the Engineer.

116. BRICKWORK.—The principal requirements with regard to brickwork are covered thus :—

All brickwork, excepting where otherwise directed, shall be well and truly laid in English (or Flemish) Bond. All brickwork shall be built solid throughout, true in face, and to the proper lines and levels. In walls less than 1½ bricks thick, each brick shall be laid in a full and close joint of cement mortar on its bed, ends, and sides at one operation, and all joints shall, in addition, be well flushed with cement mortar. When walls are 1½ bricks in thickness and over, the bricks shall be rubbed in on a floating bed of cement mortar. No joint shall exceed ¼ in. in thickness. As the work progresses the brickwork shall be racked back in courses, unless special permission is given by the Engineer for toothing. Bricks shall be thoroughly wetted immediately before they are placed in the work. No broken bricks shall be used except as closers. All brickwork shall be carried up in a uniform manner without one portion being unduly raised above another.

Where stone or pre-cast concrete quoins are used, the brickwork shall be properly bonded with them, and the dimensions of the quoins shall be based on, and fixed relatively to, the size and number of the brick courses. Where existing and new work immediately adjoin they shall, if required, be bonded as directed.

Exposed brickwork shall, where specified or directed, be faced with red or blue facing bricks, as specified, which shall be of a uniform colour. Where walls or piers are faced with brickwork, and backed or hearted with concrete, the brickwork shall be coursed and properly bonded with the concrete, as shown on the Drawings or as will be directed. Plinth, skew, and birdsmouth bricks, and bricks with rounded edges or corners, shall also be provided as will be directed.

Excepting where otherwise directed, brickwork shall not be built close and hard up to steel work.

Brickwork shall not be executed during frosty or otherwise unsuitable weather, and, where necessary, precautions shall be taken by covering and by fires or otherwise to prevent any completed work from being injuriously affected by frost or otherwise. If any completed work be damaged by frost or otherwise, it shall be taken down and rebuilt.

117. Brick Arches.—Brick arches shall be built in rings with selected bricks, with the inner ring of special facing bricks unless otherwise directed. The courses of brick in arches shall be gauged and marked on the laggings over the whole length of the centering before any bricks are laid in the arch. All bricks shall be laid in full and close joints of cement mortar, the bricks after the first ring being floated into position in the mortar and well pressed into their beds, to form solid thin joints. Bricks of the proper radii and shape must be provided in circular work under 4 ft. 6 in. internal diameter.

Jack arching shall be of blue brick as specified.

118. Centering and Templates.—The centering, laggings, wedges, supports, and all other timbers, as well as templates, moulds, and profiles required for the construction of the arches and other parts of the structures shall be substantial and well suited to their purpose. The centering shall be of sufficient strength to sustain the weight of the full thickness of the arch without flexure, and shall be of such form and dimensions as will be approved by the Engineer. All arches and other works shall be left true to the curvature and form indicated in the Drawings. The Engineer will determine the period during which the sets of centering shall remain fixed after arches are keyed, and no centering shall be eased or struck without authority from the Engineer. The Contractor shall provide a sufficient number of centre frames to ensure that no centering is struck before the brickwork has had proper time to set. Neither approval of the centering nor permission to strike it shall relieve the Contractor of his risk and responsibility.

All arching shall be built and brought up uniformly on each side of the centering.

119. Pointing.—All brickwork shall be neatly pointed in cement mortar, the exterior faces having key-drawn or weathered

joints or otherwise, as will be directed, excepting arches, which shall be scraped and have the joints stopped and pointed as soon as the centering is removed ; and, should any pointing be injuriously affected by frost or weather or otherwise, the joints shall, as soon as the weather is suitable, be raked and brushed out to the depth of 1 in. and be properly repaired and repointed. Pointing shall not be executed until the brickwork is otherwise completed, and all face-work shall be cleaned of all adhering matter and dirt, and all faulty joints touched up on completion of the work.

120. Mason Work.—In building the masonry all stones shall be laid on their natural beds and, excepting where otherwise specified or shown on the Drawings, no stone shall be less in length than twice its height or have less breadth of bed than one and one-third times its height, no breadth of bed in any case being less than 9 in. The stones shall be carefully and properly bonded, and shall be laid in a full bed of mortar, carefully jointed and bedded (without pinnings), and firmly beaten down, all spaces between stones being completely filled with mortar. Masonry shall not be carried up more than 20 in. in height without being levelled and thoroughly grouted, and coursed masonry shall be grouted at every course, the grouting being in all cases sufficiently fluid to permeate the wall throughout, and, when necessary, the stones shall be well wetted by being specially watered before being built.

Where existing and new work immediately adjoin, they shall, if required, be bonded as directed.

The face of the masonry may be perpendicular or battering, or be curved in vertical section or in plan, as shown on the Drawings, or as may be directed. If vertical, the masonry shall be built in horizontal beds, but in battering walls, whether curved or straight, excepting where otherwise specified, the beds of the stones shall be normal to the plane of the face.

Excepting where otherwise directed or shown on the Drawings, all external angles shall have chisel-draughted margins, 2 in. broad, on each face, and the face arrises or rock-faced work shall be pinched off straight. The acute angles of skew corners shall be splayed to the extent of at least 6 in., and to such greater extent as will be directed, depending on the angle of skew.

Excepting where otherwise directed, masonry shall not be built close and hard up to steel work.

Masonry shall not be executed during frosty or otherwise unsuitable weather and, where necessary, precautions shall be taken by covering and by fires or otherwise, to prevent any completed work from being injuriously affected by frost or otherwise. If any completed work be damaged by frost or otherwise, it shall be taken down and rebuilt.

121. COURSED STONE WORK.—Coursed stone work shall consist of square blocked facing and rubble hearting and backing, and the stones, whether in facing, hearting, or backing, shall be flat-bedded stones, built in horizontal courses grouted at the level of each course.

The stones of the facing shall be chisel-dressed on the beds and joints, so as to be truly square and in proper contact throughout. Except where otherwise specified or directed, the height of the stones of the facing shall be the full height of the course not greater than 18 in. nor less than 9 in., and they shall be built in assorted sizes, and be brought up uniformly with the quoins as hereinafter specified. The stones of the hearting and backing shall be of substantial rubble, and, excepting where otherwise directed, they shall be about equal in size to the stones of the facing, and, to ensure proper bedding, they shall, where required, be roughly pick-dressed.

Building of the hearting and backing shall not, in any circumstances, precede building of the facing, but the whole shall be simultaneously built and brought up in courses as herebefore described, and be thoroughly incorporated by being well cross-bonded, packed, and grouted.

The stones of the several courses shall be so bonded longitudinally with the stones of the adjoining courses, above and below, as to have overlap of not less than 12 in. ; headers or bond stones extending not less than 3 ft. into the wall, having a length of not less than 1 ft. 6 in. on the exposed face, of the height of the course and carrying the full size throughout, shall be built in every course from the back and from the front and in the centre of the walls, except where the walls are not of such thickness, in which case the headers shall extend the whole thickness of the wall. About one-fifth of the superficial measurement of the facing and backing respectively shall be headers with interior headers or bond stones to correspond. Where the walls are more than 6 ft. thick, the centre or interior bond stones shall overlap the headers from the front and back to the extent of at least 12 in., and the whole shall be so built as to form a solid mass of masonry.

The dressing of the exposed faces of all the stone work shall, unless otherwise directed, be rock-faced, the greatest projection not to exceed 1 in.

122. SQUARE RUBBLE.—Square rubble shall be similar in character to the coursed stone work masonry above described, except that the stones need not be coursed throughout, that they may vary in height from 6 in. to 12 in., and that there shall be one header or bond stone to every square yard of face work. Square rubble shall, unless otherwise directed, be rock-faced.

123. COMMON RUBBLE.—Common rubble shall be similar in character to the square rubble above described excepting that the face work need not be squared and may be irregular.

124. ASHLAR.—All ashlar shall be of cube stones of the form and dimensions shown on the Drawings, or as will be directed, and the stones, carrying their full dimensions throughout, shall be truly squared, radiated, curved, chamfered, moulded, mitred, cut, weathered, and throated, as may be required, and be dressed with the chisel or axe to accurate planes on the surfaces, beds, and joints, and be worked perfectly true and out of winding throughout ; and all external surfaces and soffits shall be well tooled or polished or fine-axed or rock-faced or be otherwise dressed, with such V-jointing, grooving, channelling, chisel-draughting, and projection, as may be required and directed. Tool work may be boasting, broaching, dabbing, or droving, as will be directed. Except where shown on the Drawings or otherwise directed, no ashlar stone shall be less than 2 ft. 9 in. in length, and it shall be so built as to break bond and overlap at least 12 in. and no beds or joints shall exceed $\frac{1}{8}$ in. in thickness. Where required, ashlar stones shall be of specially large size to allow of the several mouldings and members being cut, formed, dressed, and returned in one stone or otherwise, as shown on the detailed Drawings, and as will be directed. All ashlar work shall be hewn and dressed strictly in accordance with the detailed

Drawings, and as every course is built the joints shall be thoroughly grouted.

125. QUOINS.—All external angles of abutments, piers, pilasters, wing-walls, and retaining and other walls shall, unless otherwise ordered, be properly quoined with ashlar stones, having an area of at least 4 super feet on the bed. Stones, excepting where otherwise directed, shall be not less than 2 ft. 6 in. long, modified at skew corners and narrow piers as may be required, and they shall be laid as headers and stretchers alternately. Quoins shall be the same height as the course in which they are built, and have the 2-in. margin draught specified in Clause 130. Where directed, quoins shall project 2 in. from the solid building line of the masonry, in which case they shall, on the exposed faces, be rock-faced, and have a chamfer, 2 in. by 2 in. on the beds and joints to form V-grooves, with a 2-in. chisel-draught all round.

126. STONE BEARING BLOCKS.—Stone bearing blocks shall be of freestone or granite ashlar as directed, of the form and dimensions shown on the Drawings, and shall be square-blocked and in one stone. All bearing blocks shall be nidged or closely pick-dressed on the beds and joints, and fine-axed to the required form on the bearing and exposed faces, and shall be accurately dressed so that the entire bearing of the girders shall be perforated throughout; and girder bearing blocks shall be properly checked, sunk, and otherwise prepared for the bearers and girders, and be perforated for bolts where required. The upper surfaces of the girder bearing blocks shall be dressed and laid to suit the inclination of the girders and the gradient.

127. DADOS OF PARAPETS AND PILASTERS.—Where directed or shown on the Drawings, the dados of parapets and pilasters shall be in uniform courses about 12 in. high, or of such heights as may be indicated in the detailed Drawings, and the stones shall be about 3 ft. long and of the full thickness of the wall, tooled or fine-axed on both faces, or tooled or fine-axed on one face and left rock-faced on the other, as may be directed. All stones shall be cut to the form and dimensions shown on the Drawings, and be properly checked, cut, and sunk for plates, dowels, and cramps, and be perforated for bolts where required, and they shall be securely joined together with cement dowels 2 in. square and 4 in. long.

128. BASES, STRINGS, IMPOSTS, COPES, CAPITALS, AND CAPS.—All stone base courses, plinths, impost courses, string courses, friezes, corbels, cornices, pediments, capitals, copes, and caps shall be tooled or fine-axed and be of the form and dimensions shown on the Drawings. All stones shall be truly moulded, mitred, chamfered and dressed, and be hewn and cut with straight and curved lines and ramp and twist where necessary, and shall be properly weathered and throated as directed. The copes and caps of parapets and pilasters, except where otherwise shown on the Drawings or directed, shall be in one stone. All stones shall be properly checked and sunk for bearings, plates, dowels, and cramps, and be perforated for bolts, where required.

129. POINTING.—All masonry shall be neatly pointed, as specified for brickwork in Clause 119.

The workmanship required in connection with Steel and Iron Work is specified as follows :—

STEEL AND IRON WORK

130. FORM AND DIMENSIONS.—The girders and other steel work shall be formed of plates, tee, angle, channel, bulb, or other form of steel as delineated on the Drawings, and to the exact dimensions stated thereon. Any steel or wrought iron work of less dimensions than those shown on the Drawings, will be rejected, and no payment will be made for any excess of weight beyond 2½ per cent. due to steel or iron of greater dimensions being used.

131. WORKMANSHIP.—The whole of the workmanship of the steel and iron work shall be in accordance with the latest edition of British Standard for Girder Bridges (No. 153/1933, Part 2).

(1) *Girder Work*.—All plates and bars shall be formed and put together with the greatest accuracy ; they shall be perfectly true, uniform in thickness, and out of winding, so that the whole surface of adjoining plates or bars shall be in close contact.

The edges and ends of plates, and the ends of bars, as specified, shall be planed. If at any part planing is impracticable, the edges must be dressed off with chisel and file. The plates, etc., must be ordered of sufficient size to allow of at least one-eighth of an inch being planed off the edges, as specified.

All meeting surfaces in plates, bars, or other forms of steel must form perfect butt joints.

Wherever welds are to be formed they shall be perfectly sound and thorough, and the bars or other steel when finished shall be of the full scantlings stated upon the Drawings.

The whole of the workmanship must be of the most careful and accurate description, and everywhere neatly finished.

(2) *Rivet and Bolt Holes.*—All holes in plates over ½ in. thick must be drilled, not punched, and must be accurately gauged as to line and distance apart. Where two or more plates or bars are to be riveted together they shall be bolted together and drilled through at the same time. All holes must be at right angles to surface of plates, and perfectly true when the plates, angles, etc., are bolted together for riveting. No drifting of holes will be allowed.

Where ordered by the Engineer, slotted holes shall be formed for expansion members, and holes shall be drilled through steel members for reinforcing rods.

(3) *Riveting and Fitting Up.*—The rivets when cold shall be of the size stated upon the Drawings, and shall perfectly fill the holes when closed up. They shall have round forged hemispherical heads, with a uniform projection of not less than a quarter of the diameter of the rivet all round. All riveting, wherever practicable, must be done by hydraulic machinery. Any rivets which may be badly formed, cracked or imperfect, or the heads of which do not bear closely all round against the surface of the plate or bar, must be cut out and replaced by sound rivets.

The rivets shall be at such pitch as may be marked on the Drawings, and at all bearings, or where indicated on the Drawings, shall have countersunk heads.

No riveting shall be done until the work has been passed by the Engineer, and the work must be kept well bolted up in front of the riveting as this proceeds.

The whole of the work shall be erected, fitted, and bolted together in the Contractor's yard for inspection before being sent out.

All work must be done as much as possible under cover, and the materials kept clean and protected from the weather until painted or cement coated.

All bolts, nuts, studs, screws, rods, or straps shall be in accordance with the appropriate British Standard, and bolts shall, unless otherwise ordered, be provided with washers $\frac{3}{16}$ in. thick. Heads and nuts shall be hexagonal Whitworth screws, and all shall be well forged. All the bolts shall have one clear thread standing through the nut when screwed up. All bolts shall be screwed up perfectly tight and projecting thread riveted down. Bolts which pass through the flange of a rolled joist shall be provided with taper washers.

132. Camber of Girders.—Excepting where otherwise specified or shown on the Drawings, all girders shall be so built in the form of an arc of a circle as to have a camber at the centre equal to one-sixtieth part of an inch for each foot of clear span after the full dead load has been applied and the girders have taken their bearings. The bearing surfaces of each girder shall be in one true plane.

133. Bedding on Bearings.—All girders and bed plates bearing directly on stone shall be bedded on three thicknesses of well-tarred hair felt.

134. Cleaning, Protecting, and Painting.—The oiling of interior surfaces before assembling, and of field rivets, bolts, nuts, and washers, as described in Clause 18 of the British Standard 153 of 1933 for Girder Bridges (Part II), shall be included in the price of the steel and iron work.

All surfaces of new steel and iron work which will be exposed in the completed structure, shall be thoroughly coated with boiled linseed oil and afterwards painted with four coats of paint in the following manner :—

When the steel plates and bars have been riveted up, the whole of the exposed surfaces shall be thoroughly cleaned of all scale, rust, dirt, dust, and grease, and other impurities and imperfections by scraping and brushing with steel-wire brushes, and, where necessary, the surfaces shall be hammered, and other best-known methods of cleaning, such as by the sand blast or otherwise, shall be adopted, and the surfaces shall be made thoroughly dry. Where surfaces are in contact, great care shall be taken to ensure that all joints and corners are thoroughly cleaned out. Immediately thereafter, the cleaned surfaces shall be coated with hot boiled linseed oil. A priming coat of a mixture of red and white lead paint with pure linseed oil well worked on shall afterwards be applied on the same day that the surfaces have been oiled. After the erection of the steel-work in its permanent position a second coat of lead paint of approved colour shall be applied. The two final coats of paint shall not be put on until the whole work is otherwise completed. The proportion of turpentine or other drier used with the linseed oil shall not be greater than one part by weight of turpentine to eight parts by weight of oil. The surface shall be thoroughly cleaned immediately before the application of each of these coats of paint.

Those surfaces of the new steel and iron work which in the completed structure will be protected by concrete from the weather shall, after being thoroughly cleaned, scraped, etc., as above specified, instead of being treated with oil and paint as above described, be immediately coated with neat cement mixed with water to a stiff consistency and well worked in.

The paint on all steel and iron work shall be well worked on round all rivet and bolt heads, and into all crevices and angles, and one coat shall be completed over the whole steel and iron work and be thoroughly dry and hard before the next coat is commenced. Painting of the several coats on steel and iron work shall not be commenced until the Engineer has had inspection made after cleaning, and has intimated his approval of the work, and the several coats shall be put on at such times as the Engineer will direct.

The finishing tints in the painting of the steel and iron work may be in white or brown or blue or other colours, picked out in such different shades as will be directed.

All fitted and bright parts of the steel and iron shall be carefully protected with tallow.

All painter work shall be executed by skilled tradesmen and not by labourers, and no painting shall be done in wet, frosty, or otherwise unsuitable weather.

135. TROUGH DECKING.—The trough decking shall consist of corrugated, rolled or pressed trough flooring prepared from plates $\frac{1}{2}$ in. to $\frac{5}{8}$ in. thick of steel as specified, by methods approved by the Engineer. The depth of the troughs shall be as shown on the Drawings, the width of the bottom of the trough about the same as the depth, the sides being inclined to the vertical at an angle of about 15° to 20°.

The trough sections shall be riveted together to form the flooring by ⅞-in. rivets at 4-in. pitch unless otherwise ordered, the overlap at joints being not less than 3 in.

The riveting necessary at the site shall be done with approved machines, preferably of the hydraulic type.

136. CAST IRON PARAPETS.—The parapets shall be as shown on the Drawings, and shall be of cast iron as specified, with a minimum height of 5 ft. above heel of footpath, in raised panels 7 ft. long fitted between panelled box pilasters 12 in. by 6 in., and provided with shaped box cope; the lower part of the parapet below heel of footpath level shall be 9 in. high, of channel section to match the string course of the brick pilasters. The exposed faces shall be clean and smooth, coated with red lead paint after inspection on leaving the moulds, and painted after erection with three coats best oil paint as specified.

137. LIST OF ALL STEEL ORDERED.—The Contractor shall supply to the Engineer a list of all the steel and cast iron ordered for the work and shall also forward to him certified weight notes giving the actual weight of the whole steel work and cast iron work as completed and delivered in accordance with the Drawings.

138. SHOP DRAWINGS TO BE PROVIDED.—Before ordering the materials of the iron and steel work, the Contractor shall submit for approval of the Engineer the detail or other Workshop Drawings of the iron and steel work, and he shall also submit for approval such enlarged Drawings and details of the other works, both temporary and permanent, as the Engineer may require, and, when these are approved, he shall furnish to the Engineer four or more blue print copies of all such Drawings. No iron or steel shall be ordered until the working Drawings are approved of. Such approval shall not relieve the Contractor from any of his responsibilities.

139. ERECTION.—Before proceeding to erect the girders in position, the Contractor must give the Engineer at least one month's notice of his intention to commence that operation. No part of any plant or tackle provided by the Contractor or erected at the site of the Works for the purpose of erecting or placing girders, or for any other purpose whatever, shall be allowed when not in use to overhang the space between the abutments. Crane jibs, derrick booms, or any such appliances,

or their tackle, must be lowered or anchored in such a manner that they cannot be swung out over the railway or road or touch any vehicles passing thereon.

140. Loading Completed Structure.—The Contractor shall not at any time load the structure nor any part thereof in excess of the designed working load. No load shall be placed on any part of the structure until such part and its supporting members are at least four weeks old, unless such part is otherwise suitably supported.

141. Testing Completed Bridges.—On completion of the structures, and at such time thereafter as the Engineer may direct, the Contractor shall, for the purpose of testing the bridges, make use of the heaviest steam rollers and trailers, loaded and placed in such a manner as the Engineer may require. The rollers and trailers shall be driven across the bridges side by side, and as often as may be necessary for the completion of the tests, all to the requirements and satisfaction of the Engineer. The Contractor shall supply and fix where directed by the Engineer such instruments as are required for the measurement of deflection and stresses. If the structure stress indicates faulty workmanship or materials, the work within limits defined by the Engineer shall be removed and reconstructed by the Contractor at his own expense.

CHAPTER V

SPECIFICATIONS—MATERIALS

Having dealt with the workmanship required in the carrying out of various classes of Contracts, it is now necessary to be able to specify the materials to be used, and, as before pointed out, a great many of these are covered by the Specifications issued by the British Standards Institution.

One of the most common Engineering materials is cement, which may be specified generally as follows :—

142. CEMENT.—All cement used under the Contract shall be British made Portland cement, in every respect in strict accordance with the requirements of the latest British Standard for Ordinary Portland or rapid-hardening Portland cement, except in particulars specifically mentioned in this Specification. The sand to be used in the sand tests shall, notwithstanding the terms of the British Standard, be taken from that in regular use on the works, but the results obtained must be at least equal to those specified to be obtained with standard sand from Leighton Buzzard. At least one complete set of tests shall be made from every delivery of cement, but the number of tests may be increased at the discretion of the Engineer. All the cement shall be delivered in bags with the seals unbroken, and stored in the Contractor's cement store. Each consignment shall be kept separate and distinguished.

Note.—Four classes of cement are now available for use in concrete making, viz. ordinary Portland cement, rapid-hardening Portland cement, Portland-blastfurnace cement, and high-alumina cement. The two former should in all respects comply with British Standard No. 12 of 1947 for Portland cement and rapid-hardening Portland cement, and No. 146 of 1947 for Portland-blastfurnace cement.

High-alumina 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. High-alumina cement should comply with British Standard No. 915 of 1947. The compressive strength of good high-alumina cement (3 parts sand to 1 part cement) should be not less than 6,000 lb. per sq. in. at 24 hours.

Piles made of high-alumina cement concrete have been successfully driven when only twenty-four hours old.

When high-alumina cement sets, it generates much heat owing to the intensity of the chemical action that causes the rapid hardening, and this heat prevents the concrete becoming frozen in frosty weather until it is hard enough to resist freezing action without damage—a valuable property of this cement.

In all cements, provided the setting time and the soundness tests are satisfactory, the best cement may be taken as that with the highest tensile strength.

The above-mentioned British Standards include provisions for :—

Composition and manufacture.
Taking of samples.
Cost of tests, analyses, etc.
Tests for fineness, chemical composition, strength, setting time and soundness.
Drawings and descriptions of the apparatus required to carry out the tests.

143. FINE AGGREGATE.—British Standard 882 of 1944, for Coarse and Fine Aggregates from Natural Sources for Concrete, contains the following provisions[1] :—

Aggregates shall consist of naturally occurring sand, gravel or stone, crushed or uncrushed, or a combination thereof. They shall be hard, strong, durable, clean and free from adherent coatings. They shall contain no harmful material in sufficient quantity to affect adversely the strength or durability of the concrete, or to attack the reinforcement.

Fine Aggregate, Class A, shall be within the limits of the grading shown in the following table :—

B.S. Sieve	Per cent. passing	
	Natural or Crushed Gravel Sand	Crushed Stone Sand
$\frac{3}{16}$ in.	95–100	90–100
No. 7	70–95	60–90
,, 14	45–85	40–80
,, 25	25–60	20–50
,, 52	5–30	5–30
,, 100	0–10	0–15

[1] Abstracted by permission of the British Standards Institution for B.S. No. 882/1944, official copies of which may be obtained from the Institution, 28 Victoria Street, S.W.1.

If specially agreed by the purchaser, sand may have a grading outside the limits of the table for Class A, and shall be known as Fine Aggregate Class B, and shall not exceed the limits of the following table :—

B.S. Sieve	Per cent. passing
3/16 in.	90–100
No. 7	60–100
„ 14	25–100
„ 25	10–100
„ 52	5–40
„ 100	0–15

144. Coarse Aggregate.—British Standard 882 of 1944 gives the same general description as for fine aggregates, and specifies that the grading must be within the limits of the following table :—

B.S. Sieve	Nominal Size.							
	Graded Aggregate			Single-sized Aggregate				
	1½ to 3/16 in.	¾ to 3/16 in.	½ to 3/16 in.	2½ in.	1½ in.	¾ in.	½ in.	⅜ in.
	Per cent. passing.							
3 in.	100	—	—	100	—	—	—	—
2½ in.	—	—	—	85–100	100	—	—	—
1½ in.	95–100	100	—	0–30	85–100	100	—	—
¾ in.	30–70	95–100	100	0–5	0–70	85–100	100	—
½ in.	—	—	90–100	—	—	—	85–100	100
⅜ in.	10–35	25–55	40–85	—	0–5	0–20	0–45	85–100
3/16 in.	0–5	0–10	0–10	—	—	0–5	0–10	0–20
No. 7	—	—	—	—	—	—	—	0–5

145. All-In Aggregate.—British Standard 882 defines this as aggregate containing a proportion of material of all sizes from the pit, river bed, foreshore, quarry or crushing plant. The grading of all-in aggregate shall be in accordance with the following table :—

B.S. Sieve	Nominal Maximum Size of All-in Aggregate	
	1½ in.	¾ in.
	Per cent. passing.	
1½ in.	95–100	—
¾ in.	40–70	95–100
3/16 in.	25–45	30–50
No. 100	0–6	0–6

Methods of sampling and testing of aggregates are laid down in the appendices to this British Standard.

146. WATER-CEMENT RATIO.—A most important factor in the preparation of concrete is the water used in mixing. It must be clear, and any ordinary drinking water may be used with confidence. Sea water may also be used, but has a slight retarding effect upon the setting of the cement.

The quantity of water used is of the utmost importance as the strength of the concrete depends upon the ratio of water to cement. Beyond a certain point, an increase in the quantity of water means a decrease in the strength of the concrete.

For concrete foundations, roads, and floors without reinforcement, the concrete should be mixed with just sufficient water to form a compact mass when rammed or punned. If for reinforced concrete, it must be more liquid to flow round the reinforcement, but the quantity of water used should be the minimum consistent with this.

For nominal mixes of 1 : 1½ : 3 and 1 : 2 : 4, the water-cement ratio (by weight) should not exceed 0·51 and 0·58 respectively. (These correspond to 5¾ galls. and 6½ galls. of water to each 112 lb. of cement.) If the concrete is compacted by vibration, these values may be reduced by about 20 per cent.

One method of ensuring a uniform water content is to test the mix by means of the slump test. This is carried out by filling the concrete in layers of 4 in. at a time into a truncated cone-shaped sheet-metal mould 12 in. high, 8 in. diameter at the base, and 4 in. diameter at the top, provided with handles at the sides, and punning each layer exactly 25 times with a ⅝-in. diameter bullet-pointed metal rod 2 ft. long. After the third and last layer has been punned, the mould is lifted off and the slump measured. Tests show that concrete having a slump of from ½ in. to 1 in. will contain only a little more water than is necessary for maximum strength, but will be too stiff for most constructional work. An increase of 10 per cent. in the water content will give a slump of 3 in. to 4 in., 25 per cent. increase a slump of from 6 in. to 7 in., and a 50 per cent. increase a slump of from 8 in. to 10 in.

For various types of construction the following slumps are recommended :—

Class of Concrete.	*Maximum Slump in inches.*
Mass Concrete	2
Reinforced Concrete :—	
Thin Vertical Sections	6
Heavy Sections	2
Thin Confined Horizontal Sections	8
Roads and Pavements :—	
Hand Finished	4
Machine Finished	1
Mortar for Floor Finish	2

147. Proportioning of Concrete.—The theoretically correct proportions of the concrete materials are met by filling the voids in the coarse aggregate with sand, and all the voids in the fine aggregate with cement paste. The percentages of voids are not easy to determine with accuracy, so it is usual to increase the sand and cement somewhat above these theoretical amounts.

In practice it is usual to work on a basis of 1 part of cement to *n* parts of fine aggregate and 2*n* parts of coarse aggregate.

The quantities of aggregate are usually worked out in relation to a 112-lb. bag of cement, and provided the aggregates are well graded and the workmanship good, this method of proportioning will give good results.

Measurement by weight is more accurate than by volume, as a moisture content may increase the bulk of fine aggregate by as much as 30 per cent.

The following table is a guide to the materials required for various common mixes of concrete :—

Mix.	Weight of Materials lbs.			Volume of Materials Cu. ft.			Water per 112 lb. bag of Cement (galls.)	Water per cu. yd. of Aggregate (galls.)
	Cement	Fine Aggregate	Coarse Aggregate	Cement	Fine Aggregate	Coarse Aggregate		
1 : 4 : 8	112	448	896	1¼	5	10	8·5	15·3
1 : 3 : 6	112	336	672	1¼	3¾	7½	7·1	17·1
1 : 2 : 4	112	224	448	1¼	2½	5	5·8	20·9
1 : 1½ : 3	112	168	336	1¼	1⅞	3¾	5·1	24·5
1 : 1 : 2	112	112	224	1¼	1¼	2½	4·4	31·6

The materials required for 1 cu. yd. of concrete of various proportions are as follows :—

They are based on loose cement weighing 90 lb. per cu. ft. and sand weighing 90 lb. per cu. ft. when dried.

Proportions by Volume	Kind of Aggregate	Portland Cement lb.	Sand cu. yd.	Coarse Material, cu. yd.
1 : 1 : 2	Gravel (40 per cent. Voids) –	899	·37	·74
	Broken Stone (45 per cent. Voids)	923	·38	·76
1 : 1½ : 2½	Gravel – – – – – –	705	·44	·73
	Broken Stone – – – –	729	·45	·74
1 : 1½ : 3	Gravel – – – – – –	656	·40	·80
	Broken Stone – – – –	680	·42	·84
1 : 2 : 4	Gravel – – – – – –	510	·42	·84
	Broken Stone – – – –	547	·45	·90
1 : 2½ : 5	Gravel – – – – – –	430	·44	·88
	Broken Stone – – – –	450	·46	·92
1 : 2⅔ : 5⅓	Gravel – – – – – –	413	·45	·90
	Broken Stone – – – –	420	·46	·92
1 : 3 : 6	Gravel – – – – – –	364	·45	·90
	Broken Stone – – – –	382	·47	·94
1 : 4 : 8	Gravel – – – – – –	280	·46	·92
	Broken Stone – – – –	292	·48	·96

In some districts, an aggregate of coarse material and sand intimately mixed is found, and used largely by Contractors where it is found suitable, and in this case the mixture is specified as say 6 to 1, or 8 to 1, and so on as the case may be. In such cases, since the cement used is only that required to fill the voids in the shingle (plus the small extra amount required in mixing), the quantity of shingle required to produce 1 cu. yd. of concrete will be approximately $1\frac{1}{5}$ cu. yd., and thus, in a 6 to 1 mixture, the quantities required would be $\frac{1}{5}$ cu. yd. cement = 486 lb. to $1\frac{1}{5}$ cu. yd. shingle.

148. Plums.—In large concrete structures such as foundations, dams, piers, retaining walls, etc., large stones, known as "plums" or displacers, are sometimes embedded in the concrete. The concrete for large masses such as these should be stiff and the "plums" should be sound and clean and completely surrounded by concrete. They should be at least 6 in. from each other and from an exposed surface and must be placed quickly as the concreting progresses to avoid construction joints due to the concrete setting. The advantages of using "plums" in concrete are that a much smaller quantity of concrete is required, while they do not interfere with the strength of the structure. On the other hand their use is decreasing owing to the cost of the extra labour and plant required for the handling and rapid placing of the stones,

which often counterbalances the saving in concrete. (See also Clause 150.)

149. Placing Concrete under Water.—Where it is necessary to deposit concrete under water a fairly rich mix, containing at least 650 lb. of cement per cu. yd. of concrete, should be used. A tremie (Fig. 5), which usually consists of a steel pipe or tube long enough for the lower end to reach the

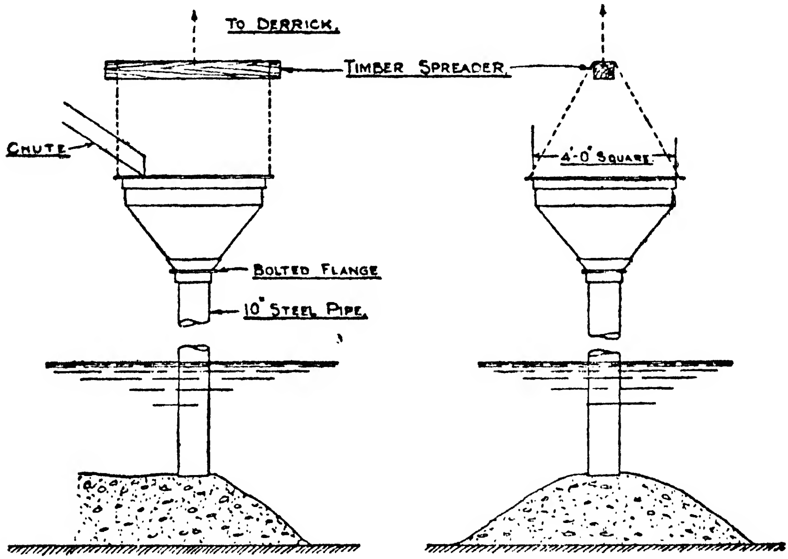


Fig. 5—Tremie for Depositing Concrete under Water.

bottom of the work when the upper end is above water level, should be used. It is usually provided with a hopper at the upper end to receive the concrete. When placing operations are to start the lower end of the tremie is plugged to prevent the entrance of water or the escape of concrete. The tremie is filled with concrete and lowered into position. When the lower end reaches the bottom of the work, the plug is removed and the concrete allowed to flow out slowly. As concreting proceeds the lower end should be kept submerged in the concrete for several feet and the tremie kept constantly full of concrete.

Drop-bottom buckets are also used for placing concrete under water. The bucket should be of a type that cannot be dumped until it rests on the surface on which the concrete is to be deposited. The bucket should be completely filled and slowly lowered to avoid backwash. When discharged, it should be withdrawn slowly until it is well above the concrete, and the concrete that is in place should be disturbed as little as possible. If the water in which the concrete is to be deposited is much agitated, top covering doors should be provided to the buckets.

For underpinning walls under water, or for placing in selected positions in relatively small quantities, concrete is sometimes filled into hessian bags and deposited in position by divers.

Concrete deposited under water should be mixed stiff.

The following Clauses give particulars of various mixes for concretes and mortars :—

150. RUBBLE CONCRETE.—Rubble concrete shall consist of irregular sized stones or displacers set and packed solid on all sides with ordinary concrete. No stones shall be allowed to touch one another, but in all cases there shall be a clear space of at least 9 in. filled with concrete and cement mortar between the stones. No stone shall be placed nearer than 12 in. to the front face of the wall, or nearer than 6 in. to any other surface.

