BUILDING AND STRUCTURAL TABLES

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AND
STRUCTURAL TABLES

for Architects, Builders and Engineers

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PREFACE

The object of this volume of Tables is to present in convenient form the data most frequently required in the design and construction of buildings.

Formerly, the lack of standard specifications and corresponding permissible stresses for the numerous materials used in engineering and building construction resulted in a great waste of time, as each engineer and architect was obliged to concoct his own rules. To-day, the very multiplicity of regulations brings its own problem, and it is the aim of the compiler of the present volume to marshal and compare the data most often needed.

The requirements of the rival authorities generally differ only to a trivial extent, and it is earnestly hoped that the various Ministries now concerning themselves with building standards will come together and cause to be produced, by men who understand the subject, a comprehensive code which shall supplant all existing structural regulations and become a national code by force of law. Any special conditions peculiar to particular localities, unusual cases of design or the proposed use of new materials, could readily be provided for by local powers of waiver or addition to such a national code, and provision could be made for its periodical revision.

A number of codes have been in preparation since 1943 under the direction of the Codes of Practice Committee, Ministry of Works. The only one affecting the field of this book which has appeared at the time of going to press is Chapter V of the Code of Functional Requirements of Buildings. In the codes which have yet to appear, increased working stresses in concrete and structural steel are forecast, but the changes will not take effect unless and until they become incorporated in revised by-laws. The codes themselves are not mandatory and do not constitute a national code as envisaged in the preceding paragraph ; to the extent that their contents prove unacceptable to local authorities, they will provide yet another series of recommendations to bewilder the designer.

Building codes of practice, reports and by-laws and the invaluable specifications of the British Standards Institution have been examined for the purposes of this book, and abstracted wherever it appeared that the data could be presented with advantage in tabular form. In several cases Tables have been prepared to enable the rules to be applied without calculation. A list of the codes and regulations referred to will be found immediately preceding the Index.

The information has been grouped by subjects, and the general system of arrangement keeps to the same order as the designer normally follows in computing his loads, commencing with the roof and following through to the foundations.

The subject matter has been carefully arranged and indexed for rapid reference and care has been taken to ensure that the information is accurate and in accordance with current practice. Attention has been paid to the needs of those who, while not regularly engaged in designing, find themselves confronted from time to time with design problems.

The extensive information on steel design given in the well-known manufacturers' handbooks has been excluded, with one exception. Particulars of rolled steel sections and beam loads are so frequently required as to be deemed worthy of repetition.

Tables of reinforced concrete solid and hollow floor slabs, of general application, have been computed ; they are arranged in direct-reading form and include constants to facilitate the preparation of calculations for submission to local authorities. Columns and beams are not included because of the great diversity of sizes at present in use. In this connection, attention is drawn to a pamphlet issued by the Reinforced Concrete Association Ltd., viz., " Recommended Dimensions of Reinforced Concrete Structural Members " (March 1946, price 6d.).

The Tables which are based on L.C.C. and other regulations do not claim to deal with every clause and must be read in conjunction with the originals.

In recent years there have been many forecasts of revolutionary methods of building. Notable improvements have indeed been introduced in the field of fittings and prefabricated internal plumbing, but as far as the structure is concerned there is as yet little indication that established methods and materials will be ousted by radically different technique, at least for the majority of permanent buildings.

Some information on plastics is included in the book, but it seems to be generally agreed that, with the possible exception of resin-bonded plywood as a surfacing material, no plastic has yet emerged which has all the qualities necessary for a structural member. Some plastics are, nevertheless, eminently suitable for internal fittings.

Most architects and engineers have experienced the annoyance and delay arising from the necessity to search for the weight of materials with which they are concerned. The book includes a comprehensive list of the densities of materials used in construction, or which may form a structural load, and although omissions are inevitable it is hoped that the collection will be found useful.

The Author records his thanks to the British Standards Institution, the London County Council, the Institution of Structural Engineers, and to certain other authorities mentioned in the text, for permission to quote from the publications named, and to professional friends for valuable suggestions and encouragement.

CONTENTS

ABBREVIATIONS

B.S.	British Standard Specification.
L.C.C.	London County Council.
M.O.H.	Ministry of Health.
M.W.B.	Metropolitan Water Board.

ROOFS

TABLES 1—44

ROOFS

ROOF COVERINGS ALLOWED BY BY-LAWS

Many local authorities have based their building requirements on the *Ministry of Health Model By-laws*, Series IV, but as numerous variations from the model have been made it is still necessary to consult the by-laws of the district concerned.

The following list gives the roof coverings which are generally acceptable.

TABLE 1. Roof Coverings

1. Asbestos cement sheets.
2. Asphalt, not more than 17% bitumen
3. Copper sheet.
4. Galvanised corrugated steel sheet not thinner than 24 B.G.*
5. Glass, wired ; no restriction on area if in hard metal frames.
6. Lead sheet.
7. Macadam, not more than 7% bitumen, $\frac{1}{2}''$ to 1″ thick.
8. Mortar 1″ thick on boards.
9. Roofing felt laid in mastic, variously stipulated as not more than $\frac{3}{8}''$ and not less than $\frac{3}{10}''$ total thickness.
10. Shingles, permitted in some areas.
11. Slates, asbestos.
12. Slates, natural.
13. Stone slabs.
14. Thatch, permitted in some areas.
15. Tiles, clay.
16. Tiles, concrete.
17. Zinc sheet, not thinner than 14 Zinc Gauge according to B.S. 849.†

* By-laws generally say 24 B.W.G. Corrugated steel is sold by Birmingham Gauge and not Birmingham Wire Gauge. See Tables 20 and 21 for details of the gauges.

† See list of British Standard Specifications immediately preceding the Index.

WEIGHT AND PITCH OF ROOF COVERINGS

The weights given are per sq. ft. of actual surface and to the nearest $\frac{1}{4}$ lb. To obtain the weight per sq. ft. covered in plan, for sloping roofs, multiply by the appropriate figure in column 3, Table 5. For relation between gauge and lap see page 5. For lining materials see Table 82.

TABLE 2

Material (see later Tables for details)	Weight lb./sq. ft. of slope	Minimum Pitch (ordinary exposure)
Asbestos Cement		
¼″ Sheets, 3″ or 6″ corrugations, including laps and fastenings.	3¼	1 in 2 (if in one length, 1 in 10)
15¾″ Diamond or Honeycomb Slating to B.S. 690 3″ lap	2½	1 in 1·5 33½°
4″ ,,	3	1 in 1·7 30°
15¾″ Rectangular Slating to B.S. 690 3″ lap	4	1 in 1·7 30°
24″ ,, ,, ,, 3″ ,,	4	1 in 2 26½°
Asphalt per inch of thickness	11	1 in 50
Bitumen Macadam ,, ,, ,,	11	,, ,,
Bituminous Felt in layers	1½	,, ,,
Boards, softwood ¾″ thick	2	—
1″ ,,	2½	—
1¼″ ,,	3	—
Copper Sheet incl. laps and rolls, 24 S.W.G.	1¼	1 in 64 with standing seam, 1 in 100 with drips.
22 ,,	1¾	
Corrugated Sheets, see Asbestos ; Galvanised.		
Felt, Roofing, in layers	1½	1 in 50
,, **Sarking**	¼	—
Galvanised Corrugated Steel Sheets incl. laps and fastenings. 26 S.W.G.	1¼	1 in 2½ (if in one length, 1 in 10)
24 ,,	1½	
22 ,,	1¾	
Glazing, patent, lead covered steel astragals	6	1 in 2·7 20°
Lead Sheet, including laps and rolls 3 lb.	3½	1 in 64 plus drips or 1 in 8 without drips ; max. pitch 10°
4 ,,	4¾	
Macadam, tar or bitumen per inch of thickness	11	Any pitch if water-proofed.
Mortar Screeding ,, ,, ,,	11	
Perspex, corrugated, to fit asbestos or galvanised sheets	1	—
Roofing Felt in layers	1½	1 in 50
Ruberoid, 5 layer	1¾	,,
Shingles (cedar tiles) 16″ long 6″ lap	1½	1 in 1·5 33½°
8½″ ,,	2	1 in 1·7 30°
Slates, Welsh, 0·2″ thick, 24″ long 3″ ,,	6½	1 in 2·5 22°
20″ ,, 3″ ,,	7	1 in 2 26½°
16″ ,, 3″ ,,	7¼	1 in 1·5 33½°
Steel, see Galvanised.		
Tarmac per inch of thickness	11	Any pitch if water-proofed.
Thatch, 12″ thick, incl. battens	8½	1 in 1 45°
Tiling, Clay : Marseilles	6½	1 in 2 26½°
Pan 3″ overlap	8½	1 in 1·5 33½°
Pan, pointed in mortar	11	1 in 2 26½°
Plain 10½″ × 6½″ (B.S. 402) :		
handmade 2½″ lap	14½	1 in 1·2 40°
3½″ ,,	16½	1 in 1·3 37½°
machine made 2½″ ,,	13	1 in 1·2 40°
3½″ ,,	15	1 in 1·5 33½°
Tiling, Concrete :		
Plain 10½″ × 6½″ × 7/16″ (B.S. 473) 2½″ lap	14½	1 in 1·2 40°
Interlocking 15″ × 9″ × ⅜″ (B.S. 550)	7¾	1 in 1·7 30°
Zinc Sheet, incl. laps and rolls 12 ZG	1¼	1 in 64 plus drips or 1 in 8 without drips.
14 ,,	1½	
16 ,,	2	

The *L.C.C.* By-laws prohibit the slope of a roof exceeding 75°, and in warehouses 47° unless against a street or open space and of incombustible materials.

RELATION BETWEEN GAUGE AND LAP

The gauge is the spacing of slates or tiles measured from centre to centre up the slope, and is equal to the spacing of the battens. It is also equal to the width of the visible portion of each row of slates or tiles, as may be seen from the sketch.

$$\text{Gauge } g = \tfrac{1}{2}\,(\text{length of slate–lap})$$
$$\text{Lap} = \text{length–2 (gauge)}$$

Thus for a given length of slate, it is sufficient to specify either gauge or lap to control the degree of weathering and the number of slates per square.

In the case of diamond tiling the lap is measured differently, see the figure opposite Table 9.

TABLE 3. Maximum Span and Spacing of Steel Angle Purlins

Roof Covering (see next Table)	Usual Maximum Purlin Spacing	Size of Purlin			
		3″×2″×5/16″	4″×3″×5/16″	5″×3″×5/16″	6″×3″×3/8″
24 B.G. galv. corrugated steel sheets 10′ long	4′ 9″	9′ 6″	13′	16′	
6′ 6″ long	6′ 0″	8′	11′ 6″	14′	
Boards and felt, Asbestos sheets 6″ corr.	4′ 6″	9′ 3″	12′ 6″	15′ 6″	
,, ,, 3″ corr.	3′ 0″	11′	15′		
Patent glazing	6′ 0″	7′ 6″	10′	12′ 6″	16′
Asbestos slating and boards	4′ 6″	8′ 6″	11′ 6″	14′	18′
Welsh slating and boards	4′ 6″	8′	10′ 6″	13′	17′

The above are suitable for slopes not less than 20° and not more than 1 in 2 ; wind pressure 15 lb./sq. ft. normal to slope.

TABLE 4. Weights of Typical Roof Constructions

Construction	lb. per sq. ft. on slope	lb. per sq. ft. on plan *
Asbestos rect. slating 15¾" long, 3" lap.	4·0	
Black sheathing felt	·2	
1" Boards	2·5	
Common rafters 8' span (size from Table 33)	1·1	
Purlin and ridge	·5	
	8·3	9·3
24 B.G. galv. corrugated sheets incl. laps, fixed.	1·5	
Steel purlins 4' 9" centres	1·5	
	3·0	3·3
Steel roof truss		2·5
		5·8
Asbestos corr. sheets incl. laps, fixed.	3·3	
Steel purlins 3' centres	2·4	
	5·7	6·4
Steel roof truss		2·5
		8·9
Bituminous felt	1·5	
1" Boards	2·5	
Steel purlins 4' 6" centres	1·6	
Firring on purlins	·3	
	5·9	6·6
Steel roof truss		2·5
		9·1

Construction	lb. per sq. ft. on slope	lb. per sq. ft. on plan *
Patent metal glazing	6·0	
Steel purlins 6' centres	1·3	
	7·3	8·2
Steel roof truss		2·5
		10·7
Asbestos diamond slating 15¾" side, 4" lap.	2·9	
1" Boards	2·5	
Steel purlins 4' 6" centres	1·6	
Firring on purlins	·3	
	7·3	8·2
Steel roof truss		2·5
		10·7
Welsh slating ·2" thick, 14" long, 3" lap.	7·5	
1" Boards	2·5	
Steel purlins 4' 6" centres	1·7	
Firring on purlins	·3	
	12·0	13·5
Steel roof truss		2·5
		16·0
Asbestos corr. sheets	3·3	
Reinforced concrete purlins	5·0	
	8·3	9·3
Reinforced concrete 30' truss.		15·
		24·3
2" × 1" Battens at 5" centres	1·0	1·2

* Calculated for 1 in 2 slope ; for other slopes convert total in previous column with appropriate value of S in Table 5.

The purlin weights and steel truss allowance are adequate for all ordinary spans ; different purlin spacings do not materially affect the totals.

Other Typical Roof Constructions

Reinforced concrete roofs 25–40 ft. span :—	lb. per sq. ft. on plan
Flat beams (T section) about 3 ft. centres . .	20
Precast coffered slabs on the above . . .	16
Bituminous felt	1·5
	37·5

Portal truss or 3-pin arch, 10–12 ft. centres, excluding part below eaves level	16·5
Precast purlins	5
Precast coffered slabs on 1 in 2 slope . . .	18
Bituminous felt	1·7
	41·2

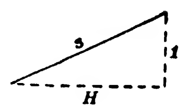
For spans between 25 and 70 ft., width of barrel 15 to 30 ft. :—

Barrel vault 2¼ in. thick	30
Stiffening and edge beams	10
Bituminous felt	1·5
	41·5

Asbestos-cement tubular members in truss and purlins, 20–24 ft. span :—

Rafters	1·7
Purlins	2·8
Asbestos corrugated sheets	3·9
	8·4

TABLE 5. Equivalent Slopes and Length up Slope



Exact figures are in **bold type.**

Slope 1 in H	Angle °	Length S	Slope 1 in H	Angle °	Length S
1 in 57·29	**1**	1·0001 × H	1 in **3½**	16	1·040 × H
20	3	1·001	**3**	18½	1·054
10	5¾	1·005	2·747	**20**	1·064
8	7	1·008	**2½**	22	1·077
6	9½	1·014	**2**	26½	1·118
5·671	**10**	1·015	1·732	**30**	1·155
5	11½	1·020	**1½**	33½	1·202
4	14	1·031	1·303	37½	1·260
3·73	**15**	1·035	1·192	**40**	1·305
			1	**45**	1·414

MAXIMUM SPACING OF DOWNPIPES

Based on 1 sq. in. of downpipe cross-section for each 90 sq. ft. of roof measure on slope, for slope 1 in 2. For other slopes multiply result by $\frac{1 \cdot 118}{s}$, obtaining s from table above. The smaller values for cast iron pipes arise from the bore being smaller than the nominal diameter, see table.

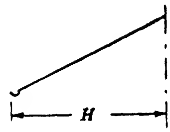


TABLE 6. Spacing of Downpipes, feet

Nominal Diameter of Downpipes	Distance H in feet					
	15	20	25	30	35	40
2″ cast iron	15	11				
2½″ asbestos	26	20	16	13		
,, cast iron	24	18	14	12		
3″ asbestos	38	28	23	19	16	
,, cast iron	35	26	21	17	15	
3½″ asbestos		39	31	26	22	19
,, cast iron		36	29	24	20	18
4″ asbestos			40	34	29	25
,, cast iron			38	32	27	24
4½″ asbestos			51	43	37	32
,, cast iron			48	40	35	30
5″ asbestos				53	45	39
,, cast iron				50	43	38
5½″ asbestos						48
6″ asbestos						57
,, cast iron						54

For particulars of cast iron and asbestos pipes see tables 140, 141.

ASBESTOS CEMENT SLATES

As standardised in B.S. 690. The thicknesses are specified in mm., but are given here in approximate decimal equivalents.

TABLE 7. Rectangular Slates

The number per square can be obtained from the Welsh Slate Table.

Size in.	Av. Thickness in.	Dimension D in.	
		3″ lap	4″ lap
24 × 12	·18	13⅝	14⅛
20 × 10	·16	11⅝	12⅛
15¾ × 7⅞	,,	9½	10
11¾ × 5⅞	—	2½″ lap, 7¼	

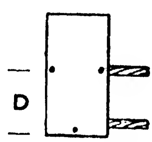
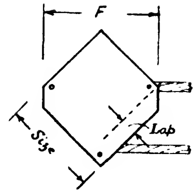


TABLE 8. Diamond Pattern Slates

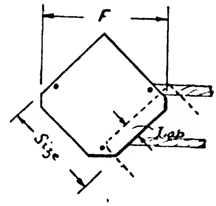
Size in.	Av. Thickness in.	Lap* in.	Gauge in.	F in.	No. per square, nett.
24 × 24	·18	4	$13\frac{1}{2}$	$29\frac{1}{8}$	37
$15\frac{3}{4} \times 15\frac{3}{4}$	·16	$2\frac{3}{4}$	$8\frac{7}{8}$	$18\frac{15}{16}$	86
,,	,,	3	$8\frac{1}{2}$	,,	90
,,	,,	$3\frac{1}{2}$	$8\frac{1}{4}$	$17\frac{15}{16}$	98
,,	,,	4	$7\frac{5}{8}$	,,	105
$11\frac{3}{4} \times 11\frac{3}{4}$	,,	$2\frac{1}{2}$	$6\frac{1}{8}$	$13\frac{3}{4}$	171



* The lap is measured diagonally between successive rows of slates, as shown in the sketch.

TABLE 9. Honeycomb Pattern Slates

Size in.	Av. Thickness in.	Lap* in.	Gauge in.	F. in.	No. per square, nett.
24 × 24	·18	4	12	$32\frac{1}{2}$	37
$15\frac{3}{4} \times 15\frac{3}{4}$	·16	$2\frac{3}{4}$	$8\frac{1}{8}$	$20\frac{1}{4}$	88
,,	,,	$3\frac{1}{2}$	$7\frac{3}{8}$	$19\frac{3}{4}$	99
$11\frac{3}{4} \times 11\frac{3}{4}$	,,	$2\frac{1}{2}$	$5\frac{5}{8}$	$14\frac{7}{8}$	172



Each slate requires two nails and one rivet.

WELSH SLATES

The *British Standards Institution* gave, in B.S. 680—*Welsh Roofing Slates*, a test for quality and noted the wide variety of thicknesses produced (ranging from 16 in. to 45 in. per 100 slates), but found itself unable to obtain agreement from the quarries to lay down standard thicknesses. The weights given below are based on Welsh slate weighing 175 lb./cu. ft. and 0·20 in. thick, i.e. light weights. Slates are sold by the "thousand" of 1200 pieces, and sometimes by weight.

[See *overleaf*.

TABLE 10

Name of Slates	Size in.	No. per 100 sq. ft. Lap 2½″	Lap 3″	Lap 3½″	Lap 4″	Weight each lb.	Weight per 1200 cwt.	Weight per sq. ft. of roof, lb. Lap 3″	Lap 4″
Empresses	26 × 16	77	79	80	82	8·43	90	6·7	6·9
Princesses	24 × 14	96	98	101	103	6·81	73	,,	7·0
Duchesses	24 × 12	112	115	118	120	5·84	63	,,	,,
Small Duchesses	22 × 12	124	127	130	134	5·35	57	6·8	7·2
Marchionesses	22 × 11	135	138	142	146	4·91	53	,,	,,
Wide Countesses	20 × 12	138	142	146	150	4·87	52	6·9	7·3
Countesses	20 × 10	165	170	175	180	4·06	44	,,	,,
Outsize Countesses	18 × 12	155	160	166	171	4·38	47	7·0	7·5
Viscountesses	18 × 9	207	214	221	229	3·28	35	,,	,,
Outsize Viscountesses.	16 × 12	178	185	192	200	3·90	42	7·2	7·8
Wide Ladies	16 × 10	214	222	231	240	3·25	35	,,	,,
Broad Ladies	16 × 9	237	246	256	267	2·92	31	,,	,,
Ladies	16 × 8	267	277	288	300	2·60	28	,,	,,
Wide Headers	14 × 12	209	219	229	240	3·41	37	7·5	8·2
Headers	14 × 10	251	262	275	288	2·84	30	,,	,,
Small Ladies	14 × 8	314	328	343	360	2·27	24	,,	,,
Narrow Ladies	14 × 7	358	374	392	411	1·99	21	,,	,,
Small Headers	13 × 10	275	288	304	320	2·64	28	7·6	8·4
Long Doubles	13 × 7	392	412	434	458	1·85	20	,,	,,
Wide Doubles	12 × 10	304	320	339	360	2·44	26	7·8	8·8
Small Doubles	12 × 8	380	400	424	450	1·94	21	,,	,,

SHINGLES (cedar tiles)

Length 16 in., widths random from 4 in. to 12 in.
Thickness 0·4 in. tapering towards the upper end.
When hung on walls, lap 3 in., i.e. gauge 6½ in. is satisfactory.
Shingles are sold in bundles of about 100 and the quantities required are as follow :—

TABLE 11

Lap	3″	6″	8½″
Gauge	6½″	5″	3¾″
Bundles per square	3	4	5

PLAIN TILES, Clay or Concrete

10½ in. × 6½ in. :	Lap.	2½ in.	3½ in.
	Gauge	4 in.	3½ in.
	No. per square . .	554	633

Battens 1 in. × ⅝ in. Two nails to each tile in every third course.
Two courses nailed next to eaves, hips and ridges.
On vertical courses nail all tiles.

CONCRETE INTERLOCKING TILES

15 in. × 9 in. : Overlap . . . 2 in.
Gauge . . . 13 in.
No. per square . . 144

Battens 1½ in. × 1 in. One nail or wire to each tile in every third course.

MARSEILLES TILES

Gauge 13¾ in.

Battens 1 in. × ¾ in. One nail or wire to each tile every third course.

WELSH SLATES

Sizes and quantities in Table 10.

Battens 1½ in. × ¾ in. Two nails to each slate.

TRAFFORD TILES

These are really sheets measuring 4 ft. by 3 ft. 8 in., and require purlins at 3 ft. 6 in. centres. No. per square 8½
Wt., lb/sq. ft. 3·4

Longer sheets of the same width are also obtainable.

FOOTAGE OF SLATING OR TILING BATTENS PER SQUARE, nett

TABLE 12. Rectangular Slates or Tiles

Length of Slate	Lap			
	2½″	3″	3½″	4″
26″	102	105	107	109
24″	112	115	118	120
22″	123	127	130	134
20″	138	142	146	150
18″	153	160	166	172
16″	178	185	192	200
14″	209	219	229	240
13″	229	240	253	266
12″	253	267	284	300

TABLE 13. Diamond or Honeycomb Slates
Obtain the gauge from Table 9 for the lap required.

Gauge in.	Feet per square	Gauge in.	Feet per square
12	100	7⅝	158
8⅞	135	7⅜	163
8½	141	6⅛	196
8¼	145	5⅝	214
8⅛	148	5	240

GALVANISED CORRUGATED STEEL SHEETS

According to B.S. 798, the flat sheets for 8/3 in. corrugations (about 2 ft. 2 in. wide) are to be from 29½ in. to 29¾ in. wide, and for 10/3 in. corrugations (about 2 ft. 8 in. wide) are to be from 35½ in. to 35¾ in. wide, before corrugating. The effective widths with one corrugation overlap are 24 in. and 30 in. respectively. The weight of galvanising is to be not less than 1¾ oz./sq. ft., including both sides. The finished weight varies slightly.

TABLE 14. 8/3 in. Weight in lb. per sheet

Length of Sheet	Birmingham Gauge						
	16	18	20	22	24	26	28
5′	32·2	25·9	19·6	16·1	13·3	10·7	8·7
5′ 6″	35·4	28·5	21·6	17·7	14·6	11·7	9·6
6′	38·6	31·1	23·6	19·3	16·0	12·9	10·5
6′ 6″	41·8	33·7	25·6	20·9	17·3	13·9	11·3
7′	45·0	36·3	27·5	22·5	18·7	15·0	12·3
7′ 6″	48·2	38·9	29·5	24·1	20·0	16·1	13·1
8′	51·5	41·5	31·4	25·7	21·3	17·1	14·0
8′ 6″	54·7	44·1	33·4	27·3	22·6	18·2	14·8
9′	57·9	46·7	35·3	28·9	24·0	19·3	15·7
9′ 6″	61·1	49·3	37·3	30·5	25·3	20·4	16·6
10′	64·3	51·9	39·2	32·2	26·7	21·5	17·5

TABLE 15. 10/3 in. Weight in lb. per sheet

5′	38·7	31·2	23·6	19·4	16·0	12·9	10·5
5′ 6″	42·5	34·3	26·0	21·3	17·5	14·1	11·5
6′	46·4	37·5	28·4	23·2	19·2	15·5	12·6
6′ 6″	50·4	40·5	30·8	25·1	20·8	16·7	13·6
7′	54·1	43·6	33·1	27·1	22·5	18·0	14·8
7′ 6″	58·0	46·7	35·5	29·0	24·1	19·4	15·7
8′	62·0	49·9	37·8	30·9	25·6	20·6	16·8
8′ 6″	65·8	53·1	40·1	32·8	27·2	21·9	17·8
9′	69·6	56·1	42·5	34·8	28·9	23·3	18·9
9′ 6″	73·5	59·3	44·8	36·7	30·4	24·6	20·0
10′	77·4	62·4	47·1	38·7	32·1	25·8	21·1

GALVANISED STEEL SHEETS—*Continued.*

TABLE 16. Flat and Corrugated Sheets

Birmingham Gauge	16	18	20	22	24	26	28
Approx. thickness after galvanising, in.	·065	·052	·042	·034	·028	·023	·019
Weight of flat sheet lb./sq. ft.	2·62	2·09	1·68	1·35	1·09	·88	·71
Weight of corr. sheet lb./sq. ft.	2·96	2·37	1·90	1·53	1·23	·99	·81
Weight of corr. sheet allowing for laps* lb./sq. ft.	3·49	2·80	2·24	1·80	1·45	1·17	·96

* Based on 6 ft. sheets with 6 in. end lap and 2 in. side lap, exclusive of fastenings, for which add 0·04 lb./sq. ft.

ASBESTOS CEMENT SHEETS

Flat sheets ¼ in. thick weigh	2·3 lb./sq. ft.
Corrugated sheets ¼ in. thick weigh	2·6 „ „
Ditto allowing for 6 in. end lap and side lap weigh	3·3 „ „

Sheets with $10\frac{1}{2}/2\frac{7}{8}$ in. corrugations are $29\frac{1}{2}$–30 in. wide and the effective width is $25\frac{7}{8}$ or $28\frac{3}{4}$ in. according to the side lap. The overall depth is $1\frac{1}{8}$ in. Sheets with $7\frac{1}{2}/5\frac{3}{4}$ in. corrugations are $41\frac{1}{2}$–43 in. wide and the effective width is $34\frac{1}{2}$ or $40\frac{1}{4}$ in. according to the side lap. The overall depth is 2 in. or $2\frac{1}{8}$ in.

For tiles see Tables 7–9.

WEIGHTS OF METAL SHEET AND WIRE

For copper sheet see Table 18.
,, lead ,, ,, ,, 19.
,, zinc ,, ,, ,, 22.
,, iron sheet and wire see Tables 20 (S.W.G.) and 21 (B.G.).

For other metals multiply the weight for iron sheet or wire in Tables 20 and 21 by the following conversion factors :—

TABLE 17

Metal	Factor	Metal	Factor
Aluminium	·350	Monel metal	1·14
Brass	1·11	Muntz metal	1·09
Copper	1·16	Steel	1·02
Gunmetal	1·10	Tungum	1·11
Lead	1·47	Zinc	·935

TABLE 18. Weight and Thickness of Copper Sheet

24 S.W.G. is the usual thickness for roofing. For gauges not given below see Tables 17 and 20.

S.W.G.	Thickness in.	Weight lb./sq. ft.	Trade Description
20	·036	1·67	
22	·028	1·30	
23	·024	1·11	"19 oz."
24	·022	1·02	"16 oz."
Per inch of thickness		46·5	

TABLE 19. Weight and Thickness of Lead Sheet

Weight lb./sq. ft.	Thickness in.	Weight lb./sq. ft.	Thickness in.
2	·034	5	·085
$2\frac{1}{2}$	·042	6	·102
3	·051	7	·119
$3\frac{1}{2}$	·059	8	·136
4	·068	9	·152
$4\frac{1}{2}$	·076	10	·170
Per inch of thickness		59·0	

Lead sheet should not be used on slopes greater than 10°.
Copper nails should be used if nailing is unavoidable.
The usual weights in good-class work are as follows :—

(*a*) Roofs and main gutters . 7 lb./sq. ft.
(*b*) Hip, ridge and small gutters 6 ,, ,,
(*c*) Flashings and aprons . . 5 ,, ,,
(*d*) Damp course and soakers . 4 ,, ,,

For houses use 2 lb./sq. ft., lighter in classes (*a*) and (*b*).
1 ,, ,, ,, ,, ,, (*c*) and (*d*).