The concrete shall be firmly beaten down and rammed so as to leave no interstices between the rubble stones. All displacers shall be subject to the Engineer's approval, and no stone measuring more than 3 ft. by 2 ft. by 2 ft. shall be used. The sizes of stones shall be proportional to the various thicknesses of walls. In all cases the displacers shall be put in their permanent positions in the concrete within half an hour after the concrete has been deposited, and at the periodical cessation of building operations the displacers shall be set in position and embedded in the concrete to a depth of not less than 6 in., and be left projecting upwards, so as to make a thorough bond with the succeeding mass or layer. A foundation bed at least 12 in. thick shall in all cases be deposited before any displacers are put in.

151. CONCRETE FOR KERBS, FENCE POSTS, ETC.—Where specified for reinforced concrete kerbs, etc., Portland cement concrete shall consist of one part (by measure) of Portland cement, one and one-half parts of washed sand as specified in Clause 143, and three parts of washed stone graded from ¾-in. to ¼-in. gauges. For reinforced concrete fencing, corner and straining posts, and struts, the Portland cement concrete shall be as previously specified for reinforced concrete kerbs, etc.,

in this Clause, but the washed stone shall be graded from ½-in. to ¼-in. gauges.

152. Granolithic Concrete.—Granolithic concrete, unless otherwise specified, shall be composed of one part Portland cement (by measure) to two parts ⅛-in. granite chippings to dust, gauged and mixed as described for ordinary concrete.

153. Cement Mortar.—Cement mortar, where specified, shall be composed of Portland cement and clean sharp sand, as previously specified, in the following proportions (see Clause 159) :—

(3 to 1) 1 volume Portland cement to 3 volumes sand.
(2 to 1) 1 ,, ,, ,, ,, 2 volumes sand.
(1 to 1) 1 ,, ,, ,, ,, 1 volume sand.

The ingredients shall be properly gauged as described for ordinary concrete and properly mixed.

Note.—Insufficient sand in mortar frequently causes fine surface hair-cracks, especially in rendering, due to expansion and contraction. Experiments have proved conclusively that neat cement slightly contracts when hardening in air, and slightly expands when hardening in water. Mortars of cement and sand show the same effects, but in a much less degree, hence mortars of cement and sand are better for such purposes as rendering than neat cement.

For laying bricks or for grouting the sand should be comparatively fine—not too fine—while for concrete or coarse mortar it should range from fine to coarse.

Mortar containing too large a proportion of sand will be " short " and brittle and will not work well, since its adhesion to the stone or brick is imperfect. Where a quickly-hardening mortar is required of no great strength but of good adhesive properties, a weak mix may be used by adding in addition to the sand and cement a proportion of slaked or hydraulic lime, as such a mortar is cheap and satisfactory, hardens rapidly, and attains considerable strength on exposure to air.

For face work, where Portland cement mortar is being used, a little lime " putty " (made by mixing lime with water, passing it through a sieve and leaving it to settle and take a thick paste-like form), if added to the mortar, will make it work smoothly. Lime putty added to Portland cement mortar increases its adhesive qualities and impermeability to water.

The following proportions by volume are suitable for mortars :—

1 Portland cement, 5 sand, ½ lime paste.
1 „ „ 6 to 7 sand, 1 lime paste.
1 „ „ 8 sand, 1½ lime paste.
1 „ „ 10 sand, 2 lime paste.

The method of preparing Portland cement and lime mortar is to mix the sand and cement dry, then prepare milk of lime with the necessary quantity of lime paste and water, and thoroughly mix and work it up with the mixture of sand and cement.

In using mortar with bricks, it is advisable to wet the bricks thoroughly and use a stiff mortar.

154. Cement Grout.—Cement grout shall be composed of Portland cement and clean sharp sand in the following proportions :—

(2 to 1) 1 volume Portland cement to 2 volumes sand.

The ingredients shall be properly gauged and mixed as described for ordinary concrete, but with sufficient water to enable it to be poured into joints or voids.

155. Lime Mortar.—Lime mortar shall consist of finely ground burnt lime and either clean sharp sand or clean well-burnt ashes in the proportion of one volume of lime measured dry, to two volumes of sand or ashes.

156. Concrete Pipes.—These should be in accordance with British Standard No. 556 for Concrete Cylindrical Pipes and Fittings. This Standard includes pre-cast manholes, inspection chambers and street gullies, and contains clauses dealing with materials and methods of manufacture, dimensions, tests and methods of testing, the information to be supplied by a purchaser in his enquiry, and drawings of standard bends, fittings and pre-cast manholes.

157. Concrete Kerbs, Channels, and Quadrants.—These should comply in all respects with British Standard No. 340 of 1936, which contains the following provisions :—[1]

Cement.—The cement used shall comply with the provisions of the British Standard Specifications for Portland cement, normal or rapid-hardening, or for Portland-blastfurnace cement.

[1] Abstracted by permission of the British Standards Institution from British Standard No. 340/1936, official copies of which can be obtained from the Institution, 28 Victoria Street, Westminster, S.W.1.

Aggregate.—To be of best quality, thoroughly clean, and to pass a B.S. test sieve having meshes ¾ in. square.

Proportions.—To be one part by volume of cement to not more than four parts by volume of aggregate, and to be mixed in an efficient mechanical mixer.

Moulding.—Hydraulically pressed Kerbs, Channels, and Quadrants shall be subjected to an even pressure over their entire surface of not less than 1,000 lb. per sq. in.

Dimensions.—Straight Kerbs shall be manufactured to a uniform length of 3 ft. and the Radius Kerbs 2 ft. long to radii of 6 ft., 8 ft., and 10 ft., and 3 ft. long to radii of 20 ft. and 30 ft., the radius in each case being measured half-way down the outer face of the Kerb.

The Straight Channels shall be manufactured to a uniform length of 3 ft., and the Radius Channels 2 ft. long to radii of 6 ft., 8 ft., and 10 ft., and 3 ft. long to radii of 20 ft. and 30 ft., the radius in each case being that of the inner face of the Channel.

The Quadrants shall be manufactured 10 in. deep, of 18 in. radius, and with faces to match the corresponding kerbs.

Tests for Transverse Strength.—The Kerb or Channel shall be simply supported on two hard unyielding bearers, each ¼ in. wide on the top and of a length equal to at least the width of the kerb or channel being tested, parallel to each other and 2 ft. 6 in. clear span, with the greatest width of wearing face uppermost, and shall be subjected to a central load applied to a space 2 in. wide and extending the whole width of the section uniformly at a rate not exceeding 112 lb. per foot of width per ten seconds. They shall support without injury, for at least one minute, the specified loads, varying from 180 lb. to 400 lb. per in. of width.

Tests for Absorption.—Sample cubes cut from Kerbs and Channels, having at least three faces, shall, after being thoroughly dried to a constant weight at a temperature between 185° F. and 204° F. and weighed, be submerged in water for twenty-four hours, then removed from the water, wiped with a cloth, and again weighed, and the increase in weight of each sample by absorption of water shall not exceed 8·5 per cent.

158. Salt-Glazed Ware Pipes.—British Standard Salt-Glazed Ware Pipes are those conforming otherwise to B.S.

65 (1937) but of which only 5 per cent. are hydraulically tested. British Standard Salt-Glazed Ware Tested Pipes are those conforming to this Specification, all of which have been tested.

B.S. No. 65 for Salt-Glazed Ware Pipes contain the following provisions[1] :—

Dimensions.—To be in accordance with those specified.

Length of Straight Pipes.—The Standard length of the barrel to be as follows :—

Up to and including 6 in.,	2 ft.
7 in. and 8 in.,	2 ft. and 2 ft. 6 in.
9 in. to 36 in.,	2 ft., 2 ft. 6 in., and 3 ft.

as may be specified.

Grooving.—The interior of the sockets, and the exterior of the spigots for a length equal to 1½ times the depth of the sockets, shall be grooved to a depth of not less than $\frac{1}{16}$ in.

Glazing.—The glazing shall be obtained by the action of the fumes of volatilized common salt on the material of the Pipes during the process of burning. The glaze shall cover the interior and the exterior surface of the Pipes which will remain exposed after jointing.

Hydraulic Test.—20 lb. per sq. in. applied at a rate not exceeding 10 lb. per sq. in. in five seconds, and full pressure shall be maintained for at least five seconds.

Absorption Test.—Test pieces shall be taken from the body of the Pipe and not within 6 in. of the end, and have two glazed surfaces, each having an area of not less than 8 sq. in. nor more than 20 sq. in. They shall be dried at a temperature of not less than 150° C. until no further loss of weight can be noted, then immersed in cold water and the temperature raised to 100° C. at which temperature it shall be maintained for one hour. After the water has cooled, the test pieces shall be removed, carefully wiped with a dry cloth, and on re-weighing the percentage increase in weight shall not exceed :—

Thickness of Pipe.	*Percentage increase in Weight.*
¾ in. and under – –	6
Over ¾ in. up to 1 in. – –	7
Over 1 in. up to 1¼ in. –	8
Over 1¼ in. up to 1½ in. –	9
Over 1½ in. – – –	10

[1] Abstracted by permission of the British Standards Institution from British Standard No. 65/1937, official copies of which can be obtained from the Institution, 28 Victoria Street, Westminster, S.W.1.

It should be noted that it is usual in Scotland to use Salt-glazed (glass) vitreous enamelled fireclay pipes, which should comply with British Standard No. 540.

159. Clay Bricks.—The bricks shall be hard, sound, with sharp arrises and of true shape, uniform in colour, free from particles of lime and other imperfections. All bricks shall be selected, of a suitable size to bond properly with the other classes of bricks in use on the Works, and shall ring well on being struck together. The Contractor shall submit to the Engineer sample bricks for approval, and all bricks used on the Works shall in all respects be equal to the sample approved.

The common bricks shall not absorb more than 10 per cent. of their weight of water after being thoroughly dried and then immersed for twenty-four hours.

The red facing bricks shall be best pressed Accrington or Enfield engineering bricks, or bricks of a similar character if specially approved by the Engineer, specially selected, machine made, true to gauge, of uniform size to bond with the other classes of bricks in use on the Works, and shall not absorb more than 2 per cent. of their weight of water after being thoroughly dried and then immersed for twenty-four hours.

The blue facing bricks shall be the best pressed Staffordshire blue bricks, or bricks of a similar character if specially approved by the Engineer, specially selected, machine-made, true to gauge, of suitable size to bond with the other classes of bricks in use on the Works, and shall not absorb more than 2 per cent. of their weight of water after being thoroughly dried and then immersed for twenty-four hours.

All bricks brought to the ground shall be carefully and properly handled, and all facing bricks shall be cased in transit, and be carefully unloaded and handled and properly stacked on delivery, so as to avoid the chipping of arrises and faces.

Note.—The most important bricks in general use are (*a*) Common bricks, which include stock bricks, Flettons, and pressed and wire-cuts, and hand-made bricks produced in various localities, and are used for ordinary building purposes. (*b*) Facing bricks, which include hand-made, sand-faced reds, purples, and greys, and various descriptions of machine-made bricks of suitable colours, and are used for external work where appearance is important ; and (*c*) Engineering bricks, consisting of the Blue Staffordshire, Sussex, and Accrington types, pressed reds, and wire-cuts, and are used where exceptional strength and impermeability are required.

There are three main classes of bricks, as follows :—

(*a*) Plastic, stiff plastic, or semi-dry.

(*b*) Sand-faced or smooth sand-faced, which are made by hand or by machine, hand-made being considered to have a better appearance. Smooth-faced bricks are made by wire-cut machines or presses.

(*c*) Clamp- or kiln-burnt. The old type of country clamp is still used for burning stock bricks, but all other types are now burnt in either intermittent or continuous closed kilns. English hand-made bricks have a frog on one side ; pressed bricks a frog on one or both sides, and wire-cuts have no frog.

In bricks with a frog on one side only, the brick is laid frog upwards, and ordinary brickwork usually measures four courses per foot in height, including joints.

The R.I.B.A. in consultation with the Brick Makers' Association and representatives of the Institution of Civil Engineers, recommended, in 1904, an R.I.B.A. Standard Size of Brick, as follows :—

(*a*) The length of the brick should be double the width, plus the thickness of one vertical joint.

(*b*) Brickwork should measure four courses of bricks and four joints to a foot.

Joints should be ¼ in. thick and an extra $\frac{1}{16}$ in., making $\frac{5}{16}$ in. for the bed joint to cover irregularities in the bricks. This gives a standard length of 9¼ in., centre to centre of joints.

The bricks, laid dry, to be measured in the following manner :—

(1) Eight stretchers laid square end and splay end in contact in a straight line to measure 72 in.

(2) Eight headers laid side by side, frog upwards, in a straight line to measure 35 in.

(3) Eight bricks, the first brick frog downwards and then alternately frog to frog and back to back, to measure 21½ in.

A margin of 1 in. less will be allowed as to (1), and ½ in. less as to (2) and (3).

This is to apply to all classes of walling bricks, both machine and hand made.

The modern red or brindle engineering bricks are considerably harder than the well-known engineering blue bricks. They are made at Ruabon, Accrington, Bristol, Yorkshire, etc.

All dry bricks should ring clearly when two, held in the hands, are struck sharply together. If a dull sound is emitted the bricks are either saturated with water or they have not been sufficiently well burnt. They should be hard, and the surfaces may be tested with a knife which should make practically no impression.

The following data as to brickwork is useful :—

All brickwork in engineering work is measured in cubic yards, special facings in square yards, extra over general brickwork.

The following are the quantities of mortar produced from 1 cu. ft. of loose Portland cement in various mixes :—

1 cu. ft. of loose Portland cement neat as cement mortar will cover about 10·4 sq. ft. 1 in. thick.

1 cu. ft. of loose Portland cement to 1 sand will cover about 17 sq. ft. 1 in. thick.

1 cu. ft. of loose Portland cement to 2 sand will cover about 25 sq. ft. 1 in. thick.

1 cu. ft. of loose Portland cement to 3 sand will cover about 34 sq. ft. 1 in. thick.

1 cu. ft. of loose Portland cement to 2 sand will lay about 146 bricks with ⅜-in. joint, or 247 bricks with ¼-in. joint.

1 cu. ft. of loose Portland cement to 3 sand will lay about 212 bricks with ⅜-in. joint, or 317 bricks with ¼-in. joint.

1 cu. ft. of loose Portland cement neat as cement mortar will point about 11¼ sq. yd. of brickwork.

1 cu. ft. of loose Portland cement to 1 sand will plaster about 2¼ sq. yd. 1 in. thick.

1 cu. ft. of loose Portland cement to 2 sand will plaster about 3 sq. yd. 1 in. thick.

Brickwork joints are usually finished by one of the following methods :—

(*a*) With a weathered or flush joint as the work proceeds, this joint being formed of the actual mortar used in bedding the bricks, which forms the most durable method.

(*b*) Joints raked out while the mortar is soft, and cleaned down and pointed at completion.

(*c*) Joints raked out and left as key for plaster or roughcast.

Another type of brick which is being manufactured in increasing quantities is the Sand-Lime (Calcium-Silicate) Brick, which consists of sand and lime of suitable quality thoroughly mixed in suitable proportions, then passed into well-formed, strong, metallic moulds and subjected to mechanical pressure. On emerging from the machine, the bricks are stacked on a trolley and run into a hardening chamber in which they are subjected to steam. The British Standards

Institution issue a Specification (No. 187)[1] for Sand-Lime Bricks, the principal provisions of which are as follows :—

Sand-Lime Bricks consist essentially of a mixture of sand and lime, combined by the action of steam under pressure.

Crushing Tests.—Bricks to be tested shall be immersed for twenty-four hours in clean fresh water at a temperature of 59° F. to 68° F. The average crushing strength of twelve such bricks, tested flat shall be not less than the following :—

For special purposes, 3,000 lb. per sq. in.
Building, Class A, 2,000 lb. per sq. in.
Building, Class B, 1,000 lb. per sq. in.

160. MASONRY.—The three descriptions of masonry in ordinary use are Rubble, Block-in-Course, and ashlar. Where the stone to be used is thinly bedded, rough, or intractable, it should be used as Rubble work. If it is obtainable in blocks, and more or less easily worked, it should be used as Block-in-Course or ashlar according to circumstances. (See also Clauses 120 to 124.)

Rubble may be either uncoursed, irregular, or random coursed, worked up to courses, or coursed, depending principally upon the character of the stone to be used. From their intractable nature and the absence of bedding lines some stones are specially adaptable for uncoursed rubble, whilst others may be easily worked into courses and are therefore more suitable for coursed rubble.

Block-in-Course is the name given to a class of masonry which is commonly used in engineering works such as piers, abutments, wing-walls, etc., where good solid work is required. In this class of work the stones are all squared and brought to good fair joints, the courses consisting of single stones only in depth. The size of the stones used is smaller and the depth of the courses less than in ashlar, usually under 12 in. deep. The stones are generally rougher and more thinly bedded than in ashlar and the best stones are hard, self-bedded stones which will work easily into courses from 3 in. to 10 in. or 12 in. in depth, the length of each stone being from four to five times its depth. The depth of each course is made to suit the stones available, no attention being paid to uniformity.

[1] Abstracted by permission of the British Standards Institution from B.S. No. 187/1942, official copies of which can be obtained from the Institution, 28 Victoria Street, Westminster, S.W.1.

Ashlar masonry is built up of a thick-bedded stone which admits of being scabbled, or sawn into square blocks of stone over 12 in. deep, as delivered from the quarry or stone-cutter. It is expensive and is often used as a facing only, the remaining thickness being made up by rubble or brickwork. Ashlar work is built in courses of uniform (or nearly uniform) depth—generally from 10 in. to 14 in.—ranging throughout with the quoins and dressings. It is described by different names according to the face put upon the stone.

Building stones may be divided into four classes :—

(*a*) Sandstones, in which silica constitutes the base.
(*b*) Limestones, in which carbonate of lime forms the base.
(*c*) Slates.
(*d*) Granites.

When the stones are granular in structure, with no planes of cleavage and therefore no tendency to split in any direction, they are termed freestones.

No stone should be laid in mortar without being first fitted into place and any irregularities in shape corrected. Large ashlars are first accurately fitted into place, and then set on a bed of mortar carefully spread out to receive them, after which the vertical joints have to be filled up by stopping them up on the outsides with cement and pouring in cement grout or mortar grout, which should be worked about with a piece of hoop iron so as to ensure its completely filling the joints. The beds and joints are worked to plane surfaces to allow close fitting joints. These surfaces should not be too smooth, otherwise the mortar will not adhere so well to the stones, but in good work should be true enough to allow joints not over ⅛ in. thick.

The deeper stones should be used for the lower courses, and at least one-sixth of the area of the face of the masonry should be composed of headers which should project at least 3 ft. into the wall unless in the case of walls of less thickness, in which they should project to the back of the wall.

Where there is a rubble backing, this should consist of good hard stone of not less than 4 in. in thickness, and 1 ft. square in plan, the stones properly bonded with each other and the facing.

All stones should be laid on their natural bed.

In building masonry, the stones are usually lifted by means of a derrick crane, and the various methods of gripping the stone blocks are shown in Figs. 6 to 10. Fig. 6 shows the method of lifting by a sling chain, but this method is apt to chip the stone unless strips of wood are inserted to keep the chain off the edges. Fig. 7 shows lifting tongs, commonly used in lifting soft stones, and Fig. 8 shows the method of lifting by

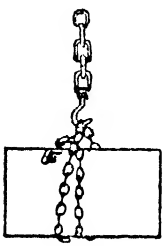


FIG. 6—Sling Chain.

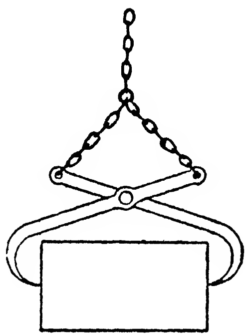


FIG. 7.—Lifting Tongs.

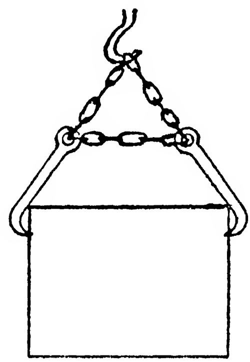


FIG. 8.—Dogs or Nippers.

dogs. These methods are useful where the face and back of the stone are rough enough to give a good grip to the points. In other cases, the best methods are by cutting dove-tailed mortices in the top of the stone and using a common lewis of the types shown in Figs. 9 and 10. Granite blocks are sometimes lifted by using taper plugs, preferably two in number connected

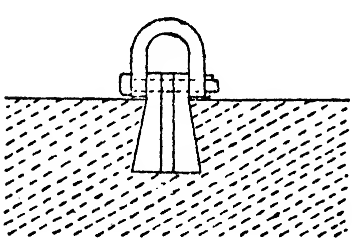


FIG. 9.—Lewis.

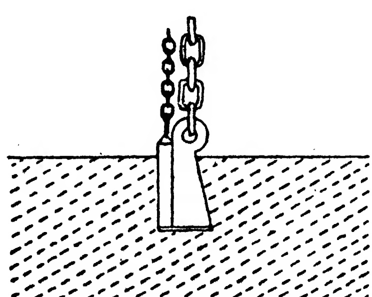


FIG. 10.—Lewis (for Laying under Water).

with bridle chains, and driven firmly into parallel holes, the plugs being loosened by striking a few side blows after the stone is set.

161. GRANITE AND WHINSTONE KERBS, CHANNELS, QUADRANTS, AND SETTS.—These are covered in British Standard No. 435/1931,[1] particulars of which are given below :—

General.—Granite and Whinstone shall be deemed to include all rocks of igneous origin.

KERBS AND CHANNELS

Material and Finish.—The kerbs and channels shall be of granite or whinstone as may be specified, and shall be good, sound, and free from defects. They shall be worked truly straight or circular, square and out of wind, with the top front and back edges parallel or concentric, to the dimensions hereinafter specified.

They shall be supplied to one of the three standard dressings specified below, as may be ordered.

(*a*) Standard Dressing " A " shall be " Fine Picked ".

(*b*) Standard Dressing " B " shall be " Fair Picked " or " Single Axed or Nidged ".

Note :—The provision of alternative methods of finishing kerbs and channels to standard dressing " B " is made so that the different methods of tooling practised in the various quarrying localities may be covered.

(*c*) Standard Dressing " C " shall be " Rough Punched ".

Straight Dressed Edge Kerb.—Shall be worked to the following seven sizes, namely :—

Section. *Width.* in.		*Depth.* in.	*Minimum Length, unless otherwise specified by the Purchaser or stipulated by the Supplier.* ft. in.
8	×	12	2 6
6	×	12	2 6
6	×	10	2 0
6	×	9	1 9
6	×	8	1 9
5	×	10	2 0
4	×	10	2 0

The top surface shall be finished to one of the standard

[1] Abstracted by permission of the British Standards Institution from B.S. No. 435/1931, official copies of which can be obtained from the Institution, 28 Victoria Street, Westminster, S.W.1.

dressings, " A " or " B " as may be specified, and shall have 1-in. chisel-drafted margins.

The front face to a depth of 5 in. in the case of the 8-in. by 12-in. and 6-in. by 12-in. sections, and 4 in. in the case of the other five sections, shall be finished to the same standard dressing as the top surface, and shall have a 1-in. chisel-drafted margin along the top edge. The face of the kerb below the dressing shall be so worked that it in no place projects in front of the dressed portion of the face.

The back shall be dressed clear to a depth of 3 in. with a 1-in. chisel-drafted margin to form a joint with the footway paving. The back below the dressing may be left rough.

The ends shall be chisel dressed neatly and accurately square with the face of the kerb to a depth of 4 in., the remainder of the depth being rough punched to enable a close butt joint to be formed.

The bottom may be left rough. A variation between the limits of 1 in. under, and 1 in. over, the nominal depths shall be permitted, but in no case shall there be a greater difference than 1 in. between the minimum and maximum depths of any one kerb.

Straight Dressed Flat Kerb.—Shall be worked to the following five sizes, namely :—

Section. *Width.*		*Depth.*	*Minimum Length, unless otherwise specified by the Purchaser or stipulated by the Supplier.*	
in.		in.	ft.	in.
12	×	8	2	6
12	×	6	2	6
10	×	6	2	0
9	×	6	1	9
8	×	6	1	9

The top surface, back, and bottom shall be as specified above.

The front face shall be dressed similar to the top surface and shall have a 1-in. chisel-drafted margin along the top edge.

The ends shall be chisel dressed neatly and accurately square for their full depth, to form a close butt joint on top and face.

Straight Rough Punched Edge Kerb.—Shall be worked to the following three sizes, namely :—

Section. Width. in.		Depth. in.	Minimum Length, unless otherwise specified by the Purchaser or stipulated by the Supplier. ft. in.
6	×	12	2 6
5	×	10	2 0
4	×	9	1 3

The top surface, face, and back shall be finished to standard dressing " C ". The ends shall be hammer-dressed or punched to form a butt joint.

The bottom may be as specified above.

Straight Dressed Channel.—Shall be worked to the following two sizes, namely :—

Section. Width. in.		Depth. in.	Minimum Length, unless otherwise specified by the Purchaser or stipulated by the Supplier. ft. in.
12	×	6	2 0
10	×	6	2 0

The top surface, ends, and bottom shall be as specified for Straight Dressed Flat Kerb.

The sides shall be dressed clear for the full depth of the channel and shall have 1-in. chisel-drafted margins along the edges joining the top surface.

Radius Kerbs and Channels.—Shall be worked to the sections, and have the same corresponding dressings, as the straight kerbs and channels specified above. They shall be worked to the following radii, namely : 4, 6, 8, 10, 12, 20, 30, and 40 ft., these radii being those of the outer faces of the kerbs and the inner faces of the channels. The minimum lengths of radius kerbs and channels, measured on the outer faces, shall be 1 ft. 9 in.

QUADRANTS

Material and Finish.—Shall be of granite or whinstone as may be specified, and shall be worked and have the same standard dressings as the kerbs against which they are to abut.

Dimensions.—The radius of the outer face shall be 18 in. for all sections, and the width of the ends and the depth shall be the same as the width and depth, respectively, of the kerb against which the quadrants are to abut.

Setts

Materials and Finish.—Shall be of granite or whinstone as may be specified, and shall be squarely hammer dressed. They shall not be crooked, feather edged, or tapering, nor shall they show drill-holes.

Dimensions.—Setts shall be worked to the following eight sizes. They shall not be more than ¼ in. above or below the specified dimensions :—

Width. in.		*Depth.* in.	*Length.* in.
4	×	4	4
3	×	5	Not less than 5 in. nor more than 10 in.
3	×	6	
4	×	4	
4	×	5	
4	×	6	Not less than 6 in. nor more than 10 in.
5	×	4	
5	×	6	

162. Clay Plain Roofing Tiles and Fittings.—The following particulars are taken from British Standard No. 402/1945.[1]

These may be either hand made or machine made as specified.

Manufacture.—Plain roofing tiles shall be manufactured from well-weathered or well-prepared clay or marl.

Particles of lime, visible to the naked eye, either on a surface or a fracture, shall be a cause for rejection, unless the tiles have been so treated by " docking " on removal from kiln that the lime has been water-slaked.

The tiles shall be free from fire cracks, true in shape, dense, tough, shall show a clean fracture when broken and shall be well burnt throughout.

Tiles shall have not less than two nibs of a width not less than ⅜ in. at the base, or a continuous nib of a depth not less than ¼ in. and not more than ½ in.

The hanging side of the nib shall be such that the tile will support itself when hanging vertically from a batten.

Size.—The size of standard tiles shall be 10½ in. by 6½ in.

[1] Abstracted by permission of the British Standards Institution from B.S. No. 402/1945, official copies of which can be obtained from the Institution, 28 Victoria Street, Westminster, S.W.1.

with a nominal plus or minus variation not exceeding ⅛ in. on the width and length.

Note.—Where the size of hand-made tiles is required to be 11 in. by 7 in., this shall be clearly stated on the order.

The number of tiles as laid to cover 100 sq. ft. (one square) of roof surface is as follows :—

Sizes,	10½ in. × 6½ in.	laid to a	4-in.	gauge	– 550
,,	,,	,,	3¾-in.	,,	– 590
,,	,,	,,	3½-in.	,,	– 635
,,	11 in. × 7 in.	,,	4-in.	,,	– 514
,,	,,	,,	3¾-in.	,,	– 550
,,	,,	,,	3½-in.	,,	– 588

Thickness.—Tiles shall be not less than ⅜ in. nor more than ⅝ in. thick.

Camber.—Tiles shall have a camber not less than half their thickness and not more than half their thickness plus ⅛ in.

Nail holes.—Two shall be provided. The centre of each shall be pierced not less than 1 in. and not more than 1¾ in. from the side of the tile and not less than ½ in. nor more than ⅝ in. from the underside on the nib, and shall be not less than 3/16 in. nor larger than ¼ in. in diameter.

TESTS

Transverse Test.—The average breaking load applied along the width of the tile midway between the supports, after the tile has been soaked in water at about 50° F. to 77° F. for twenty-four hours (tile being tested wet) shall be not less than 175 lb.

Water Absorption Test.—The average water absorption, as determined in the manner described in appendix B, shall not exceed 10·5 per cent.

163. TIMBER.—Timber is not now so much in use in permanent structures as it once was owing to the much-extended use of iron and steel and reinforced concrete. There are, however, numerous occasions on which its use is still to be advocated, such as for temporary works, shuttering, centerings, piers and jetties, piles, moulds, etc., and the following Clauses are incorporated to deal with it :—

164. QUALITY OF TIMBER AND SAWING TO SCANTLINGS.—The whole of the timber supplied by the Contractor and put into the work shall be of the best quality, thoroughly seasoned, and fresh, straight in the fibre, free from sapwood, large or loose knots, breaks, shakes, or any imperfections, and all

timber condemned by the Engineer or by the Inspector as not being of the specified kind or quality must be removed from the Works at once.

All the timbers used in the Contract shall have all sides and ends sawn fair, straight, square, and uniform throughout.

165. Piles.—The piles are to be of selected greenheart (or, alternatively, of pitch pine or Oregon pine) in one length, at least 14 in. square, perfectly sound, straight, and free from defects of every description, dressed or sawn to take all cross-ties, wales, fenders, chocks, etc., and tenoned for the cope. The piles are to average . . . . ft. in length, but after the first pile is driven, should the Engineer consider it necessary to shorten or to lengthen the remainder of the piles, then the Contractor is to provide and drive piles to the depths fixed by the Engineer, and no additional price will be allowed to the Contractor for extra driving over his schedule rate per cubic foot.

The piles are to be carefully driven to a batter of 1 in 24. Any piles driven out of line, broken, split, or otherwise damaged, are to be drawn and replaced by the Contractor at his own expense, with piles of approved quality and dimensions.

The lengths given for the whole of the piles are the complete lengths, exclusive of shoes, to which the piles must be left after being driven and their heads cut off. Sufficient extra allowance in length must therefore be made in ordering the timber. A maximum variation of ½ in. will be allowed on either side in the scantlings. All piles shall be carefully pointed to fit their respective shoes without packing pieces of any kind, and proper allowance in length must be made for shoeing.

In the case of piles which are not driven to the full depth specified and shown on the drawings, the net length only of each pile as driven will be paid for, and the difference between the length shown on the Drawings and specified and the net length of each pile actually driven shall form a deduction from the contract amount at the relative schedule rate.

Note.—As timber increases in price per cubic foot with its length, for obvious reasons, the Contractor, without the provision contained in the first paragraph above, might justifiably claim for an extra price for his piling if it were longer than provided for or shown on the Drawings.

166. Sheeting Piles.—The longitudinal spaces between

the main or guide piles are to be filled in with sheeting piles accurately gauged, made up as hereinafter specified, and driven in two or three bays so as to fill completely the spaces between the guide piles.

If, in making up the bays of sheet piles, the adjacent faces are not fair when tried off the saw, the defective surfaces must be planed and made fair and joined closely throughout.

The driving faces, whether of guide piles, single sheet piles, or sheet piles in bays, shall have feather and groove junctions. They shall be grooved by proper machinery and accurately fitted with American white oak feathers of the same width as the grooves, and of the section and length shown, firmly fitted, when dry, and securely screwed into the groove with $\frac{3}{8}$-in. iron screws 7 in. long to a pitch of 24 in., the screw heads being countersunk.

The piles of each bay of two, three, or more sheet piles made up for driving are to be securely fixed together by oak dowels and wrought iron dogs driven a little below the flush, the dowels and dogs to be to the sizes, positions, and pitch shown on the Contract Drawings or as may be found necessary or directed. Proper clamps are to be used in making up the bays of piles.

If the increase or decrease in the width, or a variation in the pitch, of piles or bays of sheet piles renders it necessary to have a single closing pile, no extra payment will be made therefor.

When driving the sheet piles, proper temporary walings and other appliances are to be used to guide the piles properly so that they may drive evenly without twist in each case and so as to ensure a complete fit of the sheet piles with each other and also with the main guide piles and existing sheet piling, and the formation of a complete watertight casing.

The outside faces of the guide piles and the sheet piles driven between them shall be in one line and in one plane throughout the entire lengths of the lines of piling.

Since it is necessary to provide shoes and hoops for timber piles, these may be inserted here as follows :—

167. Pile Shoes and Hoops.—The Contractor shall provide all the iron main and sheet pile shoes of the best make and most suitable weight and shall fit and fix them substantially to the prepared pile points.

The form, weight, and method of fixing all pile shoes shall be determined by the Contractor, and he shall have the responsibility of their suitability for driving in any strata met with, but in all cases subject to the approval of the Engineer, whose approval shall not, however, relieve the Contractor of his responsibility. He shall use well-made and accurately fitted substantial hoops for the pileheads while driving, and shall be held responsible for their suitability in every respect.

Note.—Main pile shoes may be about 45 lb. each, made of cast iron, and including wrought iron straps for fixing. The sheet piling shoes are commonly made of wrought iron plate weighing about 40 lb. per foot.

Whilst on the subject of piles, the following Clause relating to Piling Machines may suitably be introduced :—

168. Piling Machines.—All the piling machines used on the Works shall be steam driven and of proper power and construction for the work. The rams for driving the main and guide piles shall be not less than 35 cwt., and the rams for driving the sheet piles not less than 55 cwt. in weight. The weight in each case shall be regulated to suit the stratum or strata and the depth to which the pile or bay of piles is to be driven. The drop of the ram shall in no case exceed 6 ft., and in no case shall the Contractor use a dolly without the approval of the Engineer in writing. The above shall not prohibit the Contractor using an automatic pile hammer should he so desire, so long as the latter meets with the approval of the Engineer.

In Dock and Harbour Work, the front of the wharf or quay, when the latter is constructed of timber, takes the form of a Cope, usually made of oak or pitch pine ; the front of the main piles is protected from chafing of ships by fenders which must be constructed of strong tough fibrous material such as elm, and the bracings of the piles and the other timber work are usually of pitch pine. Typical Clauses involving these are as follows :—

169. Cope.—The cope shall be of American white oak, shaped and fixed, 12 in. by 12 in. (to 15 in. by 15 in.), in lengths between centres of scarfings of not less than 24 ft. or as may be required to suit the respective bays. All scarfings to occur at piles. The cope to be tenoned on to the pileheads, the tenon

being full breadth of pile by 6 in. wide and 6 in. deep, and to be bolted to each pilehead with one rag bolt 25 in. by $1\frac{1}{8}$ in., let 1 in. into the cope, and the holes plugged up with cement or completely filled with oak plugs dipped in pitch and securely driven home.

170. FENDERS.—The fenders shall be of American rock elm, 12 in. by 6 in. (to 14 in. by 7 in.) in section, ... ft. in length, rounded top and bottom and fixed to each pile by rag bolts 14 in. long by $\frac{3}{4}$ in. diameter, 18 in. apart, and driven in 1 in. beneath the exposed surface of the fender, the hole being pointed up with neat cement. The fenders are to receive a coat of Stockholm tar before being fitted.

171. BRACINGS.—All bracings are to be of pitch pine, and accurately fitted to each other and to the piles, wales, and other timbers to which they are to be secured by two 1-in. diameter bolts at each intersection.