BRITISH GAUGES IN CURRENT USE

The Imperial Standard Wire Gauge was authorised in 1884 and is the only legal wire gauge in the U.K. It is also commonly used for sheets, although the Birmingham Gauge is still frequently used for sheet iron and the Zinc Gauge for sheet zinc. It is to be hoped that these two gauges, and others seldom used, will become obsolete.

The Whitworth Decimal Gauge, used by the Admiralty and others, has the advantage that the gauge sizes denote the thickness in mils so that a table is unnecessary, e.g. No. 20 W.D.G. is ·020 in. thick.

For sectional areas of S.W.G. sizes see Table 184.

TABLE 20. Standard Wire Gauge
Weight of Iron Wire and Sheet

S.W.G. No.	Diameter or Thickness In.	Weight of 100 ft. of Iron Wire lb.	Weight per sq. foot Sheet Iron lb.	S.W.G. No.	Diameter or Thickness in.	Weight of 100 ft. of Iron Wire lb.	Weight per sq. foot Sheet Iron lb.
7/0	·500			**13**	·092		
6/0	·464			**14**	·080	1·67	3·20
5/0	·432			**15**	·072		
4/0	·400			**16**	·064	1·07	2·56
3/0	·372			**17**	·056		
2/0	·348			**18**	·048	·603	1·92
0	·324			**19**	·040		
1	·300			**20**	·036	·340	1·44
2	·276			**21**	·032		
3	·252			**22**	·028	·205	1·12
4	·232	14·09	9·28	**23**	·024		
5	·212			**24**	·022	·127	·88
6	·192	9·62	7·68	**25**	·020		
7	·176			**26**	·018	·085	·72
8	·160	7·39	6·40	**27**	·016*		
9	·144			**28**	·015	·057	·60
10	·128	4·29	5·12	**29**	·014		
11	·116			**30**	·012	·040	·48
12	·104	2·83	4·16	*The last four sizes approx. The gauge goes to No. 50.			

For other metals see Table 17.

TABLE 21. Birmingham Gauge. Weight of Sheet Iron

This gauge (for Sheet and Hoops) differs from the Birmingham Wire Gauge and Birmingham Plate Gauge. Birmingham Wire Gauge between sizes 20 and 30 is almost identical with S.W.G.

B.G. No.	Thickness in.	Wt. per sq. ft. lb.	B.G. No.	Thickness in.	Wt. per sq. ft. lb.
8	·157	6·28	**20**	·0392	1·57
9	·1398	5·59	**21**	·0349	1·40
10	·1250	5·00	**22**	·0312	1·25
11	·1113	4·45	**23**	·0278	1·11
12	·0991	3·96	**24**	·0248	·99
13	·0882	3·53	**25**	·0220	·88
14	·0785	3·14	**26**	·0196	·78
15	·0699	2·80	**27**	·0174	·70
16	·0625	2·50	**28**	·0156	·62
17	·0556	2·24	**29**	·0139	·56
18	·0495	1·98	**30**	·0123	·49
19	·0440	1·76	**31**	·0110	·44

TABLE 22. Zinc Gauge. Weight of Sheet Zinc

In accordance with B.S. 849—*Plain Sheet Zinc Roofing*

Zinc Gauge No.	Thickness in.	Approx. Weight per sq. ft. lb.	7 ft. × 3 ft. Sheets		8 ft. × 3 ft. Sheets.	
			Wt. per sheet lb.	No. per ton	Wt. per Sheet lb.	No. per Ton.
6	·011	·41	8·6	259	9·9	227
7	·013	·49	10·2	219	11·7	192
8	·015	·56	11·8	190	13·5	166
9	·017	·64	13·4	168	15·3	147
10	·019	·71	14·9	150	17·1	131
11	·022	·82	17·3	129	19·7	113
12	·025	·94	19·7	114	22·5	100
13	·028	1·05	22·0	102	25·2	89
14	·031	1·16	24·4	92	27·9	80
15	·036	1·35	28·3	79	32·4	69
16	·041	1·54	32·2	69	36·9	61
17	·046	1·73	36·2	62	41·4	54
18	·051	1·91	40·1	56	45·9	49
19	·057	2·14	44·8	50	51·2	44
20	·063	2·36	49·6	45	56·6	40
21	·070	2·62	55·1	41	62·9	36

TABLE 23. Hook Bolts $\frac{5}{16}$ in. diam.

Length		in.	3½	4	4½	5
Weight	Per 100	lb.	13·0	14·2	15·5	17·3
	Per gross	lb.	18·7	20·4	22·4	24·9

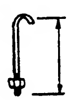
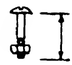


TABLE 24. Roofing Nails and Screws

Length		in.	2½"	3"
Weight of nails	Per 100	lb.	3·5	4·1
	Per gross	lb.	5·1	5·9
Weight of screws	Per 100	lb.	3·7	4·9
	Per gross	lb.	5·3	7·0

TABLE 25. Sheeting Bolts ¼ in. diam.

Length	in.	¾	1	1¼	1½
Weight per 100	lb.	2·5	2·9	3·2	3·5
„ „ gross	lb.	3·6	4·1	4·6	5·1



CURVED DIAMOND WASHERS for roof bolts

Weight per 100 —4·3 lb.
„ per gross—6·2 lb.

LIMPET WASHERS for roof bolts

Weight per 100 —1·0 lb.
„ per gross—1·4 lb.

For FLAT WASHERS see Table 170.

WIND, SNOW AND OTHER LOADING ON ROOFS

WIND LOADS ON WALLS

For convenience, wind loading on portions of the structure other than the roof is considered here in addition to loading on roofs.

The *Institution of Structural Engineers Technical Report No.* 8 contains regulations for wind loading (repeated in Report No. 10) which are more detailed than and differ from the requirements of the *L.C.C.*

Post-War Building Study No. 8 of the *Ministry of Works* ("Reinforced Concrete Structures") recommends the adoption of the above Technical Report for wind loading with the exception of the provisions relating to sloping roofs, for which the *L.C.C.* by-laws are to be retained.

(i) **Sloping Roofs,** *L.C.C.* requirements, including repair party and snow loads.

(*a*) Slope exceeding 20°. Minimum superimposed load, deemed to include the wind load, of 15 lb./sq. ft. of roof surface acting normal to the surface inwards on the windward side, and 10 lb./sq. ft. outwards on the leeward side, the two loadings to be designed for separately and not simultaneously.

(*b*) Slope not exceeding 20° (including flat roofs). A minimum superimposed load of 50 lb./sq. ft. of covered area on slabs or 30 lb./sq. ft. on beams, e.g. purlins. Beams not spaced further apart than 30 in. are to be designed for slab loading.

(ii) **Vertical Surfaces.** *Technical Report No.* 8.

Wind pressure, acting normal to the surface, varies with the height and is to be taken as 5 lb./sq. ft. at mean ground level, increasing at the rate of 1 lb./sq. ft. for each 10 ft. of height up to a maximum of 15 lb./sq. ft. for heights of 100 ft. and over. The corresponding values are tabulated for various heights below.

TABLE 26. Wind Pressures at Various Heights.

Height above Ground, ft.	Lb./sq. ft.	Height above Ground, ft.	Lb./sq. ft.
0	5	60	11
10	6	70	12
20	7	80	13
30	8	90	14
40	9	100	15
50	10	and over	

These pressures apply to areas where the wind velocity at a height of 50 ft. does not exceed 80 m.p.h. In more exposed situations the pressures shall be increased in the ratio of the square of the anticipated velocity (m.p.h.) to the square of 80.

(iii) **Isolated Projections,** *Technical Report No.* 8.

On isolated projections, chimneys, etc., above the general roof level the pressure is to be taken as 50% greater than in (ii). See also (vii).

(iv) **Gable Ends,** *Technical Report No.* 8.

The pressure up to eaves level shall be taken as varying with the height, as in (ii). Above eaves level the pressure shall be taken as uniform, its value being as given in (ii) for a height midway between eaves and ridge.

(v) **Wind Drag,** *Technical Report No.* 8.

In addition to the pressures acting normal to the foregoing surfaces, all surfaces, whether vertical, inclined or horizontal, parallel to the direction of the wind shall be considered as subject to a drag tangential to the surface and equal to 2½% of the appropriate value given in (ii).

(vi) **Multiple Spans,** *Technical Report No.* 8.

Spans connected together and arranged so that the windward span shelters the others : relief of wind load on the structure supporting the spans may be allowed as follows :—

	Reduced by
On the span adjoining the windward span .	50%
On the next span	75%
On the remaining spans	87½%

The relief does not apply to the roof structure or valley beams.

(vii) **Cylindrical Areas,** *Technical Report No.* 8.

On cylindrical areas with axis vertical, e.g. chimneys, 60% of the pressures given in (ii) shall be taken as acting on the projected area exposed to the wind.

The B.S. Code of Practice C.P.4 (Chapter V) recommends the following loads :—

(i) Superimposed load, deemed to include snow :—

(a) On roofs sloping up to 10° (including flat roofs), 30 lb./sq. ft measured on plan ; for spans l less than 8 ft., $\frac{240}{l}$ lb./sq. ft.

(b) On slopes greater than 10° and up to 65°, 10 lb./sq. ft. measured on plan ; the roof also to be capable of carrying at any point a concentrated load of 200 lb. if workmen can stand directly on the roof, or 100 lb. if the slope is such that they would have to use a ladder or other support.

(c) On slopes greater than 65°, no allowance necessary.

(ii) Wind loads.

This section of *Chapter V* contains valuable information on the effect of wind on buildings, but as a design code is not very satisfactory. The process involves making two difficult decisions, viz., which of six different wind velocities shall be adopted for the site, and what part of the height of the building may be considered as shielded by permanent near-by obstacles. From these considerations the appropriate wind pressure p is obtained, and $0{\cdot}5p$ is taken as acting uniformly over the whole height of the windward vertical face of the building, with an equal suction on the lee side.

For roofs, various factors are applied to p according to the slope and other conditions. The salient points which emerge from the recommendations are that external pressure is considerably less than 15 lb./sq. ft, on most roofs, while the suction may exceed 10 lb./sq. ft. The latter figure is adequate for roofs, of any slope, not exceeding 60 ft. in effective height in localities where a 55 m.p.h. wind is appropriate, but the suction may reach 40 lb./sq. ft. on very high buildings in exposed sites.

It would appear that much simpler rules for wind loading could be devised within the Code for the majority of buildings in inland towns.

HOUSE CONSTRUCTION—Snow and Wind Loading

Post-War Building Study No. 1 of the *Ministry of Works* ("House Construction") makes the following recommendations.

(i) **Sloping Roofs.**

(a) Slope of 10° and over. A snow load of 10 lb./sq. ft. measured on plan, and a negative pressure (suction) of 8* lb./sq. ft. on the leeward slope, acting separately or in conjunction with the snow load.

(b) Slope of less than 10° (including flat roofs). A superimposed load including snow of 30 lb./sq. ft. measured on plan, alternatively an upward pressure of 10 lb./sq. ft.

The roof covering and framing should be able to withstand a concentrated load of 100 lb. at any point accessible by ladder, or 200 lb. if accessible without a ladder.

(ii) **Vertical Surfaces**

For buildings not more than 20 ft. high to the eaves, a horizontal wind pressure of 8* lb./sq. ft. When the building height does not exceed three times the width and there is reasonable stiffening by crosswalls calculations are unnecessary.

* In very exposed situations these pressures should be taken as 16 lb./sq. ft.

TIMBER DATA

1 Standard = 165 cu. ft. (Petrograd standard) = 1980 Board feet (U.S.).

1 Load	= 50 cu. ft.	1 Square	= 100 sq. ft.
1 Cord	= 128 cu. ft.	1 Stack	= 108 cu. ft.

B.S. 565—*Terms and Definitions applicable to Hardwoods and Softwoods* gives the following terms for different sizes of timber, but they are not yet in universal use :—

Batten	2 in. to 4 in. thick incl.	5 in. to 8 in. wide incl.
Board	Under 2 in. thick.	4 in. and over wide.
Deal	2 in. to 4 in. thick incl.	Not under 9 in. but under 11 in. wide.
Plank	2 in. to 6 in. thick incl.	11 in. and over wide.
Scantling	2 in. to 4 in. thick incl.	2 in. to $4\frac{1}{2}$ in. wide incl.
Strip	Under 2 in. thick.	Under 4 in. wide.
Square	Equal dimensions from 1 in. × 1 in. to 6 in. × 6 in.	

The term " scantling " is also used in the sense of cross-section or size.

Cost. £1 per standard = 1·454 pence per cu. ft.

If the dimensions of a timber are d inches by b inches and the cost of timber is £N per standard, then

$$\frac{d \times b \times N}{100} = \text{pence per foot run, within } 1\%.$$

PROPERTIES OF TIMBERS

English green timber contains in the case of hardwoods about 40% of its weight of water, in softwoods from 50% to 60% ; from 8% to 12% is retained even when thoroughly seasoned. The difference in weight from the green state to normally dry and seasoned is therefore some 10–15 lb./cu. ft. The weights given below and in the Table of Densities are for timber containing 15% water, that is, seasoned and apparently dry.

The distinction between hardwoods and softwoods has no relation to hardness. A former convention called timber weighing over 40 lb./cu. ft. hardwood. The *British Standards Institution* adopts a distinction based solely on botanical type.

The safe working stress in timber is usually taken as one-sixth of the ultimate stress. For working stresses under *L.C.C.* by-laws see p. 25. For weight of other timbers see Table of Densities, Table 93.

TABLE 27.

Name	Weight lb./cu. ft.	Ultimate Stress lb. per sq. in. Tension	Compression	Young's Modulus lb./sq. in.
				Millions
Ash, English	43	5–15000	7–9000	1·3–2·0
Beech	48	10–20000		1·4–1·8
Birch, yellow *	44	15000	7000	
Cedar, Western red	24	11000	6000	
Deal, see Yellow Pine				
Elm, English	36	5–7000	5000	1·0–1·2
Fir, Douglas	33	7000	6000	1·6
Greenheart	62–70	18000	15000	2–3·4
Hickory *	51	19000	9000	
Hornbeam	44	12000	7000	
Larch	37	4000		1·0–1·6
Lignum vitae	75–83	12000	11000	
Mahogany, Honduras	34	20000	8000	1·6–2·0
Spanish	43	14000	8000	1·3–3·0
Maple *	43	15000	7500	
Oak, American red	45	7–10000	7–9000	2·1
white	48	12000	10000	2·1
English	45	8–16000	6–10000	1·2–1·7
Oregon pine, see Fir, Douglas				
Pine, American yellow	27	2000	4000	1·6–2·5
Dantzig	36	3–10000	6000	2·3
Kauri (N.Z.)	38	5000	5000	2·9
Pitch-	41	5–9000	7000	1·3–3·0
Riga	34–47	4–11000	4000	1·3–3·0
Poplar *	28	9000	5000	
Pyinkado	62	12000	11000	2·5
Redwood, non-graded	27	see	Table 37	
graded	33 or 41	,,	,,	
Spruce, Norway *	29	9000	5000	1·5
Teak	41	8–13000	8–11000	1·8–2·4
Whitewood	29	9000	5000	1·5

* The stresses given for these timbers apply to specimens for use in aircraft construction

WORKING STRESSES

For timber the working stress is generally taken at one-sixth of the ultimate stress. The following values may be adopted for selected seasoned timber. See p. 25 for *L.C.C.* requirements.

TABLE 28. Working Stresses, lb./sq. in.

Timber	Fibre Stress in Bending	Compressive Stress
Greenheart	3000	2500
Ash, Beech, Oak, Teak	1500	1200
Douglas Fir, Larch, Pitch-pine.	1200	1000
Elm, Spruce, Redwood	1000	800

LENGTH OF TIMBER IN ONE STANDARD

The Petrograd standard of 165 cu. ft. is used in the tables below. The standard terminology recommended in B.S. 565 is indicated by the frames. Sizes printed in italics are termed "squares."

TABLE 29. Feet Run per Standard

Width, in.	Thickness, in. ½	⅝	¾	⅞	1	1¼	1½	2	2½	3	3½	4
	Strips											
1	47520		31680		*23760*							
1½	31680		21120		17820		*10560*					
								Scantlings				
2	23760	19008	15840	13577	11880	9504	7920	*5940*				
2½			12670	10862	9504		6336	4750	*3800*			
3	15840	12672	10560	9052	7920	6336	5280	3960	3168	*2640*		
3½								3394	2715	2263	*1940*	
	Boards											
4	11880	9504	7920	6788	5940	4752	3960	2790	2376	1980	1697	*1485*
4½								2640	2112	1760	1508	1320
								Battens				
5					4752			2376	1900	1584	1357	1188
6	7920	6336	5280	4526	3960	3168	2640	1980	1584	1320		990
7	6788	5430	4525	3879	3394	2715	2263	1697	1357	1131	969	848
8					2970		1980	1485	1188	990	848	742
								Deals				
9			3520		2640	2112	1760	1320	1056	880		660
10								1188	950	792		594
								Planks				
11			2880		2160	1728	1440	1080	864	720		540
12					1980			990	792	660		495

TABLE 30. Equivalents of One Standard of Flooring or Shuttering

Thickness	Sq. yds.	Sq. ft.
½"	440	3960
⅝"	352	3170
¾"	293	2640
1"	220	1980
1¼"	176	1580
1½"	147	1320
2"	110	990

LENGTH OF TIMBER IN 1 CU. FT.

The standard terminology recommended in B.S. 565 is indicated by the frames. Sizes printed in italics are termed "squares."

TABLE 31. Feet Run per cu. ft.

Width in.	Thickness, in. ½	⅝	¾	⅞	1	1¼	1½	2	2½	3	3½	4
	Strips											
1	288		192		*144*							
1½	192		128		96·0		*64.0*					
								Scantlings				
2	144	115	96·0	82·3	72·0	57·6	48·0	*36·0*				
2½			76·9	65·8	57·6		38·4	28·5	*23·0*			
3	96	76·8	64·1	54·9	48·0	38·4	32·0	24·0	19·2	*16·0*		
3½								20·6	16·5	13·7	*11·7*	
	Boards											
4	72·0	57·6	48·0	41·1	36·0	28·9	24·0	18·0	14·4	12·0	10·3	*9·0*
4½								16·0	12·8	10·7	9·1	8·0
								Battens				
5					28·9			14·4	11·5	9·6	8·2	7·2
6	48·0	38·4	32·0	27·4	24·0	19·2	16·0	12·0	9·6	8·0	6·9	6·0
7	41·2	32·9	27·5	23·5	20·6	16·5	13·7	10·3	8·2	6·3		
8					18·0		12·0	9·0	7·2	6·0		4·5
								Deals				
9			21·4		16·0		10·7	8·0	6·4	5·3		4·0
10								7·2				3·6
								Planks				
11					13·1	10·5	8·7	6·5	5·2	4·4		3·3
12					12·0			6·0	4·8	4·0		3·0

EQUIVALENTS OF ONE SQUARE (100 sq. ft.) OF TONGUED AND GROOVED FLOORING

The effective width of T. & G. boarding as laid is indefinite and should be checked with the supplier if ordering by length.

TABLE 32. Feet Run per Square

Nominal Width in.	Length ft.	Nominal Width in.	Length ft.	Nominal Width in.	Length ft.
3	480	4½	300	6	220
3½	400	5	270	6½	200
4	340	5½	240	7	180

TIMBER ROOF CONSTRUCTION

The *L.C.C.* by-laws permit alternative methods of determining the sizes and spacing of timbers in roof construction.

(*a*) Provided that the construction and covering materials are not of abnormal weight, e.g. the covering of flat roofs is not heavier than 1 in. of asphalt, the size and spacing of timbers may be obtained by the use of a table of spacing factors.

The following three tables have been calculated to give this information direct ; they are based on the factors for " non-graded " timber (working fibre stress in bending 800 lb./sq. in.), see Table 37.

The alternative (*b*) is discussed later.

Cantilevers may project clear of support by a distance not exceeding one-quarter of the supported span for which the timber would be permitted.

Non-graded timbers, supported at each end

(i) RAFTERS, PURLINS AND CEILING JOISTS

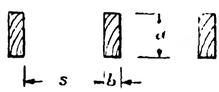


TABLE 33. Clear Spacing S in inches

Joist Size d × b in.	Clear Span in Feet 6	7	8	9	10	11	12	13	14	15
3 × 2	11	8[1]						Max. span :— [1] 6′–6″ [2] 8′–8″ [3] 9′–9″ [4] 10′–10″		
4 × 2	26	18	11	8[2]						
4½ × 2	34	23	18	11	8[3]					
5 × 1¾	34	26	18	13	9	7[4]				
5 × 2	39	30	21	15	11	8[4]				
6 × 1¾	54	39	30	23	18	13	10	7		
6 × 2	62	45	34	26	21	15	11	8		
7 × 1¾	65	54	39	30	23	20	16	11	9	7
7 × 2	74	62	45	34	26	23	18	13	11	8
8 × 2	112	74	62	45	39	30	26	21	18	13
8 × 2¼	126	83	70	51	44	34	29	23	20	15
8 × 2½	140	92	77	56	48	37	32	26	22	16

(ii) JOISTS TO FLAT ROOFS

TABLE 34. Clear Spacing S in inches

Joist Size d × b in.	Clear Span in Feet.									
	6	7	8	9	10	11	12	13	14	15
5 × 1¾	14	10	7							
5 × 2	16	12	9							
6 × 1¾	23	16	12	9	7					
6 × 2	27	19	14	10	8					
7 × 2	32	27	19	14	10	9				
8 × 2	49	32	27	19	16	12	10	8		
8 × 2¼	61	40	35	24	20	15	12	10		
8 × 2½	73	48	40	24	18	15	12			
9 × 2	56	39	32	27	19	16	14	10	9	8
9 × 2½	70	48	40	34	23	20	16	12	10	9
9 × 3	84	58	48	40	28	24	21	15	13	12
11 × 2½		70	61	48	40	34	27	20	17	15
11 × 3		84	73	58	48	40	33	24	21	18

(iii) BINDERS TO FLAT ROOFS

TABLE 35. (Also (iv) Joists and Binders to Residential Floors based on 50 lb. loading)

Joist Size d × b in.	Clear Spacing S in Inches.									
6 × 1¾	33	23	17	13	10	7				
6 × 2	38	27	20	15	12	8				
7 × 2	45	38	27	20	15	13	10	8[1]		
8 × 2	69	45	38	27	23	18	15	12	10	8[2]
8 × 2¼	77	50	42	30	26	20	17	13	11	9[2]
8 × 2½	86	56	47	33	29	22	19	15	12	10[2]
9 × 2	79	54	45	38	27	23	20	15	13	12
9 × 2½	98	67	56	47	33	28	25	18	16	15
9 × 3	118	82	67	57	40	34	30	22	19	18
11 × 2½	112	99	86	68	56	47	40	28	25	22
11 × 3	135	118	103	82	67	57	48	34	30	27

Max. span : [1] 12′–10″. [2] 14′–8″.

Local by-laws sometimes specify the minimum dimensions of rafters and joists, without specifying the spacing. The above values are not necessarily in accordance with such dimensions.

(*b*) The alternative to using the foregoing tables is to determine the size and spacing of timbers by calculation. In this event the following superimposed loadings are specified by the *L.C.C.* :—

TABLE 36.

Construction		Lb./sq. ft. of Horizontal Area Covered.
Flat-roof :— (slope not more than 20°)	boarding	200
	joists, firring	50
	binders, trusses	30
		Lb./sq. ft. of Roof Surface
All parts of pitched roof :— (slope more than 20°)	Inwards on windward side	15
	Outwards on leeward side, but not simultaneously with the above	10
Ceiling joists		25

The deflection under the specified loading is not to exceed $\frac{1}{360}$ of the length of the member. The stresses under the specified loading are not to exceed the values given below (*L.C.C.*).

TABLE 37.

Nature of Stress.	Working Stress lb./sq. in.	
	Non-graded	Grade 1200 lb. f.
Extreme fibre stress in bending	800	1200
Shear stress in direction of grain	90	100
Compression perpendicular to grain	165	325
Compression in direction of grain in posts and struts with slenderness ratio not exceeding 10 (see Table 38)	800	1000
Tension in direction of grain	800	1200
Modulus of elasticity	1200000	1600000

Timber Roof Construction—*Continued.*

The compression stress in posts and struts of slenderness ratio greater than 10 is not to exceed the values given in table 38 (*L.C.C.*).

TABLE 38.

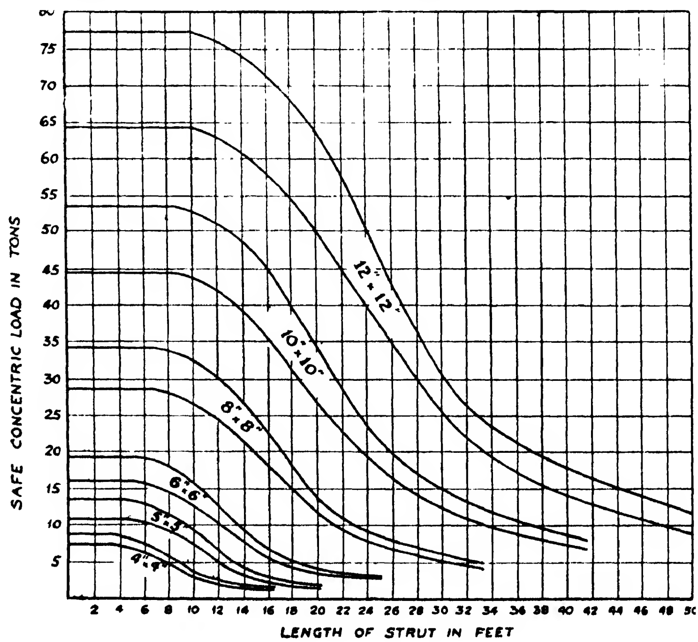
Slenderness Ratio	Lb. per sq. in.	
	Non.-graded	Graded 1200 lb. f.
Exceeding 10 but not exceeding 12	785	985
,, 12 ,, ,, 14	775	970
,, 14 ,, ,, 16	755	950
,, 16 ,, ,, 18	725	920
,, 18 ,, ,, 20	690	875
,, 20 ,, ,, 22	635	820
,, 22 ,, ,, 24	565	745
,, 24 ,, ,, 26	485	650
,, 26 ,, ,, 28	420	600
,, 28 ,, ,, 30	365	485
,, 30 ,, ,, 32	320	430
,, 32 ,, ,, 34	285	380
,, 34 ,, ,, 36	255	340
,, 36 ,, ,, 38	225	300
,, 38 ,, ,, 40	205	275

The slenderness ratio shall not exceed 40. Where bending loads are present the strut must be designed to withstand the combined bending and direct stress, for which see p. 113.

Note, the two foregoing tables apply generally to timber construction, including floors, *q.v.*

The formulæ to be used in designing timber beams are given on p. 161.

The accompanying figure gives the working loads, centrally supported, on timber columns of different sizes and lengths. The values are calculated from formulæ published by the Forest Products Laboratory, Madison, Wisconsin ; for each size shown the upper curve is for timber with a value for E of 1,600,000 lb./sq. in. and maximum safe compressive stress of 1200 lb./sq. in., while the corresponding values for the lower curve are 1,300,000 and 1000 lb./sq. in. Some English figures indicate considerably higher loads than those shown.



REACTIONS AT ROOF TRUSSES

(i) DEAD LOAD REACTIONS

The main table gives the reaction at each shoe for various spans and spacings of trusses, taking the combined weight of covering, purlins and truss at 9 lb./sq. ft. of area covered. Trusses up to 30 ft. span are usually spaced at about 12 ft. centres, for 45 ft. span at 14 ft. and over 60 ft. span, 16 ft. ; a truss allowance of 2½ lb./sq. ft. is sufficiently accurate. In accordance with the data on page 6 this table applies to *asbestos sheets* and to *boards and felt.*

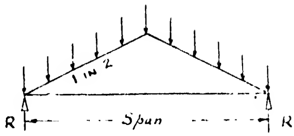


TABLE 39. Vertical Reactions R, tons

Spacing of Trusses ft.	Spans (C. to C. of Shoes), feet								
	20	25	30	35	40	45	50	55	60
8	·32	·40	·48	·56					
9	·36	·45	·54	·63	·72				
10	·40	·50	·60	·70	·80	·90			
11	·44	·55	·66	·77	·88	·99	1·10		
12	·48	·60	·72	·84	·96	1·08	1·20	1·32	
13	·52	·65	·78	·91	1·04	1·17	1·30	1·43	
14	·56	·70	·84	·98	1·12	1·26	1·40	1·54	1·69
15		·75	·90	1·05	1·20	1·35	1·50	1·66	1·81
16			·96	1·13	1·29	1·45	1·61	1·77	1·93

For other covering materials multiply the above reactions by the factors given below.

TABLE 40.

Covering	Multiply Reaction by
24 B.G. galv. corrugated sheets on steel purlins	·65
Patent glazing on steel purlins	1·1
Asbestos diamond slating, 1″ boards and steel purlins	1·1
Light Welsh slating ·2″ thick, 1″ boards and steel purlins.	1·8

(ii) WIND LOAD REACTIONS

In accordance with B.S. 449 and L.C.C. By-laws, viz., wind pressure 15 lb./sq. ft. normal to slope on windward side and 10 lb./sq. ft. suction on lee side. Table 41 gives the vertical reaction *R* under windward shoe, whether windward or lee shoe is free, *without* suction. These are the maximum vertical reactions possible.

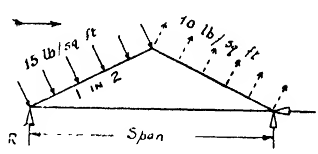


TABLE 41. Vertical Reaction R, tons

Spacing of Trusses ft.	Spans (C. to C. of Shoes), feet								
	20	25	30	35	40	45	50	55	60
8	·37	·46	·55	·65					
9	·41	·52	·62	·73	·83				
10	·46	·58	·69	·81	·92	1·04			
11	·51	·63	·76	·89	1·01	1·14	1·27		
12	·55	·69	·83	·97	1·10	1·24	1·38	1·52	
13	·60	·75	·90	1·05	1·20	1·35	1·50	1·65	1·80
14	·65	·81	·97	1·13	1·29	1·45	1·61	1·77	1·93
15		·86	1·04	1·21	1·38	1·56	1·73	1·90	2·07
16			1·10	1·29	1·47	1·66	1·84	2·02	2 21

To allow for expansion one shoe must be left free to slide, and it is assumed that the reaction under it is vertical. The horizontal component of the wind pressure and suction is resisted at the other shoe. Since the wind may blow from either side the worst combination at each shoe must be designed for. The reaction obtained from Table 41 must therefore be multiplied by the factors below to give the horizontal reactions and lee shoe reactions.

TABLE 42.

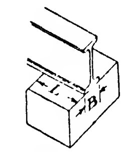
Conditions	Windward Shoe		Leeward Shoe		
	Vertical Reaction	Horizontal Reaction	Vertical Reaction	Horizontal Reaction	
Pressure only	1·00	·727	·454	0	Leeward shoe free
	1·00	0	·454	·727	Windward shoe free
Pressure and suction	·698	1·21	− ·211	0	Leeward shoe free
	·698	0	− ·211	1·21	Windward shoe free

DESIGN LOADS ON STRUCTURE BELOW ROOF

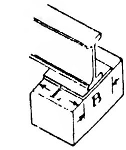
(i) DEAD LOADS. These may be obtained direct for typical roofs, pp. 6 and 7.

(ii) WIND LOADS. The vertical component is to be taken at 10 lb./sq. ft. of plan area covered (*L.C.C.*).

SAFE REACTIONS ON CONCRETE PADSTONES



(a)



(b)

Calculated for 1 : 2 : 4 concrete (*L.C.C.* Designation 111) at 42 tons/sq. ft. For 1 : 1½ : 3 mix, add one-sixth to reactions tabulated, see Table 61.

The length *L* should be not less than 4 in. ; it may be approximately equal to the depth of beam for depths up to 8 in. and two-thirds of the depth for deep beams.

When the reaction does not exceed the product of $L \times B$ times the permissible pressure in Table 61 or 63, no padstone is required.

TABLE 43. Safe Reactions in tons

Width of Bearing B in.	Length of Bearing L in.								
	4	5	6	7	8	9	10	12	14
1½	1·5	1·87							
1¾	1·75	2·19	2·62	3·06	3·50				
3	3·00	3·75	4·50	5·25	6·00	6·75	7·50	9·00	10·5
4	4·00	5·00	6·00	7·00	8·00	9·00	10·0	12·0	14·0
4½	4·50	5·62	6·75	7·87	9·00	10·1	11·2	13·5	15·7
5	5·00	6·25	7·50	8·75	10·0	11·2	12·5	15·0	17·5
5½	5·50	6·87	8·25	9·62	11·0	12·4	13·7	16·5	19·2
6	6·00	7·50	9·00	10·5	12·0	13·5	15·0	18·0	21·0
7	7·00	8·75	10·5	12·2	14·0	15·7	17·5	21·0	24·4
7½	7·50	9·37	11·2	13·1	15·0	16·8	18·7	22·5	26·2
8	8·00	10·0	12·0	14·0	16·0	18·0	20·0	24·0	28·0
10	10·0	12·5	15·0	17·5	20·0	22·5	25·0	30·0	35·0
11	11·0	13·7	16·5	19·2	22·0	24·7	27·5	33·0	38·4
12	12·0	15·0	18·0	21·0	24·0	27·0	30·0	36·0	42·0

BEARING PLATES

The reaction as given in the above table may be increased by improving the concrete mix, by increasing L or by adding bearing plates to increase B, as in Fig. (*b*). The thickness of plate required, for different loads and projections beyond the flange of the joist, is given in the next table, calculated on the usual assumption that the maximum B.M. in the plate occurs under the middle of the flange which applies the load.

THICKNESS OF BEARING PLATES

TABLE 44. See notes on preceding page.

Length of Bearing L in.	Projection of Plate (each side) in.	Thickness of Plate, in.					
		½	⅝	¾	⅞	1	1¼
		Reactions in Tons					
4	1	5·3	8·3	12·0	16·3		
	1½	3·6	5·6	8·0	10·9		
	2	2·7	4·2	6·0	8·2		
	2½	2·1	3·3	4·8	6·5		
	3	1·8	2·8	3·4	4·0		
6	1	8·0	12·5	18·0	24·5		
	1½	5·3	8·3	12·0	16·3		
	2	4·0	6·2	9·0	12·2		
	2½	3·2	5·0	7·2	9·8		
	3	2·7	4·2	6·0	8·2		
8	1	10·7	16·7	24·0	32·7	42·7	
	1½	7·1	11·1	16·0	21·8	28·4	
	2	5·3	8·3	12·0	16·3	21·3	
	2½	4·3	6·7	9·6	13·0	17·1	
	3	3·6	5·6	8·0	10·9	14·2	
	3½		4·8	6·9	9·3	12·2	
10	1½	8·9	14·8	20·0	27·2	35·5	
	2	6·7	11·1	15·0	20·4	26·6	
	2½	5·3	8·9	12·0	16·3	21·3	
	3	4·5	7·4	10·0	13·6	17·8	
	3½		6·3	8·6	11·6	15·2	
12	1½	10·7	16·7	24·0	32·7	42·7	66·7
	2	8·0	12·5	18·0	24·5	32·0	50·0
	2½	6·4	10·0	14·4	19·6	25·6	40·0
	3	5·3	8·3	12·0	16·3	21·3	33·3
	3½		7·2	10·3	14·0	18·3	28·6
14	1½	12·4	19·4	28·0	38·1	49·8	77·7
	2	9·3	14·6	21·0	28·6	37·4	58·3
	2½	7·5	11·7	16·9	22·9	29·8	46·7
	3	6·2	9·7	14·0	19·1	24·9	38·9
	3½		8·3	12·0	16·3	21·4	33·3

Example

A 12 in. × 5 in. joist carrying a symmetrical load of 28 tons is to be supported on a 9 in. brick wall. Allowing for chamfer on the padstones the length of bearing will not exceed 8 in. The reaction is 14 tons. From Table 43 the width of bearing required, for 8 in. length is 7 in., whereas the joist flange width is 5 in. A plate giving a projection of 1 in. on each side is therefore required. From Table 44, for length of bearing 8 in. and projection 1 in., the least thickness for a reaction of 14 tons is ⅝ in (16·7 tons). The bearing plate required is therefore 7 in. × ⅝ in. × 8 in. long

WALLS, FLOORS AND BEAMS

TABLES 45—83

WALLS, FLOORS AND BEAMS

CONCRETE DATA

Concrete is usually required to reach its designed strength within 28 days or less, and compressive failure at this age occurs in the mortar and not in the coarse aggregate. For a given quantity of cement per cubic yard, provided that well-graded aggregate is used, maximum concrete strength will be achieved when

(*a*) the largest maximum size of aggregate which will suit the work is chosen, as such aggregate has the lowest proportion of voids, less mortar is required and therefore it may be richer ; and

(*b*) no more water is used in the mix than is necessary to enable the concrete to be worked compactly into place.

Enriching a mix by additional cement only improves the strength and other properties, in so far as a lower ratio of water to cement is needed to obtain the same consistency.

The three mixes below, if mixed to the consistencies appropriate to their respective classes of work, will have approximately equal strength. The decreasing proportions of fine to coarse aggregate reflect the reduction in voids as the range of coarse aggregate size increases. (See note to Table 52.)

TABLE 45.

Range of Size of Coarse Aggregate	Proportions
$\frac{3}{16}''$ to $\frac{3}{8}''$	1 : $2\frac{3}{4}$: 4
$\frac{3}{16}''$ to $\frac{3}{4}''$	1 : $2\frac{1}{2}$: 5
$\frac{3}{16}''$ to $1\frac{1}{2}''$	1 : 2 : 6

TABLE 46. Usual Maximum Size of Coarse Aggregate

Purpose	Size.
Hollow reinforced concrete floors	$\frac{3}{8}''$
Precast fence posts, window frames, lintols	$\frac{1}{2}''$
Normal reinforced concrete in beams, slabs and columns.	$\frac{1}{2}''$–$\frac{3}{4}''$
Reinforced concrete when cover and clearance between bars exceed 2″.	$1\frac{1}{2}''$
Mass concrete in roads and paths	$1\frac{1}{2}''$
,, ,, up to 12″ thick	2″
,, ,, not less than 12″ thick	3″

1 Bag of cement,	U.K.	= 112 lb.
1 ,, ,, ,,	export	= 90 or 112 lb.
1 Sack ,, ,,	U.S.	= 94 lb.
1 Barrel ,,	U.K.	= 400 lb.
1 ,, ,,	U.S.	= 376 lb.

The accompanying diagrams show the effect of varying conditions on the properties of concrete.

Water/cement ratio is always calculated by weight, thus 0·5 w/c ratio means ½ cwt. (56 lb. or 5·6 gals.) of water to 1 cwt. of cement. In American units 1 U.S. gallon per sack = 0·833 Imperial gals. per 94 lb. = 1 Imperial gallon per cwt. very nearly.

The relation between slump and water ratio varies with the mix and with different aggregates; the curve given is typical. Slump is usually defined as the subsidence of the mix when it has been filled into a metal cone 12 in. high and of standard proportions and the cone is removed. A 9-in. cone will show a slump approximately three-quarters of that obtained with a 12-in. cone.

Slumps commonly necessary in practice are given below for ordinary hand placing conditions. The last column gives an indication of the water/cement ratio.

TABLE 47.

Nature of Work	Slump	Description	Water/Cement Ratio
Road slabs and paths well rammed	2″	Stiff	0·6
Mass concrete foundations and thick walls	3″	Plastic	0·7
Reinforced concrete beams and columns	3″		
Narrow reinforced beams	4″	Rather wet	0·8
Walls and partitions less than 6″ thick	4″		
Heavily reinforced beams and columns	4″–5″		
Thin horizontal sections between shutters	5″–6″	Sloppy	0·9

These slumps can be reduced by about a half when mechanical vibration is employed. The table should be read in conjunction with the preceding notes and with Table 53.

Miscellaneous Properties.

Compressive strength—see the diagrams.

Tensile strength—usually about 8% of compressive strength.

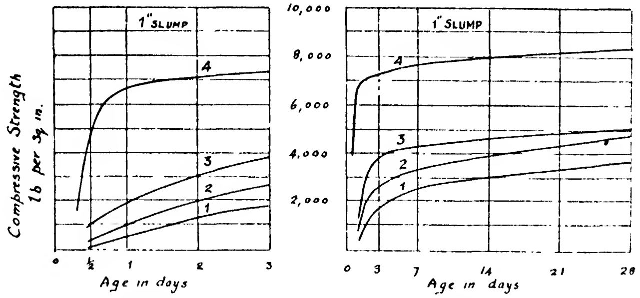
Elastic Modulus (Young's Modulus) **in compression E_c**—usually about 1000 times the compressive strength.

Elastic Modulus in tension E_t—usually about 89% of the value of E in compression (for mortar 91%).

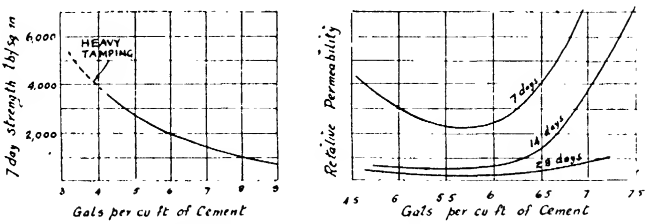
Shrinkage during hardening—about	·00025 at 28 days,	per unit length
(more for wet or rich mixes)	·00035 at 3 months	,, ,,
	·0005 at 2 years	,, ,,
Shrinkage from wet to dry—about	·0006 (reversible)	,, ,,

Poisson's Ratio—1 : 1½ : 3, 0·15 ; 1 : 2 : 4, 0·13 ; 1 : 2½ : 5, 0·11.

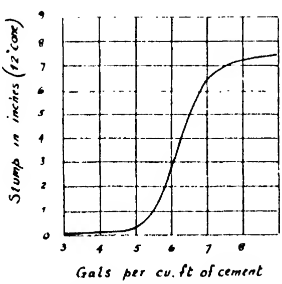
Temperature Coefficient—0·000,006 per unit length per degree F.



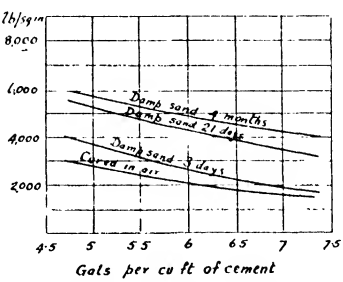
TYPICAL AGE-STRENGTH RELATIONS
1 2·4 Concrete, 5½ gals per cu ft of cement 64°F
1 - Normal Portland cement 2 - Rapid hardening cement
3 - R H Cement & Calcium chloride 4 - Aluminous cement
(6 inch cubes kept damp until 24 hrs before test)



EFFECT OF WATER/CEMENT RATIO ON STRENGTH AND PERMEABILITY
1 2 4 concrete cured at 64°F
Normal Portland cement



RELATION OF SLUMP TO WATER/CEMENT RATIO



EFFECT OF CURING PERIOD ON COMP STRENGTH AT 4 MONTHS

CONCRETE DATA

Expansion Joints

A shrinkage of ·0006 corresponds to about $\frac{3}{4}$ in. in 100 ft., and a temperature coefficient of ·000,006 represents $\frac{3}{8}$ in. per 100 ft. for a change of temperature of 50° F. If the ends were fully restrained a bar of concrete with a value of 4 million lb./sq. in. for E would have induced in it a stress of 24 lb./sq. in. for each degree F. change in its temperature.

In practice these figures are never realised because of the effects of restraint along the length, imperfect fixity at the ends and relief due to creep in the concrete. None the less expansion joints are necessary when considerable lengths of concrete are to be built ; a common rule is to provide such joints at intervals of 40 ft. A greater length is permissible when the concrete is protected from rain, where it is adequately bonded to the structure beneath or where its temperature is not likely to differ widely from the construction of which it forms a part. Concreting in alternate bays and similar precautions reduce the shrinkage stresses during the early life of the work but do not reduce the tendency to movement due to subsequent temperature and moisture changes.

Sulphate Corrosion

Pozzolana and Trass cements are obtainable for use in concrete to be subject to the action of sulphate waters, peat, etc. The strength of concrete made with these cements is appreciably less and the cost more than for normal Portland cement. The makers should be consulted for details.

Influence of Temperature on Strength

Representative figures for good quality concretes cured at different temperatures are given below. These are from laboratory tests and the water-cement ratio (about 0·5) is too low for works use without mechanical consolidation.

TABLE 48. Strength of 1 : 2 : 4 Concrete,
$5\frac{1}{2}$ gals. of Water/cu. ft. of Cement,
Normal Portland Cement
Compressive Strength of 6-in. Cubes, lb./sq. in.

Age in Days.	Temperature during Curing, Fahr.					
	36°	50°	64°	80°	95°	Steam
1	—	—	550			2000
3	—	1100	1700	2100	2200	3100
7	920	1900	2500	2800	2880	3600
14	2050	2600	3000	3150	3200	3800
28	3300	3500	3700	3850	3900	3950

TABLE 49. Strength of 1 : 2 : 4 Concrete,
5½ gals. of Water/cu. ft. of Cement,
Rapid Hardening Cement
Compressive strength of 6-in. Cubes, lb./sq. in.

Age in Days	Temperature during Curing, Fahr.			
	36°	50°	64°	80°
1	100	550	900	1100
3	400	1900	2600	2850
7	1200	3100	3300	3400
28	4200	4500	4700	4800

TABLE 50. Removal of Shuttering (Days after placing concrete)

Construction	Normal Portland Cement		Rapid-hardening P.C.	
	Cold, about freezing	Normal, about 60°	Cold, about freezing	Normal, about 60°
Beam sides, walls, columns	8	3	7	2½
Slabs, leaving props	10	4	10	3
,, props	14	8	14	5
Beam soffits, leaving props	12	6	12	4
,, ,, props	28	16	21	7

The removal of shuttering from reinforced concrete work must be judged according to the general temperature prevailing.

The shuttering of concrete made with aluminous cement may be struck in 24 hours in all the above cases provided the concrete temperature is kept below 80° F. The best curing temperature is about 61° F. No lime or Portland cement must be allowed to contaminate aluminous cement.

TABLE 51. Typical Weights /cu. ft. of Concrete.

Aggregate and Mix		lb./cu. ft.	Aggregate and Mix		lb./cu. ft.
Granite, whinstone	1 : 2 : 4	155	Clinker	1 : 2 : 4	100 (90)
Ballast	,,	145	Coke breeze	,,	90 (70)
,,	1 : 1 : 2	141	Foamed slag	,,	80
'Limestone	1 : 2 : 4	130–145	,,	1 : 2½ : 7½	70
'Slag, gran. blast furnace	,,	110 (90)	Aerocrete usually		50–60
'Brick	1 : 2 : 4	110–120	Pumice	1 : 2 : 4	48 (70)
			,,	1 : 2½ : 7½	41

The values in brackets are the maximum densities permitted for concrete partitions in B.S. 492 ; the mix is not specified.

The presence of 1% of main reinforcement adds nearly 4 lb./cu. ft. to the weight of concrete. The weight of reinforced concrete is taken for design purposes, however, at 144 lb./cu. ft., from which the following simple rules derive :—

A beam *b* in. wide and *d* in. deep weighs *bd* lb./ft. run.

A slab *D* in. thick weighs 12*D* lb./sq. ft.

PROPORTIONS FOR CONCRETE MIXES

Specifications should always stipulate a mix to be so many volumes of fine and coarse aggregate to 1 cwt. of cement, so that a definite quantity of cement is added to each batch ; measuring cement by volume is unsatisfactory.

The following table gives the mixes recognised by the *L.C.C.* by-laws and the corresponding nominal proportions by which they are generally described.

TABLE 52.

Designation of Concrete	Nominal Mix	Cu. ft. of Aggregate per 112 lb. Cement.		Minimum Crushing Resistance, 6″ Cubes at Age of 28 Days.	
		Fine	Coarse		
				lb./sq. in.	
I	1 : 1 : 2	1¼	2½	2925	
II	1 : 1½ : 3	1⅞	3¾	2550	
III	1 : 2 : 4	2½	5	2250	
IV	1 : 6	7½		1480	
V	1 : 8	10		1110	
VI	1 : 10	12½		740	
VII	1 : 12	15		370	
				Prelim.	Works
IA	1 : 1 : 2	1¼	2½	5625	3750
IIA	1 : 1½ : 3	1⅞	3¾	4850	3300
IIIA	1 : 2 : 4	2½	5	4275	2850

NOTE. Mixes intermediate between those stated may be used, provided that the ratio of fine to coarse is 1 to 2, and the properties of such intermediate mixes may be taken, on the basis of the combined volumes of fine and coarse aggregate, as *pro rata* between the two nearest mixes tabulated. The District Surveyor may approve ratios of fine to coarse aggregate between 1 to 1½ and 1 to 2½.

Fine aggregate is defined as that which will pass a $\frac{3}{16}$ in. mesh, and coarse aggregate that which will be retained on a $\frac{3}{16}$ in. mesh. The maximum size of coarse aggregate is not limited by the by-laws except for reinforced work, in which it shall pass a mesh ¼ in. smaller than the minimum lateral distance between the bars. The size should not exceed one-quarter of the smallest dimension of the concrete work.

CONCRETE MIXES FOR VARIOUS PURPOSES

(1 cwt. of cement = 1¼ cu. ft.)

TABLE 53.

Purpose	Specification			Nominal Mix
	Cem.	Sand	Coarse	
	cwt.	cu. ft.	cu. ft.	
1. Highly stressed reinforced concrete, see Table 58	1	1¼	2½	1 : 1 : 2
2. Reinf. concrete stressed intermediately between classes 1 and 3. Thin r.c. walls, concrete cast between horizontal shutters, water-retaining structures, hollow tile floors, precast piles, roads (wearing carpet)	1	1⅞	3¾	1 : 1½ : 3
3. General reinforced concrete in *walls, floors, beams, columns*, roads, in situ piles, *encasing steelwork*	1	2½	5	1 : 2 : 4
4. Foundations on variable bottom or in tidal ground, concrete supporting walls and columns	1	3	6	1 : 2½ : 5
	or 1	8*		approx.
5. *Covering site under building (6″ thick, or 4″ if on hard core)*	1	3½	7	1 : 2·8 : 5·6
6. Foundations, gravity retaining walls, roads (base course)	1	10*		1 : 8
7. *Bedding and haunching drains*, filling, blinding	1	15*		1 : 12

* Unseparated aggregate, e.g. ballast "all-ups" or "crusher run" stone.
Local by-laws items are shown in italics.

BATCHES USING 1 CWT. BAG OF CEMENT

TABLE 54.

Nominal Mix	Volume of Dry Materials cu. ft. *	Gallons of Water per Batch †	Smallest Mixer Size	Volume of Finished Concrete cu. ft.
1 : 1 : 2	5·0	4¼	5/3½	3·2
1 : 1½ : 3	6·9	5	7/5	4·5
1 : 2 : 4	8·7	6	9/7	5·8
1 : 6	8·7	8	,,	7·0
1 : 2½ : 5	10·6	8	14/10	7·1
1 : 3 : 6	12·5	10	,,	8·4
1 : 8	11·2	11½	,,	9·2
1 : 10	13·7	14	,,	11·2

* Sum of separate volumes before mixing.

† Approximate total mixing water including water in the aggregates, to give a slump of 3 in. with crushed or angular aggregate or 4 in. with rounded aggregate.

ALL-IN MIXES

When neither strength nor impermeability is important it is unnecessary to gauge the coarse and fine aggregate separately.

Unseparated ballast all-ups or crusher-run stone is then used. Such materials vary considerably in grading and figures relating to them are necessarily rough. The following table may be used, with reserve, for either class of material.

TABLE 55.

Nomina Mix by vol. Cem. Agg.	Cu. ft. of All-in Aggregate to 1 cwt. Cement	Cwt. Cement per cu. yd. of All-in Aggregate	Per Cubic Yard of Concrete		
			Cement		All-in Aggregate cu. yd.
			lb.	ton	
1 : 3	3¾	7·25	740	·33	·91
1 : 4	5	5·46	600	·27	·98
1 : 5	6¼	4·38	500	·22	1·04
1 : 6	7½	3·62	430	·19	1·06
1 : 7	8¾	3·13	380	·17	1·09
1 : 8	10	2·67	330	·15	1·10
1 : 9	11¼	2·42	300	·13	1·11
1 : 10	12½	2·17	270	·12	1·11

CONCRETE QUANTITIES

The quantities given in the next two tables are based on proportions by volume of fine and coarse aggregate as ordinarily measured in gauge boxes, the weight of cement being calculated at the standard equivalent of 90 lb./cu. ft.; this assumes that whole cwt. bags are used in each batch. Ordinary Portland cement measured in a box weighs only about 80 lb., and rapid-hardening cement 70–75 lb./cu. ft.

The coarse aggregate is taken as graded material from $\frac{3}{16}$ in. up, with usual percentages of voids, viz., for shingle 40%, broken stone 45%.

In view of the wide variation in the volume of sand through bulking (p. 92) the sand quantities can only be a rough guide to the purchaser: sometimes 20% more than the volume stated is required to give a good mix.

The weight figures for sand are adequate for estimating purposes. The weight figures for broken stone aggregate apply to stone of density 150 lb./cu. ft., i.e., average sandstone. For granite add 0·10 ton and for most limestones deduct 0·07 ton, in last column of Table 56.

The quantities in the tables include appropriate allowances for waste.

Typical weights of aggregates per cu. yd.:—

Wet sand . .	1¼ tons
Shingle, graded .	1⅛ ,,
Broken stone . .	1 ton
Ballast all-ups . .	1⅓ tons
Crusher run granite .	1⅓ ,,

MATERIALS REQUIRED PER CUBIC YARD OF FINISHED CONCRETE

TABLE 56.

Nominal Mix	Type of Aggregate	Portland Cement		Sand See note above		Coarse Aggregate	
		lb.	ton	cu. yd.	ton	cu. yd.	ton
1 : 1 : 2	Shingle	950	·425	·39	·49	·78	·90
	Broken Stone	1000	·447	·41	·51	·82	·82
1 : 1½ : 3	Shingle	670	·300	·42	·52	·83	·96
	Broken Stone	710	·318	·44	·55	·87	·87
1 : 2 : 3	Shingle	620	·278	·51	·64	·76	·86
	Broken Stone	650	·291	·53	·65	·80	·80
1 : 1⅔ : 3⅓	Shingle	610	·273	·42	·52	·84	·97
	Broken Stone	640	·286	·44	·55	·88	·88
1 : 2 : 4	Shingle	520	·233	·44	·55	·87	1·00
	Broken Stone	550	·246	·46	·57	·91	·91
1 : 2½ : 5	Shingle	430	·192	·44	·55	·88	1·01
	Broken Stone	450	·201	·46	·57	·92	·92
1 : 3 : 6	Shingle	360	·161	·45	·56	·90	1·03
	Broken Stone	380	·170	·47	·59	·94	·94
1 : 4 : 8	Shingle	280	·125	·46	·57	·92	1·06
	Broken Stone	295	·132	·49	·61	·97	·97

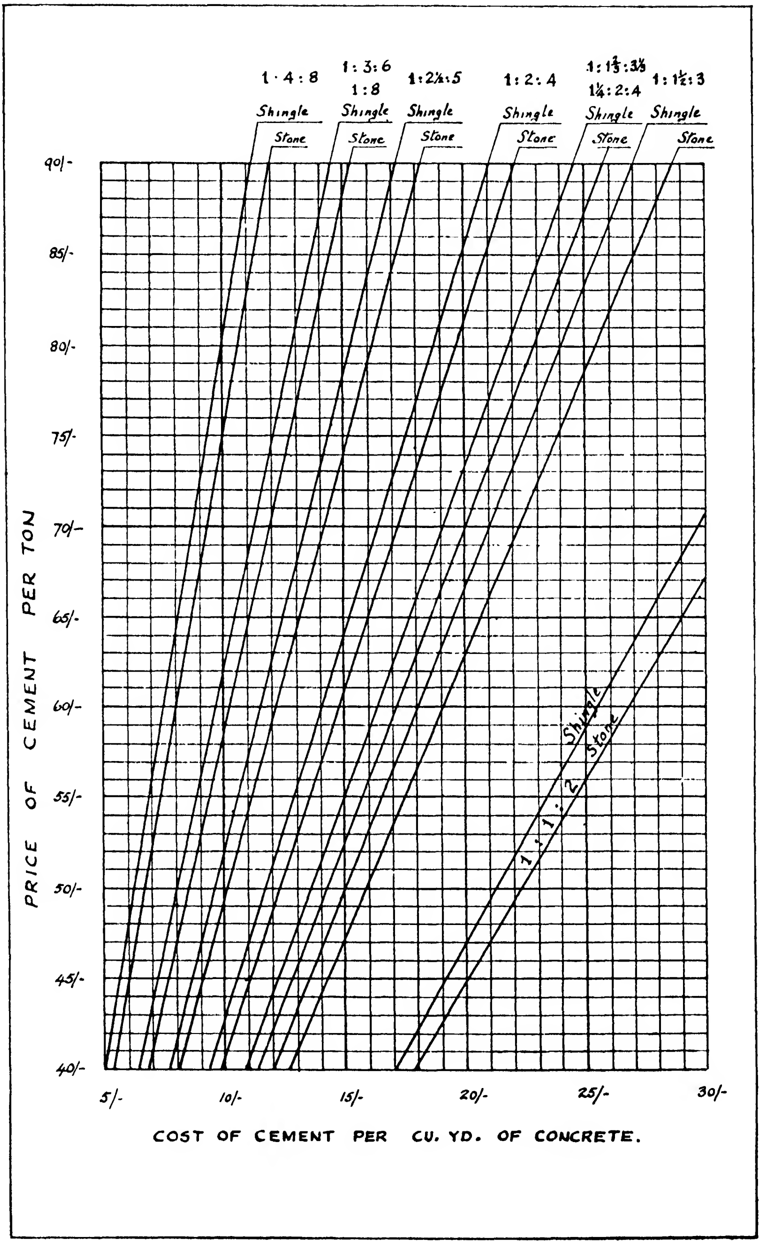
MATERIALS REQUIRED PER 100 SQ. YDS.