172. PLANKING.—The whole of the planking shall be 4 in. (to 6 in.) thick and not less than 9 in. wide and shall be in lengths of not less than four bays, and be butt-jointed in the middle between packing joists, the lengths to break joint and fall in line at every fourth plank transversely. Each plank is to be fixed to each joist by one $\frac{1}{2}$-in. spike 9 in. long, with two at the joists next the butt. All planking shall present a fair and uniform surface and shall be bedded solidly, evenly, and fairly on the joists with a $\frac{3}{4}$-in. space between the planks.

173. CREOSOTING.—All new timber, excepting the elm, greenheart, oak, and teak used in the works, shall be thoroughly creosoted with best creosote under pressure in a creosoting tank and plant, all as approved by the Engineer. (See also Clause 112, para. (6), p. 108.)

All new pitch pine shall have at least 6 lb. (up to 8 lb.) of creosote and the Oregon pine 9 lb. of creosote forced into each cubic foot of timber. Each piece of timber shall be weighed in the presence and to the satisfaction of the Inspector or other representative of the Engineer before and after being creosoted. Every piece found deficient in weight after being creosoted must be re-creosoted until the full weight of creosote has been injected, after which it shall be marked by the Inspector as passed for use on the Works.

No timber shall be creosoted until it has been prepared to the required form and properly dried, inspected, passed, and marked by the Inspector, and no new timber shall be used in the Works under the Contract without having the passing marks of the Inspector.

The cost of the creosoting shall be borne by the Contractor, and the prices for creosoting, including all expenses for cartage, weighing, etc., in connection with same, included in the price of the timber.

174. TARRING.—The fenders, copes, and all bearing surfaces, scarfs, tenons, mortices, checks, junctions, half-laps, crossings, laps, etc., and the ends of all timbers, are to receive two coats of tar, the covered portions of the fenders and copes to have the first coat before fixing. All tarring is to be done with tar put on hot. The tar is to be composed of two parts Archangel tar and one part coal tar (or of Stockholm tar).

175. STRUCTURAL STEEL.—One of the most important materials used in structural work is Steel, and the following is a summary of the British Standard for Structural Steel for Bridges, etc., and General Building Construction (No. 15/1948).[1]

No. 1 Quality steel to be made by Open Hearth Process (Acid or Basic) or by the Acid Bessemer process unless one of these processes is required or specified. It must not show on analysis more than 0·06 per cent. Sulphur or Phosphorus.

No. 2 Quality steel to be as above but containing copper to one of the following limits :—

(*a*) 0·20 to 0·35 per cent.
(*b*) 0·35 to 0·50 per cent.

Quality of Finished Steel.—Finished steel to be well and cleanly rolled to dimensions, sections, and weights specified or required ; sound and free from cracks, surface flaws, laminations, and rough, jagged, and imperfect edges, and all other defects ; finished in workmanlike manner, and comply with the specified tests.

Tensile Test Pieces.—To be cut lengthwise and crosswise

[1] Abstracted by permission of the British Standards Institution from B.S. No. 15/1948, official copies of which can be obtained from the Institution, 28 Victoria Street, Westminster, S.W.1.

from plates, and lengthwise from sections and bars. Not to be annealed or heat-treated unless material from which they are cut is similarly treated. Rolled surface (where practicable) to be retained on two opposite sides of test piece. Any straightening of test pieces required to be done cold.

Selection of Test Pieces.—To be selected by Purchaser or Engineer or Inspector—

(*a*) either from shearings or cuttings, or, if he so desire

(*b*) from the plates, sections, and bars, after they have been cut to the sizes required, in which case the plate, etc., must be paid for by the Purchaser if the tests are satisfactory.

Tensile Tests.—(*a*) Plates, Sections, and Flat Bars to have a tensile breaking strength of 28 to 33 tons per sq. in. of section, and elongation of not less than 20 per cent. for steel ⅜ in. thick and over, and not less than 16 per cent. for steel less than ⅜ in. thick, on a gauge length of 8 in., on Standard Test Piece A, Fig. 11.

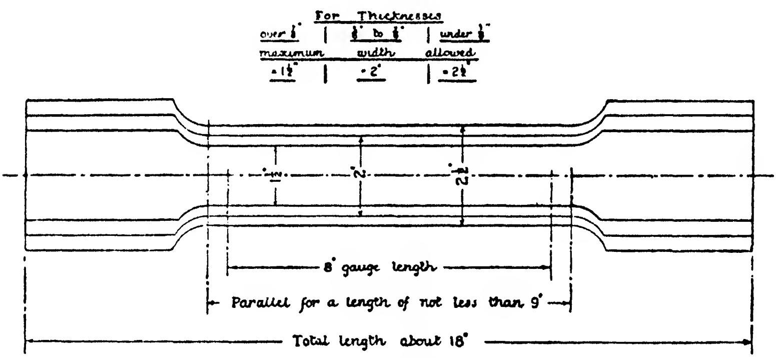


FIG. 11.—Standard Test Piece A.

(*b*) Round and Square Bars to have tensile breaking strength of 28 to 33 tons per sq. in. of section, and elongation of not less than 20 per cent. measured on the Standard Test Piece B, Fig. 12, or not less than 24 per cent. measured on the Standard Test Piece F, Fig. 13. The bars may be tested the full size as rolled.

(*c*) Rivet Bars to have a tensile breaking strength of 25 to 30 tons per sq. in. of section, and an elongation of not less than 26 per cent. measured on the Standard Test Piece B, Fig. 12, or not less than 30 per cent. measured on the Standard Test Piece F, Fig. 13. The bars may be tested full size as rolled.

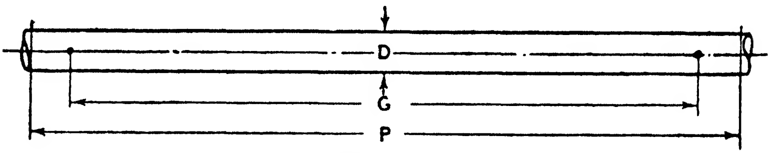


Fig. 12.—Standard Test Piece B.

Generally.—Provided that, for round and square bars, bend tests only shall be required for steel under ⅜ in. in thickness or diameter.

Cold Bend Test Pieces.—Bend Tests of all steel (other than rivet bars) to be made from test pieces sheared or cut lengthwise and crosswise from plates and lengthwise from sections and bars, and shall be not less than 1½ in. wide, unless in the case

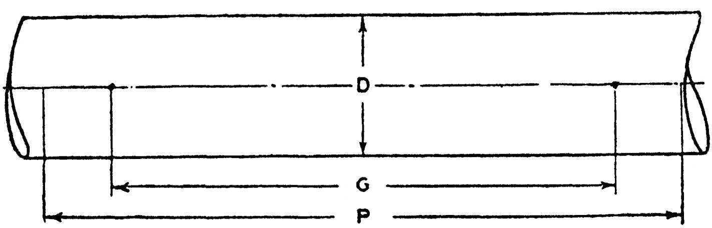


Fig. 13.—Standard Test Piece F.

where the section is less than 1½ in. wide, when round, square, and flat bars shall be bent in the full section of the bar as rolled. The rough edge or arris caused by shearing may be removed by filing or grinding, and pieces 1 in. in thickness and over may have the edges machined, but no other preparation. No annealing or heat treatment will be allowed unless the material from which the test pieces are cut is similarly treated.

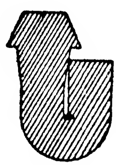
Selection of Cold Bend Test Pieces.—As for Tensile Test Pieces.

Cold Bend Tests.—Except in the case of round bars 1-in. diameter and under, to be doubled over, without fracture, 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. For round bars, 1-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 in. wide, the bend tests may be made from the flattened section.

Number and Kind of Tests of Manufactured Rivets.—To be selected from bulk in such numbers as may be specified or approved by the Purchaser or the Engineer, and to withstand the following tests :—

(*a*) Rivet shanks to be bent cold, and hammered until the two parts of the shank touch as shown in Fig. 14, without fracture on the outside of the bend.

(*b*) Rivet head to be flattened to 2½ times the diameter of the shank, while hot, in the manner shown in Fig. 15, without cracking at the edges.



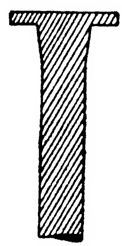


FIG. 14.—Bend Test for Rivets. FIG. 15.—Head Flattening Test for Rivets.

Tests by Chemical Analysis.—Shall be supplied by the Maker when required, or samples may be taken by the Purchaser or the Engineer for testing, at his own expense, by a metallurgist appointed by him.

Margin over and under Dimensions and Weights :—

(*a*) *Specified Lengths.*—When bars and sections are specified to be cut to certain lengths, from 1 in. under to 1 in. over shall be allowed, but when minimum lengths are specified up to 2 in. over shall be allowed.

(*b*) *Exact Lengths.*—When " exact " lengths are specified, the bars or sections shall be cold sawn or machined within a margin of ⅛ in. over and ⅛ in. under the specified length.

(*c*) *Weights.*—The rolling margin on sections, flat bars and round and square bars over ⅜ in. diameter shall be between

2½ per cent. over and 2½ per cent. under the specified weight unless a minimum weight is specified, when the margin shall be 5 per cent. over, or a maximum weight is specified, when it shall be 5 per cent. under, the margin to be ascertained separately for each section, and bars.

In the case of heat-treated wire, the tolerance shall be 1 per cent. over and 1 per cent. under the specified diameter unless a minimum diameter is specified, when the tolerance shall be 2 per cent. over ; or a maximum diameter is specified, when it shall be 2 per cent. under.

(*d*) *Cross Sectional Dimensions of Beams and Channels.*—The permissible upwards and downwards variation in the specified depths of these shall not exceed the following :—

Up to and including 12 in., $\frac{1}{8}$ in. upwards, $\frac{1}{32}$ in. downwards.
Over 12 in. up to and including 16 in., $\frac{5}{32}$ in. upwards, $\frac{1}{16}$ in. downwards.
Over 16 in. up to and including 24 in., $\frac{3}{16}$ in. upwards, $\frac{1}{16}$ in. downwards.

Calculation of Weights.—Plates to be calculated on the basis that steel weighs 40·8 lb. per sq. ft. per in. of thickness, and sections and bars on the basis that steel weighs 3·4 lb. per sq. in. of sectional area per ft. run.

176. BRITISH STANDARD FOR GIRDER BRIDGES.—No. 153 (parts 3, 4, and 5) 1937.[1] This specification is intended to apply to fixed Girder Bridges of spans up to and including 300 ft. between centres of bearings, and its principal provisions are as follows :—

For road bridges it may be assumed that each line of rolling load traffic for type "A" loading occupies a width of 10 ft. and for type "B" loading a width of 9 ft., and it is desirable that the width of carriageway should be a multiple of that distance.

Dead load.—The dead load carried by a girder or member shall consist of that portion of the weight of the superstructure, and the fixed loads carried thereon, which is supported wholly or in part by the girder or member (including its own weight),

[1] Abstracted by permission of the British Standards Institution from B.S. No. 153/1937, official copies of which can be obtained from the Institution, 28 Victoria Street, Westminster, S.W.1.

the following unit weights of materials being used in determining the load :—

Steel	489·6 lb. per cu. ft.
Wrought Iron	480 ,, ,, ,,
Cast Iron	450 ,, ,, ,,
Brickwork (engineering)	140 ,, ,, ,,
Brickwork (ordinary)	125 ,, ,, ,,
Concrete (cement)	140 ,, ,, ,,
Concrete (breeze)	90 ,, ,, ,,
Concrete (cement reinforced)	150 ,, ,, ,,
Ashlar (sandstone)	140 ,, ,, ,,
Ashlar (granite)	165 ,, ,, ,,
Macadam (waterbound)	160 ,, ,, ,,
Macadam (tar)	140 ,, ,, ,,
Asphalt (rock)	132 ,, ,, ,,
Asphaltic bitumen	90 ,, ,, ,,
Sand (wet compressed)	120 ,, ,, ,,
Ballast (slag or stone, screened, broken 1 in. to 2 in. ; or granite chippings)	90 ,, ,, ,,
Ballast (gravel)	112 ,, ,, ,,
Timber (pitch pine, etc.)	41 ,, ,, ,,
Timber (oak)	45 ,, ,, ,,
Timber (teak)	41 ,, ,, ,,
Timber (quebracho)	80 ,, ,, ,,
Snow (new fallen)	6 ,, ,, ,,
Basalt Sett Paving	170 ,, ,, ,,
Granite Sett Paving	160 ,, ,, ,,

Live Load.—The live load to be as specified by the Engineer, and, for rolling loads, preferably a multiple or multiples of one of the systems of unit loadings set out in Appendix No. 1. For pedestrian or equivalent light traffic, a minimum distributed load of 84 lb. per sq. ft. over the area so covered to be taken.

Impact Effect.—This shall be allowed for by additions to the live loads as follows :—

(*a*) Railway Bridges. Additions shall be made to allow for the effects of rail joints and track and wheel irregularities, and of the hammer blow of locomotives due to the balancing of reciprocating parts, or to the lack of balance of revolving parts. Guidance as to the appropriate values of these additions is given in Appendix 3 of the Standard.

(*b*) Road bridges. Additions to the live load, which shall cover all impact effects due to the vehicle and its load, or to irregularity of surface, shall be ascertained by multiplying the live load by a factor derived from the following formulae :—

(i) For bridges carrying one line of traffic only

$$I = 0{\cdot}75 - 0{\cdot}002\, l.$$ (with a maximum value of 0·60);

(ii) For bridges—carrying two or three lines of traffic

$$I = 0{\cdot}65 - 0{\cdot}002\, l.$$ (with a maximum value of 0·50),

where I = the factor and l = the effective span in feet.

Wind Pressure.—Where taken into consideration, this shall be treated as a moving load not subject to impact effect and assumed to act horizontally at a slight angle to the transverse axis of the structure so as to take effect on the exposed area of the flooring and the leeward parts in the case of openwork structure, except where any portion may be temporarily screened by a moving load. Where the leeward girder is at a distance from the windward girder not exceeding twice its depth, the effective area of the former shall be taken at half the exposed surface, but where the distance apart exceeds twice the depth, the whole exposed surface shall be taken into account.

When the structure is unoccupied by a moving load, the maximum pressure shall be assumed to be 50 lb. per sq. ft., but when there is a moving load thereon a pressure of 30 lb. per sq. ft. in the case of railway bridges, and 20 lb. per sq. ft. in the case of road bridges, shall be assumed as acting on the exposed surfaces both of the structure and the moving load, the pressure on the latter being taken as acting through the centre of gravity of the exposed area. The maximum results from the wind blowing in either direction, and with the structure loaded or unloaded, shall be taken.

Centrifugal Force.—Where a structure carrying a railway is situated on a curve, provision shall be made in designing the members for the stresses due to the centrifugal action of the moving loads, each track on the structure being considered as occupied. The allowance for the centrifugal effect shall be calculated from the following formula :—

$$C = \frac{WV^2}{15R}$$

where C = the centrifugal effect per lineal foot considered as a moving load acting at a height of 6 feet above the level of the rails, unless otherwise specified by the Engineer ;

W = the equivalent distributed live load per lineal foot ;

V = the allowable maximum speed of the train in miles per hour,

and R = the radius of the curve in feet.

No increase for impact effect shall be made on these stresses.

Longitudinal Forces.—Where a structure carries a railway, provision shall be made for the stresses due to the tractive effort of the live load and the braking effect resulting from the application of the brakes to such load while passing thereover, these forces being considered as acting at rail level.

(*a*) For railways worked by steam or electric locomotives, the amount of tractive effort on one track shall be ascertained by multiplying $1\frac{3}{4}$ times the maximum end shear due to the live load on that track by a factor equal to :—

$$\frac{20}{L + 75}$$

where L = the span in feet. The factor shall not exceed 0·15 as a maximum.

The braking effect shall be similarly determined by using a factor equal to :—

$$\frac{12}{L + 90} + 0{\cdot}075$$

also limited to a maximum of 0·15.

(*b*) In the case of lines worked solely on the electrical multiple unit system, the amount of the tractive effort on one track shall be ascertained by multiplying the sum of the actual wheel loads on the span by a factor equal to:—

$$\frac{3}{L - 10} + 0{\cdot}10$$

where L = the span in feet. The factor shall not exceed 0·20 as a maximum.

The braking effect shall be similarly determined by using a factor of 0·20 for all spans.

(*c*) Where the structure carries more than one track, all the tracks shall be considered as being occupied simultaneously by the live loads, tractive and braking forces being applied to alternate tracks. The maximum effect on any girder with two tracks so occupied shall be allowed for but, where there are more than two tracks, a suitable reduction may be made on these forces for the additional tracks at the discretion of the Engineer.

No increase for impact effect shall be made on these forces.

Temperature Effect.—Where any portion of the structure is not free to expand or contract under variations of temperature, allowance shall be made for the stresses resulting from this condition, the coefficient of expansion for each degree Fahrenheit in variation of temperature above or below the normal being taken at 0·000006.

Anchorage.—To be provided in any structure, wherever necessary, to the extent of at least 50 per cent. in excess of the overturning effect of the longitudinal and lateral horizontal forces which may be produced by any of the following conditions :—

(*a*) when the structure is fully loaded ;

(*b*) when wind pressure of the full force of 50 lb. per sq. ft. is acting on the unloaded structure ;

(*c*) where the structure carries a railway, when a wind pressure of 30 lb. per sq. ft. is acting thereon, the track, or, if more than one, the leeward track only, being assumed to be occupied by empty covered vehicles such as carriages or box vans of the lightest tare in use on the railway ; or

(*d*) where the structure carries a roadway, when a wind pressure of 20 lb. per sq. ft. is acting thereon, the leeward side of the carriageway being assumed to be occupied by a continuous line of vehicles of a height and weight to be specified by the Engineer.

Provision is to be made for that condition or permissible combination of conditions which produces the greatest effect.

Relief of Stress.—In riveted truss girders a reduction not exceeding 15 per cent. in the primary stresses (as calculated by rigid body statics) set up by dead load, live load, impact effect, and wind may be made before these primary stresses are combined with the stresses produced by deformation, centrifugal action (if any), longitudinal forces, and temperature.

Combined Stresses.—In designing a structure, members shall in the first instance be so proportioned that in no case shall the stresses (as calculated by rigid body statics) set up by the combined action of dead load, live load, impact effect, and lurching, and subject to any relief afforded by adjacent members, produce in any member a working axial stress exceeding the working stress specified in the Specification. The design shall then be analysed, as may be necessary, to determine the secondary stresses as detailed above. When these, together with any coexistent stresses due to wind, centrifugal force, longitudinal forces, and temperature, are combined with the primary stresses due to dead load, live load, impact effect, and lurching, it shall not be necessary to enlarge the sectional area of any member to meet the increased stress unless the working stress in that member is thereby raised to more than 20 per cent. above the specified working stress, in which case such additional material shall be provided as will bring the working stress within that limit.

Erection Stresses.—Where erection stresses, combined with the other permissible coexistent stresses, would produce a working stress in any member or part of the structure in excess of 20 per cent. above the specified working stress, such additional material shall be added to the section, or other provision made, as is necessary to bring the working stress within that limit.

Variation in Stresses due to Eccentricity of Loading.—Allowance to be made for this.

Bending.—The maximum working tensile or compressive stress on the outer fibres of any part subjected to bending only shall not exceed the respective specified limits of the direct axial stress.

When any member continuous over several points of support is subjected to bending in addition to axial stress, it shall be considered as a semi-continuous beam. In no case shall the section be less than that required for axial alone, nor shall the working stress on the outer fibres, due to the algebraic sum of the axial and the bending stresses, exceed the specified limits for the axial stress by more than 10 per cent. For the purpose of calculation, the maximum bending moments may be assumed to be three-quarters of that for a beam of span equal to the distance between adjacent points of support and freely supported at the ends, the bending moments at the points of support being taken as equal to that at the centre but of opposite effect.

Reversal Stresses.—Members subject to reversal of stress shall be proportioned for the stress requiring the larger section.

Working Stresses.—This British Standard gives full information as to the working stresses to be used in structural steel, special steels, cast steel, wrought iron, cast iron, and copper alloy, together with the frictional coefficients to be used in designing expansion bearings.

DETAILS OF CONSTRUCTION.

Effective Spans and Lengths.—For the purpose of calculating the bending moments, stresses, shears, and working strengths, the effective spans and lengths shall be taken as follows :—

For main girders, the distance between centres of bearing plates or rocker pins.

For cross girders, the distance between the centres of the main girders or trusses.

For rail or road bearers, the distance between the centres of the cross girders.

Where a cross girder or bearer terminates on an abutment or pier the centre of the bearing thereon shall be taken as one end of the effective span.

For web compression members :—

(*a*) where the web consists of a single system of triangulation, the distance between the centres of gravity of the upper and lower chords measured along the axis of the compression member ;

(*b*) where the web consists of more than one system, the effective length shall be taken :—

(i) between two points of intersection of the web members,

(ii) between one point of intersection and the centre of gravity of the chord, or

(iii) between the centres of gravity of the upper and lower chords,

whichever gives the greatest value of $\frac{l}{k}$ of the member,

where $l =$ effective length and $k =$ least radius of gyration.

For compression chords and end posts of truss girders, the effective length shall be taken in the weakest plane of bending, either between the points of intersection of the vertical or lateral bracing with the chords or end posts, or between the points at which rigidly connected cross girders rest on the chords. Where there is no lateral bracing between the compression chords, the effective length shall be taken as three-quarters of the length of the chord from centre to centre of the tops of the end posts, unless it is efficiently bracketed to the cross girders to give it adequate support, when the effective length may be reduced but shall not be less than the distance between alternate brackets.

For bending in pins the effective span shall be the distance between the centre of bearings.

Effective Depth.—The effective depth of riveted plate or truss girders shall be taken as the distance between centres of gravity of the upper and lower flanges of chords.

Sectional Areas.—The effective net sectional area shall be taken for all tension members. This area shall be the least that can be determined from any plane or planes cutting each component plate or section either perpendicularly to its axis, diagonally, or following a zig-zag line through adjacent rivet holes. From the gross sectional area in each case the cross sectional area of the plate or section cut out by the intersecting holes shall be deducted. Where any portion of the sectional area is measured along a diagonal plane, four-fifths only of the net area of such portion shall be taken in computing the effective area with a minimum equal to that obtained by assuming all the holes to be in one perpendicular plane.

The gross sectional area shall be taken for all compression members.

The shearing stress on the web plates of plate girders shall be calculated on the gross sectional area of the full depth of the web plate.

For rolled beams and channels, the gross sectional area of the web resisting shearing stress shall be calculated on the full depth of the beam or channel.

Symmetry of Sections.—All sections shall, as far as possible, be symmetrical about the line of resultant stress, and all rivets grouped symmetrically about the same line. The neutral axes of intersecting main members shall meet in a common point.

Minimum Sections.—No plate or bar less than $\frac{5}{16}$ in. in thickness shall be used in the main members of the structure when both sides are accessible for painting, nor less than $\frac{3}{8}$ in. when only one side is accessible, except where it is riveted to another plate or rolled section. In floor plates and parapets a minimum thickness of $\frac{1}{4}$ in. may be used.

No angle less than 3 in. by 2 in. shall be used for the main members of girders or trusses.

No angle less than $2\frac{1}{2}$ in. by 2 in. nor flat bar less than 2 in. shall be used in any part of a bridge structure, except for hand railing.

End angles connecting longitudinal bearers to cross girders or cross girders to main girders shall be not less in thickness than three-quarters of the thickness of the web plates of the longitudinal bearers and cross girders respectively.

PLATE GIRDERS.

Flanges and Webs.—The flange plates and flange angles shall be calculated as resisting the whole of the bending stresses, and web plates as resisting the whole of the shearing stresses, but one-eighth of the web plates may be included in the estimated sectional areas of each of the flanges if the web plates are efficiently covered at joints to transmit the horizontal stresses.

Flange Rivets.—The flanges of plate girders shall be connected to the web plate by sufficient rivets through the flange angles to transmit the horizontal shearing force, combined with any vertical loads, including impact effect, that are directly applied to the flange. The computed stress on any rivet shall be the resultant stress due to the horizontal shear and the shear from the vertical load.

The horizontal shearing force on the rivets per unit of length at any section may be calculated by the formula :—

$$F = \frac{S}{d} \times \frac{A_1}{A_1 + \frac{A_2}{8}}$$

where F = horizontal shearing force per unit of length;
S = total vertical shearing force at section being considered;
d = effective depth at the section being considered;
A_1 = gross sectional area of flange, neglecting portion of web included in area of flange,
and A_2 = gross sectional area of web plate.

Where railway sleepers rest directly upon the flanges, each wheel load shall be assumed to be uniformly distributed over a distance equal to twice the spacing of the sleepers with a maximum of 4 feet.

Flange Section.—Flange angles shall form as large a part of the area of the flange as practicable and the number of flange plates shall be reduced to a minimum. To obtain an even distribution of stress over the cross section of the flange plates, they shall not project beyond the outer line of rivets which pass through the flange angles more than sixteen times the thickness of the thinnest outside flange plate, or 8 in., whichever dimension is the smaller. The unsupported length of the compression flange between effective stiffeners or side brackets riveted to deep cross girders in the case of half through spans, or of the cross frames in the case of open deck spans, should not exceed eighteen times its width in the case of unstiffened edges, and 24 times its width in the case of stiffened edges, nor should the total length of the flange exceed forty-five times its width unless effective lateral stays are provided. At the end of each flange plate, rivets shall be provided at a pitch not exceeding four and a half diameters and equal in strength to that of the flange plate, and the part of the flange plate extending beyond its theoretical end shall contain half of these rivets.

Web Stiffeners.—Web plates shall be adequately stiffened on both sides over the bearing plates, and at all points of local and concentrated loads, and also at points throughout the length of the girder, generally not farther apart than the depth of the girder, with a maximum spacing of 6 feet, when the thickness of the web is less than one-sixtieth of the unsupported distance between the flange angles.

Stiffeners shall have sufficient area to carry the entire shear without exceeding the specified intensity of working stress.

Lateral Bracing.—In spans with open floors, rigid lateral diagonal bracing shall extend from end to end, of sufficient strength to transmit to the piers or abutments the lateral stresses due to wind pressure and centrifugal action.

The diagonal bracing shall, where possible, be rigidly secured to the rail or road bearers so as to transmit to the main girders the longitudinal thrust due to the tractive effort and braking effect, in order to relieve the cross girders of horizontal bending stresses.

In plated floors such bracing may be omitted where the plating is of sufficient strength to resist these forces.

RIVETED TRUSS OR LATTICE GIRDERS.

Chords and End Posts.—The top chords and end posts shall preferably be of trough section suitably stiffened at the edges. Both top and bottom chords shall also be stiffened where necessary by diaphragms, tie plates, or latticing. The overall width of top chords should preferably be not less than onefifteenth of the unsupported distance between points of intersection of the lateral bracing, or of substantial side brackets where the lateral bracing is omitted, nor should the total length of the chord exceed forty times its width unless effective lateral stays are provided.

Web Tension Members.—Shall preferably be of rigid construction, but may be flat bars, except near the centres of girders, where they shall be of rigid construction. Counter bracing, where employed, shall be of similar construction to the centre tension members. In order to reduce vibration, distance pieces shall be used between the plates or flat bars forming long tension members.

Where angle bars connected by one leg are used as tension members, the effective sectional areas shall be taken as that of the riveted leg added to half of the free leg.

Compression Members.—Shall, in no case, have a greater length than one hundred and twenty times their least radius of gyration, or forty-five times their least width. The open sides of long compression members shall be stayed with latticing, with or without intermediate tie plates.

Where the component parts of a member are laced together to form a unit, the ratio $\frac{l}{k}$ for any component part between the connections of the latticing shall be appreciably less than this ratio for the member as a whole.

To obtain an even distribution of stress over the cross section, the outstanding legs of compression members shall not project beyond the outer line of rivets which pass through the flange angles more than sixteen times their thickness unless suitably stiffened at the edges. The unsupported width at right angles to the line of resultant stress should not exceed forty times its thickness, and any excess over this width shall not be included in the effective sectional area.

At the ends of riveted columns or struts for a length equal to at least one and a half times the width of the member, the pitch of rivets shall not exceed four and a half diameters.

Latticing.—The latticing of compression members shall be proportioned to resist a transverse shear at any point in the length of the member equal to at least 2½ per cent. of the axial stress in the member, which shear shall be considered as divided equally among all transverse stiffening systems in parallel planes whether of continuous plates or of latticing.

The minimum width of lattice bars shall be :—

2½ in. for ⅞-in. rivets, 2¼ in. for ¾-in. rivets, and 2 in. for ⅝-in. rivets.

The minimum thickness of the lattice bars shall be not less than one-fortieth of the shortest distance between centres of rivets in the case of single latticing, and one-sixtieth of this distance for double latticing, riveted at the intersections. Rolled sections of equivalent strength may be used instead of flats.

Lattice bars should generally be inclined at an angle of about 60° to the axis of the member when single latticing is used, and at an angle of about 45° with double latticing ; furthermore, the maximum spacing of lattice bars shall be such that the ratio $\frac{l}{k}$ for the portions between consecutive connections of the latticing shall be appreciably less than this ratio for the member as a whole.

Lateral Bracing.—As for Plate Girders, but, in addition, where the depth permits, lateral bracing shall be fixed between the top chords of main girders of sufficient rigidity to maintain the chords in line, and of sufficient strength to transmit the wind pressure to the portal bracing between the end posts.

Overhead Cross Bracing between Struts.—Shall be proportioned to carry at least 50 per cent. of the panel load due to wind, and the struts shall be designed to resist the bending stresses from the wind loads.

Portal Bracing.—Of the maximum depth consistent with the required headroom shall be riveted to the end posts. Rigid knee-brackets shall be riveted to the portal bracing and end posts. In determining the sectional area of the end posts, provision must be made for the bending stresses due to the wind pressure. The end posts may be considered as fixed at the ends.

Spacing and Depth of Trusses.—The width between centres of main trusses should be sufficient to resist overturning with the specified wind pressures and loading conditions, otherwise provision must be made to prevent this. In no case shall this width be less than one-twentieth of the effective span, nor shall the depth of the trusses be greater than three times the width between centres of trusses.

Joints.—The butting ends of all spliced members, whether in tension or compression, shall be fully covered and riveted to develop the effective strength of the member.

Web joints shall have double covers of adequate width to admit of sufficient rivets to transmit the whole of the shearing stress at the joint. Where a portion of the web is included as flange section, the web covers and their connecting rivets shall be proportioned to transmit bending as well as shearing stresses.

The sectional area shall be not less than 5 per cent. in excess of the section covered in the case of symmetrical covers, and 10 per cent. in the case of unsymmetrical covers.

The centre of gravity of the covers shall coincide as nearly as possible with the centre of gravity of the section covered.

RIVETS, BOLTS, AND PINS.

Effective Diameter.—In calculating the number of rivets required, the diameter of the closed rivets shall be taken as the effective diameter for calculating area.

Rivets, bolts, or pins in double shear shall be considered as having twice the shearing strength of those in single shear.

The effective bearing area of a pin, rivet, or fitted bolt shall be the diameter multiplied by the thickness of the member or unit transmitting or receiving the stress, except that for rivets or bolts with countersunk heads half of the depth of the countersink shall be omitted. In the case of black bolts three-quarters of the diameter shall be taken.

Net Section at Rivet and Bolt Holes.—In deducting for snap-headed rivets or for bolts, the diameter of the hole shall be taken as the diameter of the finished rivet or bolt as marked on the Drawings, and as ⅛ in. larger for holes countersunk in the outer plate or section.

Minimum Pitch of Rivets.—The distance between centres of rivets shall be not less than three times the diameter of the rivet.

Maximum Pitch of Rivets.—In built tension members the rivet pitch shall not exceed sixteen times the thickness of the thinnest outside plate or angle except in angles having two lines of staggered rivets, where the pitch on each line may be twice this limit, but it shall not exceed 12 in. on each line of staggered riveting. In built compression members the rivet pitch shall not exceed twelve times the thickness of the thinnest outside plate or angle except in the case of angles having two lines of staggered rivets, where the pitch on each line may be one and a half times this distance, but not more than 12 in. In no case shall the rivet pitch exceed 8 in. for single riveting.

Edge Distance of Rivets.—The minimum distance from the centre of any rivet to a sheared edge shall be :—

$1\frac{3}{4}$ in. for 1-in. rivets ; $1\frac{1}{2}$ in. for $\frac{7}{8}$-in. rivets ; $1\frac{1}{4}$ in. for $\frac{3}{4}$-in. rivets, and $1\frac{1}{8}$ in. for $\frac{5}{8}$-in. rivets.

and, to a rolled or planed edge :—

$1\frac{1}{2}$ in. for 1-in. rivets ; $1\frac{1}{4}$ in. for $\frac{7}{8}$-in. rivets ; $1\frac{1}{8}$ in. for $\frac{3}{4}$-in. rivets, and 1 in. for $\frac{5}{8}$-in. rivets.

Where two or more flange plates are employed, the edge distance from the centre line of the nearest rivet shall be not greater than eight times the thickness of the thinnest outside plate.

Rivets through Packings.—Rivets carrying calculated stress and passing through packings over $\frac{3}{8}$ in. in thickness shall be increased by at least 20 per cent. over the net number required. The additional rivets shall preferably be placed outside one of the connected members.

Provision for Temperature and Deflection.—Where provision for expansion and contraction due to changes of temperature is necessary, it shall be provided to the extent of not less than 1 in. for every 100 ft. of length. The expansion bearings shall allow free movement in a longitudinal direction and at the same time prevent any transverse motion. Where the span exceeds 100 ft. in length, bearings shall be provided at both ends of the main girders to permit deflection of the girders without unduly loading the face of the abutment or pier.

Loads.—All dead loads shall be assumed to be evenly distributed in the case of plate girders, except the load brought upon the main girders from the cross girders when they exceed 10-ft. centres. In the case of lattice or truss girders, the dead load shall be assumed to be concentrated at the panel points.

177. CAST IRON PIPES AND SPECIAL CASTINGS.—The British Standards Institution issue a Standard (No. 78/1938)[1] for Cast Iron Pipes (vertically cast) for Water, Gas, and Sewage, the main provisions of which are as follows :—

Quality of Metal used in Casting the Pipes.—The metal used for casting the pipes shall be a suitable mixture of pig iron and scrap, and shall be remelted in the cupola or air-furnace. The pig iron shall be best tough grey foundry pig iron, and the scrap shall be clean, unburnt, and of good quality. There shall be no admixture of cinder iron or any material calculated to render the metal inferior in quality, and the resulting casting shall not be white or vitreous on fracture.

Tests.—The dimensions of test bars, numbers of transverse and tensile tests to be made, the minimum breaking loads and deflections required, etc., are all given in this British Standard.

Mode of Casting.—The straight pipes shall be cast vertically in dry sand moulds formed from turned iron patterns and in accurately faced and truly jointed boxes, and without the use of core nails, chaplets, or thickness pieces, or any substitute therefor. They shall be cast with a sufficient head of metal to ensure soundness, which head shall be afterwards cut off in a lathe and the finished pipe left the length and shape required. Spigot and socket pipes shall be cast socket downwards.

The pipes shall not be removed from the moulds until cooling has proceeded so far as to prevent all risk of straining, cracking, or other injury consequent on their removal.

Freedom from Defects.—The pipes to be in all respects sound and good castings, easily worked with a drill or file, free from laps or other imperfections. They shall be neatly dressed and carefully fettled so that no lumps or rough places shall be left in the barrels or sockets ; their inner and outer surfaces shall be smooth, and the inner edge of the sockets shall be left reasonably square.