TABLE 57. See notes on page 40.

Nominal Mix	Material	Unit	Thickness of 1"	1½"	2"	3"	4"
1 : 1 : 2 Shingle	Cement	ton	1·17	1·76	2·35		
	Sand	cu. yd.	1·08	1·62	2·16		
	Shingle	cu. yd.	2·16	3·24	4·32		
1 : 1 : 2 Broken Stone	Cement	ton	1·24	1·86	2·48		
	Sand	cu. yd.	1·14	1·70	2·27		
	Stone	cu. yd.	2·28	3·41	4·55		
1 : 1½ : 3 Shingle	Cement	ton	·83	1·24	1·66	2·49	3·32
	Sand	cu. yd.	1·2	1·7	2·3	3·4	4·6
	Shingle	cu. yd.	2·3	3·4	4·6	6·9	9·2
1 : 1½ : 3 Broken Stone	Cement	ton	·88	1·32	1·76	2·64	3·52
	Sand	cu. yd.	1·2	1·8	2·4	3·6	4·8
	Stone	cu. yd.	2·4	3·6	4·8	7·3	9·7
1 : 2 : 4 Shingle	Cement	ton				1·94	2·58
	Sand	cu. yd.				3·7	4·9
	Shingle	cu. yd.				7·3	9·7
1 : 2 : 4 Broken Stone	Cement	ton				2·04	2·72
	Sand	cu. yd.				3·8	5·1
	Stone	cu. yd.				7·6	10·1
1 : 2½ : 5 Shingle	Cement	ton				1·60	2·14
	Sand	cu. yd.				3·7	4·9
	Shingle	cu. yd.				7·3	9·8
1 : 2½ : 5 Broken Stone	Cement	ton				1·68	2·24
	Sand	cu. yd.				3·8	5·1
	Stone	cu. yd.				7·7	10·2
1 : 3 : 6 Shingle	Cement	ton	·45	·63	·91	1·35	1·81
	Sand	cu. yd.	1·3	1·9	2·5	3·8	5·0
	Shingle	cu. yd.	2·5	3·8	5·0	7·6	10·0
1 : 3 : 6 Broken Stone	Cement	ton	·48	·71	·95	1·42	1·90
	Sand	cu. yd.	1·3	2·0	2·7	3·9	5·3
	Stone	cu. yd.	2·6	4·0	5·3	7·9	10·5
1 : 6 All-in Aggregate	Cement	ton	·53	·80	1·07	1·60	2·14
	Aggregate	cu. yd.	2·9	4·4	5·9	8·8	11·8
	,,	ton	4·0	5·9	7·9	11·8	15·8

OF CONCRETE SLAB, FINISH OR BLINDING

Slab, Finish or Blinding							
5"	6"	7"	8"	9"	10"	11"	12"
5·15	4·98	5·81	6·64	7·47			
5·7	6·9	8·1	9·2	10·3			
11·5	13·8	16·1	18·4	20·7			
4·39	5·28	6·16	7·03	7·90			
6·1	7·3	8·5	9·7	10·9			
12·1	14·5	16·9	19·3	21·8			
3·23	3·87	4·52	5·16	5·81	6·46	7·10	7·74
6·1	7·3	8·5	9·7	10·9	12·2	13·4	14·6
12·0	14·5	16·9	19·3	21·7	24·1	26·6	29·1
3·40	4·08	4·76	5·44	6·12	6·80	7·50	8·17
6·3	7·6	8·8	10·1	11·4	12·6	13·9	15·2
12·6	15·1	17·6	20·1	22·7	25·2	27·8	30·3
2·67	3·20	3·74	4·27	4·80	5·34	5·87	6·40
6·1	7·3	8·6	9·8	11·0	12·3	13·5	14·7
12·3	14·7	17·1	19·5	22·0	24·6	27·0	29·4
2·80	3·35	3·91	4·47	5·03	5·60	6·15	6·70
6·4	7·7	9·0	10·2	11·5	12·7	14·0	15·4
12·7	15·3	17·9	20·4	23·0	25·4	28·0	30·7
2·26	2·71	3·16	3·61	4·06	4·50	4·95	5·41
6·2	7·5	8·8	10·0	11·3	12·5	13·8	15·0
12·5	15·0	17·5	20·0	22·5	25·0	27·5	30·0
2·37	2·85	3·33	3·80	4·28	4·75	5·22	5·70
6·6	7·9	9·2	10·5	11·8	13·1	14·4	15·7
13·1	15·7	18·3	21·0	23·6	26·2	28·8	31·4
2·67	3·20	3·74	4·27	4·80	5·34	5·88	6·50
14·8	17·7	20·7	23·6	26·6	29·5	32·5	35·4
19·8	23·7	27·6	31·6	35·5	39·5	43·5	47·4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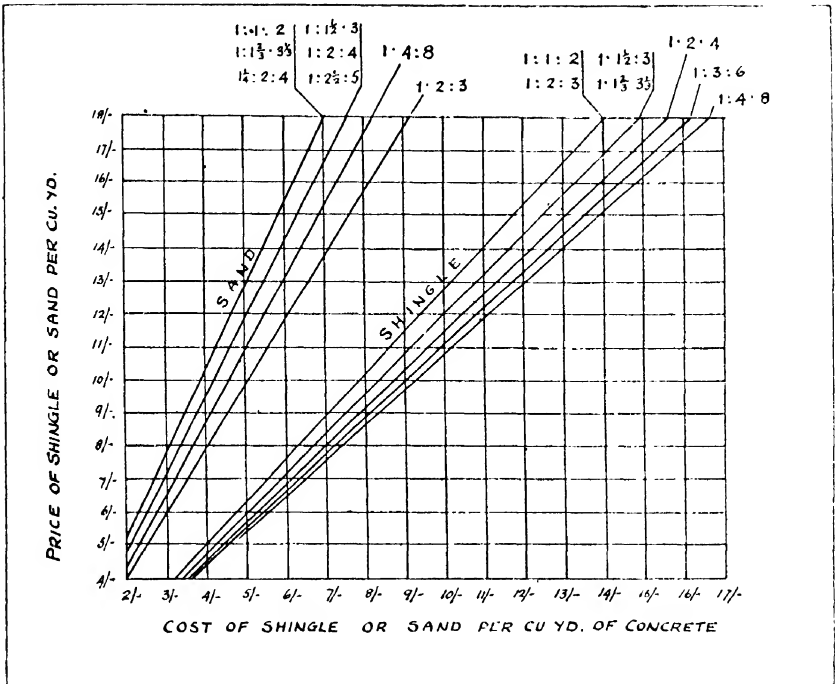
1 : 3 : 6
1 : 8
1 : 2½ : 5
1 : 2 : 4
1 : 1⅔ : 3⅓
1¼ : 2 : 4
1 : 1½ : 3
Shingle
Stone
Shingle
Stone
Shingle
Stone
Shingle
Stone
Shingle
Stone
Shingle
Stone
90/-
85/-
80/-
75/-
70/-
65/-
60/-
55/-
50/-
45/-
40/-
PRICE OF CEMENT PER TON
1 : 1 : 2
Shingle
Stone
5/-
10/-
15/-
20/-
25/-
30/-
COST OF CEMENT PER CU. YD. OF CONCRETE.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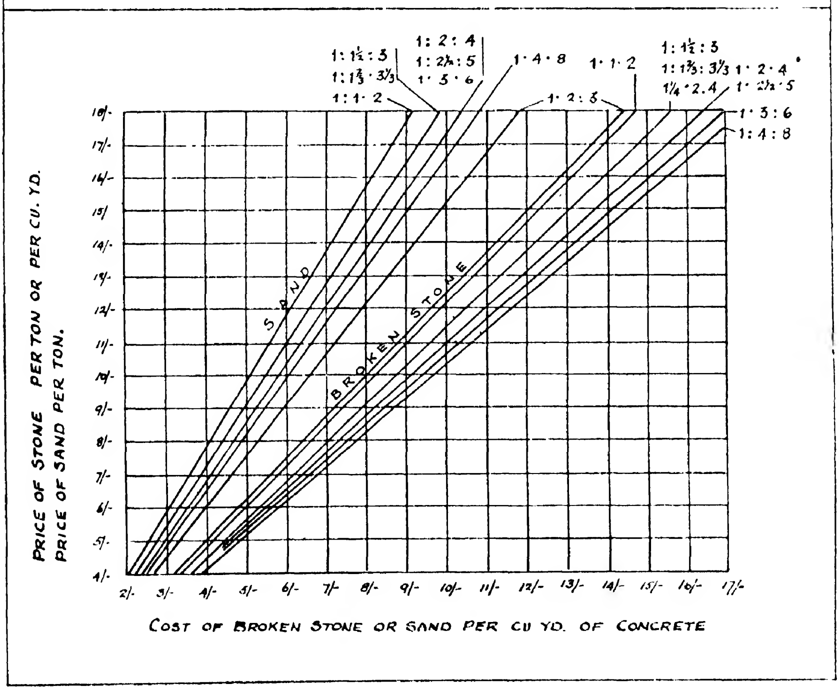
1:2:3
1:1½:3
1:1⅔:3⅓
1:2:4
1:3:6
1:4:8
SAND
SHINGLE
PRICE OF SHINGLE OR SAND PER CU. YD.
4/- 5/- 6/- 7/- 8/- 9/- 10/- 11/- 12/- 13/- 14/- 15/- 16/- 17/- 18/-
2/- 3/- 4/- 5/- 6/- 7/- 8/- 9/- 10/- 11/- 12/- 13/- 14/- 15/- 16/- 17/-
COST OF SHINGLE OR SAND PER CU YD. OF CONCRETE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1:1⅔:3⅓
1:1:2
1:2:4
1:2½:5
1:3:6
1:4:8
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1:2:3
1:1½:3
1:1⅔:3⅓
1¼:2.4
1:2:4
1:2½:5
1:3:6
1:4:8
SAND
BROKEN STONE
PRICE OF STONE PER TON OR PER CU. YD.
PRICE OF SAND PER TON.
4/- 5/- 6/- 7/- 8/- 9/- 10/- 11/- 12/- 13/- 14/- 15/- 16/- 17/- 18/-
2/- 3/- 4/- 5/- 6/- 7/- 8/- 9/- 10/- 11/- 12/- 13/- 14/- 15/- 16/- 17/-
COST OF BROKEN STONE OR SAND PER CU YD. OF CONCRETE

PERMISSIBLE STRESSES IN REINFORCED CONCRETE

(i) *L.C.C.* by-laws.

TABLE 58.

Designation of Concrete (see Table 52)	Nominal Mix	Modular Ratio m.	Permissible Concrete Stresses lb. per sq. in.			
			Compression		Shear	Bond
			Bending	Direct		
"Ordinary Concrete" I	1 : 1 : 2	15	975	780	98	123
II	1 : 1½ : 3	,,	850	680	85	110
III	1 : 2 : 4	,,	750	600	75	100
"Quality A Concrete" IA	1 : 1 : 2	,,	1250	1000	125	150
IIA	1 : 1½ : 3	,,	1100	880	110	135
IIIA	1 : 2 : 4	,,	950	760	95	120

Punching shear in footings is not to exceed twice the value given in the column headed "Shear."

Institution of Structural Engineers Report No. 10, Part IV, "Hollow Floors," recommends that the above stresses be reduced by 10% if ⅜ in. aggregate is used.

(ii) Code of Practice : *Reinforced Concrete Structures Research Committee, Department of Scientific and Industrial Research.* See remarks on p. 226.

TABLE 59.

Mix Reference	Nominal Mix	Modular Ratio m.	Permissible Concrete Stresses lb. per sq. in.			
			Compression		Shear	Bond
			Bending	Direct		
"Ordinary Grade" I	1 : 1 : 2	14	975	780	98	123
II	1 : 1·2 : 2·4	14	925	740	93	118
III	1 : 1½ : 3	16	850	680	85	110
IV	1 : 2 : 4	18	750	600	75	100
"High Grade" I	1 : 1 : 2	11	1250	1000	125	150
II	1 : 1·2 : 2·4	11	1200	960	120	145
III	1 : 1½ : 3	12	1100	880	110	135
IV	1 : 2 : 4	14	950	760	95	120

The minimum 28-day cube strength requirements are :

Preliminary tests—4·5 times the value in Col. 4 (bending stress).
Works tests —3 ,, ,, ,, ,, ,, ,,

A Special Grade is also recognised, with permissible stresses based on the test results.

PERMISSIBLE COMPRESSIVE STRESS IN R.C. BEAMS

The concrete compressive stress in bending permitted in Tables 58 and 59 can be used for beams only when the length l between adequate lateral restraints does not exceed 20 times the breadth b of the compression flange. When the ratio exceeds 20, the calculated compressive stress is to be limited so that $\frac{l}{b}$ does not exceed $20\left\{3 - 2\left(\frac{\textit{calculated compressive stress}}{\textit{permissible compressive stress}}\right)\right\}$.
Code of Practice ; *L.C.C.* Memorandum on Computation of Stresses.

The stress allowed may be obtained directly in the table below.

TABLE 60. Permissible Compressive Stress, lb./sq. in.

$\frac{l}{b}$	Concrete Designation, L.C.C.						Proportion
	I	II	III	IA	IIA	IIIA	
20	975	850	750	1250	1100	950	1·0
22	926	807	712	1187	1045	902	·95
24	877	765	675	1125	990	855	·90
26	829	722	637	1062	935	807	·85
28	780	680	600	1000	880	760	·80
30	731	637	562	937	825	712	·75
32	682	595	525	875	770	665	·70
34	634	552	487	812	715	617	·65
36	585	510	450	750	660	570	·60
38	536	467	412	687	605	522	·55
40	487	425	375	625	550	475	·50
42	439	382	337·	562	495	427	·45
44	390	340	300	500	440	380	·40
46	341	297	262	437	385	332	·35
48	292	255	225	375	330	285	30
50	243	212	187	312	275	237	·25
52	195	170	150	250	220	190	·20
54	146	127	112	187	165	142	·15
56	97	85	75	125	110	95	·10
58	48	42	37	62	'55	47	·05
60	0	0	0	0	0	0	—

PERMISSIBLE PRESSURES ON PLAIN CONCRETE

Four types of construction in plain concrete are distinguished in the *L.C.C.* by-laws, viz. : Filling, Foundations (" concrete supporting walls or piers "), Walls and Piers.

It is stipulated that concrete supporting walls and piers shall be adequately restrained at its upper and lower extremities, and if not also restrained between the extremities the permissible pressure is reduced according to figures based on the ratio of height to least horizontal dimension.

In the case of walls and piers a similar reduction of permissible pressure is made, and rules are given defining the height (" effective height ") to be taken in different cases.

These regulations have been re-arranged and are presented in a more convenient form in the two tables following :—

TABLE 61. Maximum Permissible Pressures on Plain Concrete. *L.C.C.*

Tons per sq. ft.

Designation of Concrete	Nominal Mix	Filling	Foundations *	Walls and Piers *	Local Pressure in Walls & Piers
I	1 : 1 : 2		40	40	48
II	1 : 1½ : 3		35	35	42
III	1 : 2 : 4		30	30	36
IV	1 : 6	20	20	20	24
V	1 : 8	15	15	15	18
VI	1 : 10	10	Concrete weaker than Class V is not allowed in any part of the construction		
VII	1 : 12	5			

* These pressures are to be reduced according to slenderness ratio and conditions of lateral support as specified in the next table. Walls may be designed according to rules of thickness for normal circumstances, for which see p. 58.

Slenderness Ratio and Conditions of Lateral Support :—

See notes on previous page. The reductions in permissible pressure are given below.

H is the actual storey height or height between lateral restraints (feet).

d is the least horizontal thickness measured in the direction of restraint (feet).

TABLE 62.

$\frac{H}{d}$	Foundations	Walls Horizontally restrained at the Top	Walls not restrained at the Top	Piers Horizontally restrained at the Top	Piers not restrained at the Top
	Multiply pressures in Table 61 by :				
Up to 2	1·0	1·0	1·0	1·0	1·0
3	·9	,,	,,	,,	,,
4	·8	,,	,,	,,	·8
5	·7	,,	·85	,,	·6
6	·6	,,	·7	,,	·4
7	·5	,,	·55	·9	
8	·4	,,	·4	·8	
9	·3	·925		·7	
10	·2	·85		·6	
11	·1	·775		·5	
12	0	·7		·4	
13		·625			
14		·55			
15		·475			
16		·4			

B.S. 449 recognises two cases only, viz., general load-bearing concrete and foundations for column bases, but includes an extra allowance for local pressure as at girder bearings, Column 4, and also provides for a higher pressure in foundations under column bases where the depth is not greater than $1\frac{1}{2}$ times the least width, Column 5.

TABLE 63. Maximum Permissible Pressures on Plain Concrete.
B.S. 449

Tons per sq. ft.

Type of Concrete	Nominal Mix	3 General *	4 Local *	5 Under Column Bases	6 Under Column Bases †
Fine Concrete					
I	1 : 1 : 2	40	48	$53\frac{1}{3}$	57
II	1 : $1\frac{1}{2}$: 3	35	42	$46\frac{2}{3}$	50
III	1 : 2 : 4	30	36	40	43
Mass Concrete					
IV	1 : 6	20	24	$26\frac{2}{3}$	28
V	1 : 8	15	18	20	21
VI	1 : 10	10	12	$13\frac{1}{3}$	14
VII	1 : 12	5	6	$6\frac{2}{3}$	7

The pressures in Column 5 may be increased, where the loaded area A_1 is smaller than the total area A of the upper surface of the concrete, by multiplying by the ratio $3\sqrt{\frac{A}{A_1}}$; A shall not be taken larger than the greatest square which can be symmetrically placed round the loaded area and wholly within the area of the upper surface, and the maximum pressure shall not exceed double the value in Column 3.

* The pressures in Columns 3 and 4 apply only to cases where the Slenderness Ratio, i.e. actual height divided by least horizontal dimension is not greater than 6. The following percentage reductions are to be made in other cases :—

Slenderness ratio over 6 but not more than 8 . . . 20%
over 8 „ „ 10 . . . 40%
over 10 „ „ 12 . . . 60%

The slenderness ratio shall not exceed 12. No distinction is made between piers and walls.

† *Institution of Structural Engineers Report No. 8.*

B.S. 1145 repeats Col. 3 with additional mixes, but differs for local loading and slenderness ratio.

BRICK DATA

Three sizes of brick have been standardised in B.S. 657, *Common Building Bricks*. They are :—

Type I —$8\frac{3}{4} \times 4\frac{3}{16} \times 2$ in.
Type II —$8\frac{3}{4} \times 4\frac{3}{16} \times 2\frac{5}{8}$ in.
Type III—$8\frac{3}{4} \times 4\frac{3}{16} \times 2\frac{7}{8}$ in.

A tolerance of $\pm \frac{1}{8}$ in. is allowed in the length and of $\pm \frac{1}{16}$ in. in the other dimensions.

Sand lime (or calcium silicate) bricks are standardised in B.S. 187, the sizes being Types II and III as above.

Cast iron Air Bricks and Gratings, B.S. 493, are standardised as follows :—

TABLE 64

Overall Size in.	Air Bricks — Heavy Grade	Air Bricks — Medium Grade	Gratings
	Minimum Wt. lb. per dozen		
9×3	36	12	21
9×6	57	21	36
9×9	78	33	54
9×12	102	45	66
Depth	$1\frac{3}{8}$"	$1\frac{1}{4}$"	$\frac{5}{16}$"

Glass Bricks (non load bearing) given in B.S. 952, *Glass for Glazing* are as follow :—

TABLE 65

Size, in.	Weight, lb.	oz.
$8 \times 4\frac{7}{8} \times 3\frac{7}{8}$	4	5
$5\frac{3}{4} \times 5\frac{3}{4} \times 3\frac{7}{8}$	3	11
$7\frac{3}{4} \times 7\frac{3}{4} \times 3\frac{7}{8}$	6	

BRICKWORK QUANTITIES

1 Rod of brickwork $= 30\frac{1}{4}$ sq. yds. or 272 sq. ft. of brickwork $1\frac{1}{2}$ bricks thick.
$= 45{\cdot}4$ „ „ 408 „ „ 1 brick „
$= 90{\cdot}8$ „ „ 816 „ „ $\frac{1}{2}$ „ „
$= 11\frac{1}{3}$ cu. yds. or 306 cu. ft. of brickwork.

Area of reduced brickwork = area of equivalent work $1\frac{1}{2}$ bricks ($13\frac{1}{2}$ in.) thick.

The rod is still widely used as a unit for pricing, but the custom is growing of measuring brickwork in square yards of a stated thickness.

NUMBER OF BRICKS IN BRICKWORK

The thickness of vertical joints on face is taken as $\frac{1}{4}$ in. ; in the case of English and English Garden Wall Bonds, vertical joints in header courses must be $\frac{5}{16}$ in. if the stretcher course vertical joints are $\frac{1}{4}$ in.

No allowance has been made for waste. The volume in yards cube is to be calculated on the nominal thickness, viz., $4\frac{1}{2}$ in., 9 in., $13\frac{1}{2}$ in., etc.

TABLE 66

Brick Size	Bed Joints	Number of Bricks				
		Per Yd. Super of			Per Yd. Cube	Per Rod
in.	in.	4½″	9″	13½″		
Type I $8\frac{3}{4} \times 4\frac{3}{16} \times 2$	$\frac{1}{4}$	64	128	192	512	5800
	$\frac{3}{8}$	61	121	182	484	5500
	$\frac{1}{2}$	59	117	176	468	5310
Type II $8\frac{3}{4} \times 4\frac{3}{16} \times 2\frac{5}{8}$	$\frac{1}{4}$	50	100	150	400	4530
	$\frac{3}{8}$	48	96	144	384	4350
	$\frac{1}{2}$	46	92	138	368	4170
Type III $8\frac{3}{4} \times 4\frac{3}{16} \times 2\frac{7}{8}$	$\frac{1}{4}$	46	92	138	368	4170
	$\frac{3}{8}$	44	89	133	356	4020
	$\frac{1}{2}$	43	85	128	340	3870

The number of bricks required is the same for all solid bonds.

QUANTITY OF MORTAR IN BRICKWORK

The notes at the head of the table above apply here also.

TABLE 67. For mortar data see page 54.

Brick Size	Bed Joints	Cu. Ft. of Mortar (nett)				
		Per Yd. Super of			Per Yd. Cube	Per Rod
in.	in.	4½″	9″	13½″		
Type I $8\frac{3}{4} \times 4\frac{3}{16} \times 2$	$\frac{1}{4}$	·8	1·6	2·3	6·2	70
	$\frac{3}{8}$	·9	1·8	2·8	7·4	84
	$\frac{1}{2}$	1·0	2·0	3·0	8·0	90
Type II $8\frac{3}{4} \times 4\frac{3}{16} \times 2\frac{5}{8}$	$\frac{1}{4}$	·6	1·3	2·0	5·3	60
	$\frac{3}{8}$	·8	1·6	2·3	6·2	70
	$\frac{1}{2}$	·9	1·8	2·6	7·0	79
Type III $8\frac{3}{4} \times 4\frac{3}{16} \times 2\frac{7}{8}$	$\frac{1}{4}$	·6	1·3	1·9	5·1	57
	$\frac{3}{8}$	·7	1·4	2·1	5·7	65
	$\frac{1}{2}$	·8	1·7	2·5	6·6	75

NUMBER OF FACING BRICKS IN BRICKWORK

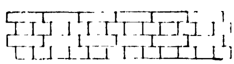
Headers are counted as whole bricks.
No allowance has been made for waste.

TABLE 68. Facing Bricks per yard super

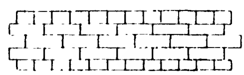
Brick Size In.	Bed Joints In.	Bond				
		English	English Garden Wall.	Flemish or Quetta	Flemish Garden Wall	Stretcher
Type I $8\frac{3}{4} \times 4\frac{3}{16} \times 2$	$\frac{1}{4}$	96	80	86	74	64
	$\frac{3}{8}$	91	76	81	69	61
	$\frac{1}{2}$	88	73	78	67	58
Type II $8\frac{3}{4} \times 4\frac{3}{16} \times 2\frac{5}{8}$	$\frac{1}{4}$	75	63	67	57	50
	$\frac{3}{8}$	72	60	65	55	48
	$\frac{1}{2}$	69	58	62	53	46
Type III $8\frac{3}{4} \times 4\frac{3}{16} \times 2\frac{7}{8}$	$\frac{1}{4}$	69	58	62	53	46
	$\frac{3}{8}$	67	56	60	51	44
	$\frac{1}{2}$	64	53	57	49	43

COMMON BRICK BONDS

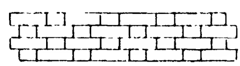
English



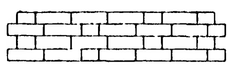
English Garden Wall



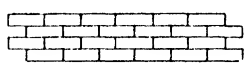
Flemish ; Quetta



Flemish Garden Wall



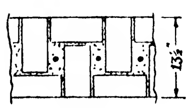
Stretcher



QUETTA BOND QUANTITIES

This useful construction costs little more than plain brickwork but has much of the strength and resistance to destruction of reinforced concrete. In common with engineering brickwork its joints are best made $\frac{1}{4}$ in. thick.

By omitting the concrete and reinforcement, Bergen Hollow Bond is obtained.



PLAN

TABLE 69

Brick Size in.	Bed Joint	Number of Bricks Per Yd. Super	Number of Bricks Per Yd. Cube	Number of Bricks Per Rod
$8\frac{3}{4} \times 4\frac{3}{16} \times 2$	$\frac{1}{4}''$	171	471	5160
$8\frac{3}{4} \times 4\frac{3}{16} \times 2\frac{5}{8}$	$\frac{1}{4}''$	133	356	4030
$8\frac{3}{4} \times 4\frac{3}{16} \times 2\frac{7}{8}$	$\frac{1}{4}''$	123	327	3710
		Cu. Ft. of Concrete		
All sizes of brick		1·36	3·63	41·1
		Weight of Steel, lb.		
$\frac{1}{4}''$ ϕ at $6\frac{3}{4}''$ c.c.		2·68	7·16	81·1
$\frac{5}{16}''$,, ,, ,,		4·19	11·2	127

PROPERTIES OF BRICKWORK

(Stock bricks in cement mortar)

E = 1,000,000 lb./sq. in.
Temperature coefficient 0·000,003/degree F.
Safe loads, pages 62 and 64. Ultimate loads, next page.
Heat transmittance, Tables 166 and 168.
Weight, Table 70.
Strength of individual bricks, Table 78.

TYPICAL WEIGHTS OF BRICKWORK (DRY)

TABLE 70

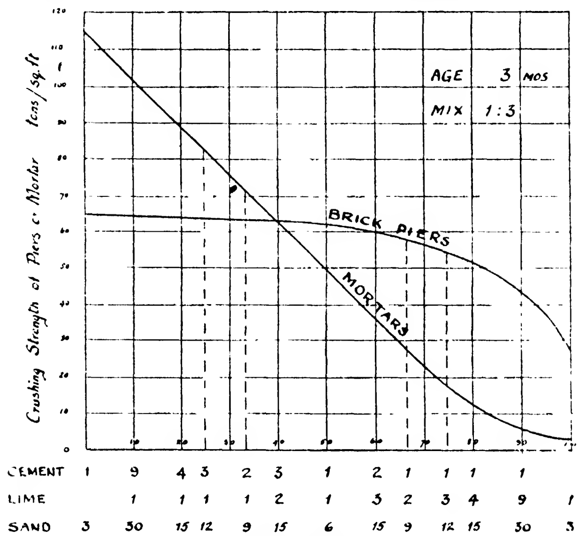
Type of Brick	Weight, lb./cu. ft.	Weight, lb./sq. ft. $4\frac{1}{2}''$	$9''$	$13\frac{1}{2}''$
Blue	150	56	112	169
Diatomaceous	30			
Engineering	135	51	101	152
Firebrick	110–125			
Flettons	110–115	42	84	126
,, cavity	90	34	68	101
London stocks	115	43	86	129
Red	100–120	41	83	124
Sand-cement	130	49	98	146
Sand-lime	115	43	86	129

Plaster 1 in. thick weighs 9 lb./sq. ft.

ULTIMATE STRENGTH OF BRICK PIERS

The figure below shows the compressive strength at failure of brick piers laid in mortars with varying proportions of lime and cement. The mortar in all cases is composed of 3 parts sand to 1 part of cementing material, i.e. lime and cement combined. The data on which the figure is based were given in the *Building Research Board Annual Report*, 1934.