Tests for Straightness, Regularity of Thickness, etc.—Each straight pipe shall be tested for straightness, regularity of thickness, and diameter, by being rolled on a level iron gantry and by the use of suitable straight edges, gauges, and callipers,

[1] Abstracted by permission of the British Standards Institution from B.S. No. 78/1938, official copies of which can be obtained from the Institution, 28 Victoria Street, Westminster, S.W.1.

which, with the iron gantry, are to be provided and maintained in proper condition for the purpose by the Manufacturer.

Plain Sockets and Tests thereof.—Great care must be taken with plain sockets in spigot and socket pipes, that the sockets will in all cases receive the spigots, and that the spigots will in all cases enter to the bottom of the sockets. The internal diameter of the plain sockets of the straight pipes shall not deviate by more than $\frac{1}{8}$ in. above or below the specified diameter, and the internal diameter of the plain sockets of the special castings by more than $\frac{3}{16}$ in. above or below the specified diameter. Manufacturers shall provide and use iron templates of suitable dimensions which shall be passed to the bottom of every socket, and circular iron rings of suitable dimensions which shall be passed over every spigot.

Half Turned and Bored Joints and Tests thereof.—Spigot and socket pipes having half turned and bored joints shall have the spigots accurately turned and the sockets accurately bored, and these shall be conical, having a taper of $\frac{1}{16}$ in. measured on the diameter per inch of length (i.e. 1 in 32). When fitted tightly together the spigot end of each pipe shall have a clearance space as shown by dimension 'Q' in tables 4 and 5, between it and the bottom of the socket of the pipe into which it is inserted. Suitable coned gauges shall be provided and applied by the Manufacturer to every pipe.

Length of Straight Pipes.—The standard lengths of the straight spigot and socket pipes (exclusive of the internal depth of the sockets), and of the straight flange pipes (measured over the flanges), shall be as follows :—

Pipes, $1\frac{1}{2}$ in. and 2 in. internal diameter :—spigot and socket, and flange, 6-ft. lengths;

Pipes, $2\frac{1}{2}$ in. and 3 in. internal diameter :—spigot and socket, and flange, 9-ft. lengths;

Pipes, 4 in. to 12 in. inclusive, internal diameter :—spigot and socket, and flange, 9 ft. or 12 ft. as may be specified;

Pipes, 14 in. to 48 in. inclusive, internal diameter :—spigot and socket, and flange, 12-ft. lengths,

with a permissible variation in the spigot and socket pipes of not more than $\frac{1}{2}$ in., and the flange pipes of not more than $\frac{1}{8}$ in. under or over the standard lengths.

Hydraulic Test.—Before being coated, the straight pipes shall respectively withstand hydraulic test pressures without showing any leakage, sweating, or other defects of any kind varying from 200 ft. head for gas pipes to 400, 600, or 800 ft. head for water pipes (depending on the thickness of metal). While under the test pressure each pipe shall be smartly struck with a suitable hand hammer weighing not less than 1½ lb.

In addition, the Engineer shall have power to select for the hydraulic test any Special Castings he may require.

The working pressure on the pipes should not exceed half the test pressure.

Coating.—As soon as each pipe has satisfactorily withstood the hydraulic tests, and before it shall have become affected by rust, it shall be heated to a suitable temperature not exceeding 250° F. and perfectly coated by being dipped (except in the case of pipes which are to be only partially coated) in a bath of approved composition having a tar base, and maintained at a temperature between 290° F. and 330° F. When removed from the bath the pipe shall be properly drained and the coating must fume freely, and set hard within an hour, otherwise the pipe shall be re-coated.

In the case of gas pipes, the coating shall, except when otherwise specified, be applied only to the exterior of the pipe, and shall be carried up to a distance from the spigot end equal to one and a half times the depth of the socket.

All faced pipes and all turned and bored joints shall, before they become affected by rust, have their machined surfaces coated with a mixture of white lead and tallow or other approved protective composition.

General.—In the British Standard are given complete tables of standard dimensions and standard weights of straight pipes, and particulars of standard bends, tees, branches, tapers, collars, and flanges.

178. CAST IRON PIPES FOR HYDRAULIC POWER.—Cast iron pipes are commonly used for Hydraulic Power, and these are covered by the following Standard issued by the British Standards Institution (No. 44/1909),[1] which contains the following provisions :—

[1] Abstracted by permission of the British Standards Institution from B.S. No. 44/1909, official copies of which can be obtained from the Institution, 28 Victoria Street, Westminster, S.W.1.

Pipes and Castings.—The Straight Pipes, Bends, Tees, and Special Castings shall be manufactured in two classes, viz. :—

Class " A " for working pressures from 700 lb. to 900 lb. per sq. in. and

Class " B " for working pressures from 900 lb. to 1,200 lb. per sq. in.

Quality of Material.—Cast iron for these shall not be from first runnings, but shall be remelted in the cupola or air-furnace. It shall be made from a mixture of strong grey cast iron, the composition of which shall be left to the discretion of the Manufacturer. The metal shall be sufficiently tough to allow of the castings being readily drilled and tapped with a clean and strong thread.

Mode of Casting.—The whole of the Straight Pipes, and the Bends, Tees, and Special Castings when practicable, shall be cast vertically, in dry sand moulds and in accurately faced and truly jointed boxes, and without the use of core nails, chaplets, or thickness pieces, or any substitute therefor. They shall in all cases have a sufficient head of metal to ensure soundness, which head shall be afterwards cut off in a lathe.

Freedom from Defects.—The castings shall be true and cylindrical, their inner and outer surfaces being smooth and as nearly as may be concentric. They shall be in all respects sound and good castings, free from laps or other imperfections, and shall be neatly dressed and carefully fettled.

Machining.—The castings shall have their faces, spigots, and faucets, truly machined to templates. They shall be truly machined to length and shall be interchangeable in all dimensions.

Deflection Test.—A bar, 1 in. wide and 2 in. deep and 3 ft. 6 in. in length, when supported on edge on bearings 3 ft. apart shall sustain a load of 30 cwt. applied at the centre with a deflection of not less than $\frac{3}{8}$ in. The bar shall be tested to destruction.

Hydraulic Test before Coating.—Before being coated the castings shall be tested under cover and must withstand a hydraulic pressure of 2,500 lb. per sq. in. for Class "A" and 3,300 lb. per sq. in. for Class "B" without showing any leakage, sweating, or defect of any kind.

Coating.—Every casting, after having been tested, and before it shall have become affected by rust, shall be heated to a

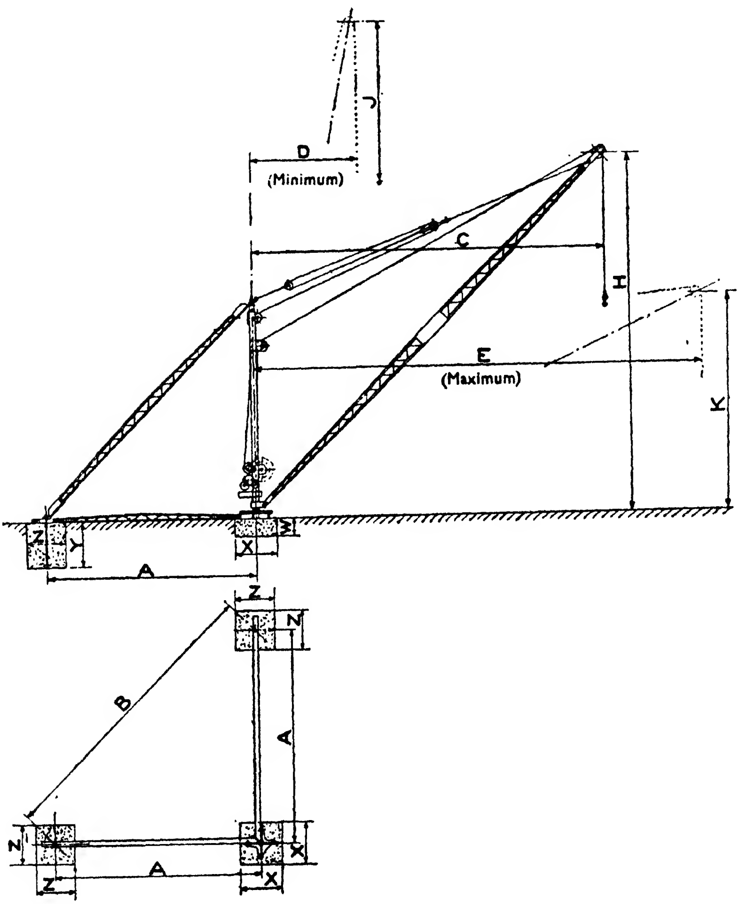


FIG. 16.—Diagram of " Scotch Derrick " Type of Crane.

suitable temperature and dipped in a bath of approved composition.

Spun-iron Pipes.—There is a British Standard No. 1211 which covers cast iron pipes made by the centrifugal process in either metal or sand moulds.

179. DERRICK CRANES (POWER DRIVEN).—This Standard (No. 327/1930)[1] applies to power driven Derrick Cranes of

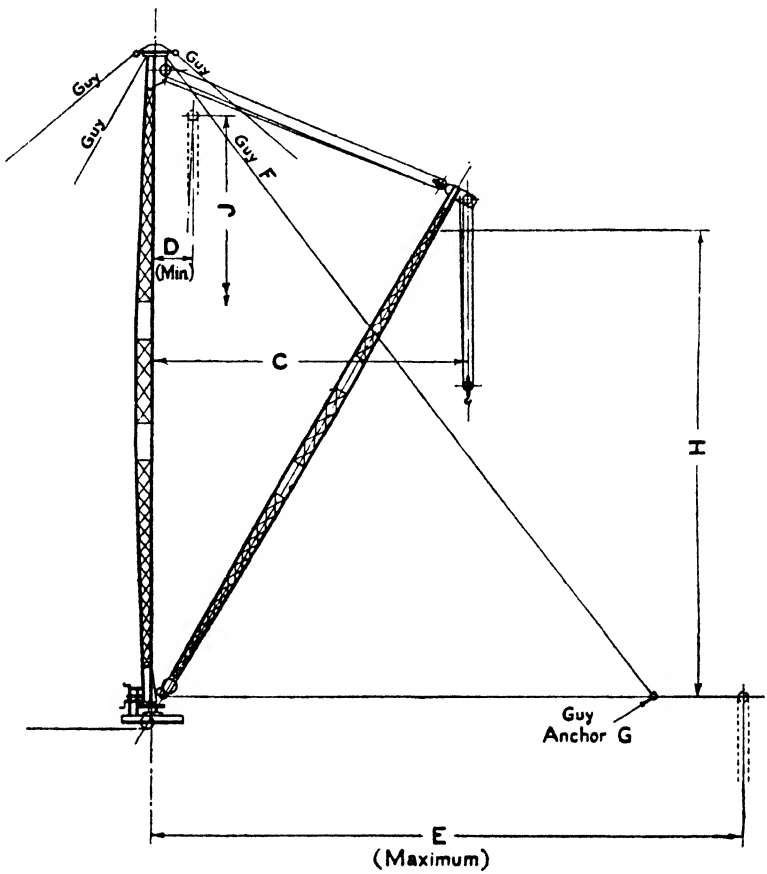


FIG. 17.—Diagram of " Guy Derrick " Type of Crane.

the " Scotch Derrick " or " Stiff Legged ", " Guy Derrick ", and " Tower Derrick " types. See Figs. 16, 17 and 18.

[1] Abstracted by permission of the British Standards Institution from B.S. No. 327/1930, official copies of which can be obtained from the Institution, 28 Victoria Street, Westminster, S.W.1.

With the inquiry or order, the following particulars should be supplied :—

(1) Type of crane and nature of drive—electric, steam, oil engine, compressed air, or hydraulic.

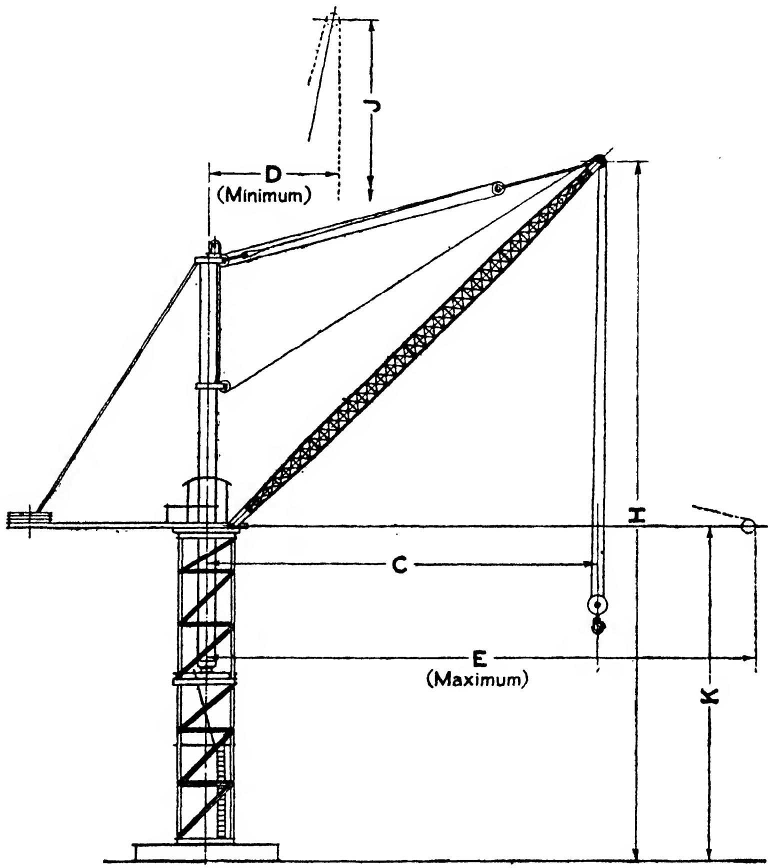


FIG. 18.—Diagram of " Tower Derrick " Type of Crane.

(2) *a.* Nature of electric supply, d.c. or a.c. .... volts, ... phase, ... periods.

b. Air pressure.

c. Hydraulic pressure.

(3) Capacity of crane .... tons (max. load) at .... ft. radius.

Capacity of crane .... tons (max. load) at .... ft. radius.

(4) Maximum and minimum height of lift (J and K, Figs. 16, 17, and 18) .... ft. at (D and E, Figs. 16, 17, and 18) .... ft. radius.

(5) Depth of lift (below baseplate) .... ft. at .... ft. radius.

(6) Speeds :—Hoisting (full load) .... ft. per min.
Hoisting (.... tons) .... ft. per min.
Slewing (full load) .... ft. per min.
Derricking (full load) .... ft. per min.

(7) Nature of foundations.

(8) Specifications and/or Surveys to be complied with :—
General.
Ropes and rope attachments.
Boiler.
Electrical equipment including type and rating of motor.

(9) Duty for which crane is required.

(10) Other requirements.

(11) *a.* Maximum and minimum radii of guying rope anchorages required with a sketch plan if possible.

b. Whether special anchors for the guy ropes are required.

With the tender the Manufacturer should supply the following information regarding the construction of the crane :

(1) Type offered .... Drawing No. ......

(2) Capacity :—
.... tons (max. rated load) at .... ft. radius.
.... tons („ „ „) at .... ft. radius.
.... tons (overload test load) at .... ft. radius.

(3) Height of hook .... ft. at .... ft. radius.
.... ft. at .... ft. radius.

(4) Depth of lift below baseplate .... ft. at .... ft. radius.

(5) Jib, length .... ft. ; angle of swing .... degrees.

(6) Centres between pivot and anchorage (sleeper centres, A, Fig. 16, or horizontal distance from pivot point of crane to intersection with opposing guy).

(7) Back cross centres of sleeper and anchorage (B, Fig. 16).

(8) Ballast required at anchorage of each sleeper or guy .... tons to give .... per cent. margin of stability when lifting .... tons at .... ft. radius.

(9) Maximum downward load on crane base (XX, Fig. 16) = ... tons.

(10) Maximum downward load on the anchorage of each

back leg (ZZ, Fig. 16) = ... tons plus the weight of the ballast provided.

(11) Speeds :—

Motion	*Maximum rated Load (.... tons) ft. per min.*	*Light Load (.... tons) ft. per min.*
Hoisting, slow gear	....	....
Hoisting, fast gear	....	....
Slewing – –	....	....
Derricking – –	....	....

(12) *a.* Dimensions of engines ....

b. Dimensions of boiler ....

c. Description of boiler ....

d. Working pressure of boiler. ....

e. Capacity of water tank .... gallons.

f. Nature of boiler feed arrangement ....

(13) *a.* Number of motors .... Type ....

b. B.h.p. and speed of motors at full load ....

c. Rating of motors . . . ° F. temperature rise after .... hours.

d. Maximum current demand from mains ....

e. Particulars of electrical equipment ....

(14) Construction of gearing, cast or cut ....

Material of gearing ....

(15) Ropes ..... Type.

Circumference.

Hoist ..... in. Derrick ..... in.

Guaranteed breaking load.

Hoist ..... tons. ,, ... tons.

Falls. ,, ... ,, ,, ... ,,

Factor of safety.

Hoist ..... ,, ,, ... ,,

(16) Diameter drums (at bottom of groove) : Hoist..... in. Derrick ..... in.

(17) Diameter pulleys (at bottom of groove) : Hoist ..... in. ; Derrick ..... in.

(18) Hook particulars ....

(19) Type of crane housing ....

(20) Type of safety and indicating devices ....

(21) Type of brakes ....

(22) Type of tools and accessories supplied ....

(23) Factors of safety provided in various parts ....

(24) Approximate total weight in tons...................

(25) Shipping particulars (if required) ....

The materials, etc., used in the construction of the crane shall comply with the appropriate British Standards.

No timber shall be used in any stress-bearing part of the crane structure.

The crane shall bear a legible and permanent inscription naming the *length* of the jib, the maximum rated load, and the radius appropriate thereto.

For cranes of variable radius, clear indication of the permissible loads at the various radii shall be given by means of an automatic radius indicator and a safe load indicator and/or table.

When change speed gear is used on the lifting motion, the maximum rated load for each speed shall be similarly indicated.

A table of maximum rated loads at all working radii together with the associated minimum radii of the opposing guys shall be provided for guy derrick cranes.

The factor of safety for all parts of the crane structure shall be not less than 4½, except where a maximum allowable working stress is specified. This factor, and the allowable working stresses, include allowances for impact and acceleration, except in the case of the acceleration and retardation of the slewing motion which shall be assumed to be not less than 1 ft. per sec. at the jib head when the crane is working at the radius at which the maximum stress is induced (not to apply to cranes with manually-operated slewing motion), and in the case of the jib and its attachments which shall be designed to withstand :—

(*a*) All the stresses arising under all working conditions.

(*b*) The bending and shear stresses caused by slewing the jib in either direction, with an assumed acceleration of 1 ft. per sec. per sec., measured at the jib head.[1]

In the case of Struts (which includes Masts, Jibs, Back Stays, and Sleepers), the slenderness ratio $\frac{l}{r}$ of any members entirely of lattice construction shall not exceed 100, l being the full length of the strut in inches and r the minimum

[1] Not to apply to cranes with manually-operated slewing motion.

radius of gyration in inches of any cross section within the middle third of the length. For the purpose of this clause, where a strut consists of two channels or plated sections connected by latticing, the ratio $\frac{l}{r}$ shall not exceed 100 in the latticed direction.

The latticing and plating of a strut member shall be proportioned to resist the maximum transverse shear at any cross section, such shear being assumed to be divided equally between the planes of bracing concerned, but the value allowed for transverse shear in the direction of each principal axis of the cross section shall in no case be less than 2½ per cent. of the maximum axial load under full working conditions, plus the shear at such planes of bracing due to simultaneous transverse loads on the member.

The factor of safety for struts should not be less than 4½.

NOTE.—Suitable formulae for the calculation of the stresses in struts due to (*a*) Axial Compression, (*b*) Combined Axial Compression and Bending, (*c*) Allowance at Ends of Struts of Uniform Section, and (*d*) Component Parts of Lattice Struts are appended in the British Standard as a guide to users and designers.

The working stress in shear for steel rivets and bolts used in the crane structure shall not exceed 4½ tons per sq. in., and in bearing shall not exceed 10 tons per sq. in. when the stress is unidirectional, and 7 tons per sq. in. when the stress is subject to reversal.

The tensile stress on the net section of a bolt or set screw other than those used in the Crane Structure shall not exceed 3 tons per sq. in. for steel, or 2½ tons per sq. in. for wrought iron.

The breaking load of the lifting and derricking ropes shall be not less than six times the maximum dead working load thereon.

The breaking load of a guying rope (assuming that in service the guys will be spaced not more than 60° apart in plan) used for Guy Derrick cranes shall be not less than 2½ times the maximum tension induced therein on the assumption that only one guy rope is opposing the load. Sockets, thimbles, and rope anchorages shall be capable of withstanding 90 per cent. of the guaranteed breaking strength of the rope or ropes to which they are attached, and eye splices 75 per cent.

Gearing shall have a factor of safety of not less than 6 under full working conditions, which factor includes allowances for impact and inertia.

The factors of safety given do not cover prime movers or shafting.

It should be noted that the minimum factors of safety and the allowable working stresses referred to above are only applicable to cranes intended for ordinary duty. A higher factor of safety and proportionately lower allowed working stresses are essential for duty of greater severity or where there is a liability to accidental overloads as in dockside, quarrying, or magnet cranes.

The crane shall be designed and constructed for operating under a steady wind pressure of not less than 5 lb. per sq. ft. When at rest under storm conditions, the crane shall be capable of withstanding a steady wind pressure of not less than 35 lb. per sq. ft. In both cases the calculation shall be made on an area equivalent to 1½ times the projected area of the unloaded crane, except for cabins, machinery houses, and other single surfaces, of which the projected area only shall be taken.

The anchoring and/or ballasting of the crane shall be such as to ensure that with the jib in any position the righting moment will be at least 50 per cent. greater than the overturning moment imposed under full working conditions or under storm conditions.

In determining the stability of a crane used with a grab an equivalent hook load of 1·33 times the combined weight of the load and grab should be assumed.

The diameters of the drums used shall be not less than the following for speeds not exceeding 120 ft. per min. when dealing with full load.

Minimum Drum Diameter (D = Diameter of Rope).

Class of Material.	4×37	6×19	6×24	6×37	6×61
80–110 tons -	20D	23D	19D	16½D	13D
110–130 tons -	23D	27D	22D	19D	15D

For each increase in full load speed of 60 ft. per min., 2D shall be added to the diameter of the drum.

The diameter of lifting-rope and derricking-rope pulleys at the bottom of the groove shall be not less than that of the drums specified above.

Hoisting-motion brakes shall be designed to exert a restraining torque 25 per cent. greater than the torque transmitted under full working conditions to the brake drum from the suspended maximum rated load, and the stresses in any part of the brake construction while such restraining torque is being exerted shall not exceed one half of those allowed for the respective materials in this Specification.

Brakes applied by hand shall not require a force greater than 35 lb. at the handle, and those applied by foot a force more than 70 lb. on the pedal to exert the full restraining torque.

Crane boilers shall be designed and constructed to give a minimum factor of safety of 5 at the intended safety valve load, and on completion shall be tested hydraulically to a pressure 1½ times the intended safety valve load.

Before being put into service the crane shall have each motion tested under the following conditions :—

(*a*) When the hook is carrying the maximum rated load at the specified radius.

(*b*) When the hook is unloaded.

(*c*) When the hook is carrying an overload of at least 25 per cent. in excess of the maximum rated load under conditions (*a*) of this paragraph.

(*d*) Braking under maximum rated load conditions.

During the tests (*a*) and (*b*) the speeds enumerated in para. (11) of the information to be supplied by the Manufacturer shall be substantially as specified. The derricking motion shall be tested in both directions between the maximum and minimum radius, and the slewing motion shall be tested in both directions through the maximum angle for which the crane is designed to slew.

During the test (*c*) the specified speeds need not be attained but the crane shall show itself capable of dealing with the overload without difficulty.

Where two surfaces will be in permanent contact, each shall receive, immediately before being assembled and after being thoroughly scraped and cleaned, one coat of hot linseed oil, red-lead, or oil paint, the surfaces being brought together while the oil is still wet.

Two coats of paint conforming to British Standard No. 261 [Ready-mixed Paints (Oil Gloss), Tinted Paints (White Lead Base)] or No. 295 (Red Oxide of Iron Paint, Oil Gloss) shall be applied to all structural parts of the crane before they leave the Manufacturer's works. No painting or oiling shall be carried out unless the surface of the metal is dry, and the first coat shall be allowed to dry thoroughly before the next is applied.

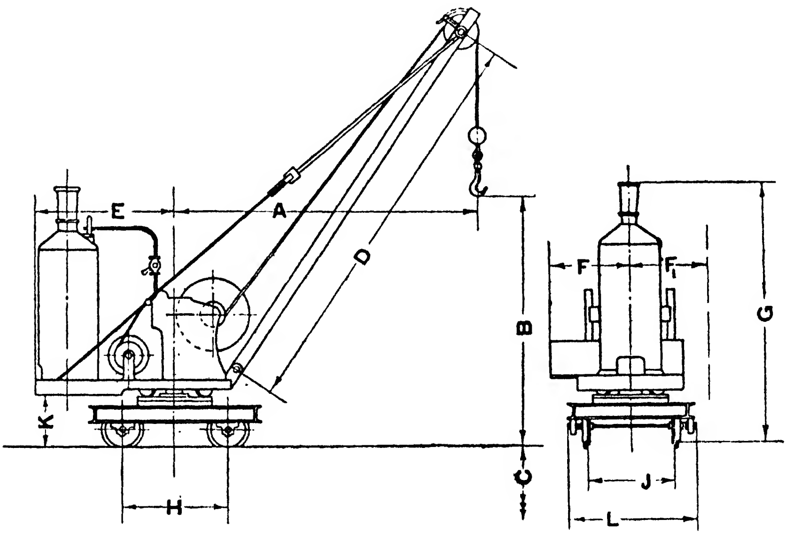


FIG. 19.—Steam Travelling Jib Crane.

180. DERRICK CRANES (HAND OPERATED).—Part 2 of this Standard (No. 327/1930) applies to hand-operated Derrick Cranes and is identical, so far as the clauses apply, to that given above for Power-driven Derrick Cranes. With regard to manual power, it is assumed that a man, when turning a handle, exerts a mean force of 25 lb. continuously or 40 lb. as a maximum upon the handle, and that the mean speed (at handles) is 150 ft. per min.

181. TRAVELLING JIB CRANES (CONTRACTOR'S TYPE).—A further Standard for Cranes is that issued by the British Standards Institution for Travelling Jib Cranes (Contractor's

Type) (No. 357/1930),[1] which incorporates the following provisions :—

With the inquiry or order the following particulars should be supplied :—

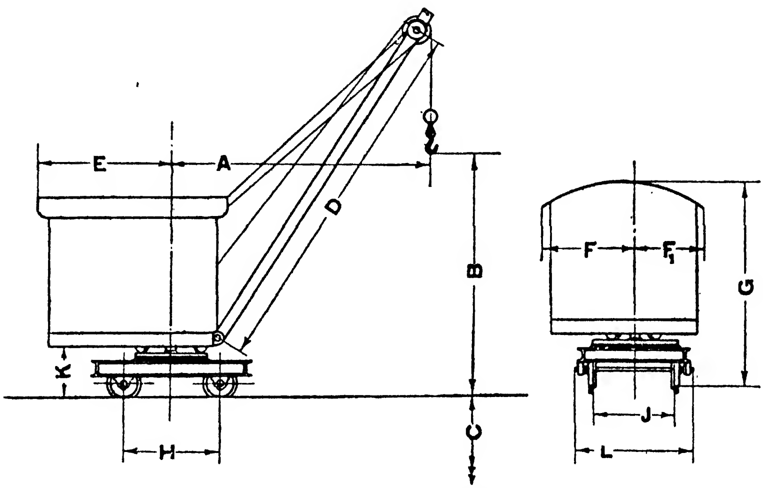


FIG. 20.—Electric Travelling Jib Crane.

(1) Duty for which crane is required.
If required for grabbing, state :—
(*a*) Type of grab, e.g.
single rope with ring discharge, or
single rope with dumping discharge, or
double rope.
(*b*) Class and specific gravity of material to be grabbed.
(*c*) If grab is to be supplied by crane builder or purchaser.
In the latter case state gross weight of grab and contents.

(2) Will the crane work on the ground or on a building or gantry ?

(3) Capacity of crane ..... tons (max. load) at ..... ft. radius (A).

..... tons at ..... ft. radius.

For grabbing cranes state quantity in cubic feet, or weight of material to be grabbed at each lift.

[1] Abstracted by permission of the British Standards Institution from B.S. No. 357/1930, official copies of which can be obtained from the Institution, 28 Victoria Street, Westminster, S.W.1.

(4) Nature of drive :—

(*a*) Hand.

(*b*) Steam.

(*c*) Electric—state whether d.c. or a.c. and volts, number of phases and periods, and type and rating of motor.

(*d*) Internal combustion engine—state character of fuel.

(*e*) Compressed air—state pressure.

(5) Travelling track.

(*a*) Gauge (J)—state whether the crane must travel with the maximum load at its rated radius or if it can be blocked up for this duty.

(*b*) Weight and class of rail.

(*c*) Maximum permissible load per wheel.

(*d*) Radius of sharpest curve.

(*e*) Maximum gradient.

(6) Range of lift of underside of hook—from ..... ft. below rail level (C) to ..... ft. above (B) max. at ..... ft. radius.

(7) Maximum permissible tail radius (E) ft.

(8) Speeds :—Hoisting (max. load) ..... ft. per min.
,, (light load) ..... ,, ,, ,,
Slewing (max. load) ..... ,, ,, ,,
Derricking (max. load)..... ,, ,, ,,
Travelling (max. load) .... ,, ,, ,,

(9) Limiting dimensions and minimum head room available. If crane is to pass under bridges or through a loading gauge, give full particulars and/or dimensioned sketch.

(10) Specifications and/or Surveys to be complied with :—

(*a*) General.

(*b*) Ropes.

(*c*) Boiler.

(*d*) Electrical Equipment.

(11) Housing—state requirements, i.e. complete house, three-quarter housing, or canopy.

(12) If any special conditions necessitate limitations of weights or dimensions of pieces give full particulars.

(13) Other requirements.

The following information is to be supplied by the Manufacturer :—

(1) Type offered .... Drawing No. .....

(2) Capacity of crane :—
..... tons (max. load) at ..... ft. radius (A).
..... tons (light load) at ..... ft. radius.

(3) Type, full description and weight of grab with method of discharge and capacity in cubic feet.

(4) Number of men to operate crane at maximum load.

(5) (*a*) Dimensions of engines.
(*b*) Dimensions of boiler.
(*c*) Description of boiler.
(*d*) Working pressure of boiler in lb. per sq. in.
(*e*) Capacity of feed water tank in gallons.
(*f*) Nature of boiler feed arrangement.

(6) (*a*) Number of motors, type, and enclosed ventilated or totally enclosed.
(*b*) B.h.p. and speed of motors at full load.
(*c*) Rating of motors, and ..... ° F. temperature rise after ..... hours.
(*d*) Maximum current demand from mains.
(*e*) Type of controller and rating of resistances.
(*f*) Further particulars of electrical equipment.

(7) (*a*) Type of internal combustion engine.
(*b*) B.h.p. and number of cylinders.
(*c*) Speed in r.p.m.
(*d*) Fuel capacity for ..... hours normal working at full load.

(8) Particulars of compressed air drive.

(9) Travelling track :—
(*a*) Gauge (J).
(*b*) Maximum load with which crane can travel ..... tons at ..... ft. radius with jib at right angles to track.
(*c*) Weight and class of rail recommended.
(*d*) Maximum load per wheel in tons.
(*e*) Sharpest curve that crane can negotiate in ft. radius.
(*f*) Maximum gradient that crane can negotiate, 1 in .....

(10) Range of lift (C and B) of underside of hook from ..... ft. below to ..... ft. above rail level.

(11) Tail radius (E) in ft.

(12) Speeds :—

Hoisting (max. load)	.....	ft.	per.	min.
„ (light load)	.....	„	„	„
Slewing (max. load)	.....	„	„	„
Derricking (max. load)	.....	„	„	„
Travelling (max. load)	.....	„	„	„

(13) Gearing :—
(*a*) Material.
(*b*) Cast teeth or cut teeth.

(14) Travelling wheels—state type of construction and material.

(15) Supports for rotating parts of crane structure—state whether :—

(*a*) Centre post, or
(*b*) Live ring of rollers, or
(*c*) Rollers on fixed axles.

(16) Ropes (British Standard No. 302) :—

(*a*) Quality of material.
(*b*) Description of wire.
(*c*) Construction. Hoist ..... Derrick .....
(*d*) Circumference. Hoist ..... Derrick .....
(*e*) Guaranteed breaking load. Hoist ..... tons, Derrick ..... tons.
(*f*) Factor of safety. Hoist ..... Derrick .....

(17) Diameter of drums (at bottom of groove)—Hoist ..... Derrick .....

(18) Diameter of pulleys (at bottom of groove)—Hoist ..... Derrick .....

(19) Type of housing or shelter.

(20) Particulars of safety and indicating devices.

(21) Description of brakes.

(22) Tools and accessories supplied.

(23) Ballast, if any, to be supplied by purchaser ..... tons ..... material.

(24) Approximate total weight :—

(*a*) Net (excluding ..... tons ballast, supplied by purchaser) ..... tons.
(*b*) Gross ..... tons.
(*c*) In working order ..... tons.

(25) Weight of heaviest part or parts in tons. Dimensions of bulkiest part or parts in feet.

(26) Other important particulars not scheduled.

The following travelling speeds, upon a straight and level track, are recommended as maximum values for a self-propelled crane handling any load up to the maximum for which it has been designed :—

Combined weight of Crane and Load in Tons.	*Up to* 10	11 *to* 20	21 *to* 30	31 *to* 40	41 *to* 50
Maximum Travelling Speed (feet per minute)	500	450	400	300	250

For the purpose of this Specification the forward stability of the crane, when handling any load at the appropriate radius and working on a level track and with the jib at right angles to the track, shall be taken as being the percentage additional load required to bring the crane to the point of tipping. The forward stability shall be not less than :—

$$\frac{\text{Radius of crane}}{\text{Gauge (or Blocking-up Base)}} \times \text{F}$$

where F is a coefficient the numerical value of which depends upon the gauge (or blocking-up base), and upon the classification of the crane, the blocking-up base being measured between centres of supports.

For the two classes of crane included in the Specification, namely :—

(*A*) Cranes working on elevated structures, dock, or quay walls, and cranes working grabs, and

(*B*) Cranes working on the ground (not waterside cranes) on ordinary service.

the coefficient F shall be taken at the following values :—

	Coefficient F.	
Gauge (or Blocking-up Base).	*For (A) Cranes.*	*For (B) Cranes.*
10 ft. or more	11·1	7·6
9 ft.	11·2	7·7
8 ft.	11·5	7·9
7 ft.	11·9	8·2
5 ft. 6 in.	12·8	8·9
4 ft. 8½ in.	13·4	9·4
3 ft. 6 in.	14·7	10·3
3 ft. 3⅜ in. (1 metre) or less	15·0	10·5

The forward stability shall in no case be less than 50 per cent. for "A" cranes and 33⅓ per cent. for " B " cranes.

Cranes of 4 ft. 8½ in. gauge and over shall be stable backwards, when not blocked, with the jib removed, and with the tail at right angles to the track.

For a crane designed to travel under load, the gauge of the track shall be used in determining the stability, but for a crane intended to travel without load on the hook, the blocking-up base shall be used.

The other requirements of the specification are similar to those already given for Derrick Cranes (Power Driven), with the addition of a travelling test in which the motion shall be tested in both directions with the maximum rated load on the hook for cranes designed and specified to travel with this load, and with no load for those requiring blocking-up.