It will be seen that the strength of brickwork laid in mortar containing equal parts of cement and lime is practically as great as when laid in cement mortar, although the strength of the *mortar* is less than one-half as great ; this is attributed to the improvement in workability which accompanies the admixture of lime. The strength of the bricks was 2685 lb./sq. in.



MORTARS

For quantities of mortar in brickwork see Table 67.

Tensile strength of mortar at 28 days :—

1 cement : 3 sand—450 lb./sq. in. = 29 tons/sq. ft.

Compressive strength of mortars, see previous paragraph.

TABLE 71. Materials for 1 cu. yd. of mortar

Proportions by vol.			Cement or Lime cu. ft.		Cement or Lime		Sand		
Cement or Lime		Sand			lb.	lb.	cu. ft.	cu. yd.	ton
1		1	20		1750	720	20	·70	·87
1		2	13		1150	470	26	·96	1·20
1		3	10		870	360	30	1·11	1·38
1		4	8		700	290	32	1·18	1·47
Cement	Lime	Sand	Cem.	Lime	Cement	Lime			
1	1	6	5	5	430	180	30	1·11	1·38
1	2	9	3⅓	6⅔	287	240	,,	,,	,,
1	3	12	2½	7½	215	270	,,	,,	,,
1	4	15	2	8	172	288	,,	,,	,,
1	5	18	1⅔	8⅓	143	300	,,	,,	,,

Rendering and Plastering

I cu. yd. of mortar will cover the following areas :—

TABLE 72

Surface	Minimum Thickness in.	Area Covered yd. sup.	Surface	Minimum Thickness in.	Area Covered yd. sup.
Concrete or plaster	⅛	288	Brickwork	⅜	72
,,	¼	144	,,	⅝	48
,,	⅜	96	Rubble	⅜	57
,,	½	72	,,	⅝	41
,,	⅝	57	Laths	⅜	50
,,	¾	48	,,	⅝	37

Mixes

Cement stucco, I cement : 2½ or 3 sand.
,, (waterproof) render, I cement : 2 sand.
,, dampcourse, I cement : I sand.
Coarse stuff, I lime putty : 2 or 3 sand.
Fine stuff, I lime putty : I sand.
I ton of chalk lime makes about 2 cu. yds. lime putty.

HEIGHTS OF BRICK COURSES

For standard bricks, measured from top of footing to top of brick course

TABLE 73

No. of Courses	2" Bricks						2⅝" Bricks						2⅞" Bricks					
	Bed. Joints : ¼"		⅜"		½"		¼"		⅜"		½" ¼"		⅜"		½"			
	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.		
1		2¼		2⅜		2½		2⅞		3		3⅛		3¼		3⅜		
2		4½		4¾		5		5¾		6		6¼		6½		6¾		
3		6¾		7⅛		7½		8⅝		9		9⅜		9¾		10⅛		
4		9		9½		10		11½	1	0	1	0½	1	1	1	1½		
5		11¼		11⅞	1	0½	1	2⅜		3		3⅝		4¼		4⅞		
6	1	1¼	1	2¼		3		5¼		6		6¾		7½		8¼		
7		3¾		4⅝		5½		8⅛		9		9⅞		10¾		11⅝		
8		6		7		8		11	2	0	2	1	2	2	2	3		
9		8¼		9⅜		10½	2	1⅞		3		4⅛		5¼		6⅜		
10		10½		11¾	2	1		4¾		6		7¼		8½		9¾		
11	2	0¾	2	2⅛		3½		7⅝		9		10⅜		11¾	3	1⅛		
12		3		4½		6		10½	3	0	3	1½	3	3		4½		
13		5¼		6⅞		8½	3	1⅜		3		4⅝		6¼		7⅞		
14		7½		9¼		11		4¼		6		7¾		9½		11¾		
15		9¾		11⅝	3	1½		7⅛		9		10⅞	4	0¾	4	2⅝		

Table 73—*Continued.*

No. of Courses	2" Bricks						2⅝" Bricks						2⅞" Bricks			
	Bed Joints: ¼"		⅜"		½"		¼"		⅜"		½" ¼"		⅜"		½"	
	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.
16	3	0	3	2	3	4	3	10	4	0	4	2	4	4	4	6
17		2¼		4⅜		6½	4	0⅞		3		5⅛		7¼		9⅜
18		4½		6¾		9		3¾		6		8¼		10½	5	0¾
19		6¾		9⅛		11½		6⅝		9		11⅜	5	1¾		4⅛
20		9		11½	4	2		9½	5	0	5	2½		5		7½
21		11¼	4	1⅞		4½	5	0⅜		3		5⅝		8¼		10⅞
22	4	1½		4¼		7		3¼		6		8¾		11½	6	2¼
23		3¾		6⅝		9½		6⅛		9		11⅞	6	2¾		5⅝
24		6		9	5	0		9	6	0	6	3		6		9
25		8¼		11⅜		2½		11⅞		3		6⅛		9¼	7	0⅜
26		10½	5	1¾		5	6	2¾		6		9¼	7	0½		3¾
27	5	0¾		4⅛		7½		5⅝		9	7	0⅜		3¾		7⅛
28		3		6½		10		8½	7	0		3½		7		10½
29		5¼		8⅞	6	0½		11⅜		3		6⅝		10¼	8	1⅞
30		7½		11¼		3	7	2¼		6		9¾	8	1½		5¼
31		9¾	6	1⅝		5½		5⅛		9	8	0⅞		4¾		8⅝
32	6	0		4		8		8	8	0		4		8	9	0
33		2¼		6⅜		10½		10⅞		3		7⅛		11¼		3⅜
34		4½		8¾	7	1	8	1¾		6		10¼	9	2½		6¾
35		6¾		11⅛		3½		4⅝		9	9	1⅜		5¾		10⅛
36		9	7	1½		6		7½	9	0		4½		9	10	1½
37		11¼		3⅞		8½		10⅜		3		7⅝	10	0¼		4⅞
38	7	1½		6¼		11	9	1¼		6		10¾		3½		8¼
39		3¾		8⅝	8	1½		4⅛		9	10	1⅞		6¾		11⅝
40		6		11		4		7	10	0		5		10	11	3
41		8¼	8	1⅜		6½		9⅞		3		8⅛	11	1¼		6⅜
42		10½		3¾		9	10	0¾		6		11¼		4½		9¾
43	8	0¾		6⅛		11½		3⅝		9	11	2⅜		7¾	12	1⅛
44		3		8½	9	2		6½	11	0		5½		11		4½
45		5¼		10⅞		4½		9⅜		3		8⅝	12	2¼		7⅞
46		7½	9	1¼		7	11	0¼		6		11¾		5½		11¼
47		9¾		3⅝		9½		3⅛		9	12	2⅞		8¾	13	2⅝
48	9	0		6	10	0		6	12	0		6	13	0		6
49		2¼		8⅜		2½		8⅞		3		9⅛		3¼		9⅜
50		4½		10¾		5		11¾		6	13	0¼		6½	14	0¾
51		6¾	10	1⅛		7½	12	2⅝		9		3⅜		9¾		4⅛
52		9		3½		10		5½	13	0		6½	14	1		7½
53		11¼		5⅞	11	0½		8⅜		3		9⅝		4¼		10⅞
54	10	1½		8¼		3		11¼		6	14	0¾		7½	15	2¼
55		3¾		10⅝		5½	13	2⅛		9		3⅞		10¾		5⅝
56		6	11	1		8		5	14	0		7	15	2		9
57		8¼		3⅜		10½		7⅞		3		10⅛		5¼	16	0⅜
58		10½		5¾	12	1		10¾		6	15	1¼		8½		3¾
59	11	0¾		8⅛		3½	14	1⅝		9		4⅜		11¾		7⅛
60		3		10½		6		4½	15	0		7½	16	3		10½
61		5¼	12	0⅞		8½		7⅜		3		10⅝		6¼	17	1⅞
62		7½		3¼		11		10¼		6	16	1¾		9½		5¼
63		9¾		5⅝	13	1½	15	1⅛		9		4⅞	17	0¾		8⅝
64	12	0		8		4		4	16	0		8		4	18	0

Table 73—*Continued.*

No. of Courses	2" Bricks			2⅝" Bricks			2⅞" Bricks	
	Bed Joints : ¼"	⅜"	½"	¼"	⅜"	½" ¼"	⅜"	½"
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
65	12 2¼	12 10⅜	13 6½	15 6⅞	16 3	16 11⅛	17 7¼	18 3⅜
66	4½	13 0¾	9	9¾	6	17 2¼	10½	6¾
67	6¾	3⅛	11½	16 0⅝	9	5⅜	18 1¾	10⅛
68	9	5½	14 2	3½	17 0	8½	5	19 1½
69	11¼	7⅞	4½	6⅜	3	11⅝	8¼	4⅞
70	13 1½	10¼	7	9¼	6	18 2¾	11½	8¼
71	3¾	14 0⅝	9½	17 0⅛	9	5⅞	19 2¾	11⅝
72	6	3	15 0	3	18 0	9	6	20 3
73	8¼	5⅜	2½	5⅞	3	19 0⅛	9¼	6⅜
74	10½	7¾	5	8¾	6	3¼	20 0½	9¾
75	14 0¾	10⅛	7½	11⅝	9	6⅜	3¾	21 1⅛
76	3	15 0½	10	18 2½	19 0	9½	7	4½
77	5¼	2⅞	16 0½	5⅜	3	20 0⅝	10¼	7⅞
78	7½	5¼	3	8¼	6	3¾	21 1½	11¼
79	9¾	7⅝	5½	11⅛	9	6⅞	4¾	22 2⅝
80	15 0	10	8	19 2	20 0	10	8	6
81	2¼	16 0⅜	10½	4⅞	3	21 1⅛	11¼	9⅜
82	4½	2¾	17 1	7¾	6	4¼	22 2½	23 0¾
83	6¾	5⅛	3½	10⅝	9	7⅜	5¾	4⅛
84	9	7½	6	20 1½	21 0	10½	9	7½
85	11¼	9⅞	8½	4⅜	3	22 1⅝	23 0¼	10⅞
86	16 1¼	17 0¼	11	7¼	6	4¾	3½	24 2¼
87	3¾	2⅝	18 1½	10⅛	9	7⅞	6¾	5⅝
88	6	5	4	21 1	22 0	11	10	9
89	8¼	7⅜	6½	3⅞	3	23 2⅛	24 1¼	25 0⅜
90	10½	9¾	9	6¾	6	5¼	4½	3¾
91	17 0¾	18 0⅛	11½	9⅝	9	8⅜	7¾	7⅛
92	3	2½	19 2	22 0½	23 0	11½	11	10½
93	5¼	4⅞	4½	3⅜	3	24 2⅝	25 2¼	26 1⅞
94	7½	7¼	7	6¼	6	5¾	5½	5¼
95	9¾	9⅜	9½	9⅛	9	8⅞	8¾	8⅝

LINTOL BEAMS CARRYING BRICKWORK

British Standard Beams as in Table 103, encased in concrete with a minimum cover of 2 in. and supported at each end.

B.S.B.	4½" Brickwork	9" Brickwork
3" × 3" × 8½ lb.	Max. clear span 8 ft.	Max. clear span 7 ft.
4" × 3" × 10 lb.	,, ,, ,, 10 ft.	,, ,, ,, 9 ft.
5" × 3" × 11 lb.	,, ,, ,, 12 ft.	,, ,, ,, 10 ft.
6" × 3" × 12 lb.	,, ,, ,, 13 ft.	,, ,, ,, 12 ft.
7" × 4" × 16 lb.	,, ,, ,, 16 ft.	,, ,, ,, 14 ft.
8" × 4" × 18 lb.		,, ,, ,, 15 ft.
9" × 4" × 21 lb.		,, ,, ,, 16 ft.

WALLS AND PIERS

of Brickwork, Masonry or Plain Concrete

L.C.C. by-laws

(i) *Definition of Walls and Piers.*

Where a pier is built integrally with a wall and projects on one side of it for a distance not exceeding $\frac{1}{4}$ of the wall thickness (or projects on both sides so that the sum of the projections does not exceed $\frac{1}{3}$ of the wall thickness) the combination is deemed to be a wall. Where the projections exceed these limits the combination is deemed to be a pier.

(ii) *Definition of Length of Wall.*

The length of a wall is taken as the clear distance between any buttressing walls or piers (see (i) above) which are bonded to it ; the buttressing walls or piers must extend to the top of the wall in single storey buildings, or to the underside of floor of the topmost storey when there is more than one storey.

(iii) *Rules for Thickness.*

The thickness of walls and piers of brickwork, masonry or plain concrete may be decided under the *L.C.C.* by-laws either from a set of rules prescribing the thickness in various circumstances, or by calculation of the pressures. In *either* case, certain minimum thicknesses are laid down, and these are reproduced shortly in Table 74 and paragraphs (*b*) to (*e*) below. Thickness is always exclusive of rendering, stone facing or other finishes. The regulations may only be applied to walls carrying distributed loads, including joists up to 42 in. centres. In general, openings in the walls are limited to one-half of the elevation area in any storey. Isolated piers come under column regulations. Certain single-storey buildings are exempted from the rules.

(*a*) Minimum Wall Thicknesses in general.

TABLE 74

Type of Wall	Material of Wall	Warehouses	Buildings other than Warehouses
External wall or buttressing wall	B	8½″	8½″
	RC	4″	4″
Party wall : Not exceeding 30′ high	B	13″	8½″
	RC	8″	8″
Exceeding 30′ and not exceeding 40′ (or 50′ high if the length is not over 35′)	B	13″	8½″
	RC	,,	8″
Any other height	B	,,	13″
	RC	,,	,,

B = brickwork, masonry or plain concrete.

RC = reinforced concrete.

(*b*) Party Walls.

Every party wall and pier combined with it must be of a thickness at any level not less than one-fortieth of the height from that level to the top of the wall.

(*c*) Panels.

When a part of a wall is so constructed that it does not aid in sustaining any of the loads on the rest of the wall, e.g. a panel in a framed structure, such part or panel may be deemed to be a separate wall for the purpose of determining the thickness.

(*d*) Other Walls.

In every other wall and pier the thickness at any level must not be less than one-sixtieth of the height from that level to the top of the wall.

(*e*) Cavity Walls.

These must consist of two leaves each not less than 4 in. thick, and the cavity must be from 2 in. to 6 in. wide. Iron ties not less than $\frac{3}{4}$ in. $\times$ $\frac{3}{16}$ in. in cross-section are required at the rate of two per square yard for cavities up to 3 in. wide, increasing proportionately up to four per square yard for a 6-in. cavity. Local by-laws sometimes limit the cavity width to $3\frac{1}{2}$ in.

For walls of brickwork, masonry or plain concrete where calculations of pressure are not made, the following stipulations must also be met.

(iv) *External and Party Walls.*

(*a*) Tables 75 and 76 give in summary form the minimum thicknesses for these two classes of walls. They are also subject to a further condition, viz. :—

> In buildings other than public buildings and warehouses, where in any storey height the thickness of wall as determined by Table 75 is less than one-sixteenth of the storey height, the thickness shall be increased to one-sixteenth and the thickness below that storey shall be increased to a like extent.
>
> In warehouses, the fraction stated above is to be one-fourteenth. The increased thickness may be confined to piers, the combined widths of which amount to not less than $\frac{1}{4}$ of the wall length. An external wall not over 25 ft. high and not more than 30 ft. long may be constructed as a cavity wall in accordance with paragraph iii (e) and the thickness given in Tables 75 and 76 shall then be the sum of the thicknesses of the two leaves.

(*b*) See Tables 75 and 76 ; for lengths exceeding 45 ft., the thickness in the two uppermost storeys is to be as stated for lengths not exceeding 45 ft., and $4\frac{1}{2}$ in. greater in the remaining storeys. The increase may be confined to piers as above defined.

(*c*) See Table 76 ; for cases below the thick line, the thickness at any level between the base and 16 ft. from the top shall be not less than is indicated by joining with straight lines the specified thicknesses at the base and at 16 ft. from the top, as shown in the sketch.

THICKNESS OF EXTERNAL AND PARTY WALLS
in Brickwork, Masonry or Plain Concrete
(i) Buildings other than Public Buildings or Warehouses
(See notes iii, iv (*a*))

TABLE 75

<table>
<tr><th colspan="2">Height</th><th colspan="4">Length not exceeding</th><th rowspan="2">Length exceeding 45′</th></tr>
<tr><th>Exceeding</th><th>Not exceeding</th><th>20′</th><th>30′</th><th>35′</th><th>45′</th></tr>
<tr><td></td><td>12′</td><td>8½″</td><td>8½″</td><td>8½″</td><td>8½″</td><td>8½″</td></tr>
<tr><td>12′</td><td>25′</td><td>,,</td><td>,,</td><td colspan="3">Lowest storey 13″, others 8½″</td></tr>
<tr><td>25′</td><td>30′</td><td>,,</td><td>Lowest 13″
Others 8½″</td><td colspan="3">Lowest two storeys 13″, others 8½″</td></tr>
<tr><td>30′</td><td>40′</td><td colspan="3">Top storey 8½″, others 13″</td><td colspan="2">Lowest 17½″, top 8½″, others 13″</td></tr>
<tr><td>40′</td><td>50′</td><td colspan="3">Lowest 17½″, top 8½″, others 13″</td><td>Lowest two 17½″
Others 13″</td><td>Lowest 21½″
Next 17½″
Others 13″</td></tr>
<tr><td>50′</td><td>60′</td><td colspan="4">Lowest two storeys 17½″, others 13″</td><td>Lowest 21½″
Next two 17½″
Others 13″</td></tr>
<tr><td>60′</td><td>70′</td><td colspan="4">Lowest storey 21½″, next two 17½″, others 13″</td><td>See note iv(b)</td></tr>
<tr><td>70′</td><td>80′</td><td colspan="4">Lowest 21½″, next three 17½″, others 13″</td><td>,,</td></tr>
<tr><td>80′</td><td>90′</td><td colspan="4">Lowest 26″, next 21½″, next three 17½″, others 13″</td><td>,,</td></tr>
<tr><td>90′</td><td>100′</td><td colspan="4">Lowest 26″, next two 21½″, next three 17½″, others 13″</td><td>,,</td></tr>
<tr><td>100′</td><td>120′</td><td colspan="4">Lowest 30″, next two 26″, next two 21½″, next three 17½″, others 13″</td><td>,,</td></tr>
</table>

(ii) Warehouses. (See notes iii, iv (*a*) ; for cases below the thick line see also note iv (*c*))

TABLE 76

Height		Length not exceeding			Length exceeding 45′
Exceeding	Not exceeding	30′	35′	45′	
	25′	Top storey 8½″, others 13″			
25′	30′	Top storey 8½″, others 13″			Top storey 8½″ To 16′ from top 13″ At base 17½″
30′	40′	13″ throughout		For 16′ from top, 13″ At base, 17½″	For 16′ from top, 13″ At base, 21½″
40′	50′	For 16′ from top, 13″ At base, 17½″	For 16′ from top, 13″ At base, 21½″		For 16′ from top, 13″ At base, 26″
50′	60′	For 16′ from top, 13″ At base, 21½″			As above
60′	80′	As above			See note iv (b)
80′	100′	For 16′ from top, 13″ At base, 26″			,, ,,
100′	120′	For 16′ from top, 13″ At base, 31″			,, ,,

(v) *Buttressing Walls* (other than external or party walls).

The thickness of buttressing walls is to be not less than two-thirds of the thickness specified for external and party walls of the same height, length and class of building.

(vi) *Partition Walls.*

Partition walls and walls buttressing partition walls shall be of a thickness not less than half of the thickness specified for external and party walls of the same height, length and class of building ; provided that a non-load-bearing partition wall adequately restrained on all four edges may be of less than the above thickness so long as the sum of its length and three times its height does not exceed 200 times its thickness.

Where the thickness is not determined in accordance with regulations iv to vi, or where exceptional circumstances make it necessary, calculation of the pressures on walls and piers must be made.

The following table gives the maximum permissible pressures on walls and piers for various qualities of brick or block and of mortar mixture.

The reductions in permissible pressure on brick walls and piers for different conditions of lateral support and slenderness ratio are the same as those for concrete, and are given in Table 62.

The permissible stresses in plain concrete are given in Tables 61 and 63 and in reinforced concrete in Tables 58 and 59.

TABLE 77. Permissible Pressures on Brickwork or Masonry (L.C.C.) (Slenderness Ratio not exceeding 6)

Ref. No.	Test Load on Brick or Block (see note below) lb. per sq. in.	Mortar Proportions by Volume			Maximum Pressure "Column A" tons per sq. ft.
		Cement	Lime	Sand	
1	15000	1	—	2	40
2	10000				30
	Not less than :—				
3	7500	1	—	2½	23
4	5000	1	—	3	16
5	4000	1	—	3	13½
6	3000	1	—	4	11
7	,,	1	1	6	10
8	1500	1	—	4	8
9	,,	1	1	6	7
10	,,	1	2	9	6
11	,,	1	3	12	5½
12	,,	1	4	15	5
13	,,	1	5	18	4½
14	,,	—	1	3	4

For local loading under beams, etc., see p. 63.

Note. The test load is defined as the maximum load which the brick or block can withstand, when saturated with water, without cracking or breaking. It follows that bricks which fail at less than 1500 lb./sq. in. are not permitted for load-bearing walls ; that if the test gives a value between 1500 and 3000 lb. the permissible pressure must be taken, according to the mortar proportions, from the figures in the 1500 lb. group, and so on.

Bricks or blocks in parts of the structure other than load-bearing walls or piers must have a test value of not less than 1000 lb./sq. in., with the exception that the value may be not less than 200 lb./sq. in. for non-load-bearing partitions built in accordance with the proviso in paragraph vi.

For test load values between 10,000 and 15,000, the permissible pressure may be taken as the appropriate proportionate value between 30 and 40 tons/sq. ft. ; for example with bricks failing at 12,500 lb./sq. in. the permitted pressure is 35, provided that the mortar is 1 : 2 cement mortar.

The permissible pressure on brickwork is seen to be based on the crushing strength of the bricks and on the proportions of the mortar, the general rule being that strong bricks should be laid in strong mortar.

Test results on a particular brand of brick vary widely, and it would be necessary in practice to obtain from the supplier an undertaking that the bricks to be supplied for work designed in accordance with these permissible pressures will exceed the stipulated test strength.

The list below gives an indication of the classification to be expected of various well-known types of brick, based on tests at the *Building Research Station* and elsewhere.

TABLE 78

Test Load lb. per sq. in.	Type of Brick
Over :	
10000	Stafford blue
Not less than :	
7500	Stafford blue, engineering bricks
5000	Engineering bricks, brindles
4000	Phorpres Fletton, Leicester red
3000	Pressed common Fletton, best sand-lime
1500	Sand-lime, hand-made multi-stocks, Aylesford pink, Hard London stocks.
Not permitted in load-bearing brickwork	London stocks (backings), multi-stocks

For weight of brickwork, see Table 70.

Local loading under beam or column (*L.C.C.*)

The pressures permitted in Table 77 may be increased by 20% under beams, columns or similar local loads, provided the stresses are immediately distributed over material not so stressed.

Local loading, Eccentric and Lateral Forces (B.S. 449)

More elaborate allowances for these loads are provided in B.S. 449. The same test loads and mortars are covered, and " Column A " of Table 77 gives the permitted pressures " due to combined live and dead loads where considered as uniformly distributed," on piers and bearing walls which have a slenderness ratio (i.e. actual height divided by least lateral dimension) not greater than 6.

The stresses due to eccentric loading (see page 113) and lateral forces are to be calculated and added to the uniformly distributed pressures, and the total so obtained is not to exceed the values given in Column B in the next table.

Local pressures under beams and columns are to be calculated, and the combination of such pressures with either of the two foregoing types of loading is not to exceed the values given in Column C.

Where the slenderness ratio exceeds 6, the following percentage reductions are to be made to the pressures permitted in Columns A, B and C :—

Slenderness ratio	over 6 but not more than 8 . . .	20%
	over 8 ,, ,, ,, 10 . . .	40%
	over 10 ,, ,, ,, 12 . . .	60%
	over 12	not permitted

TABLE 79. Permissible Pressures, B.S. 449 (see foregoing notes)

Ref. No. in Table 77	Maximum Pressures tons per sq. ft.	
	Column B	Column C
1, 2	40	48
3	34·5	34·5
4	24	24
5	20·25	20·25
6	16·5	16·5
7	15	15
8	12	12
9	10·5	10·5
10	9	9
11	8·25	8·25
12	7·5	7·5
13	6·75	6·75
14	6	6

PROPERTIES OF BUILDING STONES

For a good list of weights of English stones see B.S. 648—*Unit Weights of Building Materials*

TABLE 80

Stone	Weight Dry lb./cu. ft.	Working Load tons/sq. ft. (see Table 77)	Ultimate Strength tons/sq. ft.		Young's Modulus tons/sq. ft. × 1000	Temperature Coefficient per deg. F parts per million
			Compn.	Shear		
Ancaster *	156		200			
Bath *	130	4	up to 200			
Darley Dale †	148					
Forest of Dean †	152					
Granite	165	48	1300–1600	150	450	3·6
Ham Hill yellow *	135	10				
Hopton Wood *	158					
Limestones		18 if	not less than 150	90	380–510	2·9
Mansfield stone *	141·	11				
Marble	170		750	90	510	3·9
Millstone grit †	145		400–500			
Portland stone *	140					
Sandstones		30 if	not less than 250	110	160–210	
Slate, Welsh	175	22	900	low	900	
Westmorland.	187	,,	,,	,,	,,	
Terra Cotta	110–140		250–560	110–250	150–500	1·1
York stone †	140	17				

Limestones. † Sandstones.

If saturated add, for	granite, marble or slate	1	lb./cu. ft.
	sandstones	7	,, ,,
	Portland stone	11	,, ,,
	Bath stone	15	,, ,,
	other limestones	7–12	,, ,,

For permissible pressures on masonry see also Tables 77 and 79.

LOADS ON SLABS

The load to be provided for includes

(i) Specified imposed load.
(ii) Weight of finish, filling and ceiling.
(iii) Allowance for partitions.
(iv) Self-weight of slab.

Regulations covering (i) make a distinction between slabs and beams, on the ground that slabs must be able to withstand local excessive loading while beams are able to average the load over an appreciable area. (The model by-laws of the *Ministry of Health* make no such distinction.)

Load regulations for beams are given on page 111.

The following table gives the *L.C.C.* requirements and is accompanied by references to B.S. 449–1937, *Institution of Structural Engineers Report No.* 8 (*Report No.* 10 is nearly identical on the subject of floor loads), the model by-laws, *Post-War Building Study No.* 8, 1944 and the *Housing Manual* 1944 of the *Ministries of Health and Works.*

The *B.S. Code of Practice C.P.*4 (*Chapter V*) proposes imposed loads some of which are considerably lower than those in Table 81.

The class load per sq. ft. recommended for private dwellings of not more than two storeys is 30 lb.; for rooms in other dwellings, hospitals and hotels, 40 lb.; offices, 50 lb.; classrooms, 60 lb.; banking halls and offices where the public may congregate, 70 lb.; churches, restaurants and garages for vehicles up to $2\frac{1}{2}$ tons gross weight, 80 lb.; other garages and light workshops generally, 100 lb.

An appendix will give a comprehensive list of occupancies and the appropriate class.

The distinction between beam and slab loading is dropped, except in respect of the strip load requirements which are as follows :—

The minimum load on slabs (applying only to spans of less than 8 ft.) is 8 times the class load distributed over the span on a strip 1 ft. wide; the load on short spans in the 50 lb. class, for example, is $\frac{8 \times 50}{l}$ lb./sq. ft.

The minimum load on beams (applying only to beams carrying less than 64 sq. ft. of floor) is 64 times the class load distributed along the span.

(i) IMPOSED LOADING ON FLOOR SLABS

Load classes in accordance with *L.C.C.* by-laws ; the $\frac{1}{4}$ ton and $\frac{3}{8}$ ton uniformly distributed strip load requirements are expressed below in terms of the span *l*, so that no separate check need be made for those requirements.