182. ELECTRICAL AND OTHER SPECIAL EQUIPMENT.—In cases where it is necessary to specify any large electrical or other equipment, the British Standards Institution should be consulted as there are now British Standards which cover a very large field of specialised equipment, and where these exist they should always be made the basis of an Engineer's Specification.

CHAPTER VI

GENERAL SPECIFICATIONS FOR ENGINEERING PLANT

The following general Specifications for various plants have been compiled from information supplied by various manufacturers, and the figures prepared from drawings which they supplied :—

(*a*) Specification of a 3-ton Electric Travelling Quay Crane. (Supplied by Messrs. Cowans, Sheldon & Co., Ltd., Carlisle.)

(*b*) General Specification of a Lancashire Boiler. (Supplied by Messrs. Ruston & Hornsby, Ltd., Lincoln.)

(*c*) Specification of a Three-Throw Motor-Driven Hydraulic Pump, suitable for operating the Hydraulic Accumulator in Item (*d*).

(*d*) Specification for a Hydraulic Accumulator, suitable for operating the Hydraulic Press in Item (*e*).

The particulars for Items (*c*), and (*d*), were supplied by Messrs. Sir Wm. Arrol & Co., Ltd., Glasgow.

183. SPECIFICATION OF A 3-TON ELECTRIC TRAVELLING QUAY CRANE.—The crane is to be of the electrically-operated, level luffing type as shown on Fig. 21 and in general accordance with the following specification, designed to handle a maximum working load of 3 tons, and to have the motions of hoisting, slewing, luffing and travelling, each operated by an independent motor.

Leading Particulars.

(1) *Duty for which crane is required.*
General cargo handling at quayside.

(2) *Capacity of Crane.* (Max. load to be lifted).
Three tons at 65 ft. radius.

(3) *Gauge of Track.*
14 ft. centre to centre of wheels.

(4) *Working Clearances.*
To be in accordance with the Engineer's requirements and as embodied in Fig. 21.

(5) *Section of Track Rails.*
To be specified by the Engineer.

(6) *Speeds.*

Hoisting	3 tons at 175 ft. per minute.
Slewing	3 tons at $1\frac{1}{2}$ revs. per minute.
Luffing	3 tons at 120 ft. per minute.
Travelling	3 tons at 50 ft. per minute.

(7) *Lift of hook* 60 ft. above quay level.
Depth of lower of hook 35 ft. below quay level.

(8) *Current Supply* to be defined by Engineer.

(9) *General Atmosphere.* Marine.

Electrical Gear.—The electrical equipment of the crane is to comply with the electrical specification.

Design.—The crane is to be of substantial construction arranged to permit easy accessibility for inspection and maintenance repairs.

Materials.—All materials used in construction of the crane shall comply with the latest relevant British Standards.

No plate or rolled steel section carrying stress to be less than $\frac{5}{16}$ in. thick and subsidiary and platform details to have a minimum thickness of $\frac{1}{4}$ in.

Factors of Safety.—The following factors of safety shall apply :—

Steel wire ropes - - - - - - -	8
Machinery and gears - - - -	6
Structures - - - - - - - - -	5

Workmanship.—The workmanship throughout is to be strictly first class and in respect of gearing, finish, tolerances, etc., shall comply with the requirements of British Standards.

Any welding work is to be carried out with approved electrodes and all welds of exposed portions shall be with sealed runs.

Gantry.—The crane gantry is to be constructed of rolled steel sections and plates, rigidly braced in all directions and assembled to permit of scaling and painting any part subject to corrosion.

The gantry to be mounted on four 2-wheel bogies arranged one bogie per corner, and constructed to run on rail tracks at 14-ft. centres.

The gantry to be of the portal type arranged to allow passage of rolling stock.

The portal to be surmounted by a heavy girder construction designed to support the circular pathway on which the superstructure of the crane rotates.

The maximum individual wheel load of the crane shall not exceed 15 tons.

Travelling Gear.—Two rail wheels on each rail to be driven from the travel motor through the necessary reductions of spur and bevel gearing as indicated in Fig. 21.

An electro-mechanical brake to be fitted to the motion.

The rail wheels to be fitted with gun-metal bushes of ample area and thickness to run on steel axles secured in the bogie frame. The bogie frame to be pivoted to ensure equalisation of loading on the rail wheels.

Platforms.—A chequered plate platform is to extend around three sides of the gantry top to provide access to the travel motor and also to the machinery house.

Platforms to be protected by means of double tier handrailing.

Live Ring and Centre Pin.—The superstructure of the crane to revolve upon a live ring of tapered steel rollers and centred by a forged steel centre pin secured in gantry top centre girders. The centre pin to be bored through the centre for the passage of electric cables.

The live ring rollers to be equally spaced and centred by rods radiating from an iron casting located by the centre pin. Adequate provision to be made for lubricating the rollers. Gun-metal washers between the rollers and the ring will be provided to take the end thrust.

Revolving Frame.—The revolving frame to be constructed of heavy rolled steel sections securely framed and cleated together and arranged to support the machinery and to receive the centre pin castings. The frame to be covered by a ¼-in. thick steel plate flooring.

Superstructure Frame.—The superstructure frame to be constructed of rolled steel sections and plates braced in all directions to ensure rigidity. The frame to be arranged to carry the jib pivot bearings and at the apex the necessary rope pulleys.

The superstructure frame to be rigidly attached to the revolving frame.

Machinery House and Control Cabin.—The whole of the machinery for the hoist, slew and luff motions to be contained in a house constructed of timber or sheet metal on suitable framing. The house to be made in sections so that any portion may be removed without the necessity of dismantling the whole.

The roof to be made watertight with approved material and a suitable hood provided where the hoisting rope passes through the roof.

The whole of the control equipment to be mounted in a cabin at the front of the machinery house and separated therefrom by a partition.

The cabin to be provided with large windows to enable the driver to obtain an unobstructed view of the space commanded by the crane.

Jib.—The jib to be of lattice construction fabricated of rolled steel sections securely braced to withstand the stresses imposed by sudden starting or stopping with the crane under maximum load.

The fulcrum pin to be carried in heavy cast iron, gunmetal bushed bearings attached to the superstructure frame.

The jib to be provided with extended tails which form quadrants, to which are fitted the pin racks which operate the luffing motion, and also carry the ballast weights which balance the jib about the fulcrum pin.

The jib head pulleys to be of cast iron, fitted with gunmetal bushes carried on steel pins fixed in the structure.

The pulleys to be of the self-oiling type.

A ladder with handrailing to be provided to give access to the jib head for servicing.

Hoisting Gear.—The load to be lifted on a single part of steel wire rope of extra flexible construction having 6 strands of 37 wires each, 100 to 110 tons per sq. in. tensile strength. Test certificate to be supplied.

The winch drum to take the whole of the working length plus three spare coils in one layer.

The drum to be driven from the motor through a high-efficiency worm gear totally enclosed in an oil bath gear-box, and suitable reductions of spur gearing. All spur gearing to be of steel with machine-cut teeth of stub formation.

The lifting hook to be of forged steel, cargo type, fitted with ball thrust bearing and an adequate overhauling weight.

The motion to be provided with an electro-mechanical brake operating on drum forming one half of the flexible coupling between the motor and the worm gear.

In addition a foot-operated brake to be fitted to the barrel pinion shaft capable of arresting and holding the maximum working load in any position.

Slewing Gear.—The slewing gear to be transmitted from the motor to the rack through a reduction of worm gearing enclosed in a cast iron gear forming an oil bath. The worm shaft bearings to be of the ball bearing type with one of the duplex type to take both journal and thrust loads.

The gearing to be protected from shock by an adjustable spring-loaded slipping device which is incorporated in the worm wheel centre.

A foot-operated brake is to be provided to give complete control of the motion.

The slewing rack is to be of the pin type consisting of hard steel pins accurately pitched around the pathway circular girder secured to the gantry top.

Luffing Gear.—The luffing gear is to maintain the load at a constant level during luffing. The jib radius to be varied by means of quadrant pin type racks fitted to the extended tails of the jib driven by pinions through suitable reductions of worm and spur gearing from the luffing motor.

The cast iron weights fitted to the jib tails ensure the jib being in equilibrium in all positions between maximum and minimum radii.

The forces due to the load are entirely compensated throughout the working range by reeving the hoist rope in three parts between the jib head and the apex of the superstructure frame. The position of the apex pulleys being a geometrical one which ensures that practically no unbalanced forces occur, as the resultant of these forces passes through the jib fulcrum pin.

An electro-mechanical brake to be fitted to the flexible coupling on the motor extension shaft to give complete control of the motion.

Automatic limit switches to be provided to operate at both ends of the jib travel.

A radius indicator to be mounted in a prominent position in the operator's cabin and to be actuated by the movement of the jib.

Ballast.—All necessary ballast for the jib and for the tail of the superstructure to be provided.

Lubrication.—All bearings and pulleys other than the jib head to be lubricated by high pressure Tecalemit grease gun. Lubrication chart to be provided indicating frequency and grade of lubricant to be used.

Tools.—Complete set of spanners and grease gun to be provided in a lock-up box in the operator's cabin.

Guards.—Moving and dangerous parts to be protected to comply with safety Regulations.

Erection at Maker's Works.—For overseas contracts the first crane is to be completely erected in the Maker's Works and tested in all motions with 25 per cent. overload.

The remaining cranes to be assembled in sections for inspecting purposes and to ensure correct site erection.

For "home" contracts this latter procedure shall be adopted and all tests shall be carried out after erection at site.

Painting.—All steelwork to be thoroughly cleaned to remove rust and mill scale, given one coat of genuine red lead and one coat of grey oil paint before despatch.

Marking.—After assembly all parts to be painted and hard marked to ensure correct and rapid erection at site.

Electrical Equipment

Motors.—The motors to be of the totally enclosed, reversing type, one-hour rated, to comply with British Standard No. 168/1936.

The particulars of the motors to be as follows :—

Hoisting - - - - - - - - - - 50 b.h.p.
Slewing - - - - - - - - - - - 8 b.h.p.
Luffing - - - - - - - - - - - 8 b.h.p.
Travelling - - - - - - - - - 10 b.h.p.

Controllers.—All controllers to be of the air break, drum, reversing type, fitted with crank handle and interlock rings for interlocking electrically with the crane protective panel.

The hoist and luff controllers to have auxiliary rings for operating in conjunction with shunt limit switches.

Resistances.—The resistances to be of the drip proof, ventilated, unbreakable type, 5 min. B.S.S. rated.

The hoist resistance to be designed to pass 75 per cent. of full load current on the first notch, while those for the remaining motions should pass 100 per cent.

Crane Protective Panel.—The crane protective panel to be of the 4-motor type comprising the following :—

Air break contactor type circuit breaker, fitted with arc shields and magnetic blow-out.

Adjustable time lags and current setting dash-pots giving overload protection.

Hand lamp.

Hand lamp plug and socket, with 30 ft. of cab tyre cable.

Transformer switch fuse for hand lamp circuit.

Switch fuse for contactor operating coil with pilot indicating lamp.

Main Isolating Switch.—Main isolating switch to be supplied suitable for mounting on the crane gantry.

Limit Switches.—Shunt type limit switches to be provided for over-hoisting and over-lowering, and also for both directions of the luffing motion.

Collector Column.—Collector column to be provided for conveying the current from the gantry to the revolving superstructure. The collector rings are to be fully accessible for inspection and maintenance.

Lighting.

One 4-light cargo cluster for 60-watt lamps to be provided on the underside of the jib.

Three 60-watt bulkhead fittings to be supplied for the driver's cabin and machinery house.

Two 60-watt lamps to be fitted on the gantry for lighting platforms and access ladders.

Wiring.—The whole of the crane interconnecting wiring to be of the single core V.I.R., insulated to British Standard and to be run in screwed conduit.

Trailing Cable.—A length of tough rubber sheathed flexible cable 660 volt C.M.A. grade to be provided.

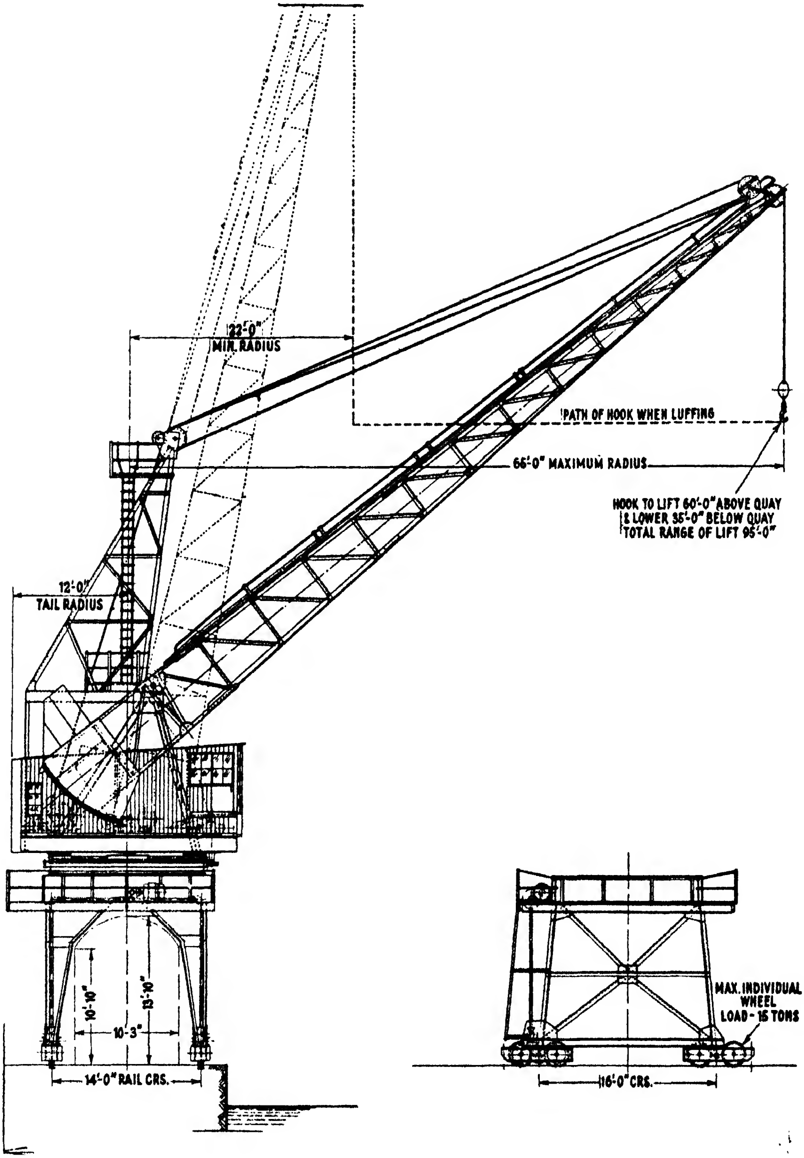


FIG. 21.—Three Ton Electric Quay Crane (Level Luffing).

Trailing Cable Plug and Plug Boxes.—Plug boxes and plug for the trailing cable to be supplied by purchasers.

Cable Drum.—A totally enclosed counterweight-operated cable reeling drum to be provided and fixed to the gantry structure.

The drum to be suitable for coiling the whole working length of trailing cable.

Inspection.—The whole of the electrical equipment of the crane to be tested at the manufacturer's works in the presence of the Purchaser's Engineer, and test certificates to be provided.

The following particulars should be supplied to the Makers when ordering an electric travelling crane.

Is crane required for grabbing or general cargo or both ?
If grabbing is required :—Type of grab.
Material to be handled.
Maximum load to be lifted.
Maximum radius.
Minimum radius.
Is level luffing required ?
Height of lift above rail level at maximum radius.
Depth of lift below rail level at minimum radius.
What speed of operation is required ?
Centres of track rails.
Particulars of track rails.
Is there a curve on track ?
Maximum permissible tail radius.
Is portal required under carriage ? If so what clearances are desired ?
Current supply :—A.C. or D.C., and voltage.
Cable drum or trailing cable.
Are we to supply ground plug boxes ? If so, distance crane will travel along track.
Are we to erect at site ? If so, are any existing cranes available, free of cost to us, and what is capacity and height of lift of existing cranes ?
Are there any limiting dimensions, i.e. nearby buildings, or other obstructions ?
Position of centre of track to edge of quay (if dockside crane).
Is there any maximum permissible wheel load ?

184. GENERAL SPECIFICATION OF A LANCASHIRE BOILER.—All materials used in the construction of the Boiler to be of

Siemens-Martin mild steel of good ductile quality, by approved makers ; the tensile strength and elongation to be as follows :—

	Tensile Strength.	*Minimum Elongation.*
Shell and End Plates –	28–32 tons per sq. in.	20 per cent on 8 in. length
Flues – – – – –	26–30 ,,	23 ,, 8 in. ,,
Rivets – – – – –	26–30 ,,	25 ,, 10 in. ,,

The shell to be formed of parallel belts of plating, each belt being made of one plate, all to be bent cold in powerful rolls to truly circular form, no flat being left at the ends. The longitudinal seams to break joint, and to be so arranged on the upper side of the Boiler to the right and left alternately, that when the Boiler is seated they shall clear the brickwork and mountings.

The Flues to be composed of a number of rings, each ring formed of one plate flanged at each end. The longitudinal seams to be electrically welded, and each flange to be finished at one heat by special machinery. No rivet heads to be exposed to the action of the fire. A caulking ring to be inserted between each flanged joint, and the joints of each flue to be so arranged that they do not come in line with one another or with the circular seams of the shell. All flanges to have their edges turned and rivet holes drilled. The first and last ring to be of extra thickness, except when the front plate is flanged outwards for flue, when the thickness is not to be altered.

The front end may be attached to the shell by a solid welded mild steel external angle ring, or it may be attached by the same method as is used for the back end, i.e. be flanged inwards to meet the shell. All flanging to be done at one heat in a powerful hydraulic press. The edges of the end plates and angle rings to be turned, and the openings for furnaces to be cut out by machinery. The end plates are to be efficiently stayed by means of suitable gusset plates, secured to both shell and ends by double angles, suitable breathing space being allowed for the expansion of the flues.

All edges of shell plates to be planed.

All the rivet holes throughout the boiler to be drilled. Those for the shell to be drilled after the plates have been bent to form and placed accurately in position, thus ensuring perfectly fair and parallel holes, accurately fitting rivets, and avoiding drifting or any other injury to the plates.

All the riveting is to be carefully done, and performed, so far as is practicable, by hydraulic riveters.

All the flanging is to be done at one heat by means of hydraulic presses.

The edges of all plates are to be caulked inside, and fullered and caulked outside.

The boiler is to be designed and constructed in accordance with the best modern practice, for the specified steam pressure, and is to be tested by hydraulic pressure before leaving the Works, to the pressure specified and to the satisfaction of the Engineer or of the Insurance Company.

The boiler is to be fitted with one 16 in. by 12 in. oval manhole with strong wrought steel flanged compensating ring which is to be double riveted to the boiler shell and fitted with a steel door complete with crossbars and bolts, the joint surfaces being machined.

For the mudholes one strong wrought steel flanged compensating ring is to be riveted on the front end plate below the flues and fitted with steel cover, crossbars, and bolts, the joint surfaces being machined.

Seatings, consisting of strong wrought steel stand pipes or pads, truly faced on the joint surfaces, are to be riveted on the top of the shell to receive the stop valve and safety valves, and one on the underside of the boiler for the blow-off elbow.

Provision is to be made on the front end of the boiler for feed valve and water gauges.

The boiler is to be equipped with a full complement of steam and water fittings of approved make as follows :—

One junction stop valve with external regulating screw.

One anti-priming pipe perforated on upper side, to be placed horizontally inside the boiler steam space.

One double safety valve.

One high steam and low water alarm.

One back-pressure check feed valve, with external regulating screw and cleaning branch.

One perforated internal dispersion feed pipe with open end, to be fitted inside boiler, and connected to the feed valve.

One gun-metal compound gland, asbestos packed, blow-off cock, having gland constructed so as to prevent the key being removed until the cock has been closed.

One taper elbow for attachment of blow-off cock.

One wrought iron box-key suitable for use with blow-off cock.

One steam pressure gauge graduated to twice the working pressure, the latter being indicated by a red line.

One syphon with asbestos-packed gun-metal cock having provision for attaching test cock.

Two sets of asbestos-packed gun-metal flanged water gauge cocks, right- and left-hand, complete with glasses, glass protectors, and rubber rings.

One brass water-level pointer to be fixed between the gauge glasses to indicate the working level of water.

The boiler is also to be equipped with the following furnace fittings :—

One fusible plug to be screwed into the crown of each flue and arranged so that the fusible centre can be easily renewed.

Mild steel furnace fronts with cast iron fire doors fitted with brass air-regulating doors and mild steel baffle plates, and finished off with neat polished brass beading.

Bearers consisting of cast iron dead plate and back bridge plate, with mild steel centre bearer, supported on wrought iron brackets.

A complete set of firebars constructed so as to give an air space of not less than $\frac{3}{8}$ in.

Two cast iron dampers and frames with wire ropes, pulleys, fixings, and balance weights.

Cast iron chequer floor plates fitted in frame.

A complete set of spanners and firing tools.

The arrangement of the boiler is as shown in Fig. 22.

185. SPECIFICATION FOR A HYDRAULIC ACCUMULATOR.—The accumulator is to be of the independent self-contained type, in accordance with Fig. 23, and to be proportioned throughout for a working pressure of 1,500 lb. per sq. in. It is to be operated by the three-throw electrically-driven hydraulic pump described in the previous specification.

The cylinder is to be of cast iron with a stuffing box at the top end and a branch for pipe connection at the bottom end. The ram is to be of cast iron machined all over. The stuffing gland also to be of cast iron and machined to fit the cylinder stuffing box. The necessary air and drain cocks to be fitted to cylinder.

The crosshead is to be of cast iron or of welded mild steel construction and provided with heavy mild steel adjustable links to support the casing. The ram is to be securely fitted in the crosshead.

The sole-plate is to be of cast iron or of welded mild steel construction of heavy design, and to have a machined recess for the cylinder.

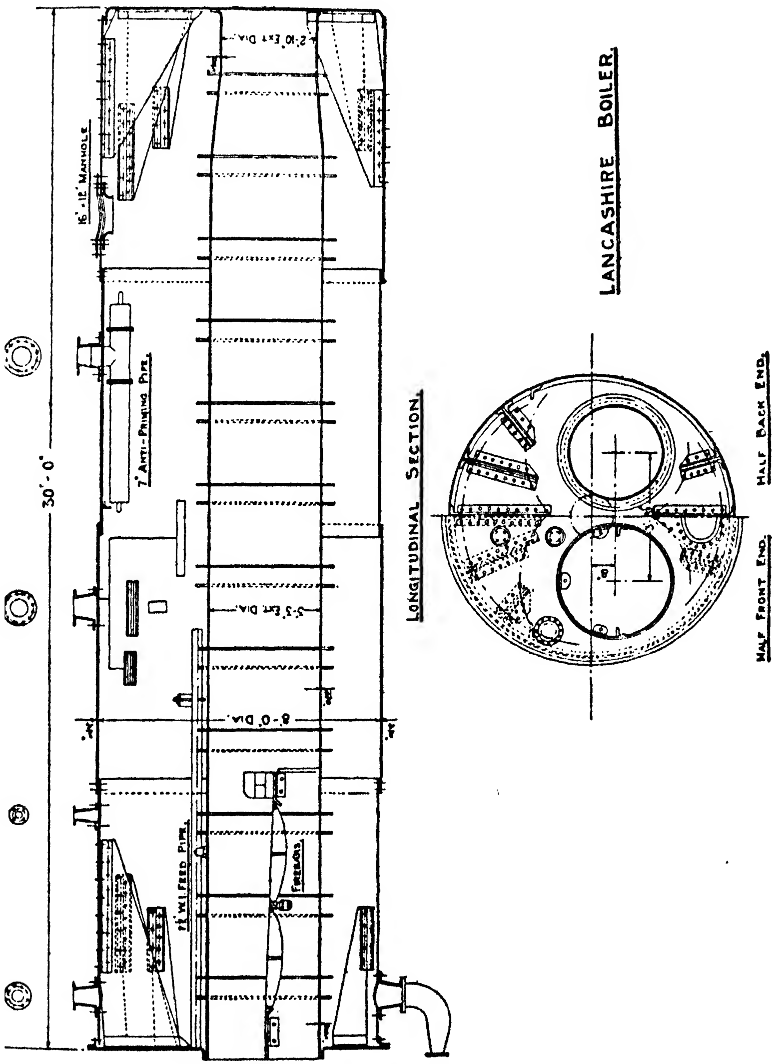
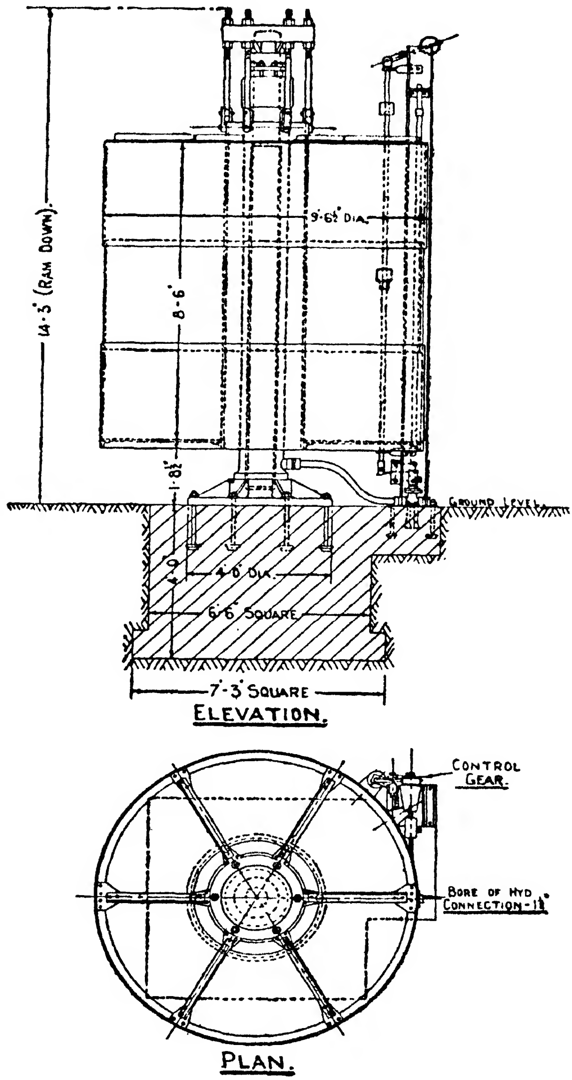


FIG. 22.—Lancashire Boiler.

The casing is to be a cylindrical tank built up of mild steel plates and angles securely riveted and braced together, the whole being suspended from the crosshead.



General Particulars.

Ram Load - 34 Tons.	Capacity - 21·7 Gallons.
Ram - 0'·8" Dia. × 10'·0" Stroke.	Working Pressure - 1500 Lbs/□".
Total Ballast Req^{d} - 31·65 Tons.	Density of Ballast - 130 Lbs/Ft.^{3}

Fig. 23.—Hydraulic Accumulator.

Rollers are to be fitted to the bottom of the casing and arranged to work on four guide strips on the cylinder.

A loaded safety valve is to be provided and to be operated by an arrangement of tappet rods and levers from the cylindrical casing so that it will be positively opened by the accumulator before the ram has reached the top limit of its stroke.

A control gear column, suitable for carrying the control gear is to be provided.

The whole of the materials and workmanship are to be the best of their respective kinds, and to the entire satisfaction of the Engineer.

CHAPTER VII

QUANTITIES

In preparing the Schedule of Quantities, it should be kept in view that it is of paramount importance to define clearly all the items so that reference may be easy, and that the work should be done systematically to eliminate, or at least to minimize, the possibility of omitting any items.

Where several Assistants are taking off the quantities in one Contract, each should be clear as to the exact limits of the work to be included in his portion. This may be done by dividing the work into sections and making each man responsible for all the quantities in a particular section, or, alternatively, by dividing up the work according to its nature (i.e. into excavations and earthworks, masonry and brickwork, timber work, iron and steel work, etc.), clearly defining what is to be included under each heading, and allocating a specific portion to each Assistant.

The work of preparing the Schedule of Quantities may be divided into four sections, viz. taking off, multiplying, abstracting, and billing. Abstracting is necessary only where there is more than one portion of identical work, each of which may be combined at the finish under one item. If there is any difficulty in describing the exact location of the several portions in one item, it is preferable to have a separate item for each.

Taking off is the process of measuring from the drawings the dimensions of the various items constituting the Contract and may be done on plain paper or on paper specially ruled for the purpose.

Multiplying, as the name implies, is the process of extending the figures for the items after taking off, and reducing them to convenient units.

Billing is the name for the operation of describing the items in the final Schedule of Quantities, and filling in the quantities involved against each.

Multiplying may be carried out by ordinary arithmetical methods, or by the "duodecimal" method in which 12 is taken as the unit, the latter being the method usually employed in Building Work by Quantity Surveyors. As an example, to multiply 18 ft. 5 in. by 26 ft. 7 in., the common method would be to multiply 18·42 ft. by 26·58 ft. = 489·6 sq. ft. Alternatively, it could be done thus :—

26 ft. × 18 ft. 5 in.	=	478	10
6 in. = ½ of 1 ft.	=	9	2½
1 in. = ⅙ of 6 in.	=	1	6½
Total	=	489	7
i.e. 489 $\frac{7}{12}$ sq. ft.	=	489·6 sq. ft.	

Again, the figures in each case could be taken to inches, multiplied together and divided by 144 to bring the result to sq. ft., a laborious operation when much multiplying has to be done. By the duodecimal method the figures would be set down directly under one another as shown thus :—

18 ft. 5 in.				
26 ft. 7 in.				
478	—	10		
10	—	8	—	11
489	—	6	—	11

As feet are taken to be the unit of measurement, the 18 ft. 5 in. is first multiplied by 26 ft., thus 26 ft. by 5 in. = 130. Divide this by 12, giving 10 sq. ft. and over (the latter 10 being equal to 10/12 of a sq. ft.), the former being 10 carried to the column on the left and added to 26 by 18, giving 468 + 10 = 478. Now multiply the 18 ft. 5 in. by 7 in., thus 7 by 5 = 35. Divide this by 12, giving 2 and 11 over. The 11 is put in the third column as shown and the 2 carried to the second column. Next 7 by 18 = 126, to which the 2 from the previous multiplication is to be added, giving 128. Dividing this again by 12 gives 10 sq. ft. and 8 over. The 10 is placed in the first column and the 8 in the second column as shown. The results are then added up giving the total shown, which is 489 sq. ft., 6/12 sq. ft. and 11/144 sq. ft. (or 11 sq. in.).

For a cubic measurement, the method is merely extended in the same way. Thus to find the number of cu. ft. in a volume of 18 ft. 5 in. by 26 ft. 7 in. by 5 ft. 4 in., the first two dimensions would be worked out as above and the result multiplied by 5 ft. 4 in. as shown :—

489	—	6	—	11		
5 ft. 4 in.						
2447	—	10	—	7		
163	—	2	—	3	—	8
2611	—	0	—	10	—	8

If the result is required in cu. yd., this would then be divided by 27 in the usual way.

The duodecimal system has much to recommend it and is simple to use when it is once thoroughly acquired, but the Institution of Civil Engineers in their Report on Engineering Quantities recommend that quantities be entered in the Bill of Quantities in the form of single units (i.e. tons or yd.), and not as multiple units (i.e. tons, cwt., qr., lb., or yd., ft., in.), and that where fractional quantities are necessary, these be expressed in decimals. That being the case it is probably more simple to express the inches in the original dimensions, as decimal parts of a foot, and multiply out as by common method given above. Dividing out sq. ft. by 9, or cu. ft. by 27, gives the area or volume in sq. yd. and cu. yd. respectively, the result still being in single units and decimals as recommended.

Any slight rounding-off of figures as entered in the Bill of Quantities should be done on a " give and take " basis, so that the quantities agree as nearly as possible with the work shown on the drawings.

In their Report on Engineering Quantities, the Committee of the Institution of Civil Engineers give the following rules (which are those commonly followed) for Drafting the Bill of Quantities :—

The introductory clauses or preamble to a Bill of Quantities are to embody any necessary instructions and references to the obligations intended to be imposed by the documents on which the tender is to be based, so as to assist firms tendering to price the bill. The following directions are amongst those which it is generally considered necessary to give to firms tendering :—

(*a*) Attention is directed to the form of contract, the conditions of contract, the specification, and the drawings, and these documents are to be read in conjunction with the Bill of Quantities.

(*b*) The prices and rates to be inserted in the Bill of Quantities are to be the full inclusive value of the work described under the several items, including all costs, and expenses which may be required in and for the construction of the work described, together with all general risks, liabilities, and obligations set forth or implied in the documents on which the tender is to be based ; where special risks, liabilities, and obligations cannot be dealt with as above, then the price thereof is to be separately stated in the item or items provided for the purpose.

(*c*) A price or rate is to be entered against each item in the Bill of Quantities, whether quantities are stated or not. Items against which no price is entered are to be considered as covered by the other prices or rates in the Bill.

(*d*) Any special methods of measurement used are stated at the head of, or in the text of, the Bill of Quantities for the trades or items affected. All other items are measured net in accordance with the drawings, and no allowance has been made for waste.

(*e*) The quantities of work and material in the Bill of Quantities in the specification are not necessarily repeated in the Bill of Quantities. Reference is to be made to the specification for this information.

(*f*) Provisional sums and prime costs items (if any) are to be dealt with as provided for in the conditions of contract and in the specification.

The preamble to the daywork schedule is to be drawn up in accordance with the following (see p. 257) :—

(*a*) That the time of gangers or charge hands working with their gangs is to be paid for under appropriate items, but the time of foremen and walking gangers is not to be included but is to be covered by superintendence.

(*b*) That overtime, when chargeable under the contract, is to be paid for in the same proportion as is paid to the workmen —thus, if a man works 1 hour overtime for which he is paid for 1½ hours, the contractor is to be paid for 1½ hours for such a man.

(*c*) That the rates for heavy plant are only to apply to plant which the contractor has available upon the site.

(*d*) That the rates for such materials are to cover delivery at the usual points at which materials are received on the site and not distribution to the individual sites where daywork is in progress, the cost of such distribution being chargeable in addition.

(*e*) That the daywork rates are to cover the use of contractor's wagons and temporary tracks as are available upon the site.

(*f*) Whether the cost of watching and lighting specially necessitated by daywork is to be paid for separately.

In preparing the quantities to be inserted in the Bill of Quantities, due regard is to be given to the procedure to be adopted for final measurement. In so far as may be practicable they are to be those which would result if the contract drawings were to be treated as drawings of work as executed ; but where the contract drawings do not admit of a definite measurement, the extent to which the quantities are to be regarded as provisional is to be stated. For example, provisional quantities may be inserted in the Bill of Quantities for work which may be required to cover variations from the quantities based upon the contract drawings, e.g. extra depths of foundations. Such quantities are to be kept distinct from those of work based upon the contract drawings, and are to be described as " Provisional ". Also, provision for contingencies and additional works is to be made by including a provisional sum to be expended as occasion arises under the direction of the Engineer—the work executed being measured and valued at the rates contained in the priced Bill of Quantities, or where such rates are not applicable, then as provided for in the conditions of contract. It should be noted that in no circumstances is provision to be made for contingencies or additional works by increasing (whether by uniform percentage or otherwise) the quantities of work whether shown on the contract drawings, or otherwise definitely indicated as intended to be carried out—the intention being that the Bill of Quantities should distinguish between work regarded as definite and any provision for contingencies and additional works.

The dimensions and arithmetical calculations are to be entered on separate dimension sheets or in books and so drafted as to admit of an independent check, and every entry is to be adequately described. Each sheet or page is to be headed and numbered.

The numbers of the drawings from which the quantities are taken are to be stated at the beginning of the dimensions and ensuing calculations for each section of the work.