TABLE 81

Class	Type of Building or Floor	Lb./sq. ft. of Slab
1	Rooms used for residential purposes ; and corridors, stairs and landings within the curtilage of a flat or residence.	For spans up to 11·2′ $\frac{560}{l \text{ ft.}}$ For greater spans, 50
★	Bedrooms, dormitories and wards in hotels, hospitals, infirmaries, workhouses and sanatoria. (For public spaces, corridors and staircases, see starred Classes 4, 5 and 6.)	As Class 1
2 3	Offices, floors above entrance floor Offices, entrance floor and floors below ; retail shops ; garages for cars not over 2¼ tons in weight. (*Report No.* 8 gives 60 lb. for Class 2, and 2 tons instead of 2¼ tons.)	For spans up to 10·5′ $\frac{840}{l \text{ ft.}}$ For greater spans, 80
★	Churches ; classrooms and lecture rooms in schools ; reading and writing rooms in libraries, clubs and hotels ; art galleries ; show-rooms for light goods.	As Class 3
4	Corridors, stairs and landings not provided for in Class 1. (*Report No.* 8 stipulates 300 lb. point load on each step or landing.)	For spans up to 8·4′ $\frac{840}{l \text{ ft.}}$ For greater spans, 100
★	Dance and drill halls, restaurants, cafés, concert halls, grandstands, gymnasia, light workshops ; public spaces in hotels, hospitals, restaurants, auction-rooms ; theatres, cinemas, assembly halls. (The last three if with permanent seating accommodation are put in Class 3 by *Report No.* 8).	As Class 4
5	Workshops and factories ; garages for motor vehicles other than those in Class 3 (vehicles from 2 to 3 tons loaded weight, *Report No.* 8).	For spans up to 5·6′ $\frac{840}{l \text{ ft.}}$ For greater spans, 150 (See also footnote)
★	Storage rooms, factories, workshops, retail and book shops where the average load does not exceed 150 lb./sq. ft. Staircases and corridors in this Class. (*Report No.* 8 stipulates a 360-lb. point load on each step or landing.)	As Class 5
6	Warehouses, book stores, stationery stores and the like	For spans up to 4·2′ $\frac{840}{l \text{ ft.}}$ For greater spans, 200
★	Pavements surrounding building but not adjoining a roadway. Staircases and corridors in this Class. (*Report No.* 8 stipulates a 600 lb. point load on each step or landing.)	As Class 6

Notes on Table 81

★ These cases are not specifically referred to in the *L.C.C.* by-laws, but District Surveyors and local authorities will normally accept the class loadings stated. For classes 1 and 2 see also below.

The actual loading on classes 4 to 6 is to be ascertained and is not to be taken as less than the values in the table.

The *L.C.C.* requires in addition, for garage floors in Class 5, that the slab shall be designed to carry 1·5 times the maximum possible combination of wheel loads, but each wheel load not less than 1 ton.

Beams and ribs spaced not further apart than 2 ft. 6 in. centre to centre are to be designed for these loads and not for beam loads.

B.S. 449 and the model by-laws of the *Ministry of Health* omit Class 5 and place garages for vehicles over 2 tons in weight in Class 6, but without a wheel load stipulation. In addition, the model by-laws omit the strip load requirements, and specify the loading on Class 1 at 40 lb. instead of 50, and on Class 2 at 50 lb. instead of 80.

Report No. 8 omits the strip load requirements.

Post-War Building Study No. 1 and *Housing Manual* 1944 of the *Ministries of Health and Works* suggest an even further reduction for floors in Class 1, for dwellings of not more than two storeys, to 30 lb./sq. ft. for spans over 8 ft. $\left(\frac{240}{l\text{ ft.}}\right.$ for spans not over 8 ft.$\left.\right)$ on slabs or floor boards.

(ii) WEIGHT OF SLAB FINISHES, CEILINGS AND INSULATIONS

For other materials see Table 93.

TABLE 82

Material		Weight lb. per sq.
Adamantine tiles	$1\frac{3}{4}$" *thick*	20
Aluminium foil		negligible
Asbestos cement flat sheets	$\frac{3}{16}$" *thick*	$1\frac{3}{4}$
	$\frac{1}{4}$" ,,	$2\frac{1}{4}$
	$\frac{5}{16}$" ,,	$2\frac{3}{4}$
Asbestos wood	*per inch of thickness*	7
,, spray	,, ,, ,,	2
Asphalt	,, ,, ,,	11
Beaver board	$\frac{3}{8}$" *thick*	1
Cabot's Quilt	$\frac{1}{2}$" ,,	$\frac{1}{4}$
Celotex	*per inch of thickness*	3
Cement. See mortar.		
Cemesto	$1\frac{1}{8}$" *thick*	4
Concrete, breeze aggregate	*per inch of thickness*	8
brick aggregate	,, ,, ,,	10
Cork, flooring	,, ,, ,,	2
insulation slabs	,, ,, ,,	1
Donnacona board	,, ,, ,,	$1\frac{1}{4}$
Felt, hair	,, ,, ,,	4
Fibre board	,, ,, ,,	$1\frac{1}{2}$
Firebrick (silica)	,, ,, ,,	$12\frac{1}{2}$
Glass silk	,, ,, ,,	1
Granolithic	,, ,, ,,	12
Gypklith	,, ,, ,,	3
Gyproc. See Plaster board.		
Hardwood boards, parquetry	$\frac{7}{8}$" *thick*, in mastic	4
	$1\frac{1}{8}$" ,, ,,	$4\frac{1}{2}$
Insul board	*per inch of thickness*	$1\frac{1}{2}$
Kenmore board	,, ,, ,,	3
Kieselguhr	,, ,, ,,	$2\frac{1}{2}$
Lath and plaster, average	,, ,, ,,	6
Lloyd hardboard	,, ,, ,,	3
— insulating board	,, ,, ,,	$1\frac{1}{2}$
Macadam, tar	,, ,, ,,	11

Table 82—*Continued.*

Material		Weight lb. per sq. ft.
Magnesium oxychloride, sawdust filler	*per inch of thickness*	$7\frac{1}{2}$
„ „ mineral filler	„ „ „	$11\frac{1}{2}$
Masonite	„ „ „	3
Mastic for laying wood block floors		$\frac{1}{4}$
Mortar screeding	*per inch of thickness*	11
Pitchpine boards, parquetry	$\frac{7}{8}$″ *thick*, in mastic	$3\frac{1}{2}$
	$1\frac{1}{8}$″ „ „	4
Plastered soffit	*per inch of thickness*	9
Plaster boards, $\frac{1}{2}$″ thick		$2\frac{1}{4}$
Rendering. See mortar.		
Rubber sheet $\frac{1}{4}$″ thick		$2\frac{1}{4}$
Silicate cotton (slagwool)	*per inch of thickness*	$1\frac{1}{4}$
Slagwool	„ „ „	$1\frac{1}{4}$
Tarmac	„ „ „	11
Tentest board	„ „ „	1–2
Terrazzo	„ „ „	12
Tiling, clay	„ „ „	$11\frac{1}{2}$
Treetex	„ „ „	1
Wood wool slab	„ „ „	$3\frac{3}{4}$

(iii) ALLOWANCE FOR PARTITIONS

Partition loads may be dealt with either by fixing the position and details of the partition on plan and designing to suit, or by making a general allowance by way of adding to the superimposed load on the whole floor.

TABLE 83. Typical weights are as follows :—

Construction	Lb. per sq. ft. of Partition
Breeze blocks 4″ thick	30
Brickwork $4\frac{1}{2}$″ thick (See Table 70).	42
Hollow clay blocks 3″ thick plus plaster	23
„ „ „ 4″ „ „ „	27
Timber studding plastered	20
Plaster, per inch of thickness	9

According to the *L.C.C.* by-laws, the minimum allowance for partitions or the floors of rooms used as offices, where the positions of partitions are not definitely located in the design, shall be at the rate of

20 lb./sq. ft. of floor area.

Report No. 8 *Institution of Structural Engineers* stipulates the allowance to be 10% of the weight per foot run of partitions if this amount exceeds 20 lb./sq. ft. *B.S.* C.P.4 agrees, and adds that if the 10% so obtained is less than one-fifth of the imposed load, the weight of the partition may be neglected.

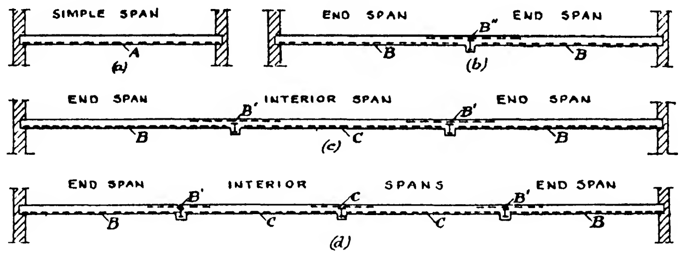
CONCRETE FLOORS

TABLES 84—93

CONCRETE FLOORS

CONDITIONS OF SUPPORT

The following tables for reinforced concrete solid, filler joist and hollow floors are calculated for simply supported spans as in Fig. (*a*). The main reinforcement tabulated is in the direction of the span and is the quantity required at mid-span A, where the bending moment is $wl^2/8$.



When adjacent spans are continuous over supports, as in Figs. (*b*) and (*c*) for example, the B.M. is less than in a simply supported span of the same length. When using the tables, adjustment for conditions of support is made by reducing the span and not the load ; the latter cannot be done directly since the slabs carry their own weight in addition to the imposed loads tabulated.

The method of using the tables for continuous spans (under *L.C.C.* rules) is then as follows :—

For **End Spans,** reduce the actual effective span by 10% before entering the tables to obtain the steel at B, Figs. (*b*) and (*c*), where $M = wl^2/10$.

(In the case of two spans, Fig. (*b*), the B.M. over the centre support is $-\ wl^2/8$ and therefore the full actual span must be used to find the steel at B″.

In the case of three or more spans, the B.M. at B′ over the support next to the end is $-\ wl^2/10$ so that the span reduced by 10% should be used.)

For **Interior Spans,** reduce the actual span by 18% before entering the tables to obtain the steel at C, where $M = wl^2/12$. Use the same amount over interior supports as at C′.

The effective span is to be taken as the distance between centres of supports, or as the clear span plus the effective depth of the slab. The moments quoted above, viz., $wl^2/10$ and $wl^2/12$ are allowable under the *L.C.C.* rules only if adjacent spans are of approximately equal length, i.e. when they do not differ by more than 15% of the longer span.

Reinforcement.

The continuity steel indicated in the diagrams over the supports should extend for one-fifth of the span in each direction. When the reinforcement is in the form of bars, it is customary to bend up half the bottom bars at this position in the span and carry them over the support, and to add sufficient top bars to make up the quantity required over the support.

Distribution bars transverse to the main bars are required by *L.C.C.*, to the extent of 10% of the weight or cross-section of the main bars.

The tables of solid reinforced concrete slabs are followed by notes on the effect of concentrated loads (page 90) and on the bending moments in slabs which are supported at all four edges (page 91).

SOLID REINFORCED CONCRETE SLABS

Selection of Slab. For a given superimposed load and span (the latter adjusted for conditions of fixity if required), the most economical slab will usually be found by trying the second or third line in each table and taking the thinnest slab which will carry the required load in the appropriate span column. The slabs below the third line are not efficiently reinforced and are only tabulated because slab thickness is often dictated in practice by other considerations, e.g. when a light span adjoins a heavily loaded one and the thickness is kept the same for convenience.

Neutral Axis and Lever Arm Factors. The columns headed n_1 and a_1 are not required for selecting a slab but are included to assist when calculations have to be submitted to the local authority, and are used as follows :—

When an entry appears under n_1, the resistance moment of slabs on that line is limited by concrete stress, and is given by (for Class III concrete) :—

$$RM_{(concrete)} = \tfrac{1}{2}\,c.b.n.a. = 375 \times 12 \times n_1\,d \times a_1\,d \text{ in./lb. or } 375\,n_1\,a_1\,d^2 \text{ ft./lb.}$$

When no entry appears under n_1, the steel stress limits the resistance moment, which is then given by :—

$$RM_{(steel)} = A_T.t.a = A_T.18000\,a_1\,d \text{ in./lb. or } A_T.1500\,a_1\,d \text{ ft./lb.}$$

In the above, n = depth of neutral axis, a = lever arm, A_T = sectional area of main steel per foot width as tabulated below, d = effective depth : in accordance with usual office practice d is to be taken as overall thickness of slab less $\frac{3}{4}$ in. except in the case of $\frac{5}{8}$ in. bars when d = actual depth from top of slab to centre of bars. The tables have been calculated with the exact value of d in all cases, but the values of n_1 and a_1 apply to the approximate values stated above. $a = a_1\,d$ $n = n_1\,d$

SECTION AREA OF ROUND BARS

TABLE 84. A_T sq. in. per ft. width of slab

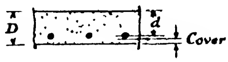
Diam.	Spacing Centre to Centre of Bars									
	3"	4"	5"	6"	7"	8"	9"	10"	12"	15"
$\frac{3}{16}$"	·110	·083	·066	·055	·047	·041	·037	·033	·028	·022
$\frac{1}{4}$"	·196	·147	·118	·098	·084	·074	·065	·059	·049	·039
$\frac{5}{16}$"	·307	·230	·184	·153	·132	·115	·102	·092	·077	·061
$\frac{3}{8}$"	·442	·331	·265	·221	·190	·166	·147	·133	·110	·088
$\frac{1}{2}$"	·785	·589	·471	·393	·337	·295	·262	·236	·196	·157
$\frac{5}{8}$"	1·23	·920	·736	·614	·526	·460	·409	·368	·307	·245

(i) SIMPLY SUPPORTED SOLID REINFORCED CONCRETE SLABS

Calculated in accordance with *L.C.C.* by-laws, for concrete designation III (1 : 2 : 4 mix), max. steel stress 18,000, max. concrete stress 750 lb./sq. in., modular ratio 15, concrete cover not less than ½ in. or diameter of bar.

See notes opposite for n_1, a_1 and effective span and for other conditions of support.

The self-weight of the slabs has been deducted.



SAFE DISTRIBUTED IMPOSED LOADS

TABLE 85. Lb. per sq. ft.

n_1	a_1	Main Steel Diam. in.	Main Steel Centres in.	Effective Span 5′	5′ 6″	6′	6′ 6″	7′	7′ 6″	8′	8′ 6″	9′
		3″ SLAB										
·45	·89	5/16	3	208	166	133	108					
·40	·91	,,	4	184	146	118	95					
	·92	,,	5	146	114	91	72					
		3½″ SLAB										
·47	·87	3/8	3	326	262	214	176	146	122			
·42	·88	3/8	4 }	294	235	192	158	130	108			
·41	·90	5/16	3 }									
	·89	3/8	5	270	216	174	142	118	97			
	·91	5/16	4	234	186	150	122	99	81			
	·92	,,	5	182	143	113	90	72	57			
		4″ SLAB										
·48	·84	½	4			310	258	215	181	153	130	111
·45	·85	½	5 }			290	240	200	168	142	120	102
·44	·87	3/8	3 }									
·40	·89	3/8	4		322	264	218	181	152	127	107	91
	·90	5/16	3	382	307	252	208	172	144	120	101	85
	,,	3/8	5	322	258	210	172	141	117	97	80	67
	·91	5/16	4	278	221	178	145	119	98	80	65	53
	,,	3/8	6	266	218	170	138	112	91	74	60	49
	·92	5/16	5	218	172	136	109	87	70	56	44	
	·93	,,	6	174	135	107	84	65	50			

SIMPLY SUPPORTED SOLID REINFORCED CONCRETE SLABS

The self-weight of slab has been deducted.

SAFE DISTRIBUTED

TABLE 85—*Continued.* Lb. per

n_1	a_1	Main Steel		Effective				
		Diam. in.	Spacing in.	5′	5′ 6″	6′	6′ 6″	7′
4½″ SLAB								
·46	·85	½	4					280
·42	·86	,,	5			372	310	260
·40	·87	,,	6			350	290	242
	·89	⅜	4 }			316	262	217
	·87	½	7 }					
	·90	$\frac{5}{16}$	3			292	241	200
	,,	⅜	5	374	300	244	200	165
	·91	,,	6	307	244	197	160	130
	·92	,,	7	260	205	164	132	106
	·93	$\frac{5}{16}$	6	203	158	125	99	77
	·94	,,	7	168	129	101	78	60
5″ SLAB								
·44	·85	½	4					352
·48	·84*	⅝	5					348
·40	·88	⅜	3					330
,,	·87	½	5					328
	,,	,,	6					298
	·90	⅜	4 }			360	298	248
	·88	½	7 }					
	·91	$\frac{5}{16}$	3			333	276	229
	,,	⅜	5			280	230	190
	,,	,,	6	352	280	226	184	150
	·92	,,	7	294	232	186	150	121
	,,	,,	8	254	199	158	126	100

* $d = 4{\cdot}06''$.

$c = 750$
$t = 18{,}000$

IMPOSED LOADS
sq. ft.

Span								
7′ 6″	8′	8′ 6″	9′	9′ 6″	10′	10′ 6″	11′	11′ 6″
237	202	173	148	128	110			
220	186	158	135	116	99			
204	173	147	125	107	92			
183	153	129	110	93	79			
168	141	119	100	84	71			
137	113	94	78	64	53			
106	87	71	57	46	36			
85	68	54	43					
60	46							
45	33							
300	256	220	190	165	142	123	107	93
295	252	216	187	162	140	121	105	91
280	238	204	176	152	131	113	98	84
278	236	202	174	150	130	112	97	83
252	214	182	156	134	115	98	85	73
209	176	149	127	108	91	77	65	54
192	161	136	115	97	82	69	57	47
158	131	109	91	76	62	50	41	
123	101	82	67	54	43	34		
98	79	63	50	38				
79	62	48	37					

SIMPLY SUPPORTED SOLID REINFORCED CONCRETE SLABS

The self-weight of slab has been deducted.

SAFE DISTRIBUTED

TABLE 85—*Continued*

Lb. per

n_1	a_1	Main Steel		Effective							
		Diam. in.	Spacing in.	5′	5′ 6″	6′	6′ 6″	7′	7′ 6″	8′	8′ 6″
		5½″ SLAB									
·46	·85*	5/8	5 }							316	272
·42	·86	1/2	4 }								
·39	·87	,,	5							292	251
	·88	3/8	3					390	332	283	243
	·88	1/2	6					337	286	242	207
	·90	,,	7					286	241	204	173
	,,	3/8	4			406	338	280	236	199	169
	·91	,,	5			315	259	214	178	148	124
	·92	,,	6	394	314	254	207	169	139	114	93
	,,	,,	7	334	265	212	171	138	112	90	72
	·93	,,	9	246	192	150	118	93	73	56	42
		6″ SLAB									
·44	·85*	5/8	5 }							383	331
·41	·86	1/2	4 }								
	·87	,,	5							334	288
	·89	3/8	3							316	272
	·88	1/2	6					376	319	270	231
	·89	,,	7					316	266	224	190
	·90	3/8	4					312	263	222	188
	·91	,,	5			352	289	239	200	166	139
	·90	1/2	9			340	280	232	193	160	133
	·92	3/8	6			284	232	188	155	128	105
	·93	,,	7	370	293	236	191	154	125	101	81
	,,	,,	9	274	214	168	133	104	81	63	47

* $d = 4{\cdot}56''$ (5½″ slab)

* $d = 5{\cdot}06''$ (6″ slab)

c = 750
t = 18,000

IMPOSED LOADS
sq. ft.

Span										
9′	9′ 6″	10′	10′ 6″	11′	11′ 6″	12′	12′ 6″	13′	13′ 6″	14′
236	206	178	156	136	119	104	91	79		
216	188	163	142	123	107	93	81	69		
210	182	157	136	118	102	89	77	66		
178	153	131	113	97	83	71	60	51		
147	125	107	91	77	65	54	45	36		
143	122	104	88	74	62	52	43	34		
103	86	71	58	47						
76	61	49								
57	44	34								
30										

Span										
9′	9′ 6″	10′	10′ 6″	11′	11′ 6″	12′	12′ 6″	13′	13′ 6″	14′
288	252	220	193	169	149	130	114	100	87	76
249	216	188	164	143	125	108	94	82	71	61
234	203	176	153	133	116	100	87	73	62	54
198	171	147	127	109	94	80	68	57	47	
162	138	117	99	84	71	59	49	40		
160	137	116	98	83	70	58	48	39		
116	97	80	66	54	43	34				
111	92	77	63	51	40					
86	70	56	44	34						
65	51	39								
35										

SIMPLY SUPPORTED SOLID REINFORCED CONCRETE SLABS

The self-weight of slab has been deducted.

SAFE DISTRIBUTED

TABLE 85—*Continued.*

Lb. per

n_1	a_1	Main Steel		Effective									
		Diam. in.	Spacing in.	6′	6′ 6″	7′	7′ 6″	8′	8′ 6″	9′	9′ 6″	10′	10′ 6″
				7″ SLAB									
·42	·86*	$\frac{5}{8}$	5									313	276
	·87	$\frac{1}{2}$	4							392	344	302	266
	·88	,,	5							302	263	228	199
	·89	,,	6					326	279	240	207	178	154
	·91	$\frac{3}{8}$	4			376	317	268	228	194	166	141	120
	·90	$\frac{1}{2}$	8			324	272	229	193	163	138	116	97
	·92	$\frac{3}{8}$	5			288	241	201	169	141	118	98	81
	·91	$\frac{1}{2}$	9			282	235	196	164	137	115	95	78
	,,	,,	10	364	299	246	204	168	139	116	96	77	62
	·92	$\frac{3}{8}$	6	340	278	228	188	154	127	104	85	69	55
	·93	,,	8	238	191	152	122	97	76	59	44		
	·94	,,	10	176	137	107	83	62	45	32			

* $d = 6{\cdot}06''$

n_1	a_1	Diam. in.	Spacing in.	6′	6′ 6″	7′	7′ 6″	8′	8′ 6″	9′	9′ 6″	10′	10′ 6″
				8″ SLAB									
·43	·86*	$\frac{5}{8}$	4										
·39	·87*	,,	5										
	·88*	,,	6									360	318
	·88	$\frac{1}{2}$	4									355	314
	·89	,,	5							354	309	268	234
	·90	,,	6					384	329	283	245	211	183
	,,	,,	7					319	272	232	199	170	145
	·91	,,	8			380	319	269	227	193	164	137	115
	,,	,,	9			328	273	229	192	160	134	112	93
	·92	,,	10		352	290	240	199	165	137	113	83	66
	·94	$\frac{3}{8}$	8	280	225	180	145	115	91	71	54		

* $d = 7{\cdot}06''$

$c = 750$
$t = 18{,}000$

IMPOSED LOADS
sq. ft.

Span													
11′	11′ 6″	12′	12′ 6″	13′	13′ 6″	14′	14′ 6″	15′	15′ 6″	16′	16′ 6″	17′	17′ 6″
244	216	192	170	151	134	118	104	92	81	71	61	53	
234	207	184	164	144	128	112	99	87	76	66	57	49	
174	152	133	116	101	88	74	63	55	46				
133	115	98	84	71	60	50							
102	86	73	61	49									
79	65	53	42										
67	54	43											
64	51	40											
50													
42													

358	319	286	256	229	206	184	165	148	133	118	105	94	83
328	292	260	232	208	186	166	148	122	108	96	84	74	64
280	248	220	195	174	154	136	121	106	93	82	72	62	53
277	246	217	193	171	152	134	119	104	91	80	69	60	51
205	180	157	138	120	104	90	77	66	56				
158	136	117	101	86	73	61	50						
123	104	88	74	61	50								
97	81	66	53										
76	61	49											

(ii) FILLER JOIST FLOORS

(Simply Supported)

In accordance with B.S. 449 and *L.C.C.* by-laws. Concrete 1 : 2 : 4 designation III. 1 in. cover to sides and bottom of joists. The cases selected require no transverse reinforcement in the slab.

The self-weight of floor has been deducted.

For adjustment when the span is continuous over a support see notes on page 71.

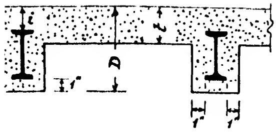
SAFE DISTRIBUTED

TABLE 85A.

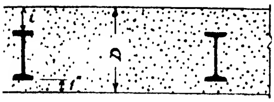
Lb. per

Steel Joists (British Standard) Size and Weight	Centre to Centre of Joists in.	Inset *i* in.	Overall Depth D in.	Slab Thickness t in.	Total Self Weight lbs./sq. ft.	Effective			
						7	8	9	10
3″×1½″×4	18	2	6	3	46	369	271	204	157
3″×3″×8½	,,	,,	,,	,,	52		397	303	235
4″×1¾×5	,,	,,	7	,,	49		399	305	237
4″×3″×10	,,	,,	,,	,,	56				369
4¾″×1¾″×6½	,,	,,	7¾	,,	52				350
5″×3″×11	24	3	9	4	66				
6″×3″×12	21	2	,,	3½	65				
7″×4″×16	24	,,	10	4	74				
8″×4″×18	,,	,,	11	,,	78				

Based on data given in their steel Handbook by permission of Messrs. Redpath Brown & Co. Ltd.



The loads tabulated refer to this type of floor.



* If the slab is built with flush soffit, the dead weight is increased. Deduct from tabular load the figure on same line in the last column.

IMPOSED LOADS
sq. ft.

Spans of Joists in Feet										See Note above
11	12	13	14	15	16	17	18	19	20	*
121	95	74								29
185	147	118								26
187	149	120	97	78	62					38
295	239	195	161	133	110					35
280	227	186	153	126	105	87	72			45
	363	299	249	208	175	148	125	105	88	48
	427	354	297	250	211	180	154	131	112	50
			410	348	296	255	219	189	163	54
				445	381	330	286	248	216	63

(iii) HOLLOW TILE FLOORS

These floors consist structurally of a series of reinforced concrete T-beams, which are so closely spaced as to require to be designed for slab loading. They are much weaker in shear than solid floors of the same thickness, for the ribs alone are taken as resisting shear and the ribs represent only $\frac{1}{4}$ or $\frac{1}{8}$th of the whole cross-section.

In consequence, the safe span of a hollow floor as determined by shear stress in the rib concrete is usually less than the safe span calculated from the bending resistance. In these cases it is customary to omit the hollow blocks in the end portions of the span where the shear exceeds the value which can be taken by the ribs. The remainder of the span is called the "Hollow Span" in Table 86, the whole span being termed the "Effective Span," as defined on page 71.

The usual concrete mix is 1 : $1\frac{1}{2}$: 3 nominal, and small aggregate, e.g. $\frac{3}{8}$ in., is used as the concrete must be worked round reinforcement in narrow ribs. The conditions also call for a fluid mix.

(i) Simply Supported Spans

Table 86 gives directly the safe distributed imposed load in lb. per sq. ft. on various floors and effective spans. Where an entry for the Hollow Span occurs under the safe load figure, this entry gives the length which may be built hollow, and the remainder of the span must be solid. If there is no entry the whole span may be hollow.

(ii) Continuous Spans

(*a*) The permissible length of the hollow portion is the same for continuous as for simple spans, when fully loaded, but it may not be equidistant from the two supports, and its position varies for different arrangements of partial loading.

(*b*) If no entry appears for *H*, the whole span may be hollow with the exception of a few inches over a support. This is to take care of reverse bending, because the plain rib even when doubly reinforced is not quite so strong in bending as the T section at mid-span : but the *BM* is falling rapidly near the support and within a few inches the rib is capable of taking it. For the floors included in the table, a length of solid over each support equal to $\frac{1}{80}$th of the span is sufficient when no value of *H* is tabulated.

(*c*) In accordance with *L.C.C.* by-laws and usual practice, the *BM* in continuous spans is taken as $\frac{Wl}{10}$ or $\frac{Wl}{12}$ as on page 71. The shear at the supports varies according to the arrangement of spans and affects the position of the hollow portions. The procedure in using the table for continuous spans is as follows :—

Two Spans

Reduce the actual span by 10% before entering the table. Select a suitable floor to carry the required superimposed load on the reduced span, and note the hollow span *H* tabulated. The distance x_1 is $\cdot 44l - \cdot 50H$, subject to note (*b*), and H_1 is $H - \cdot 06l$ *H* as tabulated

l = actual span (not reduced)

Three Spans

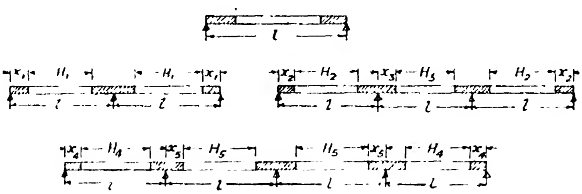
The end span is reduced by 10% and the centre span by 18% before entering the table. The distance x_2 is $\cdot 45l - \cdot 50H$, subject to note (*b*).

$$x_3 \text{ is } \cdot 58l - \cdot 50H$$
$$H_2 = H - \cdot 07l \quad H_3 = H - \cdot 16l$$

Four Spans

The end span is reduced by 10% and all inner spans by 18% before entering the table. The distance $\left.\begin{aligned} x_4 &= \cdot 45l - \cdot 50H \\ x_5 &= \cdot 60l - \cdot 50H \end{aligned}\right\}$ subject to note (*b*).

$$H_4 = H - \cdot 07l$$
$$H_5 = H - \cdot 17l$$



The continuity steel over the supports is dealt with on page 71. In columns 1 and 2 are tabulated for reference the depth of neutral axis *n* and depth to c.g. of compression *z*. Column 3 gives the number and diameter of bars in each rib. The concrete cover is the same as for solid slabs (page 73).

SIMPLY SUPPORTED HOLLOW REINFORCED CONCRETE SLABS

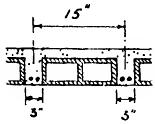
Calculated in accordance with *L.C.C.* by-laws, concrete designation II (1 : 1½ : 3 mix), viz., maximum steel stress 18,000, maximum concrete stress 850, $m = 15$, $q = 85$ lb./sq. in. For continuous slabs see notes. The self-weight has been deducted.

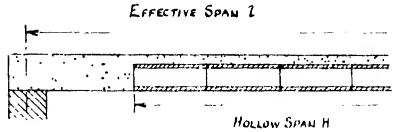
TABLE 86.

(i) 3 in. RIBS, 1½ in. TOPPING :— SAFE DISTRIBUTED

n in.	z in.	Reinforcement in each Rib		Effective 5′	5′ 6″	6′	6′ 6″	7′	7′ 6″	8′	8′ 6″
			4½″ SLAB								
1·03	·34	1–½″	Safe Load	216	172	138	111	90	74	60	49
			Hollow Span		see Notes						
1·36	·45	2–½″	Safe Load	456	370	305	252	212	181	154	132
			Hollow Span	2/9	3/3	3/11	4/7	5/4	6/1	6/11	7/10
1·56	·52	2–⅝″	Safe Load			412	343	290	249	214	186
			Hollow Span			2/9	3/3	3/9	4/3	4/10	5/6
			5″ SLAB								
1·47	·49	2–½″	Safe Load		425	362	293	247	209	179	153
			Hollow Span		3/3	3/9	4/7	5/3	6/1	6/11	7/10
1·71	·55	2–⅝″	Safe Load				436	370	316	273	236
			Hollow Span				3/0	3/6	4/0	4/6	5/2
			5½″ SLAB								
1·57	·52	2–½″	Safe Load			387	332	280	238	204	175
			Hollow Span			4/0	4/7	5/4	6/1	7/0	7/10
1·71	·55	1–½″, 1–⅝″	Safe Load				417	353	301	260	224
			Hollow Span				3/6	4/1	4/9	5/4	6/1
1·86	·58	2–⅝″	Safe Load					435	373	323	280
			Hollow Span					3/5	3/10	4/5	5/0
			6″ SLAB								
1·84	·58	1–½″, 1–⅝″	Safe Load					396	338	292	253
			Hollow Span					4/1	4/9	5/5	6/1
2·00	·60	2–⅝″	Safe Load						422	365	318
			Hollow Span						3/10	4/5	5/0
			7″ SLAB (see also next page)								
2·29	·65	2–⅝″	Safe Load							449	393
			Hollow Span							4/5	5/0

$c = 850$
$t = 18000$





IMPOSED LOADS. Lb. per sq. ft.

Spans l												
9′	9′ 6″	10′	10′ 6″	11′	11′ 6″	12′	12′ 6″	13′	13′ 6″	14′	14′ 6″	15′
111 158 6/3												
132 8/10 206 5/9	114 180 6/5	99 159 7/1	86 140 7/10	75 125 8/6								
152 8/9 196 6/9 246 5/7	132 172 7/6 216 6/3	115 151 8/4 191 6/11	100 132 9/4 169 7/7	87 116 10/3 150 8/4	76 103 11/1 133 9/2	66 91 119 10/0	58 81 107 10/9	50 71 95 11/8				
221 6/10 279 5/7	194 7/7 245 6/3	170 8/5 217 6/11	151 9/3 193 7/7	132 10/3 172 8/4	118 11/1 153 9/1	104 136 10/0	92 122 10/9	82 109 11/9	72 98 12/7	64 88 13/6		
345 5/7	305 6/3	270 6/11	241 7/7	215 8/4	192 9/2	173 10/0	155 10/10	140 11/8	126 12/7	114 13/6	109	93

Simply Supported Hollow Reinforced Concrete Slabs—*Continued.*

$t = 18000,\ c = 850,\ m = 15,\ q = 85$ lb./sq. in.

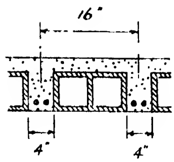
The self-weight has been deducted. For notes on n and z see page 89. Column 3 gives the number and diameter of bars in each rib.

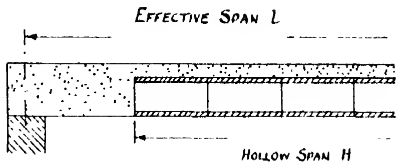
TABLE 86—*Continued.*

(ii) 4 in. RIBS, 2 in. TOPPING :— SAFE DISTRIBUTED

n in.	z in.	Reinforcement in each Rib		Effective 8′	8′ 6″	9′	9′ 6″	10′	10′ 6″	11′	11′ 6″
		7″ SLAB									
2·13	·70	2-⅝″	Safe Load	410	356	313	275	243	216	191	170
			Hollow Span	5/11	6/7	7/5	8/4	9/3	10/1		
2·27	·73	1-⅝, 1-¾″	Safe Load			374	331	293	261	232	208
			Hollow Span			6/1	6/9	7/6	8/3	9/2	10/0
2·43	·76	2-¾″	Safe Load				396	353	316	282	254
			Hollow Span				5/9	6/5	7/0	7/9	8/6
		8″ SLAB									
2·35	·75	2-⅝″	Safe Load			372	327	290	259	229	205
			Hollow Span			7/6	8/4	9/3	10/1		
2·53	·78	1-⅝″, 1-¾″	Safe Load			410	362	321	287	255	225
			Hollow Span			6/8	7/5	8/2	9/0	9/11	10/9
2·72	·80	2-¾″	Safe Load				403	358	320	286	257
			Hollow Span				6/8	7/5	8/2	9/0	9/10
		9″ SLAB									
2·59	·78	2-⅝″	Safe Load				383	340	304	270	242
			Hollow Span				8/4	9/3	10/1		
2·79	·81	1-⅝″, 1-¾″	Safe Load				436	387	346	309	278
			Hollow Span				7/3	8/0	8/10	9/8	10/6
3·01	·84	2-¾″	Safe Load							373	335
			Hollow Span							8/3	9/0
		10″ SLAB									
3·01	·84	1-⅝″, 1-¾″	Safe Load							380	342
			Hollow Span							9/2	10/0
3·31	·86	2-¾″	Safe Load								
			Hollow Span								
3·74	·88	4-⅝″	Safe Load								
			Hollow Span								

c = 850
t = 18000





IMPOSED LOADS. Lb. per sq. ft.

Spans												
12′	12′ 6″	13′	13′ 6″	14′	14′ 6″	15′	15′ 6″	16′	16′ 6″	17′	17′ 6″	18′
152	136	121	108	97	87	78						
186	168	151	136	123	111	100						
10/11	11/9	12/9	13/9	14/10	15/10	17/0						
228	206	187	169	153	139	126						
9/3	10/0	10/9	11/9	12/7	13/6	14/6						
183	162	148	132	119	107	96	86	77				
209	184	166	150	135	122	110	100	90				
11/9												
231	207	188	170	153	139	127	115	104				
10/8	11/8	12/6										
217	195	176	158	143	129	116	105	95	86	77		
250	224	203	184	167	151	137	125	113	109	93		
11/6												
313	274	249	226	206	188	172	157	143	131	120		
9/7	10/8	11/6	12/5	13/4	14/4							
309	279	253	229	209	190	173	158	144	132	120	110	100
10/8	11/10	12/9										
374	339	309	281	257	235	215	197	181	167	153	141	129
9/3	10/0	10/10	11/9	12/6	13/6	14/5	15/5					
400	362	331	301	276	252	231	212	196	180	165	153	140
8/4	9/1	9/10	10/7	11/4	12/2	13/1	14/0	14/10	15/10	16/10		

WEIGHT OF ROUND MILD STEEL BARS

TABLE 87

Diameter	Lb. per ft.	Diameter	Lb. per ft.
1/8"	·042	5/8"	1·043
3/16"	·094	3/4"	1·502
1/4"	·167	7/8"	2·044
5/16"	·261	1"	2·670
3/8"	·376	1 1/8"	3·380
7/16"	·511	1 1/4"	4·172
1/2"	·668	1 1/2"	6·008

For small sizes see also S.W.G., Table 20.
For cross-section areas see Circles, Table 184.

WEIGHT OF ROUND MILD STEEL BARS AT DIFFERENT SPACINGS
(one direction only)

TABLE 88. Lb. per sq. yd.

Diam.	Spacing Centre to Centre, in. 3	4	5	6	7	8	9	10	12	15	18	Diam.
1/8"	1·50	1·12	·90	·75	·64	·56	·50	·45	·37	·30	·25	1/8"
3/16"	3·38	2·53	2·03	1·69	1·45	1·27	1·13	1·01	·84	·68	·56	3/16"
1/4"	6·00	4·50	3·61	3·00	2·58	2·25	2·00	1·80	1·50	1·20	1·00	1/4"
5/16"	9·39	7·04	5·63	4·70	4·03	3·52	3·13	2·82	2·34	1·88	1·56	5/16"
3/8"	13·5	10·1	8·11	6·77	5·79	5·07	4·50	4·08	3·38	2·70	2·25	3/8"
7/16"	18·4	13·8	11·0	9·19	7·87	6·89	6·12	5·51	4·59	3·67	3·06	7/16"
1/2"	24·0	18·0	14·4	12·0	10·3	9·01	8·01	7·21	6·01	4·80	4·00	1/2"
5/8"	37·5	28·2	22·5	18·8	16·1	14·1	12·5	11·3	9·39	7·50	6·25	5/8"
3/4"	54·1	40·5	32·4	27·0	23·2	20·3	18·0	16·2	13·5	10·8	9·00	3/4"
7/8"	73·6	55·2	44·2	36·8	31·5	27·6	24·5	22·1	18·4	14·7	12·3	7/8"
1"	96·1	72·1	57·7	48·1	41·2	36·0	32·0	28·8	24·0	19·2	16·0	1"

WORKING STRESSES IN STEEL REINFORCEMENT

(i) Ordinary mild steel.

Bars in tension generally . . . . . 18,000 lb./sq. in.
Tension in column helical reinforcement . . 13,500 ,, ,,
Compression in beams where the resistance of the concrete is not counted . . . . 18,000 ,, ,,

(ii) Cold-worked mild steel (e.g. fabric, etc. of hard-drawn wires, or bars twisted together).

Bars in tension . . . . 25,000 lb./sq. in.

This value is generally accepted for commercial reinforcements falling in this class. *Post-War Building Study No.* 8 recommends a working stress of half the guaranteed yield point with a maximum permitted stress of 25,000 lb. in beams and 27,000 lb. in slabs.

REINFORCED CONCRETE DATA

Symbols :

- A_T Cross-sectional area of tension steel in width b, sq. in.
- a Lever arm, inches.
- b Width, inches.
- c Max. concrete compressive stress, lb./sq. in.
- d Effective depth, i.e. from compression surface to c.g. of tension steel, inches.
- M_R Moment of resistance, inch-lb.
- m Modular ratio $\frac{E_{steel}}{E_{concrete}}$
- n Depth of neutral axis from compression surface, inches.
- t Tensile stress in steel, lb./sq. in.

(I) *Neutral axis within concrete area :—*

$$a = d - \frac{n}{3} \; ; \; p = \frac{100A_T}{bd} \; ; \; n_1 = \frac{n}{d} = \sqrt{(\cdot 01\, mp)^2 + \cdot 02\, mp} - \cdot 01\, mp$$

$$M_R = \tfrac{1}{2}\, c.b.n. \left(d - \frac{n}{3}\right) \text{...failure on concrete.}$$

$$\text{or } t.A_T \left(d - \frac{n}{3}\right) \text{.........failure on steel.}$$

For $m = 15$:

$p\%$	$\frac{n}{d}$
·2	·217
·3	·258
·4	·292
·5	·320
·6	·343
·675	·359
·7	·365
·8	·384
·9	·401
1·0	·417
1·2	·445
1·4	·470
1·6	·492

The effect of increasing m is to increase the depth of neutral axis, therefore to increase the concrete compression area and to reduce the lever arm. The moment of resistance is reduced for failure on steel and increased for failure on concrete, but the effect is small for values of p less than 1%.

(II) *Neutral axis below slab :—*

d_s Thickness of slab, inches.

z Depth from compression surface to c.g. of concrete compression, inches.

$$a = d - z \; ; \; z = \frac{d_s}{3}\left(\frac{3n - 2d_s}{2n - d_s}\right)$$

$$M_R = \frac{bcd_s}{2n}(2n - d_s)(d - z) \text{...failure on concrete}$$

$$\text{or } t.A_T (d - z) \text{...........failure on steel.}$$

Shear

Maximum shear stress in concrete beam or slab $= \frac{S}{ba}$ where S is the total shearing force at section.

CONCENTRATED LOADS ON SLABS
(Slabs reinforced in one direction)

Institution of Structural Engineers Report No. 10 contains rules for dealing with concentrated loads.

If the load is in contact over a rectangular area $g \times h$, g being measured along the span and h transversely :—

(i) The width of slab to be taken as supporting the load is $x + h$ where x is the distance of load from nearest support.

(ii) Provision must also be made for resisting a transverse *BM* in the slab of value $\frac{Wx}{8}$, taken as resisted by a strip of width $g + 2D$, where D is the effective depth of slab plus any solid finish or filling.

When h is small compared with x, the design data may be obtained from the table below for different positions of a concentrated load W lb. on a span l ft.

TABLE 89

Distance of Load W from nearest Support.	In direction of Span		Transversely
	Equivalent Distributed Load lb./sq. ft.	Width of Strip exposed to Loading given in Col. ii	*BM* on strip of width $g + 2D$ lb./ft.
i	ii	iii	iv
$0{\cdot}5\,l$	$\frac{W}{l^2} \times 4{\cdot}0$	$0{\cdot}5\,l$	$Wl \times 0{\cdot}062$
$0{\cdot}4\,l$	$4{\cdot}8$	$0{\cdot}4\,l$	$\cdot 050$
$0{\cdot}3\,l$	$5{\cdot}6$	$0{\cdot}3\,l$	$\cdot 037$
$0{\cdot}2\,l$	$6{\cdot}4$	$0{\cdot}2\,l$	$\cdot 025$

The self-weight of slab and any distributed loading must be added to Column ii. Appropriate allowances may be made for conditions of fixity at the supports.

For the treatment of concentrated loads on slabs which are supported on all four sides, see *Reinforced Concrete Bridges* by W. L. Scott.

SLABS REINFORCED IN BOTH DIRECTIONS
and supported on all four sides

The tables below have been calculated from the regulations given in the *Institution of Structural Engineers Technical Report No. 10*, Part I, for ratios of span, in two directions, up to 1·5 and for any combination of end fixity conditions.

In each case the balance of total load is to be taken in the direction at right angles to that stated in the tables. Total load = self-weight plus imposed load.

TABLE 90. Square Slabs.

End Conditions	Proportion of Total Load
End conditions similar	0·5 on each span
One span fixed both ends, Other span free both ends	0·625 on fixed span
One span fixed both ends, Other span fixed one end	0·556 on fixed span

TABLE 91. Rectangular Slabs.

End Conditions	Proportion of Total Load on Shorter Span — Ratio of Spans									
	1·05	1·10	1·15	1·20	1·25	1·30	1·35	1·40	1·45	1·50
End conditions similar	·548	·594	·636	·675	·709	·741	·769	·794	·815	·835
Short span fixed both ends, Long span free both ends	·669	·709	·745	·776	·803	·827	·847	·865	·880	·894
Short span fixed both ends, Long span fixed one end	·603	·647	·685	·720	·753	·781	·806	·827	·846	·863
Short span free both ends, Long span fixed both ends	·422	·468	·512	·554	·593	·632	·666	·697	·726	·752
Short span fixed one end, Long span fixed both ends	·492	·539	·583	·624	·661	·696	·727	·754	·779	·802

If the above proportions are applied to the imposed load only (i.e. self-weight of slab excluded) the result when used in conjunction with Table 84 will be on the safe side. For greater economy, deduct the proportion of self-weight which is carried in the other direction.

WEIGHTS OF VARIOUS MATERIALS

Table 93 gives the densities in lb./cu. ft. of a variety of materials which enter into construction or may form a structural load, either on a floor slab or in bins.

The designer will generally be able to obtain reliable data from the client on the weight of the material in the actual form in which it is to be stored, but the information is not always available when preliminary designs are being made.

Minimum design loads for floors are laid down in building by-laws, but there is an obligation on the part of architect or engineer to ensure that the strength provided is adequate to support the goods concerned when stacked to the intended height, and in these days of conveyors and mobile cranes storage spaces are likely to be filled to the ceiling.

Materials in Bulk

The figure given for stone, minerals, etc., is the density of the solid material unless otherwise stated ; to obtain the weight in a broken or powdered condition a reduction must be made to allow for the voids.

Granular Materials

Broken material consisting of particles all of about the same size usually contains from 55% to 60% of voids, i.e., it will weigh from 0·4 to 0·45 of the solid weight. Material graded from $\frac{1}{4}$ in. to $\frac{3}{4}$ in. will contain from 40% to 45% voids, while a mixture of all sizes including sand or similar particles may have as little as 25% voids.

Fine Granular Materials

Materials of grain size equivalent to sand are markedly affected by the presence of moisture. Thus if a cubic foot of dry sand is mixed with 1% of its weight of water and then refilled into a measure it will be found to occupy appreciably more than a cubic foot. The effect, called " bulking," increases with further additions of water and in the case of loosely gauged sand usually attains a maximum with 4% to 5% of water, when the volume will be from 30% to 35% more than that of the dry sand. When further additions of water are made the volume begins to decrease, and when saturated the sand will again occupy its original volume. Changes of water content of sand are not accompanied by volume changes if the material remains undisturbed.

Powders

The proportion of voids in fine powders is affected by air cushioning and is usually greater than in coarse materials. Thus, the density of Portland cement particles is about 190 lb./cu. ft., but cement as loosely gauged weighs only some 80 lb./cu. ft., so that it contains 58% of voids, although graded. By applying pressure or tamping the density can be increased to 110 lb. or more, a much greater increase than is possible with coarse material.

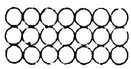
Timber

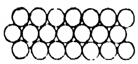
The weights of timber are given for 15% moisture content, that is, average apparently dry condition ; see notes on page 19.

Materials in Containers

The effective weights of many substances normally stored in containers are given direct in the table ; in other cases a suitable factor may be applied to the bulk density tabulated without serious inaccuracy.

TABLE 92


A


B

Condition of Storage	Multiply Bulk Density by
i Cylindrical drums stored on end, or rolled on separating battens, as in A	·70
ii Cylindrical drums stored as in B	·81
iii Cylindrical cans in wooden cases	·74
iv Barrels or casks arranged as in A	·60
v ,, ,, ,, ,, B	·70
vi Bags piled in mounds, lump material	·85
vii ,, ,, ,, granular material	·95

The bulk density must of course be the value for the actual form of the material, that is, in lumps, granular or powdered.

WEIGHTS OF MATERIALS, TABLE 93

The density given is in lb./cu. ft. for both solids and liquids. See the preceding notes on different types of material and the effect of containers.

When information appears elsewhere in the book, a page reference is given immediately after the name of the material.

TABLE 93. Weights of Materials

Material	lb./cu.ft.	Material	lb./cu.ft
ACACIA	46	ANDALUSITE	190–205
ACANTHITE	450	ANDESITE	166
ACETALDEHYDE	50	ANDRADITE	240
ACETIC ACID	66	ANGLESITE	395
ACETONE	51	ANILINE	64
ACIDS, carboys, cased	24	ANIMAL FOOD, cased	25
ACTINOLITE	193	— GUTS, casks	45
ADAMANTINE CLINKERS		ANISEED, bags	20
stacked	130	ANISEED OIL	61
AEROCRETE p. 37		ANORTHITE	172
AGAR-AGAR	45	ANTHOPHYLLITE	195
AGATE	161	ANTHRACITE, broken	54
AJOWAN OIL	57	ANTIMONY, pure	417
ALABASTER	168	ore, bags	90
ALBITE	165	APATITE	200
ALCOHOL, ABSOLUTE	49	APPLES, barrels	25
Commercial	51	APRICOTS, preserved, cases	40
,, proof spirit	57	ARACHIS OIL	57
ETHYL–	49	ARECA NUTS, bags	37
METHYL–	49	ARGENTITE	450
WOOD–, barrels	28	ARNICA	56
ALDEHYDE	50	ARROWROOT, bags	43
ALE. See BEER		boxes	32
ALLUVIUM, undisturbed	100	ARSENIC, comml., cases	100
ALMANDITE	260	ARSENO-PYRITES	380
ALMOND OIL, sweet	57	ARTICHOKES	35
bitter	66	ASBESTOS, crude	56
ALMONDS, hogsheads	20	fibre, cases	42
ALPAX cast	164	natural	190
ALUM	106	pressed	60
casks	40	— CEMENT pp. 4, 6, 67	120–130
pulverised	68	— SAND	60
ALUMINIUM cast	159	— SLATES p. 8	
rolled	167	ASH, English	43
ingots	64	Canadian	46
— BRONZE	471	ASHES, dry	40
— manufactured, cases	20	ASPHALT, natural	63
— DTD alloys	167–174	paving	130
— PAINT	75	ASSAFOETIDA, cases	56
— PASTE	92	ATACAMITE	235
— POWDER	45–50	AUTOMATIC MACHINES, cases	10
— SHEET, weight p. 13		AUTOMOBILES, cases	8
— SULPHATE, bags	45	AVIATION SPIRIT	47
ALUNDUM	250	AXLES and WHEELS	32
AMATOL	87, 97	AZURITE	238
AMMONIA liq. fort.	55		
AMMUNITION, S/A, cases	90		
AMOSITE	140		
AMPHIBOLITE	188	BABBITT'S METAL	460
AMYL ACETATE	55	BACON, barrels	34
ANALCITE	141	BAGGAGE	8
ANCASTER stone	156	BAKELITE	80–120

Table 93—*Continued.*

Material	lb./cu. ft	Material	lb./cu. ft.
BALLAST p. 166		BITUMEN, natural	68
BALSA WOOD	7	prepared	85
BALSAM, Copaiba	60	— EMULSION	70
Peru	71	BLACK POWDER	64
BAMBOO	22	cases	28
BARBED WIRE	24	BLACKWOOD, bags	35
BARIUM OXIDE, solid	290–340	BLANKETS, bales	20
BARK, coppice, bags	22	BLASTFURNACE OIL	57
oak, ,,	41	BLASTING GELATINE	100
BARLEY grain	44	BLEACH, barrels	32
bags	37	solution	72
ground	33	BLEACHING POWDER. See Bleach.	
BARRELS, empty	8		
BARS, steel, bundled	170	BLOOD	66
BARYTES	260–290	dried, casks	35
broken	180	BLUE GUM	68
BASALT	180	BLUE VITRIOL, powdered	84
BASIC SLAG, crushed	112	BOILED OIL	59
BASSWOOD	26	BOLTS and NUTS, bags	75
BATH STONE	130	Whitworth p. 200	
BATHS, iron, cases	13	BONE	110–125
BATTERIUM	478	— FAT	56
BAUXITE	160	— MANURE, bags	32
crushed	80	— MEAL, bags	50
ore, bags	75	— OIL	59
BAY OIL	61	BONES, loose	72
BEAN MEAL	39	calcined, crushed	23
BEANS, Broad	28	BOOKS, on shelves	40
French, Kidney	31	bulk	60
Haricot	36	BOOTS and SHOES, cases	24
— CANNED	43	BORACIC ACID, bags	50
BEECH	48	casks	35
BEEF, dressed, cases	20	BORATE OF LIME	43
tierces	43	BORAX	106
BEER	64	BORIC. See BORACIC.	
bottled, cases	28	BORNITE	320
barrels	33	BOTTLED GOODS, cases	56
BEESWAX	60	BOTTLES, empty, crates	26
BEET, bags	20	BOURNONITE	360
BELL METAL	530	BOX WOOD	58
BELTING, hair, bales	30	BRAN	13
leather, cases	34	BRANDY	52
BEN OIL	57	bottles, cases	37
BENTONITE	133	casks	28
BENZENE	55	BRASS, cast	520
BENZOL	55	rolled p. 13	535
BERYL	170	perforated sheets, casks	45
BERYLLIUM BRONZE	512	tubes, bundles	56
BICYCLES, crates	8	BRAUNITE	300
BIOTITE	180	BRAZIL NUT OIL	57
BIRCH, American	40	BRAZIL NUTS, barrels	25
logs	28	BREAD, cased	14
squares	39	BREEZE CONCRETE p. 37	
yellow	44	BREWER'S GRAINS, wet	31
BIRMABRIGHT	167	desiccated	16
BIRMASIL	167	BRICKS, old, stacked	100
BISCUITS, cases	14	BRICKWORK p. 53	
BISMITE	270	BRINE, common salt, comml.	75
BISMUTH	610	calcium chloride	73–78
BISMUTHIMITE	400	BRITANNIA METAL goods, cases	32
BISMUTITE	460	BRITISH COLUMBIA PINE	33

Table 93—*Continued.*

Material	lb./cu. ft.	Material	lb./cu.ft.
BROCHANTITE	245	CARPETS, rolls	16
BRONZE, cast	520	CARROTS, bulk	30
drawn, sheet	549	CASEIN	84
— ALUMINIUM-	471	CASHEW NUTS, bags	30
BERYLLIUM-	512	CASKS, empty	8
DELTA-	537	CASSIA, bundles	17
MANGANESE-	537	— OIL	66
PHOSPHOR-, cast	540	CASSITERITE	400–440
BROOKITE	240–260	CASTANHA OIL	57
BROOMS, cases	9	CASTINGS, cases	30–60
BRUCITE	145	CASTOR OIL	60
BULBS, planting, cases	70	CASTORS, casks	64
BUTTER	59	CAUSTIC SODA, drums	74
cases	32	lye (max.)	94
tubs	30	CEDAR, WESTERN RED	24
BUTYL ACETATE	55	CEDARWOOD OIL	59
		CELERY OIL	55
		— SEED, bags	30
		CELLOMOLD	78–85
CADE OIL	61–66	CELLULOID	84–100
CADMIUM	538	— GOODS, cases	10
CALAMINE	220	CELLULOSE ACETATE p. 223	
CALAVERITE	565	— NITRATE p. 223	
CALCITE	170	CEMENT, bags	80
CALCIUM CARBIDE, solid	138	bulk	80–90
drums	50	casks	60
CARBONATE.		drums	80
See Lime, Marble.		Roman	62
CHLORIDE, solid	138	— SLURRY	90
drums	45	CERALUMIN "C"	170
brine	73–78	CERARGYRITE	350
PHOSPHATE, bags	53	CERESINE	58
CAMPHOR	62	CERUSSITE	405
cases	33	CERVANTITE	260–330
— OIL	54–62	CHAINS	160
CAMWOOD	28	CHALCANTHITE	140
CANARY SEED, bags	37	CHALCEDONY	165
CANDIED FRUIT, cases	28	CHALCOCITE	340–360
CANDLENUT OIL	58	CHALCOPYRITES	260
CANDLES, cases	32	CHALK	100–170
CANES, bundles	15	broken, barrels	60
CANNED GOODS, cases	30	CHARCOAL	20–35
CANTON MATTING, rolls	14	CHEESE, cases	32
CANVAS, bales	48	CHERRY WOOD	45
CAPERS, kegs	32	CHERT	160
CARAMEL LIQ., casks	45	CHESTNUT, Horse	32
CARAWAY OIL	57	Sweet	35
— SEEDS, bags	37	CHICORY, dried roots	22
CARBOLIC ACID, comml.	67	raw roots	30
CARBON, GAS-	120	ground	30
graphite	140	CHILLIES, bags	15
— DISULPHIDE	101	CHINA GRASS, bales	17
— TETRACHLORIDE	99	— ROOT, bags	24
CARBONATE OF LIME, barrels	80	— WARE, cases	26–40
— MAGNESIA, bags	11	CHLORIDE OF LIME, leadlined	
— SODA, solution	72	cases	28
CARBORUNDUM	195	CHLORITE	170
CARDAMOM OIL	58	CHLOROFORM	92
CARDBOARD	30	CHOCOLATE, cases	34
CARPET SWEEPERS, cases	10	CHOW CHOW, cases	37

Table 93—*Continued.*

Material	lb./cu. ft.
CHRISTOBALITE	145
CHROMADOR	489
CHROMITE	270–290
CHROMIUM	443
CHRYSOCOLLA	130
CHRYSOLITE	210
CHRYSOTILE	140
CIDER	64
casks	35
CIGARETTES, cases	15
CIGARS, cased	12
CIMENT FONDU, bags	80
CINCHONA, bales	15
CINDERS	40
CINNABAR	510
— ORE, bags	75
CINNAMON, bales	16
— OIL	65
CISTERNS p. 191	
CITRONELLA OIL	56
CLAY p. 166	
CLINKER, FURNACE	64
CLOTH, AMERICAN, rolls	30
— GOODS, cases	25
— LEATHER, rolls	30
CLOVER SEED, bags	50
CLOVES, bales	20
— OIL OF	67
COACHSCREWS, bags	90
COAL, loose lumps	56
slurry	62
COBALT	536
COBALTITE	375–390
COCA, bags	9
COCHINEAL, tinlined cases	25
COCOA, bags or bulk	30
tins in cases	17
— BEANS	
— BUTTER	60
COCONUT FIBRE, bales	20
— OIL	58
COCOONS, boxes	11
CODLIVER OIL	58
COFFEE, bags	28–32
— BEANS	40
COIR FIBRE, bales	20
— YARN, ,,	33
COKE	30–35
COLEMANITE	150
COLOPHONY. See Resin.	
COLUMBIAN PINE	33
COLZA OIL	57
COMPOSITION PIPE p. 184	
CONCRETE p. 37	
CONDUITS, VITRIFIED	56
COPAL	65
COPPER, cast	547
drawn or sheet p. 13	558
ingots	224
— SULPHATE, crystals	84