In entering dimensions the length should appear first, the width second, and the depth or height third.

Where items of work of exactly similar dimensions are repeated, then the multiplier (or the number by which the dimension is repeated) is to be entered in the left-hand column of the dimensions sheet. Where there are multiple units of the same thing (such as twenty rows of piles with four piles of each), all the factors are to appear in the outer column.

The extensions relating to any given part of the work are to be totalled as they stand. The total so obtained is to be converted into the unit to be used in the Bill of Quantities. If such total does not complete the item in the bill, the quantities are to be summarized in an abstract, in which they are to be adequately described.

The items in the Bill of Quantities are to be grouped into sections under headings according to the location of the individual parts of the works in the general scheme and/or according to the character of the works to be performed.

The items in the respective sections are to be arranged in subsections embracing the various classes of work. These subsections should preferably follow one another in the following order :—

(*a*) Excavation, dredging, and filling.
(*b*) Concrete.
(*c*) Reinforced concrete.
(*d*) Brickwork.
(*e*) Masonry.
(*f*) Waterproofing.
(*g*) Piling.
(*h*) Timberwork in jetties, wharves, and similar construction.
(*i*) Steel and iron work.
(*j*) Roads and pavings.
(*k*) Sewers and drains.
(*l*) Pipes and pipe-lines.
(*m*) Railway track-work.

In subdividing the various parts of the work into items, the following principles are to be observed :—

(*a*) Different parts of engineering work may involve the use of the same permanent materials, but entail widely different costs of construction. Opportunity is to be afforded for entering different rates for work of the same nature but carried out under different conditions.

(*b*) Subdivision into items is not to be excessive, but is yet to be sufficient to differentiate between the various classes of work involved.

(*c*) Where specialists are to be invited to tender for sub-contracts and are likely to require subdivision of work covered by a single item in the bill of quantities, the additional information required is to be included in the description of the item, in the form of a subsidiary bill.

The instructions as to subdivision into items given above are intended to apply to work of substantial cost, and need not be followed in their entirety where the cost is insignificant in relation to the contract regarded as a whole.

Descriptions attached to the items in the Bill of Quantities, while being as brief as possible, are to be in sufficient detail to ensure identification of the work covered by the respective items with that shown on the contract drawings and described in the specification. The exact nature of the work to be performed is to be made clear where necessary, by reference to the relevant clauses in the specification.

It is convenient to maintain a standard form or style of setting out the information given in a Bill of Quantities. The following form is suggested for adoption :—

NAME OF CONTRACT

Bill of Quantities

N.B.—The prices to be affixed to the quantities in this bill and the amount of the estimate are to include all charges, cost of temporary works and plant, and contingent expenses of every kind to complete all the works under this Contract, and every allowance must be made in the prices for every description of work, with all conditions relative thereto as stipulated in the Specification and Conditions of Contract.

The measurements are the net lengths, areas, and contents. Allowances have, however, been made for scarfings of timbers, and all timber diagonal bracings and struts have been measured to their extreme lengths, but waste in all other materials must be allowed for in this estimate.

The offer is to be for a lump sum to complete the whole of the works under this Contract without after-measurement.

Item No.	Quantity	Unit	Description	Rate	Amount
					£ *s.* *d.*
			Total of section carried to summary.	£	

A summary is to be provided to which the total of each section is to be carried.

Items are to be numbered consecutively for convenience of reference. Clauses containing descriptive matter only, are not to be numbered.

The quantities are to be entered in the Bill of Quantities in accordance with the results of the computation. Any slight rounding-off of figures should be done on a " give-and-take " method so that the quantities agree as nearly as possible with the work shown on the drawings.

The terms used in describing one-, two-, or three-dimensional work should be linear, square, and cubic respectively, such words to precede the unit of measurement (e.g. square yards, cubic feet).

Quantities should be entered in the form of single units (e.g. tons or yd.), not as multiple units (e.g. tons, cwt., qr., lb. ; or yd., ft., in.). Where fractional quantities are necessary these are to be expressed in decimals.

If abbreviations for units are used they are to be as follows :—

cwt.	yd.	cu.
qr.	ft.	sq.
lb.	in.	lin.

Even though several classes of materials and workmanship are involved, it may be convenient to represent in one item, measured with the appropriate linear unit, a composite work of uniform type of construction throughout, such as a tunnel, wall, or pipe-line ; and similarly, repetition work, such as manholes or valve chambers, if of the same design and suitably grouped, may be measured by number. If this method is adopted, a subsidiary bill is to be included in the description column setting out in appropriate units the quantities of the component materials and workmanship in the unit of length or in one of the number of each group as the case may be, in order that the rates for the component parts as well as the rate for the composite unit of length or one of the number of each group may be entered in the bill.

In the case of an item involving a number of identical objects, such as, for instance, a wharf comprising, among other things, say, 100 front main piles, each 55 ft. long by 14 in. square, the taking off would appear thus :—

No. off	Dimensions	Quantity	Total Quantity in finished units	Description
100	55 ft. 0 in. 1 ft. 2 in. 1 ft. 2 in.	72	Cu. Ft. 72	Front Main Piles.

Again, if there were three rows of such piles, each row consisting of 100 main piles of the same dimensions as above, the following would be the method of taking off :—

No. off	Dimensions	Quantity	Total Quantity in finished units	Description
3/100	55 ft. 0 in. 1 ft. 2 in. 1 ft. 2 in.	216	Cu. Ft. 216	Main Piles.

As noted in the rules on p. 210, it is customary in taking off the quantities to give a description of the item along with the dimensions taken off; thus the taking off for the excavation for vault and foundation for the New Vault under an Existing Footway shown on Plate I might be done thus (see p. 221) :—

No. off	Dimensions	Quantity	Total Quantity in finished units	Description
1	31 ft. 0 in. 11 ft. 9 in. 10 ft. 3 in.	3916		Excavation for vault (to bottom of floor).
1	19 ft.+9 ft.+9 ft. +8½ ft.=45½ ft. 4 ft. 0 in. 2 ft. 6 in.	455		Excavations for vault wall foundations.
		3712	Cu. Yd. 138	

In taking off as above, it will be observed that the mind is occupied with two things, viz. :—

(*a*) Locating the item, and
(*b*) Measuring it.

This tends to lead to the omission of some of the items, and it is often advantageous to go over the work by sections, first locating, numbering, and describing the whole of the items, and then taking off the actual quantities in the order in which they have been scheduled. On small contracts especially this is easy to do, and there is less likelihood of missing any items.

Before working out some examples in the taking off and scheduling of quantities, the following definitions and general principles as laid down by the Committee of the Institution of Civil Engineers on Engineering Quantities in their Report[1] issued in March, 1933, are given and should be adhered to :—

DEFINITIONS.

Bill of Quantities : The term " Bill of Quantities " means a list of items giving the quantities and brief description of work comprised in an engineering contract. The Bill of Quantities forms the basis upon which tenders are obtained. When priced, it affords a means of comparing tenders received. When the contract has been entered into, the rates in the priced Bill of Quantities are applied in assessing the value of the work as carried out. A Bill of Quantities may include a list of items for daywork as defined in the succeeding clause.

Daywork : The term " Daywork " means the method of valuing work on the basis of the time spent by the workmen, the materials used, and the plant employed.

Prime Cost : The term " Prime Cost " (or the initials " P.C. ") means the net sum entered in the Bill of Quantities by the engineer as the sum provided to cover the cost of, or to be paid by the contractor to merchants or others for, specific articles or materials to be supplied, or work to be done, after deducting all trade discounts and any discount for cash in excess of 2½ per cent.

Provisional Sum : The term " Provisional Sum " means any sum of money fixed by the engineer and included in the Bill of Quantities to provide for work not otherwise included therein or for unforeseen contingencies arising out of the contract. It is only to be expended, either wholly or in part, under the Engineer's direction and at his discretion in accordance with the Conditions of Contract.

[1] Report of the Committee on Engineering Quantities, Inst.C.E., published by William Clowes & Sons, Ltd., 94 Jermyn Street, London, S.W.1. A copy of this Report should be in the possession of every Engineer.

General Principles.

Scope of Bill of Quantities : In order that the firms tendering may have as complete information as possible, the Bill of Quantities is to set out in sufficient detail the quantities of work and material necessary for carrying out the work of the contract, and of the sub-contracts if any.

Rate or price of each item to be inclusive : In the absence of specific directions to the contrary, the rates and prices to be inserted in the Bill of Quantities are to be considered as the full inclusive rates and prices for the finished work described under the respective items, and as covering all labour, materials, temporary work, plant, and overhead charges, as well as the general liabilities, obligations, and risks arising out of the Conditions of Contract. (See Clause 1—Contract, Chapter III, p. 22.)

Obligations under Conditions of Contract : The general obligations of the firm tendering as defined in the Conditions of Contract (see Chapter III) are preferably to be borne upon the rates entered for the various items in the Bill of Quantities. This direction applies to contractor's ordinary risks and services, such as temporary buildings, watching and lighting (Clause 31), insurances (Clauses 25 and 33), labour regulations (Clause 22), order of procedure (Clause 12), indemnity, maintenance (Clause 53), and the like.

Where special liabilities and obligations (as distinguished from the ordinary risks and services mentioned in the previous paragraph) may have to be met, opportunity is to be given in the Bill of Quantities for their separate valuation, reference being made if necessary by number to any appropriate clauses of the Conditions of Contract and/or Specification. Alternatively, directions are to be given for the cost of these special risks, liabilities, and obligations to be covered by the rates, in which case attention is to be called in the preamble of the Bill of Quantities to the inclusive character of the rates to be set down by the firm tendering.

The contingent and potential causes of expenditure generally classified as contractor's risks are in any case to be borne upon the rates—the Conditions of Contract and/or the Specification clearly and precisely defining the nature of these risks.

Temporary Works : The cost of temporary works is, as a general principle, to be covered by the rates entered in the Bill of Quantities. (See Clause 39, Chapter III.) This principle applies to temporary work required :—

(*a*) For the service of the works as a whole : for example, gantries, temporary tracks, structures for concrete-mixing plant, blockyard equipment, and workyard sites if not provided free under the contract.

(*b*) To form and construct permanent work described under particular items in the Bill of Quantities ; for example, timbering for trenches.

Notwithstanding the foregoing general direction, it is advisable to provide special items for temporary works in cases where the cost of such works is constant (e.g. dams to enable work to be carried out in the dry), irrespective of the quantity or value of the permanent work in connection with which the temporary works in question are provided, or where the cost of such works is disproportionately high in relation to the cost of value of the permanent work. Other examples of the class of temporary works which, in certain circumstances, may be paid for separately are housing for employees, and shafts and adits for tunnels which are not required after the completion of the permanent work. Where special items for temporary works cover provision, maintenance, and removal, it is to be stated in the description of these items at what periods and in what proportions payment will be made against the rates or prices set down for the items.

Descriptions of Items and Reference to Specification : Descriptions attached to the items in the Bill of Quantities, while being as brief as possible, are to be in sufficient detail to ensure identification of the work covered by the respective items with that shown on the contract drawings and described in the Specification. The exact nature of the work to be performed is to be made clear, where necessary, by reference to the relevant clauses in the Specification.

Method of Measurement : In the absence of special directions to the contrary, all measurements are to be net notwithstanding trade customs to the contrary, and without allowance for waste. Any methods of measurements which form exceptions to this general direction are to be specially noted in the preamble to the Bill of Quantities or in the description of the items affected.

Daywork : Provision for the valuation of work to be carried out on a daywork basis is to be made in one of the following ways :—

(*a*) By a daywork schedule prepared in such a form as to enable entry in detail of separate rates for the respective classes of labour, materials supplied, and the hire of heavy plant ; such rates to cover insurances, use and maintenance of ordinary plant (such as scaffolding, barrows, running-planks, trestles, stages, bankers, hand-pumps, hand tools, and appliances generally, but not sharpening of tools), superintendence, overhead charges and profit, and, in the case of mechanically-operated plant coming under the heading " heavy plant ", the wages of specified attendants, consumable stores, fuel, and maintenance. (See Daywork Schedule, p. 257.)

(*b*) By a daywork schedule prepared in such a form that percentages may be added by the firm tendering to the actual cost of labour and materials respectively to cover insurance, use of ordinary plant, superintendence, overhead charges, and profit. In addition, the schedule is to include items for heavy plant to enable entry to be made in detail of separate rates for the various items of heavy plant as in (*a*) above.

Prime Cost Items : In entering items in the Bill of Quantities for articles for which a prime cost is stated, provision is to be made in the bill to permit the firm tendering to fill in separate prices for the following :—

(*a*) Profit on the prime cost in the form of a percentage.

(*b*) Packing, carriage, and delivery to the site (if these services are not included in the prime cost), unloading, unpacking, fixing, returning empties, and other incidental expenses and charges, in the form of a fixed sum.

A subsidiary bill for prime cost, percentage profit, and fixed charge is to be included in the description column, the total of these three items being carried to the rate column.

Prime Cost Sub-Contracts : In entering items in the Bill of Quantities for work intended to be carried out by specialist firms as sub-contractors, the amount proposed to be expended for the sub-contractors' work is to be stated as a prime cost provision, and opportunity is to be afforded for adding separately the allowances which the contractor requires for any outlay not covered by the prime cost and for profit.

In the following examples, the recommendations of the Institution of Civil Engineers' Committee on Engineering Quantities have been adhered to.

Take out, multiply, and bill the quantities for a *New Vault under Existing Footway*, to the Drawing shown on Plate I. (Inst C.E. Examination for Associate Membership, October, 1923.)

Before beginning to take off the quantities it is necessary to study the drawing and to understand the construction, in order to have a clear conception of what is required.

Following the order of subsections already referred to on p. 209, the work will be divided into the following :—

(*a*) Excavation (including Removal of Existing Works).
(*b*) Concrete, Brickwork, Masonry, and Waterproofing.
Note.—These may be combined in this case, since the number of items is so small.
(*c*) Steel work and iron work.

Actually the work could be divided into the following sections to fulfil the Committee on Engineering Quantities recommendations, but they stipulate in subsection (*b*) that subdivision into items is not to be excessive, hence the small number of sections given above :—

(*a*) Excavation (including Removal of Existing Works).
(*b*) Concrete.
(*c*) Brickwork.
(*d*) Masonry.
(*e*) Waterproofing.
(*f*) Steel and iron work.
(*g*) Pavings.

It is advisable to follow approximately the order in which the work would be executed, hence for Section (*a*) begin at the surface and work down, whilst for Section (*b*), begin at the bottom and work up. First locate, number, and describe all the items included in the whole work, thus :—

Item No.	Quantity[1]	Unit	Description	Rate	Amount
			EXCAVATION		
1	160	Cu. Yd.	Excavation for vault and foundations, in soft soil, including use of timber for timbering and shuttering and all timber left in.		

[1] This column is completed after the quantities have been taken off and multiplied.

Item No.	Quantity [1]	Unit	Description	Rate	Amount
2	33	Sq. Yd.	Extra over for lifting and removing asphalt, 1 in. thick, of existing footway.		
3	33	Sq. Yd.	Extra over for lifting and removing concrete, 6 in. thick, of existing footway.		
4	10·3	Lin. Yd.	Extra over for lifting, laying aside, cleaning, and afterwards relaying existing 12 in. × 8 in. granite curb.		
5	13·3	Cu. Yd.	Extra over for taking down and removing existing brick wall where shown and finishing and repointing existing wall where broken off at both ends.		
			(*Note.*—Alternatively the bricks removed could be cleaned, laid aside, and re-used in building the walls of the vault.)		
6	2·3	Sq. Ft.	Extra over for cutting away and removing existing floor and brickwork, 12 in. deep, and leaving fair surface for foundation of column to support existing wall, and afterwards filling in with 6 to 1 concrete.		
7	2	No. off.	Jumping holes in existing wall foundation, 9 in. deep to take ¾-in. Lewis bolts for column, and afterwards grouting up with cement (or lead).		
8	2	No. off.	Extra over for cutting away existing wall for the insertion of stone templates and R.S.J.s, and afterwards rebuilding and finishing off.		
			CONCRETE, BRICKWORK, MASONRY, AND WATERPROOFING		
9	14	Cu. Yd.	6 to 1 concrete in foundations under wall.		
10	8·2	Cu. Yd.	6 to 1 concrete in floors, 9 in. thick, horizontal.		
11	5·9	Cu. Yd.	6 to 1 concrete in roof, 8¼ in. thick, horizontal.		
12	25·8	Sq. Yd.	Wrought shuttering for Item No. 11.		
13	23	Cu. Yd.	12 to 1 concrete in filling behind walls.		

[1] This column is completed after the quantities have been taken off and multiplied.

Item No.	Quantity[1]	Unit	Description	Rate	Amount
14	25	Sq. Yd.	Extra over for granolithic paving on floor, 1½ in. thick.		
15	23·9	Cu. Yd.	Stock brickwork in cement in walls, 18 in. thick, and foundations.		
16	2	No. off.	York stone templates, 2 ft. 3 in. × 2 ft. 3 in. × 1 ft. to support ends of R.S.J.s.		
17	30	Sq. Yd.	York stone paving, 3 in. thick, for footway.		
18	4·7	Lin. Yd.	6 in. × 6 in. York stone curb round pavement lights.		
19	25·5	Sq. Yd.	Damp course of Asphalt, ¾ in. thick, under stone paving, horizontal.		
20	50	Sq. Yd.	Damp course of Asphalt, ¾ in. thick, between brick walls and concrete filling, vertical.		
			STEEL AND IRONWORK		
21	5	Cwt.	R.S.J. Stancheon, 8 in. × 6 in. × 35 lb., complete to drawing with gussets, angles, base and cap plates, 9 ft. 3½ in. long overall, comprising :—		
	321	Lb.	8 in. × 6 in. × 35 lb. R.S.J. 9 ft. 2 in. in length.		
	19·6	Lb.	Two ½-in. top Gusset Plates, 12 in. × 6½ in. shaped to drawing.		
	28	Lb.	Two ½-in. bottom Gusset Plates, 18 in. × 9½ in., shaped to drawing.		
	45·9	Lb.	Cap Plate, 12 in. × 18 in. × ¾ in.		
	68·8	Lb.	Base Plate, 18 in. × 18 in. × ¾ in.		
	22·1	Lb.	Two 3½ in. × 3½ in. × ½ in. top Angles, each 12 in. long.		
	33·2	Lb.	Two 3½ in. × 3½ in. × ½ in. base Angles, each 18 in. long.		
	10·7	Lb.	Add for Rivet Heads.		
	549·3	Lb.			
22			R.S.J. Girders, 10 in × 6 in. × 42 lb., with 9 in. × ½ in. flange plates, 14 ft. 3 in. long, complete to drawing; 4 off, each com-		

[1] This column is completed after the quantities have been taken off and multiplied.

Item No.	Quantity [1]	Unit	Description	Rate	Amount
	38	Cwt.	prising :—		
	598·5	Lb.	10 in. × 6 in. × 42 lb. R.S.J., 14 ft. 3 in. in length.		
	436·5	Lb.	Two 9 in. × ½ in. plates, each 14 ft. 3 in. in length.		
	24·8	Lb.	Add for Rivet Heads.		
	1059·8	Lb. in each girder.			
23	5·8	Cwt.	R.S.J.s, 6 in. × 3 in. × 12 lb., each 9 ft. long (6 off).		
24	0·8	Cwt.	R.S.J., 6 in. × 3 in. × 12 lb., 7 ft. 6 in. long, for Pavement Lights (1 off).		
25	0·14	Cwt.	Angle Cleats, 6 in. × 3½ in. × ½ in., each 3 in. long, fixing Pavement Lights R.S.J. to cross R.S.J.s (4 off).		
26	4·56	Lb.	Bolts, ¾ in. dia., 3¼ in. long, complete with nuts and washers, Girders to Columns (4 off).		
27	24·24	Lb.	Bolts, ¾ in. dia., 2¼ in. long, complete with nuts and washers, Joists to Girders (24 off).		
28	3·92	Lb.	Bolts, ¾ in. dia., 2 in. long, complete with nuts and washers for Cleats (4 off).		
29	3·68	Lb.	Bolts, ¾ in. dia., 1½ in. long, complete with nuts and washers, for Cleats (4 off).		
30	4·00	Lb.	Lewis Bolts, ¾ in. dia., 9½ in. long, complete with nuts and washers, for Columns (2 off).		
	0·36	Cwt.	In bolts, nuts, and washers for Items 26 to 30 inclusive.		
31		P.C.Sum.	Pavement Lights complete to drawing.		
32		Sum.	Profit on P.C. . . . per cent =		
33		Sum.	Packing, carriage, delivery on site, unloading, unpacking, fixing, returning empties, and other incidental expenses and charges in connection with Pavement Lights.		

[1] This column is completed after the quantities have been taken off and multiplied.

Having scheduled all the items in the work, it is now a comparatively simple task to go over the drawing and take off and then multiply the quantities already described in the various items, as follows :—

Item No.	No. off	Dimensions	Quantity	Unit	Description
1	1	31 ft. 0 in. 11 ft. 9 in. 10 ft. 9 in.	3916	Cu. Ft.	Excavation for vault (to bottom of floor).
		Deduct : 31 ft. 0 in. 1 ft. 0 in. 1 ft. 6 in.	46·5		Existing wall.
			3869·5	Cu. Ft.	
		D/dt. 2/2 ft. 9 in. 1 ft. 0 in. 9 in.	4	Cu. Ft.	Buttresses of existing wall.
			3865·5	Cu. Ft.	
		2/9 ft. 6 in. + 2/9 ft. 0 in. + 8 ft. 6 in.	•		
		45 ft. 6 in. 4 ft. 0 in. 2 ft. 6 in.	455	Cu. Ft.	In wall foundations.
			4320·5 = 160	Cu. Ft. Cu. Yd.	Excavation for Vault.
2	1	31 ft. 0 in. 9 ft. 7 in.	297 = 33	Sq. Ft. Sq. Yd.	E.o. for lifting and removing Asphalt paving.
3	1	31 ft. 0 in. 9 ft. 7 in.	33	Sq. Yd.	E.o. for lifting and removing concrete of footway.
4	1	31 ft. 0 in.	10·3	Lin. Yd.	E.o. for lifting and relaying 12 in. × 8 in. granite curb.
5	1	25 ft. 6 in. 1 ft. 6 in. 9 ft. 4 in.	357 = 13·3	Cu. Ft. Cu. Yd.	E.o. for removing existing brick wall.
6	1	1 ft. 6 in. 1 ft. 6 in.	2·3	Sq. Ft.	E.o. for cutting floor and brickwork for column.
7	2		2	No.	Jumping holes for Lewis bolts.

Item No.	No. off	Dimensions	Quantity	Unit	Description
8	2		2	No.	E.o. for cutting walls for templates and R.S.J.s.
9	1	2/9 ft. 6 in. +			
		2/9 ft. 0 in. +			
		8 ft. 6 in.			
		45 ft. 6 in.			
		4 ft. 0 in.			
		2 ft. 0 in.	364	Cu. Ft.	
			= 14	Cu. Yd.	Concrete in wall foundations.
10	1	28 ft. 6 in.			
		10 ft. 6 in.			
		9 in.	225	Cu. Ft.	
			= 8·2	Cu. Yd.	Concrete in floors.
11	1	28 ft. 6 in.			
		9 ft. 0 in.	256·5	Sq. Ft.	
		D/dt.			
		7 ft. 6 in.			
		3 ft. 3 in.	24·4	Sq. Ft.	For pavement lights.
			232·1	Sq. Ft.	
		× 8¼ in.	= 5·9	Cu. Yd.	Concrete in roof.
12	1	232·1 Sq. Ft.	= 25·8	Sq. Yd.	Shuttering for Item 11.
13	1	28 ft. 7½ in. +			
		9 ft. 6 in. +			
		9 ft. 6 in.			
		47 ft. 7½ in.			
		11 ft. 0 in.			
		1 ft. 2¼ in.	622	Cu. Ft.	
			= 23	Cu. Yd.	Concrete filling behind walls.
14	1	25 ft. 6 in.			
		9 ft. 0 in.	230	Sq. Ft.	
		D/dt.			
		4 ft. 6 in.			
		1 ft. 6 in.	7	Sq. Ft.	
			233	Sq. Ft.	
			= 25	Sq. Yd.	Granolithic paving on floor.
15	1	25 ft. 6 in. +			
		2/8 ft. 3 in. +			
		4 ft. 6 in.			
		46 ft. 6 in.			
		9 ft. 3 in.			
		1 ft. 6 in.	645	Cu. Ft.	
			= 23·9	Cu. Yd.	Brickwork in walls.
16	2		2	No.	York stone templates.
17	1	31 ft. 0 in.			
		9 ft. 7 in.	298	Sq. Ft.	

Item No.	No. off	Dimensions	Quantity	Unit	Description
		D/dt. 8 ft. 0 in. 3 ft. 6 in.	28	Sq. Ft.	For pavement lights.
			270 = 30	Sq. Ft. Sq. Yd.	York stone paving in footway.
18	1		4·7	Lin. Yd.	6 in. × 6 in. York stone curb round pavement lights.
19	1	28 ft. 6 in. 9 ft. 0 in.	257	Sq. Ft.	
		D/dt. 8 ft. 0 in. 3 ft. 6 in.	28	Sq. Ft.	For pavement lights.
			229 = 25·5	Sq. Ft. Sq. Yd.	Asphalt under stone paving.
20	1	28 ft. 6 in. + 2/8 ft. 3 in.			
		45 ft. 0 in. 10 ft. 0 in.	450 = 50	Sq. Ft. Sq. Yd.	Asphalt between brick walls and concrete filling.
21	1	9 ft. 2 in. at 35 lb.	321	Lb.	In R.S.J., 9 ft. 2 in. long.
		2/12 in. × 3½ in. + 9 in. × 3 in. = 2/42 + 27 = 138 sq. in. ½ in.	19·6	Lb.	$\frac{138}{144} \times \frac{1}{2} \times 40{\cdot}8$ lb. = 19·6 lb. In top Gusset Plates.
		2/18 in. × 3½ in. + 12 in. × 6 in. = 2/63 + 72 = 198 sq. in. ½ in.	28	Lb.	$\frac{198}{144} \times \frac{1}{2} \times 40{\cdot}8$ lb. = 28 lb. In bottom Gusset Plates.
		12 × 18 in. = 216 sq. in. ¾ in.	45·9	Lb.	$\frac{216}{144} \times \frac{3}{4} \times 40{\cdot}8$ lb. = 45·9 lb. In Cap Plate.
		18 × 18 in. = 324 sq. in. ¾ in.	68·8	Lb.	$\frac{324}{144} \times \frac{3}{4} \times 40{\cdot}8$ lb. = 68·8 lb. In Base Plate.

Item No.	No. off	Dimensions	Quantity	Unit	Description
		2(3½ in. + 3 in.) = 13 × 12 in. = 156 sq. in. ½ in.	22·1	Lb.	$\frac{156}{144}$ × ½ × 40·8 = 22·1 lb. In top Angles.
		2(3½ in. + 3 in.) = 13 × 18 in. = 234 sq. in. ½ in.	33·2	Lb.	$\frac{234}{144}$ × ½ × 40·8 lb. = 33·2 lb. In base Angles.
		76 Rivet Heads	10·7	Lb.	76 heads at 14·08 lb. per 100. In Rivet Heads.
			549·3 = 5	Lb. Cwt.	In R.S.J. Stancheon, complete.
22	4	14 ft. 3 in. at 42 lb.	598·5	Lb.	In 10 in. × 6 in. R.S.J., 14 ft. 3 in. long.
		2/14 ft. 3 in. 9 in.	436·5	Lb.	2/14¼ ft. × ¾ in. × ½ in. × 40·8 lb. = 436·5 lb. In 9 in. × ½ in. Flange Plates.
		176 Rivet Heads	24·8	Lb.	174 Heads at 14·08 lb./100. In Rivet Heads.
			1059·8 = 9·5	Lb. Cwt.	In R.S.J. Girder complete.
			= 38	Cwt.	In 4 R.S.J. Girders complete.
23	6	6/9 ft. 0 in. 12 lb./ft.	5·8	Cwt.	648 lb. = 5·8 cwt. In 6 in. × 3 in. R.S.J.s.
24	1	7 ft. 6 in. 12 lb./ft.	0·8	Cwt.	90 lb. = 0·8 cwt. In 6 in. × 3 in. pavement lights joist.
25	4	4(6 in. + 3 in.) = 3 ft. 0 in. 3 in. ½ in.	0·14	Cwt.	0·75 × ½ × 40·8 lb. = 15·3 lb. = ·14 cwt. In 6 in. × 3½ in. Angle Cleats.
26	4	1·14 lb. ea.	4·56	Lb.	In ¾ in. dia. bolts, 3¼ in. long.
27	24	1·01 lb. ea.	24·24	Lb.	In ¾ lb. dia. bolts, 2¼ in. long.
28	4	0·98 lb. ea.	3·92	Lb.	In ¾ lb. dia. bolts, 2 in. long.
29	4	0·92 lb. ea.	3·68	Lb.	In ¾ in. dia. bolts, 1½ in. long.
30	2	2 lb. ea.	4	Lb.	In ¾ in. dia. Lewis bolts.
			40·40 = 0·36	Lb. Cwt.	In ¾ dia. bolts complete.

It will be observed that mass concrete is measured in cubic yards, shuttering in square yards, and special face work is measured extra over mass concrete in square yards. In the above, for example, the flooring is measured as 9 in. thick of concrete and the granolithic finish as an extra over the concrete in the floor. No deductions are made in the measurement of mass concrete for small cavities, chamfers, nosings, bolt-holes, rails, joists, or the like and separate items are introduced for concrete 12 in. thick or under, indicating the thickness and whether vertical, sloping, or horizontal. (Items 10, 11, and 14.)

The shuttering is measured as the area of the surfaces of the finished structure which require to be supported during the deposition of the concrete (see Item 12).

Rails or joists introduced into mass concrete should be measured in tons, but, due to the small quantities in the above, they have been scheduled in cwts.

Brickwork is measured in cubic yards, special facings being measured extra over general brickwork in square yards.

Excavations are measured in cubic yards, with an extra over for removing and reinstating roads and other paved surfaces, measured in square yards, unless in the case of trenches for drains, pipes, cables, etc., which are measured in linear yards both for the excavations and for the extra over for lifting and reinstating the surfaces (e.g. Items 1, 2, and 3).

Item 5, for taking down and removing existing brickwork shows the usual method of measurement, i.e. in cubic yards extra over the excavation in which it is contained. This also applies to breaking up masonry and concrete contained in excavations.

The excavation in Item 1 is stated to be in soft soil. If both soft and hard material are encountered in excavations, a definition of hard material or rock should be given, and also the sizes of boulders encountered which are to constitute rock. (See Clause 86, p. 67.)

In Items 19 and 20 the asphalt is measured in square yards, the horizontal surfaces being scheduled separately from the vertical surfaces.

The steel and iron work should be measured in tons, but again, owing to the small quantities, it has been given in cwt. The weights of steel and iron should be calculated on the basis of 40·8 lb. per sq. ft. of metal 1 in. thick for rolled and cast steel. It will be observed that, since the R.S.J. Stancheon and the R.S.J. Girders would probably be ordered complete from specialist firms, these are each entered as an item, i.e. Items 21 and 22, subsidiary bills being included for each.

These methods conform to those recommended by the

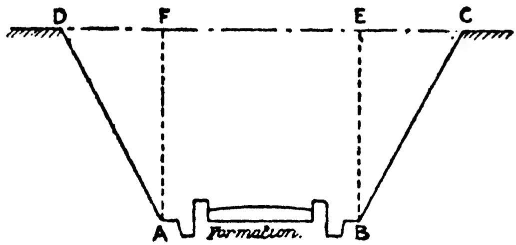


FIG. 24

Institution of Civil Engineers' Committee on Engineering Quantities.

EARTHWORK CALCULATIONS.—In calculating the volume of earthwork, the exact form of the cross section of the cutting or of the embankment is first required.

For instance, in Fig. 24, the side slopes are carried down to formation level AB, and on each side there is a ditch and a small earth bank, as shown. It is most usual to calculate the

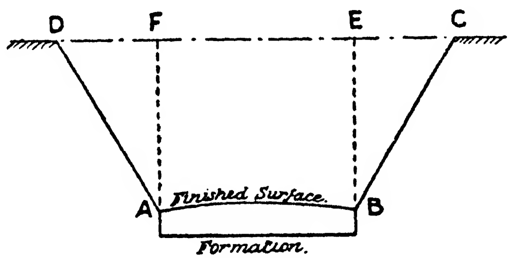


FIG. 25

volume for section ABCD in the first instance, and allow for ditches and banks afterwards if desired.

In Fig. 25, which is a possible example for a short cutting, the slopes are carried down to about the finished surface level, and the part below is excavated vertically and filled in again as shown. In this case the depth used in calculating the volumes should be taken down to the finished surface level only (i.e. to AB) in the first place and the volume of the part below worked out separately and added.

Fig. 26 shows a cross section of an embankment, without any earth bank at the sides or other additions.

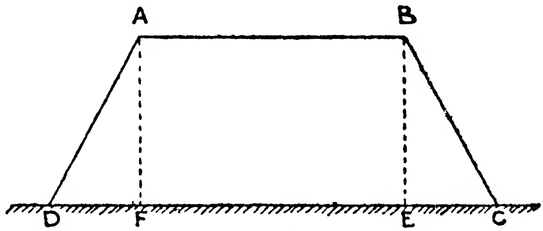


FIG. 26

The width AB is, in all cases, called the "formation width".

The side slopes are fixed according to the nature of the material and are expressed as, say n to 1, meaning n horizontal to 1 vertical.

To work without tables, an expression for the area ABCD must be found.

Let the depth BE in Figs. 24 to 26 $= h$.
width AB $= b$.
side slopes $= n$ to 1.

Then ABCD = ABEF + 2BEC.

$$= (b \times h) + (h \times nh).$$

$$= bh + nh^2.$$

Now, in Fig. 27, let Cc, Dd, and Ee be the depths of a

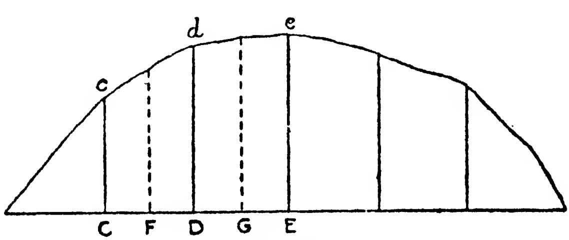


FIG. 27

cutting at known points, and F and G be the middle points of CD and DE respectively, then to find the volume between

F and G, first find the cross sectional area corresponding to the depths Cc and Dd. The average of these areas multiplied by the length CD will give the volume between C and D (Trapezoidal Formula). Alternatively, a closer approximation is got by using the Prismoidal Formula, which is given further on.

Thus, suppose $h_1, h_2, \ldots h_m$ are the depths of cutting at known points, $L_1, L_2, \ldots L_m$ the distances between these known points, b the formation width, and side slopes n to 1.

$$\text{Then Volume} = L_1 \left(\frac{b(h_1+h_2)}{2} + \frac{n(h_1^2+h_2^2)}{2}\right)$$
$$+ L_2 \left(\frac{b(h_2+h_3)}{2} + \frac{n(h_2^2+h_3^2)}{2}\right)$$
$$+ L_{m-1}\left(\frac{b(h_{m-1}+h_m)}{2} + \frac{n(h_{m-1}^2+h_m^2)}{2}\right)$$

If all the distances are equal, so that $L_1 = L_2 = L_m - 1$, etc., this becomes :—

$$\text{Volume} = L\left(b\left(\frac{h_1}{2}+h_2+h_3+\ldots\frac{h_m}{2}\right)+n\left(\frac{h_1^2}{2}+h_2^2+h_3^2+\ldots\frac{h_m^2}{2}\right)\right)$$

When, as is usually the case, the embankments or cuttings are formed on ground which is not level, but which has a side slope of r to 1, the area of the cross section may be found as follows :—

In Fig. 28, the area of the central portion ABEF
$=$width $b\times$ average height h
$= bh$ . . . . (1)

Also $h_1 = h + \frac{b}{2r}$ . . . . (2)

And $h_2 = h - \frac{b}{2r}$ . . . . (3)

Let t_1 be the perpendicular distance from C on to BE. Then area of triangle

$$BEC = \frac{h_2 \times t_1}{2}$$

Let x_1 and x_2 be the distances from B and E of the foot of the perpendicular t_1 from C on BE.

Then $x_1 + x_2 = h_2$ . . . . (4)
Also $t_1 = nx_1 = rx_2$ . . . . (5)
And $x_1 : x_2 = r : n$ . . . . (6)

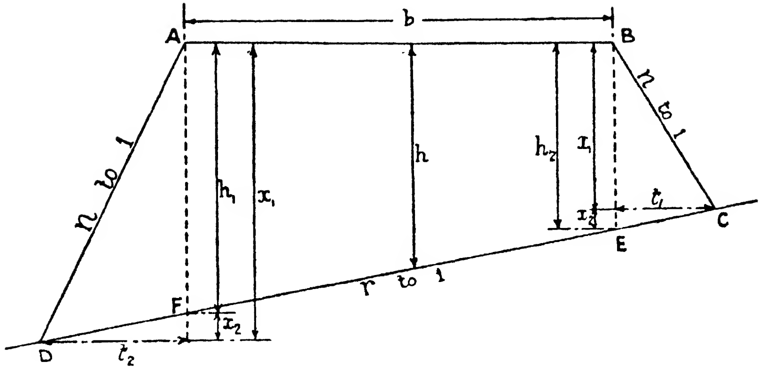


Fig. 28

Therefore $\dfrac{x_1}{x_1 + x_2} = \dfrac{r}{n + r}$

Therefore $\dfrac{t_1}{h_2} = \dfrac{nr}{n + r}$

Therefore $t_1 = \dfrac{nrh_2}{n + r}$

Therefore Area of triangle BCE $= \dfrac{nrh_2^2}{2(n + r)}$

Similarly, Area of triangle ADF $= \dfrac{nrh_1^2}{2(r - n)}$

Therefore Total Area of Cross Section

$$= bh + \frac{nr(h - \frac{b}{2r})^2}{2(n + r)} + \frac{nr(h + \frac{b}{2r})^2}{2(r - n)} \quad . \quad . \quad . \quad . \qquad (7)$$

If the sections be taken at equal distances apart, the areas as found may be set off as ordinates as in Fig. 29.

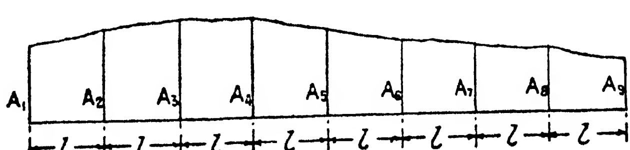


Fig. 29

The volume of the embankments or cuttings may then be found by taking the means as before, i.e. :—

$$\text{Volume} = l\left(\frac{A_1}{2} + A_2 + A_3 + A_4 + A_5 + A_6 + A_7 + A_8 + \frac{A_9}{2}\right)$$

(Trapezoidal Formula)

or by the Prismoidal Formula (which is similar to Simpson's rule for areas), and which is as follows :—

When there is an odd number of ordinates, let S = sum of lengths of first and last ordinates (i.e. in this case $A_1 + A_9$), E = sum of lengths of intermediate even ordinates, and N = sum of lengths of intermediate odd ordinates ; l = distance apart of the ordinates, then

$$\text{Volume} = \frac{S + 4E + 2N}{3} \times l$$

or, taking the section shown in Fig. 30, the volume would be :—

$$= \left\{A_1 + A_9 + 4(A_2 + A_4 + A_6 + A_8) + 2(A_3 + A_5 + A_7)\right\} \times \frac{l}{3}$$

(Prismoidal Formula)

The above has been shown worked out for an embankment, but the working is identical for a cutting.

For railway embankments the side slopes are commonly 2 to 1, and for cuttings 1½ to 1.

As an example of the working out of a cross section, take a section on a side slope of 20 to 1, in which a cutting is to be made, the mean depth of same at the centre of formation being 15 ft., and formation width 30 ft. Find the area.

From Fig. 28, if it were turned upside down, h would = 15, b = 30, r = 20, n = 1½.

Then from Equation (7) above, Area

$$= \quad 30 \times 15 + \frac{1\tfrac{1}{2} \times 20(15 - \frac{30}{40})^2}{2(1\tfrac{1}{2} + 20)} + \frac{1\tfrac{1}{2} \times 20(15 + \frac{3}{4})^2}{2(20 - 1\tfrac{1}{2})}$$

$$= 450 + \frac{30 \times 14\tfrac{1}{4}^2}{43} + \frac{30 \times 15\tfrac{3}{4}^2}{37}$$

$$= 450 + 141{\cdot}67 + 201{\cdot}13$$

$$= 792{\cdot}8 \text{ sq. ft.}$$

The following example in earthworks is taken from the April Examination paper of the Institution of Civil Engineers in 1927 :—

Prepare a Bill of Quantities clearly showing the taking out and multiplying, for earthwork quantities shown on the accompanying drawing, Plate II.

Note that the drawing asks for quantities to be billed for the following, between A and B.

(*a*) Earthwork in Embankment.
(*b*) Rock Cutting.
(*c*) Cutting in Soft Soil.
(*d*) Soiling of Slopes (6 in.).

The Bill in this case will therefore consist only of the following items :—

Item No.	Quantity[1]	Unit	Description	Rate	Amount
1	2,865	Cu. Yd.	Earthwork in Embankment.		
2	8,047	Cu. Yd.	Rock Cutting.		
3	14,617	Cu. Yd.	Cutting in Soft Soil.		
4	3,969	Sq. Yd.	Soiling of Slopes, 6 in. deep.		

In cases such as these, where no dimensions are given, it is probably most simple to measure each section and compute the area thus :—(Fig. 30).

When the ground surface is irregular as A–B, draw in a straight line E–F to average the slope, i.e. so that the amount of space between A–B and E–F, above E–F equals as nearly as possible that below E–F.

Drop DG and CH perpendicular to CD. Draw KG perpendicular to ED and HL perpendicular to CF.

Then Area of Cross Section

$$= (DC \times \frac{DG + CH}{2}) + \frac{DE \times GK}{2} + \frac{CF \times HL}{2}$$

In the figure shown, this is equal to

$$(30 \text{ ft.} \times \frac{11 \text{ ft.} + 7 \text{ ft.}}{2}) + \frac{23\tfrac{1}{2} \text{ ft.} \times 9 \text{ ft.}}{2} + \frac{10{\cdot}6 \text{ ft.} \times 6 \text{ ft.}}{2}$$

$$= 270 + 105{\cdot}75 + 31{\cdot}8$$

$$= 407{\cdot}55 \text{ sq. ft.} = \text{say, } 408 \text{ sq. ft.}$$

[1] This column is completed after the quantities have been taken off and multiplied.

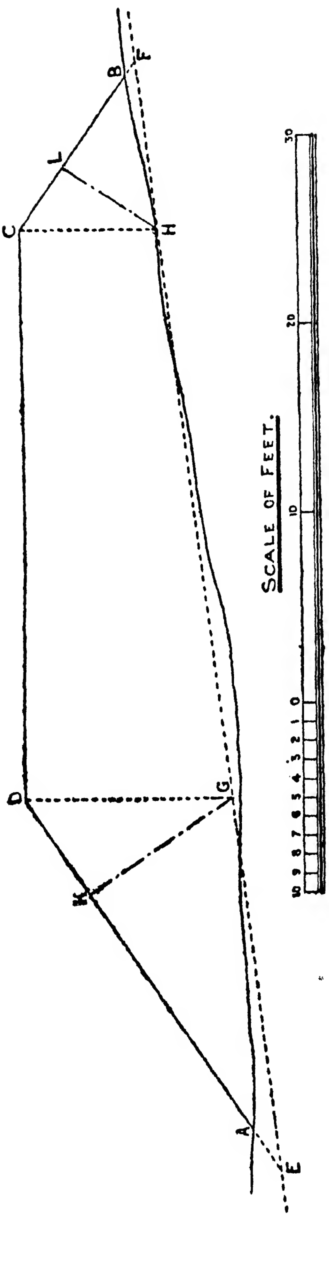


FIG. 30

When the ground surface is regular, or nearly so, as in the sections on the Drawing, the areas may be taken straight off, and the lengths of side slopes taken off are available also for the calculation of the soiling of slopes.

The quantities may now be taken off from the drawing and multiplied, thus :—

Item No.	No. off	Dimensions	Quantity	Unit	Description
1		$30 \times \frac{9{\cdot}5 + 7{\cdot}8}{2}$	259·5		Earthwork in Embankment.
		$+ \frac{18{\cdot}6 \times 7{\cdot}8}{2}$	72·5		
		$+ \frac{13 \times 6{\cdot}4}{2}$	41·6		
			374	Sq. Ft.	C.S. 2 m. 0 c.
		$30 \times \frac{1}{2}(6{\cdot}5 + 5{\cdot}1)$	174		
		$+ \frac{1}{2}(13 \times 5{\cdot}2)$	34·8		
		$+ \frac{1}{2}(8{\cdot}6 \times 4{\cdot}4)$	19		
			228	Sq. Ft.	C.S. 2 c.
		$30 \times \frac{1}{2}(4{\cdot}2 + 2{\cdot}8)$	105		
		$+ \frac{1}{2}(7{\cdot}8 \times 3{\cdot}3)$	12·9		
		$+ \frac{1}{2}(4{\cdot}8 \times 2{\cdot}5)$	6		
			124	Sq. Ft.	C.S. 4 c.
		$30 \times \frac{1}{2}(2 + 1{\cdot}4)$	51		
		$+ \frac{1}{2}(3{\cdot}6 \times 1{\cdot}6)$	2·9		
		$+ \frac{1}{2}(2{\cdot}4 \times 1{\cdot}2)$	1·5		
			55	Sq. Ft.	C.S. 6 c.
		$\frac{1}{2}(11{\cdot}5 \times 0{\cdot}6)$	3·5		
		$+ \frac{1}{2}(1{\cdot}2 \times 0{\cdot}6)$	0·4		
			4	Sq. Ft.	C.S. 8 c.

This concludes the taking off for Item No. 1. It will be observed that there are five sections concerned, so that the volume may be calculated either by the rule of average (Trapezoidal Formula), i.e. taking half the sum of the first and last areas plus the sum of the intermediate areas and multiplying this total by the distance between the sections (in this case, 2 chains), or by the Prismoidal Formula.

By the former method the volume comes out thus :—

$$\text{Volume} = \{\tfrac{1}{2}(374 + 4) + 228 + 124 + 55\} \times 66 \times 2$$
$$= 78672 \text{ cu. ft.}$$
$$= \underline{2914 \text{ cu. yd.}} \text{ Earthwork in Embankment.}$$

By the Prismoidal Formula :—

$$\text{Volume} = \frac{(374 + 4) + 4(228 + 55) + (2 \times 124)}{3} \times 66 \times 2$$
$$= 77352 \text{ cu. ft.} \qquad = \underline{2865 \text{ cu. yd.}}$$

With regard to Item No. 2 for Rock Cutting, it will be observed that the surface of the rock runs horizontally across each cross section, parallel to the formation level. This simplifies the calculations, as in such a case, if w = width of cutting at formation, and h = depth of cutting, with slopes of $\frac{1}{2}$ to 1, as shown on C.S. 28 c, on Plate II, the area of the section will be $= wh + \frac{1}{2}h^2$.

If, therefore, the heights of the various sections from C.S. 14 c to C.S. 30 c be designated h_1, h_2, h_3, to h_9 respectively, and the distances between the cross sections by l, the volume of rock cutting between the two sections using the Trapezoidal Formula will be given by :—

$$V = [w\{\tfrac{1}{2}(h_1 + h_9) + h_2 + h_3 + \;.\;.\;.\;.\;.\; + h_8\} + \tfrac{1}{2}\{\tfrac{1}{2}(h_1^2 + h_9^2) + h_2^2 + h_3^2 + \;.\;.\;.\;.\;.\;.\; + h_8^2\}] \times l.$$

Alternatively by the Prismoidal Formula, the volume may be found from :—

$$V = \Big[\frac{w}{3}\{h_1 + h_9 + 4(h_2 + h_4 + h_6 + h_8) + 2(h_3 + h_5 + h_7)\} + \tfrac{1}{3} \times \tfrac{1}{2}\{h_1^2 + h_9^2 + 4(h_2^2 + h_4^2 + h_6^2 + h_8^2) + 2(h_3^2 + h_5^2 + h_7^2)\}\Big] \times l.$$

In addition to this there is a small volume to be added between C.S. 12 c and C.S. 14 c from where, in the Longitudinal Section, the line showing the surface of the rock cuts the Formation Level Line. The length of this is 86 ft., and hence its

$$\text{Volume} = \tfrac{1}{2}\{86 \times (wh_1 + \tfrac{1}{2}h_1^2)\}$$

considering it as a triangular wedge.

Note that if it were considered to be a cone or pyramid instead of a wedge, the division would be by 3 instead of 2.

The volume, therefore, now works out as follows :—

Item No.	No. off	Dimensions	Quantity	Unit	Description
2		Width throughout $= w = 30$ ft.			
		Height $h_1 = 1{\cdot}0$ ft., $h_1^2 = 1{\cdot}0$			C.S. 14 c.
		$h_2 = 2{\cdot}6$ ft., $h_2^2 = 6{\cdot}76$			C.S. 16 c.
		$h_3 = 4{\cdot}2$ ft., $h_3^2 = 17{\cdot}64$			C.S. 18 c.
		$h_4 = 5{\cdot}7$ ft., $h_4^2 = 32{\cdot}49$			C.S. 20 c.
		$h_5 = 7{\cdot}3$ ft., $h_5^2 = 53{\cdot}29$			C.S. 22 c.
		$h_6 = 7{\cdot}7$ ft., $h_6^2 = 59{\cdot}29$			C.S. 24 c.
		$h_7 = 8{\cdot}1$ ft., $h_7^2 = 65{\cdot}61$			C.S. 26 c.
		$h_8 = 8{\cdot}3$ ft., $h_8^2 = 68{\cdot}89$			C.S. 28 c.
		$h_9 = 9{\cdot}1$ ft., $h_9^2 = 82{\cdot}81$			C.S. 30 c.
		Distance between Cross Sections $= l = 2$ chains $= 132$ ft.			
		Length of wedge between C.S. 12 c and C.S. 14 c $= 86$ ft.			
		Volume (by Prismoidal Formula) $= V = \frac{86}{2}(wh_1 + \frac{1}{2}h_1^2) + \left\{w(\frac{1}{2}h_1 + \frac{1}{2}h_9 + h_2 + \ldots + h_8) + \frac{1}{2}(\frac{1}{2}h_1^2 + \frac{1}{2}h_9^2 + h_2^2 \ldots + h_8^2)\right\} \times l$			
		$= \frac{86(30 + \frac{1}{2})}{2}$	1,311	Cu. Ft.	
		$+\left[30\left\{(\frac{1 + 9{\cdot}1}{2}) + 2{\cdot}6 + 4{\cdot}2 + 5{\cdot}7 + 7{\cdot}3 + 7{\cdot}7 + 8{\cdot}1 + 8{\cdot}3\right\} + \frac{1}{2}(\frac{1 + 82{\cdot}81}{2} + 6{\cdot}76 + 17{\cdot}74 + 32{\cdot}49 + 53{\cdot}29 + 59{\cdot}29 + 65{\cdot}61 + 68{\cdot}89)\right] \times 132$			
			216,670	Cu. Ft.	
			217,981	Cu. Ft.	Rock
			= 8,074	Cu. Yd.	Cutting.

If worked out by the Prismoidal Formula, this volume comes to :—

$$V = \left[\frac{30}{3}\left\{1 + 9{\cdot}1 + 4(2{\cdot}6 + 5{\cdot}7 + 7{\cdot}7 + 8{\cdot}3) + 2(4{\cdot}2 + 7{\cdot}3 + 8{\cdot}1)\right\} + \frac{1}{6}\left\{1 + 82{\cdot}81 + 4(6{\cdot}76 + 32{\cdot}49 + 59{\cdot}29 + 68{\cdot}89) + 2(17{\cdot}64 + 53{\cdot}29 + 65{\cdot}61)\right\}\right] \times 132$$

$$= \left[10(10{\cdot}1 + 4 \times 24{\cdot}3 + 2 \times 19{\cdot}6) + \frac{1}{6}(83{\cdot}81 + 4 \times 167{\cdot}43 + 2 \times 136{\cdot}54)\right] \times 132$$

$$= 10 \times 146{\cdot}5 \times 132 + 1026{\cdot}61 \times 22 = 193380 + 22585$$

= 215,965 cu. ft. to which is to be added the wedge of 1,311 cu. ft.

= 217,276 cu. ft. = <u>8,047 cu. yd.</u>

Item 3 is worked out in a manner similar to Item 1, as follows :—

Item No.	No. off	Dimensions	Quantity	Unit	Description
3		½(18·5 × 1) + ½(1·8 × 0·9)	10·1	Sq. Ft.	C.S. 8 c.
		30 × 1·4 + ½(1·6 × 1) + ½(3·4 × 1·5)	45·4	Sq. Ft.	C.S. 10 c.
		30 × 3·2 + ½(5·4 × 2·7) + ½(6·0 × 2·8)	111·7	Sq. Ft.	C.S. 12 c.
		32·6 × 4·0 + ½(8·0 × 3·8) + ½(5·8 × 2·7)	153·4	Sq. Ft.	C.S. 14 c.
		34·8 × 4·4 + ½(10·2 × 4·5) + ½(5·4 × 2·6)	185·0	Sq. Ft.	C.S. 16 c.
		36·6 × 4·7 + ½(10·5 × 4·6) + ½(6·2 × 3·0)	205·9	Sq. Ft.	C.S. 18 c.
		37·6 × 4·2 + ½(10·2 × 4·5) + ½(5·0 × 2·6)	187·5	Sq. Ft.	C.S. 20 c.
		39·2 × 3·2 + ½(6·8 × 3·0) + ½(5·4 × 2·6)	142·6	Sq. Ft.	C.S. 22 c.
		40·0 × 4·8 + ½(7·8 × 4·0) + ½(9·0 × 4·0)	225·6	Sq. Ft.	C.S. 24 c.
		40·2 × 9·0 + ½(13 × 6·7) + ½(19 × 8·2)	483·4	Sq. Ft.	C.S. 26 c.
		40·4 × 12·8 + ½(16·8 × 9) + ½(29·4 × 12)	769·5	Sq. Ft.	C.S. 28 c.

Item No.	No. off	Dimensions	Quantity	Unit	Description
		$41{\cdot}5 \times 14{\cdot}8 + \frac{1}{2}(18{\cdot}4 \times 10{\cdot}2) + \frac{1}{2}(35 \times 14)$	952·8	Sq. Ft.	C.S. 30 c.
		$V = (\frac{10{\cdot}1 + 952{\cdot}8}{2} + 45{\cdot}4 + 111{\cdot}7 + 153{\cdot}4 + 185 + 205{\cdot}9 + 187{\cdot}5 + 142{\cdot}6 + 225{\cdot}6 + 483{\cdot}4 + 769{\cdot}5) \times 132$	393,870 = 14,588	Cu. Ft. Cu. Yd.	Cutting in Soft Soil.

Alternatively, using the Prismoidal Formula, it will be noted that, as the number of cross sectional areas is even, it will be necessary to calculate one of the end volumes (say that between C.S. 8 c and C.S. 10 c) independently. This may be done by multiplying the average of the areas at these sections by the distance between them, and the result added to the volume between C.S. 10 c and C.S. 30 c as found by the Prismoidal Formula, thus :—

$$V = \frac{132}{3}\left\{45{\cdot}4 + 952{\cdot}8 + 4(111{\cdot}7 + 185{\cdot}0 + 187{\cdot}5 + 225{\cdot}6 + 769{\cdot}5) + 2(153{\cdot}4 + 205{\cdot}9 + 142{\cdot}6 + 483{\cdot}4)\right\} + \frac{10{\cdot}1 \times 45{\cdot}4}{2} \times 132$$

$$= 44\{998{\cdot}2 + 5917{\cdot}2 + 1970{\cdot}6\} + 55{\cdot}5 \times 66$$

$$= 390984 + 3663 = 394{,}647 \text{ cu. ft.} = \underline{14{,}617 \text{ cu. yd.}}$$

The lengths of the slopes in Item No. 4 are taken from the figures already recorded in the taking off of Items Nos. 1 and 3, and the figures and multiplication are as follows :—

Item No.	No. off	Dimensions	Quantity	Unit	Description
4		$(\frac{18{\cdot}6 + 18{\cdot}4}{2} + 13 + 7{\cdot}8 + 3{\cdot}6 + 1{\cdot}2 + 1{\cdot}6 + 5{\cdot}4 + 8{\cdot}0 + 10{\cdot}2 + 10{\cdot}5 + 10{\cdot}2 + 6{\cdot}8 + 7{\cdot}8 + 13 + 16{\cdot}8 + \frac{13 + 35}{2} + 8{\cdot}6 + 4{\cdot}8 + 2{\cdot}4 + 1{\cdot}8 + 3{\cdot}4 + 6{\cdot}0 + 5{\cdot}8 + 5{\cdot}4 + 6{\cdot}2 + 5{\cdot}0 + 5{\cdot}4 + 9{\cdot}0 + 19{\cdot}0 + 29{\cdot}4) \times 132 = 270{\cdot}6 \times 132$	35,720 = 3,969	Sq. Ft. Sq. Yd.	Soiling of Slopes (6 in.).

Note that the cost of forming the embankments for railways, roads, and other works consisting of an alternation of cuttings and embankments, is to be covered by the rates for the excavation of the cuttings or other excavation from which the material is obtained. When the cost of filling is not included in the excavation rates in accordance with the preceding paragraph, the unit of measurement of filling is to be the cubic yard, measurements being taken to the outlines and levels shown on the drawing or specified.

When the amount of filling required to be done exceeds the amount available from excavation, separate items are to be provided for the deficit. The quantities of excavation are the net cubic content of the voids to be formed by the removal of the material excavated, no allowance being made for bulking.

The unit of measurement for trimming and for soiling and sowing of surfaces, where paid for separately, is the square yard, the thickness of soiling being stated.

Surfaces on the slope, as is the above example, are to be measured separately from surfaces on the level.

The next example is to take out and bill the quantities for :—

(*a*) Reinforced Concrete in Piles.
(*b*) Pitch pine Timber in Bracing.
(*c*) Wrought iron in Plates and Bolts at Joint F only.
(*d*) Steel in Reinforcement of Piles.

of the *Concrete and Timber Dolphin* shown on Plate III, which is taken from the Institution of Civil Engineers' Examination of October, 1927.

The Schedule of the items in this case will be as follows :—

Item No.	Quantity[1]	Unit	Description	Rate	Amount
			REINFORCED CONCRETE IN PILES.		
1	332	Cu. Ft.	Reinforced Concrete in Piles 1 ft. 2 in. × 1 ft. 2 in. × 50 ft. long overall.		
2	5	No.	Handling and pitching R.C. Piles described in Item 1.		
3	5	No.	Driving above Piles to level shown on drawing.		
4	5	No.	Cutting off heads of Piles.		

[1] This column is completed after the quantities have been taken off and multiplied.

Item No.	Quantity[1]	Unit	Description	Rate	Amount
			PITCH PINE TIMBER IN BRACING.		
5	49	Cu. Ft.	Upper and Intermediate Longitudinal pitch pine Bracings, each 1 ft. 2 in. × 1 ft. × 10 ft. 4 in. long overall, above H.W.O.S.T., sawn fair to scantling and ends sawn square.		
6	24	Cu. Ft.	Lower Longitudinal pitch pine Bracings, each 1 ft. 2 in. × 1 ft. × 10 ft. 4 in. long overall, below H.W.O.S.T. and above L.W.O.S.T., sawn fair to scantling and ends sawn square.		
7	27	Cu. Ft.	Upper and Intermediate Transverse pitch pine Bracings, each 1 ft. 2 in. × 1 ft. × 5 ft. 10 in. long overall, above H.W.O.S.T., sawn fair to scantling and ends sawn square.		
8	14	Cu. Ft.	Lower Transverse pitch pine Bracings, each 1 ft. 2 in. × 1 ft. × 5 ft. 10 in. long overall, below H.W.O.S.T. and above L.W.O.S.T., sawn fair to scantling and ends sawn square.		
9	35	Cu. Ft.	Upper and Intermediate pitch pine Bracings to Rear Pile, 1 ft. 2 in. × 1 ft. × 7 ft. 4 in. long overall, above H.W.O.S.T., sawn fair to scantling, one end bevelled.		
10	15	Cu. Ft.	Lower pitch pine Bracings to Rear Pile, 1 ft. 2 in. × 1 ft. × 7 ft. 4 in. long overall, between H.W.O.S.T. and L.W.O.S.T., sawn fair to scantling, one end bevelled.		
11	32	Cu. Ft.	Upper Diagonal Longitudinal pitch pine Bracings, 1 ft. 2 in. × 1 ft. × 13 ft. 6 in. long overall, above H.W.O.S.T., sawn fair to scantling and ends cut to bevel.		

[1] This column is completed after the quantities have been taken off and multiplied.

Item No.	Quantity[1]	Unit	Description	Rate	Amount
12	31	Cu. Ft.	Lower Diagonal Longitudinal pitch pine Bracings, 1 ft. 2 in. × 1 ft. × 13 ft. 6 in. long overall, between H.W.O.S.T. and L.W.O.S.T., sawn fair to scantling and ends cut to bevel.		
13	25	Cu. Ft.	Upper Diagonal Transverse pitch pine Bracings, 1 ft. 2 in. × 1 ft. × 10 ft. 9 in. long overall, above H.W.O.S.T., sawn fair to scantling and ends cut to bevel.		
14	25	Cu. Ft.	Lower Diagonal Transverse pitch pine Bracings, 1 ft. 2 in. × 1 ft. × 10 ft. 9 in. long overall, between H.W.O.S.T. and L.W.O. S.T., sawn fair to scantling and ends cut bevel to fit between piles.		
			PLATES AND BOLTS AT JOINT F.		
15	1·15	Cwt.	Wrought Iron Plate, 1 ft. × 4 in. × ¾ in. × 3 ft. 6 in. long, cut to shape and bent to form shown on drawing.		
16	2·05	Cwt.	Wrought Iron Plate, 2 ft. 3 in. × ¾ in. × 3 ft. 6 in. long, cut to shape shown on drawing.		
17	1·24	Cwt.	Wrought Iron Plate, 9 in. × 9 in. × ¾ in. × 3 ft. 6 in. long, cut to shape and bent to form shown on drawing.		
18	0·39	Cwt.	W.I. Bolts, 1 in. dia., 14 in. long, complete with nuts and washers.		
19	0·18	Cwt.	W.I. Bolts, 1 in. dia, 17 in. long, complete with nuts and washers.		
			STEEL IN PILE REINFORCEMENT.		
20	22·29	Cwt.	Main Reinforcing Rods, 1 in. dia., each 49 ft. in length, including all necessary bending.		
21	2·37	Cwt.	Links, 3/16 in. dia., 9 in. apart, each 27 in. long, in Main Piles.		

[1] This column is completed after the quantities have been taken off and multiplied.

Item No.	Quantity[1]	Unit	Description	Rate	Amount
22	0·42	Cwt.	C.I. Forks, ½ in. dia., each 13½ in. long and 4 ft. apart, in Main Piles.		
23	5	No.	C.I. Pile Shoes, each 60 lb. in weight, and complete with 4/1½ in. × ⅜ in. W.I. Straps each 2 ft. long.		

Following this, the items are now readily taken off and multiplied as follows :—

Item No.	No. off	Dimensions	Quantity	Unit	Description
1	5	48 ft. 10 in. 1 ft. 2 in. 1 ft. 2 in.	332	Cu. Ft.	Reinforced Concrete in Piles.
2	5		5	No.	Handling and pitching Piles.
3	5		5	No.	Driving Piles.
4	5		5	No.	Cutting off Pile Heads.
5	4	10 ft. 4 in. 1 ft. 2 in. 1 ft. 0 in.	49	Cu. Ft.	Upper and Intermediate Longitudinal Bracings.
6	2	10 ft. 4 in. 1 ft. 2 in. 1 ft. 0 in.	24	Cu. Ft.	Lower Longitudinal Bracings.
7	4	5 ft. 10 in. 1 ft. 2 in. 1 ft. 0 in.	27	Cu. Ft.	Upper and Intermediate Transverse Bracings.
8	2	5 ft. 10 in. 1 ft. 2 in. 1 ft. 0 in.	14	Cu. Ft.	Lower Transverse Bracings.
9	4	7 ft. 4 in. 1 ft. 2 in. 1 ft. 0 in.	35	Cu. Ft.	Upper and Intermediate Bracings to Rear Pile.
10	2	7 ft. 4 in. 1 ft. 2 in. 1 ft. 0 in.	15	Cu. Ft.	Lower Bracings to Rear Pile.
11	2	13 ft. 6 in. 1 ft. 2 in. 1 ft. 0 in.	32	Cu. Ft.	Upper Diagonal Longl. Bracings.

[1] This column is completed after the quantities have been taken off and multiplied.

Item No.	No. off	Dimensions	Quantity	Unit	Description
12	2	13 ft. 6 in. 1 ft. 2 in. 1 ft. 0 in.	31	Cu. Ft.	Lower Diagonal Longl. Bracings.
13	2	10 ft. 9 in. 1 ft. 2 in. 1 ft. 0 in.	25	Cu. Ft.	Upper Diagonal Transverse Bracings.
14	2	10 ft. 9 in. 1 ft. 2 in. 1 ft. 0 in.	25	Cu. Ft.	Lower Diagonal Transverse Bracings.
15	1	1 ft. 0 in. + 3¾ in. = 1 ft. 3¾ in. 3 ft. 6 in. ¾ in. D/dt. ½/1 ft. 3 in. 8 in. ¾ in.			1 ft. 3¾ in. × 3 ft. 6 in. = 4·59 sq. ft. 4·59 sq. ft. × ¾ in. × 40·0 lb. = 138 lb. ½/1 ft. 3 in. × 8 in. = ·417 sq. ft. 0·417 sq. ft × ¾ × 40·0 lb. = 12 lb. Total = 138 — 12 = 126 lb. = 1·13 cwt.
			1·13	Cwt.	Wrot. Iron Bent Plate.
16	1	2 ft. 3 in. 3 ft. 6 in. ¾ in.			2 ft. 3 in. × 3 ft. 6 in. = 7·875 sq. ft. 7·875 sq. ft. × ¾ × 40·0 lb. = 236 lb.
		D/dt. ½/1 ft. 3 in. 8 in. ¾ in.	2·00	Cwt.	½/1 ft. 3 in. × 8 in. = ·417 sq. ft. 0·417 sq. ft. × ¾ × 40·0 lb. = 12 lb. Total = 236 — 12 = 224 lb. = 2·00 cwt. Wrot. Iron Plate cut to shape.
17	1	9 in. + 8¼ in. = 1 ft. 5¼ in. 3 ft. 6 in. ¾ in.			1 ft. 5¼ in. × 3 ft. 6 in. = 5·03 sq. ft. 5·03 sq. ft. × ¾ × 40·0 lb. = 151 lb.
		D/dt. ½/1 ft. 3 in. 8 in. ¾ in.	1·24	Cwt.	12 lb. as above. Total = 151 — 12 = 139 lb. = 1·24 cwt. Wrot. Iron Plate.
18	10	1 in. dia. 14 in. long	0·39	Cwt.	At 4·324 lb. per bolt, nut, and washer = 43·24 lb. = ·39 cwt. W.I. Bolts, 14 in. long.
19	4	1 in. dia. 17 in. long	0·18	Cwt.	At 4·994 lb. per bolt, nut, and washer = 19·98 lb. = ·18 cwt. W. I. Bolts, 17 in. long.

Item No.	No. off	Dimensions	Quantity	Unit	Description
20	5/4	49 ft. 0 in. ·7854 sq. in. 40/12	22·29	Cwt.	2570 lb. = 22·29 cwt. Main Reinforcing Rods, 1 in. dia.
21	5/4/ 64	2 ft. 3 in. ·7854 sq. in. ·0352 sq. in. 40/12	2·37	Cwt.	265 lb. = 2·37 cwt. 3/16 in. Links in Main Piles,
22	5/ 13	1 ft. 2 in. ·7854 sq. in. ·25 sq. in. 37·5/12	0·42	Cwt.	46·7 lb. = 0·42 cwt. C. I. Forks, ½ in. dia.
23	5		5	No.	C. I. Pile Shoes, 60 lb. each.

Although not asked for in the question, Items 2, 3, 4, and 5 are included, as recommended in the Institution of Civil Engineers' Report on Engineering Quantities.

The timberwork is classified according to its position, whether at or below low-water, between tides, or above high-water, and the finish of the timberwork is specified (e.g. sawn fair to scantlings and ends bevelled to fit between piles).

The wrought iron plates are calculated at 40 lb. per sq. ft. of plate, 1 in. thick, and the cast iron at 37·5 lb. per sq. ft. of plate, 1 in. thick. In calculating round bars, therefore, if the sectional area is taken out in square inches, since the weight of a square bar of 1 in. side is 1/12 of that of a plate of 1 sq. ft. area by 1 in. thick, the weight of the bar will be its area in square inches multiplied by 1/12 of the weight of 1 sq. ft. of plate, 1 in. thick, multiplied by the length of the bar in feet.

It will now be advisable to consider the method of taking out weights of Engineering units, such as are usually set in the above Examinations as alternative questions to the purely Civil Engineering type already dealt with.

In October, 1925, the following question was set in the Inst. C.E. Examination as an alternative to Question 1 above (Clause 216) :—

Take out, multiply, and bill the quantities for the cylinder gland and cover shown on Plate IV herewith.

If a problem of this type is to be done quite accurately, the following results should be noted :—

(*a*) In a flat ring, outside diameter D, inside diameter d, thickness t, the volume of the ring is $\cdot 7854\ (D^2 - d^2)t$.

(*b*) The volume of an ellipse, major axis D, minor axis d, thickness t, is $\cdot 7854 \times D \times d \times t$.

(*c*) The most tedious volume to calculate is that of the fillets at the corners. (These are usually allowed for in practice by a give-and-take method.) If required, probably the simplest method of calculating them is to take out the volume of a square section ring and deduct from it the volume described by a quadrant of radius equal to the side of the square moving through a circle of diameter equal to the diameter of the centroid

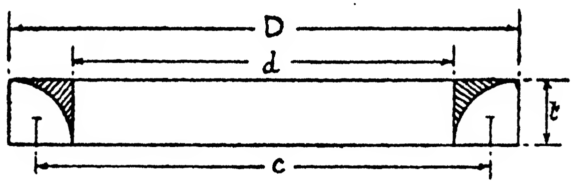


FIG. 31

of the quadrant. Thus, if D be the outside diameter and d the inside diameter of the ring, Fig. 31, and c the diameter of the centroid of the quadrant, the thickness being t, then :—

$$\text{Volume} = V = \left\{\frac{\pi}{4}(D^2 - d^2) - \frac{\pi}{4}\left(\frac{D-d}{2}\right)^2 \times \pi\left[D - \frac{4(D-d)}{3\pi\cdot}\right]\right\}t \quad . \quad . \quad . \quad . \quad . \quad (1)$$

=Volume shown shaded in Fig. 31.

This is calculated from the fact that the distance z from the centre of the circle to the centroid in a quadrant of radius $r = \frac{4r}{3\pi}$, Fig. 32.

Hence the volume swept out by the quadrant describing a circle of diameter c

$$= \left\{\frac{\pi}{4}r^2 \times \pi c\right\} = \left\{\frac{\pi}{4}\left(\frac{D-d}{2}\right)^2 \times \pi\left[D - \frac{8r}{3\pi}\right]\right\}$$

Substituting for r its value $\frac{D-d}{2}$

$$\text{this volume} = \frac{\pi}{4}\left(\frac{D-d}{2}\right)^2 \times \pi\left[D - \frac{4(D-d)}{3\pi}\right] \quad . \quad . \quad (2)$$

Whence V = equation (1) above.

As an example, take the fillet at the recess in the base of the cylinder cover, viz. :—

$$D = 10 \text{ in.}, d = 8 \text{ in.}, t = 1 \text{ in.}$$

$$\text{Therefore } V = \left\{\cdot7854(100-64) - \frac{\pi}{4}\left(\frac{2}{2}\right)^2 \times \pi\left(10 - \frac{8}{3\pi}\right)\right\} \times 1$$

$$= \cdot7854 \times 36 - \cdot7854 \times 3\cdot1416 \times 9\cdot16$$

$$= 5\cdot65 \text{ cu. in.}$$

When the fillet is the opposite way round to that shown above,

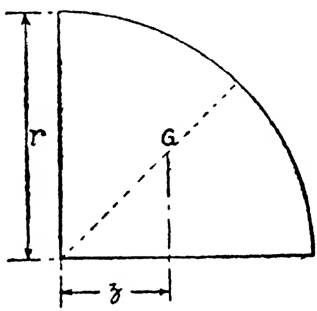


FIG. 32

thus in Fig. 33, the volume may be worked out in the manner described above and—

$$V = \left\{\frac{\pi}{4}(D^2 - d^2) - \frac{\pi}{4}\left(\frac{D-d}{2}\right)^2 \times \pi\left[d + \frac{4(D-d)}{3\pi}\right]\right\} t \quad (3)$$

Thus the volume of the fillet at the outer edge of the recess

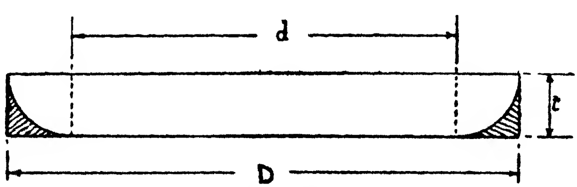


FIG. 33

in the base of the cover, where D = 16 in., d = 14 in., and t = 1 in., is :—

$$V = \cdot 7854(256 - 196) - \cdot 7854 \times 3\cdot 1416)14 + \cdot 84) \times 1 \text{ in.}$$
$$= 10\cdot 53 \text{ cu. in.}$$

Note that in each of the above cases $D - d = 2t$.

The volume of each bush may be calculated thus (Fig 34) :—

$$V = \frac{\pi}{4}(D^2 - d^2)T + \frac{\pi}{4}(W^2 - d^2)t - \tfrac{1}{2}(W - d)\tfrac{1}{2}h$$
$$\times \pi\left\{d + \left(\frac{W - d}{3}\right)\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

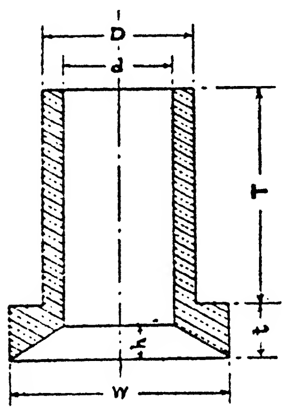


FIG. 34

In the topmost bush,

$D = 2\frac{3}{4}$ in., d = 2 in., W = 4 in., T = 4 in., t = 1 in., $h = \frac{5}{8}$ in.

$$\text{Hence } V = \cdot 7854\left(\frac{121}{16} - \frac{64}{16}\right) \times 4 + \cdot 7854(16 - 4)$$
$$\times 1 - \frac{2}{2} \times \frac{5}{16} \times \left(2 + \frac{2}{3}\right)$$
$$= \cdot 7854\,(14\cdot 25 + 12) - 2\cdot 618$$
$$= 20\cdot 62 - 2\cdot 618 = 18\cdot 002 \text{ cu. in.}$$

The Volume of the topmost flange in the Cylinder Cover Gland is got thus (Fig. 35) :—

$$V = 4\left\{L \times \tfrac{1}{2}(R + r) + \frac{a}{360} \times \pi r^2 + \frac{90 - a}{360} \times \pi R^2\right\}t - (2$$
$$\times \cdot 7854d^2 + \cdot 7854D^2)t$$

Now, if $R = 3\frac{1}{4}$ in., $r = 1\frac{5}{8}$ in., and $t = 1$ in., $D = 2\frac{3}{4}$ in., and $d = 1\frac{1}{16}$ in., $L^2 = 4^2 - (3\frac{1}{4} \text{ in.} - 1\frac{5}{8} \text{ in.})^2 = 16 - \frac{225}{64} = \frac{1024 - 225}{64} = \frac{799}{64}$

Therefore, $L = \frac{28{\cdot}27}{8} = 3{\cdot}53$ in.

Also $\sin a = \frac{3{\cdot}53}{4} = {\cdot}883$, and $a = 62°$

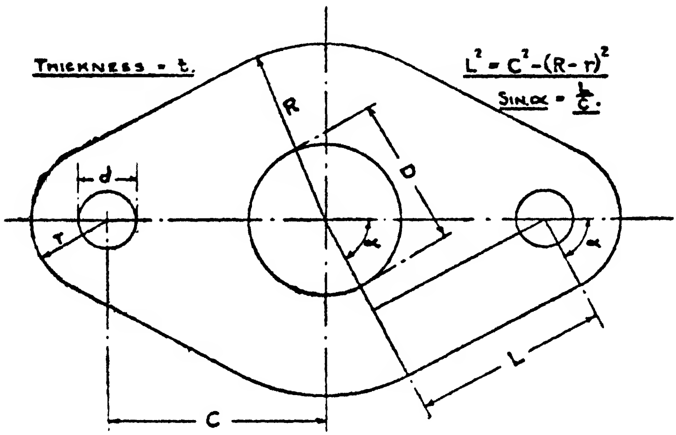


FIG. 35

$$\text{Then } V = 4\left\{3{\cdot}53 \times \tfrac{1}{2}(3\tfrac{1}{4} + 1\tfrac{5}{8}) + \frac{62}{360} \times 3{\cdot}1416 \times \frac{121}{64} + \frac{28}{360} \times 3{\cdot}1416 \times \frac{169}{16}\right\} \times 1 - {\cdot}7854(2 \times 1\tfrac{1}{16}^2 + \frac{121}{16}) \times 1$$

$$= 4\left\{3{\cdot}53 \times 2{\cdot}3125 + \frac{3{\cdot}1416}{360 \times 64}(7502 + 18928)\right\} - \frac{{\cdot}7854 \times 2514}{256}$$

$$= 4\,(8{\cdot}17 + 3{\cdot}60) - 7{\cdot}72$$

$$= 47{\cdot}07 - 7{\cdot}72 = 39{\cdot}35 \text{ cu. in.}$$

Had this flange been elliptical, the volume would have been :—

$$V = \frac{\pi}{4} \times 2R \times 2d \times t$$

In this case, $2R = 10\frac{3}{4}$ in., $2r = 6\frac{1}{2}$ in., and $t = 1$ in.

Hence V would $= \cdot 7854 \times 10\cdot 75 \times 6\cdot 5 \times 1$, minus the holes
$= 54\cdot 8 - 7\cdot 52$
$= 47\cdot 28$ cu. in.

against the 39·35 cu. in. calculated exactly.

The material of the cover and gland will be cast iron, the bushes being of brass or gun-metal, studs and nuts of steel, and $\frac{3}{16}$-in. plate of steel.

The weight of cast iron may be taken at 0·26 lb. per cu. in., that of steel at 0·284 lb. per cu. in., and that of gun-metal at 0·307 lb. per cu. in.

The parts and materials will be tabulated thus :—

Part No.	Description	Material	No. off	Weight [1]	Weight [1]
1	Cylinder Cover.	Cast Iron.	1	235 lb.	
2	Cylinder Cover Gland.	Cast Iron.	1	15 lb.	2·23 cwt.
3	Cylinder Cover Bush.	Brass or Gun-metal.	1	3 lb.	
4	Cylinder Cover Gland Bush.	Brass or Gun-metal.	1	5·5 lb.	8·5 lb.
5	Studs, 1 in. dia., 9 in. long.	Steel.	2	4 lb.	
6	1 in. Nuts for Part No. 5.	Steel.	4	2 lb.	
7	$\frac{3}{16}$ in. dia., Split Pins each $1\frac{1}{2}$ in. long for Part No. 5.	Steel.	2		
8	Cover Plate, $\frac{3}{16}$ in. thick.	Steel.	1	10·75 lb.	
9	Metal Screws, $\frac{1}{4}$ in. dia., csk. heads, $\frac{3}{8}$ in. long.	Steel.	12		

The quantities may now be taken out and multiplied as follows :—

1. Cylinder Cover, Cast Iron, Weight 0·26 lb. per cu. in.

cu. in. cu. in.

$\frac{\pi}{4}(25\frac{3}{4}^2 - 2\frac{3}{4}^2) \times 2\frac{1}{4}$ in. $= (520\cdot 77 - 5\cdot 94)$
$\times 2\frac{1}{4} = 514\cdot 83 \times 2\frac{1}{4} \qquad = \qquad 1158\cdot 37$

$-\frac{\pi}{4}(25\frac{3}{4}^2 - 18\frac{3}{4}^2) \times 1 = (520\cdot 77$
$- 276\cdot 12) \qquad = 244\cdot 65$

$-\frac{\pi}{4}(16^2 - 8^2) \times 1 = (201\cdot 06 - 50\cdot 26) \quad = 150\cdot 80$

$-\frac{\pi}{4}(4^2 - 2\frac{3}{4}^2) \times \frac{1}{2} = \frac{1}{2}(12\cdot 56 - 5\cdot 94) = \frac{6\cdot 62}{2} = \quad 3\cdot 31$

[1] These columns are completed after the quantities have been taken off and multiplied.

		cu. in.	cu. in.
$+\left\{\frac{\pi}{4}(10^2-8^2)-\frac{\pi}{4}\left(\frac{16-14}{2}\right)^2 \times \pi\left[10-\frac{4(10-8)}{3\pi}\right]\right\}1$	=		5·65
$+\left\{\frac{\pi}{4}(16^2-14^2)-\frac{\pi}{4}\left(\frac{16-14}{2}\right)^2 \times \pi\left[14+\frac{4(16-14)}{3\pi}\right]\right\}1$	=		10·53
$-\frac{\pi}{4}(17\tfrac{1}{2}^2-16^2)\times\frac{3}{16}=(240{\cdot}53-201{\cdot}06)\frac{3}{16}=\frac{3}{16}\times 39{\cdot}47$	=	7·40	
$-\frac{\pi}{4}(8^2-7^2)\times\frac{3}{16}=(50{\cdot}26-38{\cdot}48)\frac{3}{16}=\frac{3}{16}\times 11{\cdot}78$	=	2·21	
$+\frac{\pi}{4}(6\tfrac{1}{2}^2-4^2)\times 3\tfrac{3}{4}=(33{\cdot}18-12{\cdot}56)\times 3\tfrac{3}{4}=\frac{15}{4}\times 20{\cdot}62$	=		77·32
$+2\left\{\frac{\pi}{4}(8^2-6\tfrac{1}{2}^2)-\frac{\pi}{4}\left(\frac{8-6\frac{1}{2}}{2}\right)^2 \times \pi\left[8-\frac{4(8-6\frac{1}{2})}{3\pi}\right]\right\}$	=		13·72
$+4\left\{3{\cdot}31\times\tfrac{1}{2}(3\tfrac{5}{8}+1\tfrac{3}{8})+\frac{56}{360}\times\pi\times\frac{121}{64}+\frac{34}{360}\times\pi\times\frac{841}{64}\right\}1\tfrac{1}{2}$	=		78·57
$-\frac{\pi}{4}\times 4^2\times 1\tfrac{1}{2}$	=	18·84	
$-2\times\frac{\pi}{4}\times 1\times 1\tfrac{1}{2}$	=	2·36	
$-12\times\frac{\pi}{4}\times 1\times 1\tfrac{1}{4}$	=	11·78	
		441·35	1344·16
			441·35
Total cu. in.	=		902·81

902·81 cu. in. at 0·26 lb. per cu. in. = 234·73 lb., say, 235 lb.

2. Cylinder Cover Gland, Cast Iron, Weight 0·26 lb. per cu. in.

		cu. in.	cu. in.
$4\left\{3{\cdot}53 \times \frac{3\frac{1}{4} + 1\frac{3}{8}}{2} + \frac{62}{360} \times \pi \times \frac{121}{64} + \frac{28}{360} \times \pi \times \frac{169}{16}\right\} \times 1$	=		47·07
$-\frac{\pi}{4} \times 2\frac{3}{4}^2 \times 1$	=	5·94	
$-2 \times \frac{\pi}{4} \times 1\frac{1}{16}^2 \times 1$	=	1·78	
$+\frac{\pi}{4}(4^2 - 2\frac{3}{4}^2) \times 3 = 3(12{\cdot}56 - 5{\cdot}94)$	=		19·86
		7·72	66·93
			7·72
Total cu. in.	=		59·21

59·21 cu. in. at 0·26 lb. per cu. in. = 15·40 lb., say, 15 lb.

3. Cylinder Cover Bush, Brass or Gun-metal, Weight 0·305 lb. per cu. in.

cu. in.

$$\frac{\pi}{4}\left(\frac{121}{16} - \frac{64}{16}\right) \times 1\frac{3}{4} + \frac{\pi}{4}(16 - 4) \times \frac{3}{4} - \frac{2}{2} \times \frac{1}{4} \times \pi\left(2 + \frac{2}{3}\right) = \frac{\pi}{4}\left(\frac{57}{16} \times \frac{7}{4} + 9\right) - \frac{1}{4} \times \frac{8 \times 3{\cdot}1416}{3} = 9{\cdot}9$$

9·9 cu. in. at 0·305 lb. per cu. in. = 3·02 lb., say, 3 lb.

4. Cylinder Cover Gland Bush, Brass or Gun-metal, Weight 0·305 lb. per cu. in.

cu. in.

$$\frac{\pi}{4}\left(\frac{121}{16} - \frac{64}{16}\right)4 + \frac{\pi}{4}(16 - 4)1 - \frac{2}{2} \times \frac{5}{16} \times \pi\left(2 + \frac{2}{3}\right) = 18{\cdot}002$$

18 cu. in. at 0·305 lb. per cu. in. = 5·49 lb., say $5\frac{1}{2}$ lb.

5. Studs, 1 in. dia., 9 in. long, Steel, Weight 0·284 lb. per cu. in.

$$\cdot 7854 \times 9 \times 2 \times \cdot 284 = 4 \text{ lb.}$$

6. The weight of a 1-in. nut is ·496 lb.
   4 at ·496 = 1·984 lb., say, 2 lb.

7. Cover Plate, Steel, Weight 0·284 lb. per cu. in.

$$\frac{\pi}{4}(17{\cdot}5^2 - 7^2) \times \frac{3}{16} \times 0{\cdot}284$$

$$= (240{\cdot}53 - 38{\cdot}48) \times \frac{3}{16} \times 0{\cdot}284$$

$$= 202{\cdot}05 \times \frac{3}{16} \times 0{\cdot}284 = 37{\cdot}89 \times 0{\cdot}284$$

$$= 10{\cdot}75 \text{ lb.}$$

A further example is that shown on Plate V of a Stern Tube and Shaft, set at the April, 1931, Examination of the Institution of Civil Engineers, the question being as follows :—

Take out the weights for the various parts. Summarise the weights, and total them up, if complete. Tabulate for the workshop.

The tabulation is as follows :—

Part No.	Description	Material	No. off	Weight [1]	Total Weight [1]
1	Stern Shaft.	Steel.	1	177·5 lb.	1·59 cwt.
2	Stern Tube.	Cast Iron.	1	123·5 lb.	
3	Stern Bush.	Cast Iron.	1	36·5 lb.	
4	Stern Tube Gland.	Cast Iron.	1	14·7 lb.	
5	Shaft Coupling.	Cast Iron.	1	34·2 lb.	
6	Propeller Boss.	Cast Iron.	1	36·2 lb.	2·19 cwt.
7	Stern Nut of Shaft.	Gun-metal.	1	9·4 lb.	·084 cwt.
8	Studs, ⅝ in. dia., 2½ in. long, screwed 12 threads to the inch for Stern Bush.	Steel.	6	1·3 lb.	
9	Nuts for ⅝ in. Studs in Part No. 8.	Steel.	6	0·85 lb.	
10	Set Screw, ½ in. dia., 1½ in. long for Part No. 7.	Steel.	1		
11	Studs, ¾ in. dia., 7 in. long for Part No. 4.	Steel.	2	1·8 lb.	
12	Nuts for ¾ in. Studs in Part No. 11.	Steel.	4	·9 lb.	
13	Nut, 1¾ in. Whitworth, for Stern Shaft at Coupling.	Steel.	1	2·25 lb.	·064 cwt.
			Total	Weight =	3·928 cwt.

[1] These columns are completed after the quantities have been taken off and multiplied.

1. Stern Shaft, Steel, Weight 0·284 lb. per cu. in.

		cu. in.
1 ft. $8\frac{3}{4}$ in. $\times \frac{\pi}{4} \times \left(\frac{13}{4}\right)^2$	=	172
$+ \frac{\pi}{4} \times \frac{1}{2}\left\{\left(\frac{13}{4}\right)^2 + 3^2\right\} \times \frac{1}{8} \times 3 = \frac{\pi}{4} \times \frac{1}{2}(10{\cdot}56 + 9) \times \frac{3}{8}$	=	2·88
$+$ 1 ft. $2\frac{3}{4}$ in. $\times \frac{\pi}{4} \times 3^2$	=	104·2
$+$ 1 ft. 8 in. $\times \frac{\pi}{4} \times 3^2$	=	141·4
$+$ 1 ft. $2\frac{3}{4}$ in. $\times \frac{\pi}{4} \times \left(\frac{51}{16}\right)^2$	=	117·8
$+ 6\frac{1}{2}$ in. $\times \frac{\pi}{8}\left\{\left(\frac{13}{4}\right)^2 + \left(\frac{11}{4}\right)^2\right\} = 6\frac{1}{2} \times \frac{\pi}{8}(10{\cdot}56 + 7{\cdot}57)$	=	46·3*
$+ 4\frac{1}{8}$ in. $\times \frac{\pi}{8}\left\{3^2 + \left(\frac{19}{8}\right)^2\right\} = 4\frac{1}{8} \times \frac{\pi}{8}(9 + 5{\cdot}63)$	=	23·7†
$+ 2\frac{5}{8}$ in. $\times \frac{\pi}{4}\left(\frac{5}{2}\right)^2$	=	12·88
$+ \frac{3}{8}$ in. $\times \frac{\pi}{4} \times 2^2$	=	1·18
$+ 1\frac{3}{4}$ in. $\times \frac{\pi}{4}\left(\frac{7}{4}\right)^2$	=	4·21
		626·55
$-$ Keyways ($5\frac{1}{2}$ in. $\times \frac{3}{4}$ in. $+ 3\frac{3}{4}$ in. $\times \frac{5}{8}$ in.) $\times \frac{7}{32}$ in.	=	1·41
Total volume of Stern Shaft	=	625·14
625 cu. in. at 0·284 lb. per cu. in.	=	177·5 lb.

2. Stern Tube, Cast Iron, Weight 0·26 lb. per cu. in.

	cu. in.		cu. in.
3 ft. 3 in. $\times \frac{\pi}{4}\left\{\left(\frac{11}{2}\right)^2 - \left(\frac{17}{4}\right)^2\right\}$		=	373

		cu. in.	cu. in.
$+ 1\text{ in.} \times \frac{\pi}{4}\left\{\left(\frac{49}{8}\right)^2 - \left(\frac{11}{2}\right)^2\right\}$			= 5·11
$+ 4\text{ in.} \times \frac{\pi}{4}\left\{\left(\frac{17}{4}\right)^2 - \left(\frac{51}{16}\right)^2\right\}$			= 24·8
$+2\frac{1}{4}\text{ in.} \times \frac{\pi}{4}\left\{\left(\frac{25}{4}\right)^2 - \left(\frac{9}{2}\right)^2\right\}$			= 15·45
$+ 1\text{ in.} \times \frac{\pi}{4}\left\{\left(\frac{39}{4}\right)^2 - \left(\frac{9}{2}\right)^2\right\}$			= 58·9
$- 2 \times \frac{\pi}{4}\left(\frac{9}{16}\right) \times 1$		= ·885	
$- 5 \times \frac{\pi}{4} \times \frac{1}{4} \times 1$ in., for holes in flange		= ·98	
		1·865	477·26
			1·86
Total volume of Stern Tube			= 475·40

475·40 cu. in. at 0·26 lb. per cu. in = 123·5 lb.

3. Stern Bush, Cast Iron, Weight 0·26 lb. per cu. in.

	cu. in.
$1\text{ ft. }3\frac{1}{4}\text{ in.} \times \frac{\pi}{4}\left\{\left(\frac{35}{8}\right)^2 - \left(\frac{13}{4}\right)^2\right\}$	
$= 15\frac{1}{4} \times \frac{\pi}{4}(19{\cdot}14 - 10{\cdot}56)$	= 102·9
$+ \frac{3}{4}\text{ in.} \times \frac{\pi}{4}\left\{\left(\frac{34}{4}\right)^2 - \left(\frac{13}{4}\right)^2\right\}$	= 38·8
	141·7
$- 6 \times \frac{\pi}{4} \times \frac{25}{64} \times \frac{3}{4}$ in., for holes in flange	= 1·38
Total volume of Stern Bush	= 140·32

140·32 cu. in. at 0·26 lb. per cu. in. = 36·5 lb.

4. Stern Tube Gland, Cast Iron, Weight 0·26 lb. per cu. in.

			cu. in.
$3 \text{ in.} \times \frac{\pi}{4}\left\{\left(\frac{9}{2}\right)^2 - \left(\frac{51}{16}\right)^2\right\}$		=	23·7
$+ \frac{\pi}{4}(6 \text{ in.} \times 9\frac{3}{4} \text{ in.}) \times \frac{3}{4}$ in. (Note: This assumes flange to be ellipse)		=	34·5
$+ 5 \times 2\frac{1}{2} \text{ in.} \times \frac{3}{4}$ in.		=	9·37
			67·57
$- 4\frac{3}{4} \text{ in.} \times 2\frac{1}{2} \text{ in.} \times \frac{3}{8}$ in.	= 4·45		
$- \frac{\pi}{4}\left(\frac{51}{16}\right)^2 \times \frac{3}{4}$	= 5·98		
$- 2 \times \frac{\pi}{4}\left(\frac{9}{16}\right) \times \frac{3}{4}$	= ·66		
	——	=	11·09
Total volume of Stern Tube Gland		=	56·48

56·48 cu. in. at 0·26 lb. per cu. in. = 14·68 lb.

5. Shaft Coupling, Cast Iron, Weight 0·26 lb. per cu. in.

			cu. in.
$1 \text{ in.} \times \frac{\pi}{4} \times 5^2$		=	19·63
$+ 2\frac{1}{2} \text{ in.} \times \frac{\pi}{4} \times (4\frac{1}{2})^2$		=	35·8
$+ 1\frac{1}{2} \text{ in.} \times \frac{\pi}{4} \times (6\frac{3}{4})^2$		=	53·7
$+ 1\frac{1}{8} \times \frac{\pi}{4} \times (9\frac{1}{2})^2$		=	79·8
			188·93
$- 4\frac{3}{8} \text{ in.} \times \frac{\pi}{8}\left\{(3)^2 \times \left(\frac{19}{8}\right)^2\right\}$	= 25·17		
$- 1\frac{3}{4} \text{ in.} \times \frac{\pi}{4}(4\frac{5}{8})^2$	= 29·4		
$- 6 \times 1\frac{1}{8} \text{ in.} \times \frac{\pi}{4} \times (\frac{3}{4})^2$	= 2·98		
	——	=	57·55
Total volume of Shaft Coupling		=	131·38

131·38 cu. in. at 0·26 lb. per cu. in. = 34·16 lb.

6. Propeller Boss, Cast Iron, Weight 0·26 lb. per cu. in.

		cu. in.
$\frac{\pi}{4}(6\frac{1}{2})^2 \times 6\frac{1}{2}$ in. (Averaging in Section)	=	215·5
$- 6\frac{1}{2}$ in. $\times \frac{\pi}{8}\left\{\left(\frac{13}{4}\right)^2 + \left(\frac{11}{4}\right)^2\right\}$	=	46·3*
Total volume of Propeller Boss	=	139·2

139·2 cu. in. at 0·26 lb. per cu. in. = 36·2 lb.

7. Stern Nut of Shaft, Gun-metal, Weight 0·305 lb. per cu. in.

		cu. in.
$\frac{\pi}{4}\left\{(4\frac{1}{2})^2 - (2\frac{1}{2})^2\right\} \times 2\frac{5}{8}$ in.	=	27·85
$+ \frac{\pi}{4} \times 3^2 \times \frac{1}{4}$ in.	=	1·77
$+ \frac{\pi}{4}(3^2 - 2\frac{1}{2}^2) \times \frac{1}{2}$	=	1·08
Total volume of Stern Nut of Shaft	=	30·70

30·7 cu. in. at 0·305 lb. per cu. in. = 9·37 lb.

8. Studs, $\frac{5}{8}$ in. dia., $2\frac{1}{2}$ in. long, Steel, Weight 0·284 lb. per cu. in. cu. in.

$6 \times \frac{\pi}{4}(\frac{5}{8})^2 \times 2\frac{1}{2}$ in. $= 6 \times \cdot307 \times 2\frac{1}{2}$ = 4·605

4·6 cu. in. at 0·284 lb. per cu. in. = 1·31 lb.

9. 6 Nuts at ·141 lb. each = 0·85 lb.

11. Studs, $\frac{3}{4}$ in. dia., 7 in. long, Steel, Weight 0·284 lb. per cu. in.

$2 \times \frac{\pi}{4}(\frac{3}{4})^2 \times 7 = 2 \times \cdot442 \times 7$ = 6·19

6·19 cu. in. at 0·284 lb. per cu. in. = 1·76 lb.

12. 4 Nuts at ·233 lb. each. (allowing for two nuts to each stud) = ·93 lb.

13. A Nut at 2·25 lb. = 2·25 lb.

NOTE.—It will be noted that the volumes of the tapered portions of the shaft and of the tapered holes in the Propeller Boss and Shaft Coupling have been calculated by multiplying the length of the portion by the average area of the two ends (which is sufficiently accurate for all practical purposes). Thus, in Fig. 36 the volume is taken as :—

$$V = \frac{\pi}{8}(D^2 + d^2) \times l$$

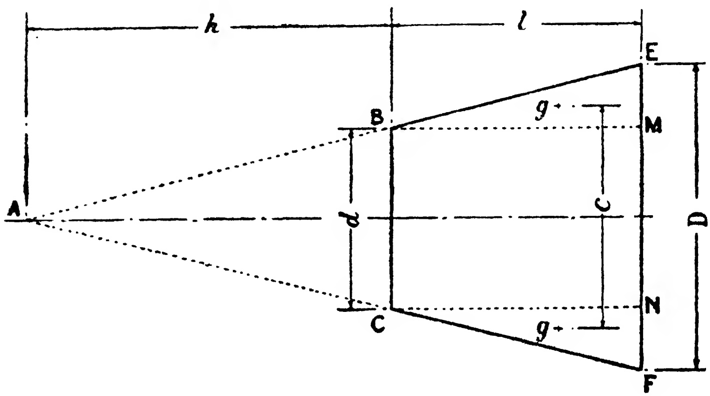


FIG. 36

The volume may be calculated accurately as the difference in volume of the two cones AFE and ACB thus :—

$$V = \frac{\pi D^2}{4} \cdot \frac{h + l}{3} - \frac{\pi d^2}{4} \cdot \frac{h}{3} = \frac{\pi}{12}\left\{D^2(h + l) - d^2h\right\}$$

$$\text{and since } \frac{h}{h + l} = \frac{d}{D}, \; h = \frac{dl}{D - d}$$

or, alternatively, using Guldinus's rule that the volume of a solid generated by a constant area rotating about a fixed axis is equal to the area multiplied by the length of the path traced by the C.G. of the area, the volume is calculated thus :—

Volume of cylindrical portion BCNM $= \frac{\pi d^2}{4}$

Volume of tapered portion $=$ Area of triangle BEM $\times\ \pi c$

(where c is the distance between the C.G.s of the equal triangles

$$\text{BEM and CFN} = d + \frac{D - d}{3}\Big)$$

$$= \frac{l}{2} \times \frac{D - d}{2} \times \pi\left(d + \frac{D - d}{3}\right)$$

Calculated accurately by either of these two methods, the volume of the tapered end of the steel shaft through the Propeller Boss is 46·05 cu. in. against 46·3 cu. in. calculated by the approximate method (See *), and that of the tapered portion at the Coupling is 23·53 cu. in. against 23·7 cu. in. (See †) ; the difference being negligible.

DAYWORK SCHEDULE.—The following is an example of a " Daywork " Schedule, often inserted in a Specification, after the Bill of Quantities, and referred to on pp. 27, 207, 213, 216 and in Clause 10. Sometimes the approximate estimated number of hours of work for the various trades and number of units of materials is given in the schedule under the heading "Quantity", to be paid for only if the actual cost is incurred, and sometimes only rates are inserted for each item, and the cost of extra works based thereon :—

SCHEDULE OF PRICES

(For Day and Hour Work and For Materials).

The following prices for day and hour work and for materials shall include insurances, use and maintenance of ordinary plant and tools, superintendence, including general foreman's and inspector's time, overhead charges, and contractor's profit.

The time of gangers or charge hands working with their gangs is to be paid for under appropriate items, but the time of foremen and walking gangers is not to be included, but is to be covered by superintendence.

Overtime, when chargeable under the contract, is to be paid for in the same proportion as is paid to the workmen.

The rates for heavy plant are only to apply to plant which the Contractor has available upon the site, unless for plant specifically mentioned in the items.

The rates for materials are to cover delivery at the usual points at which materials are received on the site and not distribution to the individual sites where daywork is in progress, the cost of such distribution being chargeable in addition.

The daywork rates are to cover the use of Contractor's wagons and such temporary tracks as are available upon the site.

The cost of watching and lighting specially necessitated by daywork is to be paid for separately at the rate entered in Item No. 24.

Only time engaged on the actual work will be paid for.

The Contractor will not be paid for any work as day and hour work unless he shall have, previous to starting the same, obtained the written sanction of the Engineer therefor.

All claims made by the Contractor for day and hour work must be supported by certified copies of the daily time sheets.

The description and quality of materials to be in accordance with the Specification, and the work to be carried out in accordance therewith.

Item No.	Quantity	Unit	Description	Rate	Amount
					£ s. d.
1		Hour.	Mason.		
2		Hour.	Mason's Labourer.		
3		Hour.	Bricklayer.		
4		Hour.	Bricklayer's Labourer.		
5		Hour.	Carpenter.		
6		Hour.	Carpenter's Labourer.		
7		Hour.	Blacksmith.		
8		Hour.	Blacksmith's Striker.		
9		Hour.	Plumber.		
10		Hour.	Plumber's Mate.		
11		Hour.	Navvies and Labourers.		
12		Hour.	Navvies and Labourers working in " Boots ".		
13		Hour.	Navvies and Labourers using compressed air-drills or pneumatic punching machines.		
14		Hour.	Steel or iron pipe Jointer or Fitter.		
15		Hour.	Engine-, Crane- or Navvy-Driver.		
16		Hour.	Driller.		
17		Hour.	Pavior.		
18		Hour.	Pavior's Labourer.		
19		Hour.	Working Ganger.		
20		Hour.	Timberman or Miner.		
21		Hour.	Timberman's Labourer.		
22		Hour.	Fireclay and concrete pipe Jointer.		
23		Hour.	Labourer for do. do.		
24		Shift.	Watchman, including fires, light, and fencing.		
25		Hour.	Horse, cart, and man.		
26		Day.	10-ton Steam Roller, including driver, fuel, and oil, etc., and water cart, per day of 8 hours.		

Item No.	Quantity	Unit	Description	Rate	Amount
					£ s. d.
27		Day.	Scarifying, extra on charge for Steam Roller.		
28		Day.	10-ton Petrol Roller, including driver, fuel, oil, etc., per day of 8 hours.		
29		Hour.	Standing time for 10-ton Roller.		
30		Day.	3-ton Petrol-driven Lorry, including driver, fuel, and oil, etc., per day of 8 hours.		
31		Day.	5-ton Steam Wagon, including driver, fuel, and oil, etc., per day of 8 hours.		
32		Hour.	Clay Puddler (to include "Boot Money" if boots are worn).		
33		Hour.	Kerb Setter.		
34		Hour.	Painter.		
35		Hour.	Steelwork Erector.		
36		Hour.	Qualified Bender and Fixer of Concrete Reinforcement.		
37		Day.	5-ton Steam Travelling Crane, including fuel and oil, and driver, per day of 8 hours.		
38		Day.	Mechanical Excavator, including driver, fuel, and oil, per day of 8 hours.		
39		Ton.	Portland Cement.		
40		Ton.	Portland Blastfurnace Cement.		
41		Ton.	Lime (ground).		
42		Ton.	Sand.		
43		Ton.	Coal.		
44		Ton.	Coke.		
45		Cwt.	Pig lead, including melting.		
46		Cwt.	Bolts, Straps, and Forgings.		
47		Cu. Yd.	Clean broken stone for concrete, graded 1½ to ¼ in.		
48		Gallon.	Portland cement mortar (3 to 1).		
49		Cu. Yd.	Portland cement mortar (3 to 1).		
50		Cu. Yd.	Do. do. (2 to 1).		
51		Cu. Yd.	Do. do. (1 to 1).		
52		Ton.	Steel slag bottoming (specify depth).		
53		Ton.	Whinstone bottoming (specify depth).		
54		Cu. Yd.	Ashes or clinker.		
55		Ton.	Broken Whinstone (specify gauge and if graded).		
56		Thousand.	Common Bricks.		
57		Thousand.	Facing Bricks.		
58		Thousand.	Special Bricks (specified).		

Item No.	Quantity	Unit	Description	Rate	Amount
59		Lin Yd.	Fireclay spigot and socket pipes (size specified).		£ *s.* *d.*
60		Lin. Yd.	Concrete tubes (size specified).		
61		Lin. Yd.	Agricultural drain pipes (size specified).		
62		Lin. Yd.	Cast iron spigot and socket pipes (size specified).		
63		Lin. Yd.	Cast iron turned and bored pipes (size specified).		
64		Cwt.	Mild steel reinforcing bars, $\frac{5}{8}$ in. dia. and upwards.		
65		Cwt.	Do. do. below $\frac{5}{8}$ in. dia.		
66		Lin. Yd.	Kerb (material and size specified).		
67		Gallon.	Bitumen.		
68		Gallon.	Tar.		
69		Gallon.	Emulsified Bitumen.		
70		Lb.	Grass Seed.		
71		Ton.	Steel sections.		
72		Lb.	Gelignite.		
73		Hank.	Fuse.		
74		Doz.	Detonators.		
75		Ton.	High-Alumina Cement.		
76		Ton.	Ferrocrete Cement.		

The above list is by no means exhaustive, but is intended to illustrate the use of a " Daywork " Schedule.

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