Material	lb./cu. ft.
COPPERAS, powdered	70
CORAL, bags or barrels	25
CORD, bales	30
CORK p. 67	8–14
bales	5
CORKBOARD	7–16
CORN, bulk	45
CORNELIAN	163
CORUNDUM	250
COTTON, raw, compressed	25–36
American, pressed bales	17
Duck, pressed bales	36
Egyptian or Indian, pressed bales	33
piece goods, cases	25–30
tickings, bales	37
waste, bales	12
— SEED CAKE, bags	43
— SEED MEAL, ,,	44
— SEED OIL	58
— WOOL, packed	10
COVELLITE	290
CRACKED SPIRIT	47
CREAM	59–63
CREAM OF TARTAR, hogsheads	37
CREOSOTE	66
CRESOL, ORTHO–	64
META–	66
CRESYLIC ACID. See CRESOL	
CROCIDOLITE	205
CROCKERY, crates	26–40
CROCOISITE	375
CRYOLITE	185
CUCUMBER OIL	57
CUPRITE	375
CUPRO-NICKEL (60–80% Cu)	558
CURRANTS, boxes	44
CUSTARD POWDER, cases	45
CUTCH, baskets	33
CUTLERY, cases	37
CYPRESS WOOD	37
DAMMAR GUM, cases	26
DARI	47
DARLEY DALE STONE	148
DATES, cases	56
DEAL, YELLOW	27
DEKALIN	56
DELTA METAL	537
DESICCATED COCONUT, cases	32
DEXONITE	80
DHOLL, bags	45
DIABASE	180
DIAKON	74
DIASPORE	220
DIATOMACEOUS BRICK	30
DIESEL OIL	55

Table 93—*Continued.*

Material	lb./cu. ft.
DIORITE	179
DOLOMITE	180
DOORS, crates	20
DOUGLAS FIR	33
DRIPPING, tins in cases	32
DRUGS, cases	26
DRY GOODS, average	30
DURALUMIN	174
DUTCH CLINKERS, stacked	100
DYES, jars in cases	28
DYNAMITE	77
EARTH p. 166	
EARTHENWARE, packed	20
EBONITE	75–80
EBONY	74–83
ECLOGITE	194
EGGS, crates	22
preserved, jars in cases	65
ELECTRIC CONDUIT	
ELEKTRON	110
ELM, American	42
Canadian	42
Dutch	36
English	36
Wych	43
EMERY	250
EMERY WHEELS, cases	37
ENARGITE	275
EPIDOTE	210
EPSOM SALTS, bulk	42
ERYTHRITE	185
ESSENTIAL OILS, bottles in cases	11
ETHER	46
ETHYL ACETATE	57
ETHYL FLUID	107
ETHYL LACTATE	65
— SILICATE	58
ETHYLENE GLYCOL	70
EUCALYPTUS OILS	53–58
EVERDUR	533
EXTRACT, bottles in cases :	
Malt and Oil	41
Meat or Vegetable	25
bulk Malt and Oil	88
FANCY GOODS, mixed	12
FARINA, bags	42
FATTY ACIDS, barrels	40
FEED GENTON, bags	22
— MARSDEN, ,,	24
FELSPAR	168
FELT, HAIR	17
— ROOFING, rolls	37
FENNEL SEED, bags	24
— — OIL	55–61
FERBERITE	450–470
FERRIC OXIDE, solid	305–330

Material	lb./cu. ft.
FERRO-SILICON	437
FIBRE BOARD	10–25
FIBRE, BRISTLE, bags	28
FIGS, boxes	40
FILBERTS	22
FILES, etc., cases	56
FINNINGS, casks	45
FIR CONES, cases	47
FIR, DOUGLAS	33
— SILVER	30
FIREBRICK, Stourbridge	125
FISH, boxes	45
— MANURE, bags	34
— OIL, casks	39
FLAX, bales	14
— MEAL, bags	28
— SEED ,,	43
— STRAW, bulk	7
— WAX	61
FLINT	160
FLINT-GLASS. See Glass.	
FLOUR	44
sacks	40
barrels	34
FLUID, BRAKE, cartons	35
FLUORITE	200
FLUORSPAR	200
FOREST OF DEAN STONE	152
FORMIC ACID, pure	76
FRANKINCENSE OIL	55
FRANKLINITE	320
FREESTONE	140–155
masonry, dressed	150
rubble	140
FRUIT JUICES, bulk	65
FRUIT, DRIED, cases	60
— STONE–, boxes	44
FULLER'S EARTH, natural	110–150
FUR CLIPPINGS, bales	10
FURFURAL	72
FURS, cases or bundles	17
FUSEL OIL	52
FUSTIC	19
GABBRO	185
GALENA	470
GALILITH	84
GALL NUTS, bags	50
GALVANISED SHEETS, bundles	56
GAMBIER, bags	22
GAMBOGE	76
cases	33
GARNET	240
GARNIERITE	140–175
GAS OIL	53
GAULTHERIA OIL	74
GELATINE	79
— BLASTING	100

Table 93—*Continued.*

Material	lb./cu. ft.	Material	lb./cu. ft.
GELIGNITE	100	GUANO	30–55
GENTIAN ROOT, bales	17	GUM, cased	26
GIBBSITE	150	GUM ARABIC	90
GILSONITE	68	GUM, BLUE	68
GINGER, cases	28	— RED	56
GIRDERS, STEEL, nested	140–200	GUNMETAL, cast	528
GLASS, Bottle	170	rolled p. 13	549
Common green	157	GUNNIE, bags	39
Crown, extra white	153	GUNPOWDER	56
silicate	137	GURJUN	46
Flint, best	192	GUTTA PERCHA	60
heavy	310–370	GYPKLITH	28
Optical	220	GYPSUM, crushed	65–100
Plate p. 4	174	solid	160
crates	50	bags	52
Pyrex	140	— PLASTER	46
— BOTTLES, crates	26		
— REFUSE (broken)	95		
— SILK	10–13		
GLASSPAPER, cases	40	HADDOCKS, cases	25
GLASSWARE, cases	11	HAEMATITE, crushed	150
GLAUBERITE	170	solid	300–330
GLUCOSE liq. (43° Beaumé)	89	HAIR, HORSE, pressed in bales	14
barrels	50	— PLASTERER'S	11
GLUE, casks	22	HALIBUT LIVER OIL	58
GLUTEN MEAL	37	HALITE	155
GLYCERINE (GLYCEROL)	79	HALLOYSITE	130
drums	50	HAM HILL STONE	135
GLYCOL	70	HAMS, barrels	34
GNEISS	172	HARDCORE	120
GOLD	1206	HARDWARE, DOMESTIC (not	
GOMA LACA	56	hollow-ware), crates	20
GOOSEBERRIES, cases	57	HAUSMANNITE	295
GOURD OIL	57	HAVEG	125
GRAIN, Barley	39	HAY, chaffed	6
Beans	51	pressed	12
Brewer's dried, bags	25	stacked	8
Buckwheat	36	HEMLOCK, WESTERN	31
Clover	37	HEMP, bales	20–30
Linseed	40	— OIL	58
Oats	26	HERRING OIL	58
Rye	45	HERRINGS, Fresh, barrels	37
GRAMOPHONES, cases	10	Salted, ,,	50
— RECORDS	50	HESSIAN, bales	22
GRANITE	165	HESSITE	520
chippings	90	HICKORY	51
dressed, cases	140	HIDES, dry, bales	28
GRANOLITHIC p. 67	140	salted, bales	40
GRAPESEED OIL	58	HIDUMINIUM	175
GRAPHITE	140	HOGGIN	110
GRAVEL p. 166		HOLLOW-WARE, Domestic,	
GREASE, tierces	34	cases	12
GREEN VITRIOL, powdered	70	HONE, Razor	180
GREENHEART, Demerara	62–70	HONEY	90
Burma	48	HOPS, pressed bales	26
GRINDSTONE	133	HORNBEAM	44
GROCERIES. See separate items		HORNBLENDE	200–220
GROSSULARITE	220	HORNS, Animal, loose	24
GROUND NUT OIL	57	HORSEHAIR, pressed bales	14
GROUND NUTS, bags	39	HOSIERY, cased	14

Table 93—*Continued.*

Material	lb./cu. ft.
HÜBNERITE	425
HYDRALIME, bags	38
HYDROCHLORIC ACID, conc.	76
HYDROZINCITE	230
HYPERSTHENE	215
ICE	57
ILMENITE	280–310
IMPLEMENTS, Agricultural, bundles	16
IMPROVED WOOD p. 223	
INCONEL	533
INDIARUBBER	70
INDIGO	63
cased	36
INK, PRINTERS', barrels	50
IRIDIUM	1400
IRIDOSMINE	12–1300
IROKO	41
IRON, cast	450
malleable cast	460–468
wrought p. 14	480
— CORRUGATED, bundles	56
— PIG, random	170
stacked	280
— PIPES. See PIPES.	
— PYRITES, ground	180
solid (60% Fe)	300–320
— SULPHATE, powdered	70
— WIRE, coils	56
IRONSTONE, CLEVELAND, lumps	135
— SPANISH ,,	150
— SWEDISH ,,	230
IRONMONGERY, packages	56
IRONWOOD	71
ISINGLASS	69
packed	25
IVORINE	84
IVORY	115
loose	80
IZAL, drums	45
JAGGERY, bags	56
JAM, bottles in cases	36
JARRAH	56
JELLIES, cased	30
JET	80
JICWOOD p. 223	
JOINTING COMPO. for tanks	50
JOISTS, STEEL, nested	140–200
JUNIPER BERRIES, bags	28
— TAR OIL	61–66
JUTE, bales	30
,, compressed	40

Material	lb./cu. ft.
KAINITE, natural	130
ground	60
KAOLIN	140
KAOLINITE	165
KAPOK, pressed bales	12
KARRI	59
KAURI, New Zealand	38
Queensland	30
KAURI GUM	66
KENTISH RAG	167
— crushed	100
KERNELS, cases	47
KEROSENE	50
KIESELGUHR, insulation	30
KUPFERNICKEL	450–475
KUPLUS	490
LACQUER, tins in cases	37
LAMPBLACK, bags	16
hogsheads	20
LAMPS, ELECTRIC, cartons	5
LARCH	37
LARD	58
cases	37
— OIL	57
LAVENDER OIL	57
LEAD, cast or rolled p. 13	707
pigs	224
— BRONZE (Cu 70 Pb 30)	610
— RED, powder	130
— WHITE, powder	86
paste in drums	174
LEATHER	60
bales or bundles	20
hides, compressed	23
rolls	10
scrap, bales	12
LEATHEROID, cases	34
LEMON PEEL, casks	35
LEMONS, boxes	26
LENTILS, bulk	49
LEUCITE	160
LEWIS BOLTS p. 201	
LIGNUM VITÆ	75–83
LIME, ACETATE OF, bags	80
— BLUE LIAS, ground	53
lump	62
— CARBONATE OF, barrels	80
— CHLORIDE OF, lead lined cases	28
— GREY CHALK, lump	44
— GREY STONE, lump	55
— HYDRATE, bags	32
— — HYDRAULIC	45
— QUICK–, ground	64
— SLAKED, ground, dry	35
,, wet	95
LIME MORTAR, dry	103

Table 93—*Continued.*

Material	lb./cu. ft.	Material	lb./cu. ft.
LIME MORTAR—*continued*		MANGOLDS	35
wet	109	MANILA, bales	26
LIME WOOD	35	— ROPE, coils	32
American	26	MAPLE, Canadian	46
LIMES, OIL OF	55	English	43
LIMESTONE p. 64		MARBLE	162–177
LIMONITE	230–260	MARCASITE	310
LINEN, Damask, bales	50	MARGARINE	57
Goods, cases	35	tubs	32
LINNÆITE	310	MARJORAM OIL	57
LINOLEUM, rolls	30	MARL p. 166	
LINSEED CAKE, broken	33	MASONITE	35
— GRAIN	44	MASONRY p. 64	
— OIL, boiled	59	MASTIC	70
raw	58	MATCHES, cases	20
refined	58	MATS and MATTING, rolls	11–14
LIQUORICE, cases	26	MATTRESSES, WIRE, bundles	8
LITHARGE, dry	130	MEAL, BEAN	39
LITHOPHONE, solid	270	— COTTON CAKE	40
LLOYD BOARD, hard	35	— GLUTEN	37
insulating	17	— OAT, bags	34
LOAM p. 166		— RYE	25
LOCKNUTS, Whitworth p. 200		— WHEAT	42
LOCUST BEANS	47	MELACONITE	370
LOESS	90	MELONS, boxes	28
LOGWOOD	57	MERANTI	35
LUBRICATING OIL	57	MERCURY	845
		METERS, GAS, cases	28
		METAL, ANTIFRICTION, cases	75
		METHYL ACETATE	58
MACADAM	130	— METHACRYLATE p. 223	
MACASSAR OIL	54	METHYLATED SPIRIT	52
MACE, cases	28	MEXICAN POPPY OIL	57
MACE OIL	58	MICA	170–190
MACHINERY, AGRICULTURAL, cases	28	bags	32
		scrap	20
MAGNALIUM	120	MICANITE	130
MAGNESIA, solid	150	MIDDLINGS	25
MAGNESITE	190	MILK	64
MAGNESIUM	108	condensed, cases	38
— ALLOYS, about	115	malted, powder	23
MAGNETIC OXIDE OF IRON	310	powdered	34
MAGNETITE	310	,, tins in cases	19
MAHOGANY, African	35	skimmed	64½
Honduras	34	MILL BOARD	70
Spanish	43	MILLERITE	340
MAIL, bags	12	MILLET	47
MAIZE, grain	47	MILLSTONE GRIT	145
husked ears	30	MINIUM	570
— OIL	58	MISPICKEL	380
MALACHITE	250	MOHAIR, bags	10
MALT	33	MOLASSES	110
— COOMBS	11	casks	80
— EXTRACT and CODLIVER		MOLYBDENITE	290
OIL	88	MOLYBDENUM	623
bottles in cases	41	MONAZITE	310–330
MANGANESE	460	MONEL	548
— BRONZE	537	MORTAR, CEMENT, set	120–130
MANGANIN	530	— LIME, set	100–110
MANGANITE	270	MOWRAH SEED, bags	37

Table 93—*Continued.*

Material	lb./cu. ft.	Material	lb./cu. ft.
MUD p. 166		ONYX	165
MUNTZ METAL, cast	524	OOLITE	120–160
sheet p. 13	557	OPIUM, chests	23
MURIATE OF LIME, cases	28	ORANGES, cases	25
MURIATIC ACID (HCl) conc.	76	ORE. See individual kinds	
MUSCOVITE	170–190	OREGON PINE	33
MUSIC ROLLS, cases	28	ORPIMENT	220
MYRRH OIL	63	ORRIS ROOT, bags	28
		ORTHOCLASE	160
		OSIERS, bundles	15
		OSMIUM	1400
NAILS, WIRE, bags	75	OXIDE OF IRON, casks	45
NAPHTHA, Heavy	59	OYSTERS, barrels	37
White	55	OYSTER SHELL, solid	130
NAPHTHALENE	71	OZOKERITE WAX	53–58
NEATS FOOT OIL	57		
NEOPRENE	75		
NEPHELITE	60		
NICCOLITE	460–480	PADAUK	49
NICKEL	550	PAINT, Aluminium	75
— SILVER	545	Bituminous emulsion	70
NITRATE OF SODA	70	Red Lead	195
NITRE, solid	120	Red Lead dispersed	95
NITRIC ACID, 100%	95	White Lead	175
68%	88	Zinc	150
NITROBENZENE	76	PALLADIUM	711
NITROCHALK, bags	40	PALM OIL	58
NUTMEGS, cases	37	PAPER, Blotting, bales	25
NUT OIL	57	Printing, reels	56
NUTS, Whitworth p. 200		Wall, rolls	24
Brazil, casks	25	Writing	60
shelled, cased	28	PARAFFIN OIL	50
Filberts	22	— WAX	56
NUX VOMICA	30	PARSNIPS	31
		PEANUT OIL	57
		PEANUTS, bags	14
		PEARL ALUM, bags	43
OAK, African	60	PEARLASH, pots	45
American red	45	PEARS	57
white	48	PEAS	50
Austrian	45	in pod	35
English	50–55	PEAT p. 166	
OATMEAL, bags	34	PENTANE	39
OATS	33	PENTLANDITE	285–310
bags	27	PEPPER, bags	28
ground	23	PEPPERMINT, cases	32
OCHRE, solid	250	PERFUMERY, cases	28
barrels	45	PERIDOTITE	182
OCTANE	44	PERILLA OIL	58
OILCAKE, bags	41	PERSPEX p. 4	84
OILS. See individual kinds :		PERUVIAN BARK, bales	15
Usually : bulk	57	PETRIFYING LIQUID	58
barrels	37	PETROL	43–48
OLIGOCLASE	166	— cans or drums	45–50
OLIVENITE	270	PETROLEUM	55
OLIVE OIL	57	barrels	35
OLIVES, casks	33	PEWTER	453
OLIVINE	210	PHENOLFORMALDEHYDE p. 223	
ONIONS	50	PHOSPHATES, ground	75
boxes	30	bags	53

Table 93—*Continued.*

Material	lb./cu. ft.	Material	lb./cu. ft.
PHOSPHOR-BRONZE, cast	540	POTATOES	40
drawn	550	barrels	37
PHOSPHORUS, RED, pure	137	PRESSPAHN	78
— YELLOW, pure	114	PRINTING INK, barrels	50
— cases	35	PROOF SPIRIT	57
PICRIC ACID, cast	100	PROUSTITE	350
PINE, American Red	33	PROVISIONS, cases	28
British Columbian	33	PRUNES, DRIED, casks	43
Christiania	43	PSILOMELANE	230–290
Columbian	33	PULP, WOOD, dry	35
Dantzig	36	wet	45
Kauri, Queensland	30	PUMICE STONE	30–57
New Zealand	38	PURBECK STONE	169
Memel	34	PYINKADO	62
Oregon	33	PYRARGYRITE	360
Pitch	41	PYREX	
Riga	34–47	PYRITES, IRON, ground	180
PINE OIL	58	solid (60% Fe)	300–320
Heavy	64	— COPPER, solid	255–270
PINE SEEDS, cases	37	PYROLUSITE	300
PINS, SPLIT, barrels	56	PYROMORPHITE	430
PIPES. See Tables 134 to 149.		PYROPE	230
— BRASS, bundles	56	PYROPHYLLITE	180
— CAST IRON, stacked	60–80	PYROXENE	210
— EARTHENWARE, loose	20	PYRRHOTITE	290
— SALT-GLAZED, stacked	25		
— WROUGHT IRON			
stacked ¾″	200		
3″	90	QUARTZ	165
6″	50	loose	90–105
PISÉ BLOCKWORK	100–120	QUARTZITE	170
PITCH	68	QUEBRACHO	80
barrels	50	QUICKLIME, ground, dry	64
— MINERAL	100	QUILT, Eel grass	11
PLAGIOCLASE	168		
PLANE	40		
PLASTER BOARD p. 68			
PLASTER OF PARIS, loose	58	RABBIT SKINS, bales	16
set	80	RAGBOLTS p. 201	
PLATINUM	1340	RAGS, baled	13
PLUMBAGO	130	RAGSTONE	150
casks	48	RAILS, RAILWAY	150
PLUMS	44	RAISINS, cases	43
PLYWOOD	30–40	RAPE-SEED OIL	57
— PLASTIC-BONDED	45–90	REALGAR	220
POLYBASITE	380	RED FIBRE, Vulcanized	90
POLYSTYRENE p. 223		RED GUM	56
POLYVINYL CHLOR.		RED LEAD powder, dry	132
ACETATE p. 223		REDRUTHITE	340–360
POPLAR	28	REDWOOD, American	33
PORCELAIN	145	Baltic	31
— Electrical	160–220	Non-graded	27
PORK, tierces	34	Rhodesian	57
PORPHYRY	175	RESIN, lumps	67
PORPOISE OIL	58	barrels	48
PORTLAND CEMENT, loose	75–85	— BONDED PLYWOOD	45–85
p. 92 bags	70–80	RESIN OIL	62
drums	75	RHEA FIBRE, bales	37
PORTLAND STONE	140	RHODIUM	777
POTASH	140	RHODOCHROSITE	220

Table 93—*Continued.*

Material	lb./cu. ft.	Material	lb./cu. ft.
RHODONITE	210–230	SEEDS—*continued.*	
RHYOLITE	160	— CLOVER	50–52
RICE, bags	50	— COCKSFOOT	14
polished, bags	36	— CRESTED DOGSTAIL	30
— BRAN, bags	25	— ITALIAN RYE GRASS	12–18
— MEAL, bags	37	— LUCERNE	48
RIPIDOLITE	170	— MEADOW FESCUE	23
ROAD METAL	80–100	— PERENNIAL RYE GRASS	16–22
ROCK. See individual kinds and Table 80.		— RAPE	37
		— ROUGH-STALKED MEADOW	22
ROCK CRYSTAL	170		
— SALT, solid	125	— SAINFOIN, rough	23
broken	60	milled	47
ROOFING MATERIALS		— TALL FESCUE	19
ROPE, bundles	17	— TIMOTHY	37
Manila, coils	32	— TURNIPS	39
Wire, coils	90	— VETCHES	50
ROSIN. See RESIN.		SEMOLINA, bags	37
ROTTEN-STONE	125	SENARMONTITE	330
ROVES, COPPER		SENECA ROOT, bags	18
RUBBER, Crepe, cases	25	SENNA LEAVES, bales	18
Processed sheet	70	SERPENTINE	160
Raw	58	SESAME OIL	58
Sponge–	3–10	SEWING MACHINES, cases	28
Vulcanized	75	SHALE	160
RUM, bottles in cases	34	granulated	70
hogsheads	32	— OIL, Scottish	59
RUTILE	265	SHARK OIL	58
RYE	45	SHEEP CARCASES, frozen	20
— MEAL	25	SHEEPSKINS, pressed	28
		unpressed	15
		SHEET, COTTON, cases	23
		— METALS p. 13	
SADDLERY, cases	28	SHELLAC, solid	68
SAGO, bags	42	flake, cases	20
boxes	40	SHELLS, bags	28
SAL AMMONIAC	90	SHINGLE p. 166	
SALMON, cans in cases	32	SHINGLES p. 10	
SAL SODA, barrels	46	SIDERITE	240
SALT, bulk	60	SILAGE, at top surface	35
bags	45	Add 1 lb./ft. of depth.	
— EPSOM, kegs	41	SILICA, fused transparent	138
— ROCK–, solid	125	translucent	128
broken	60	SILICATE COTTON	14–18
SALT-GLAZED WARE	140	— OF SODA	106
SALTPETRE, barrels	60	barrels	53
SAND pp. 92, 166		SILICON, pure	143
SANDPAPER. See GLASSPAPER		SILK, bales	22
SANDSTONE p. 64		— GLASS-	10–13
SASSAFRAS OIL	68	SILT p. 166	
SATINWOOD	60	SILUMIN	165
SAUCES, bottles in cases	25	SILVER, cast	652
SAWDUST	13	pure	655
SCHEELITE	380	— GLANCE	450
SCHIST	180	SINDANYO	120
SCREWS, IRON, packages	100	SIRAPITE, powder	64
SEA WATER	63–65	SISAL, bales	20
SEAL OIL	58	SIZE	20
SEALSKINS, bales	70	SLAG, coarse	90
SEEDS. See *also* Grain.		granulated	60

Table 93—*Continued.*

Material	lb./cu. ft.	Material	lb./cu. ft.
SLAGWOOL	14–18	STONE	
SLATE, Welsh p. 9	175	— ANCASTER	156
Westmorland	187	— BATH	130
SLATES, cases	93	— CAEN	125
SLUDGE CAKE, pressed, 50%		— DARLEY DALE	148
water	58	— FOREST OF DEAN	152
SMALTITE	410	— FREE-	140–155
SNOW, fresh	6	— GRANITE	165
wet compact	20	— HAM HILL	135
SOAP, boxed	57	— HOPTON WOOD	158
— POWDER, cases	38	— KENTISH RAG	167
— SOFT, cases	44	— LIME–p. 64	
SOAPSTONE	170	— MANSFIELD	141
SODA, bags	41	— MARBLE	170
— ASH, barrels	62	— MILLSTONE GRIT	145
powdered, bulk	62	— PORTLAND	140
— BICARBONATE, casks	39	— PURBECK	169
— CARBONATE OF,		— SAND–p. 64	
solution	72	— SLATE, Welsh	175
— CAUSTIC, drums	74	Westmorland	187
lye (max.)	94	— YORK	140
— NITRATE OF	70	STONEWARE	140
— SILICATE OF	106	STRAW, pressed	6
barrels	53	compressed bales	19
SOFT DRINKS, cases	27	STRAWBOARDS, bundles	37
SOIL p. 166		STRONTIUM WHITE, solid	240
SOLDER, pigs	170	ground	110
SOOT from	22	SUGAR, bags	45–50
SOYA BEAN OIL	58	SULPHATE OF ALUMINIUM,	
— FLOUR	36	bags	45
SPAR, CALCAREOUS	170	— AMMONIA, bags	40
— FELD–	168	— COPPER, cryst.	84
— FLUOR–	200	— IRON, powder	70
SPATHIC ORE	210–240	SULPHUR, pure solid	120–130
SPECULUM METAL	465	sticks in cases	56
SPELTER, loose	170	SULPHURIC ACID, 100%	123
SPERM OIL	55	Commercial	105–112
SPERMACETI	59	jars, cases	25
SPESSARTITE	260	SUNFLOWER OIL	58
SPHALERITE	250	SUPERPHOSPHATE, bags	40
SPIEGELEISEN	460	SWEDES	35
SPINEL	220–250	SYCAMORE	38
SPIRITS OF WINE	49	SYENITE	165–170
SPODUMENE	200	SYLVANITE	490–520
SPONGE, bundles	15	SYRUP up to	83
SPONGE RUBBER	3–10	barrels	45
SPRING WASHERS, cases	40	Golden, cases	55
SPRUCE, Canadian	29		
Norway	29		
Sitka	28		
STANNITE	280	TALC	170
STARCH	59	casks	40
boxes or barrels	28	TALLOW	59
STATIONERY, cases	32	tierces	32
STEATITE	170	— OIL	57
STEEL pp. 4, 12	489	TAMARINDS, cases	48
— BALLS, barrels	75	kegs	41
— PUNCHINGS	300	TAN EXTRACT, casks	47
STEPHANITE	390	TAPIOCA, barrels	39
STIBNITE	290	TAR	71–77

Table 93—*Continued.*

Material	lb./cu. ft.	Material	lb./cu. ft.
TAR—*continued.*		UVAROVITE	220
— barrels	50		
TARES	53		
bags	45		
TARMACADAM	130	VALENTINITE	350
TARPAULINS, bundles	45	VALERIAN, OIL OF	59
TARTAR, casks	37	VANADIUM	374
TEA, chests	22	VAPOURISING OIL	51
TEAK, Burma, African	41	VARNISH, barrels	37
TENNANTITE	280	tins in cases	45
TENORITE	360–390	VEGETABLES. *See* individual kinds.	
TERNARY ALLOY LEAD	707		
TERRA ALBA, solid	143	VERDIGRIS, barrels	40
ground	70	VERMICELLI, boxes	20
TERRA COTTA	112	VERMILION, solid	510
TETRACHLORETHANE	100	VETCHES, seed	50
TETRA ETHYL LEAD	100	VINEGAR	64
TETRAHEDRITE	280–320	VITREOSIL	170
TETRALIN	61	VITRIOL, OIL OF, 100%	123
THYME, bales	16	Commercial	105–112
TILES, bulk	47	— BLUE, powder	84
TIMBERS. *See* individual kinds and Table 27.		— GREEN, powder	70
TIN	454		
TINFOIL, cases	56		
TINNED GOODS, cases	30–40	WAD	190–260
TINPLATE, boxes	200–280	WALNUT	41
TINSTONE	400–440	— OIL	58
TINWARE, cases	12	WASHERS, Flat, bags	90
TITANITE	220	Spring, cases	40
TITANIUM	280	WASTE PAPER	22
— OXIDE, solid	230	pressed packed	28–32
TOBACCO, packets	18	WATER, Fresh	62·3
pressed leaf	28	Salt	63–75
TOLUENE (TOLUOL)	54	WATERGLASS	106
TOMATO PASTE, casks	37	barrels	53
TOOLS, HAND, cases	56	WAX, Bees	60
TOWELS, cases	40	Brazil	62
TOYS, cases	8	cases or barrels	37
TRACHYTE	170	Paraffin	56
TRAIN OIL	47	WHALE OIL	58
TRAP	170	WHEAT	49
TREACLE	110	bags	39
TREETEX	13	— MEAL	42
TREMOLITE	190	WHISKY	
TROLITOL p. 223	66	bottles in cases	37
TUBES. *See* PIPES.		casks	28
TUFNOL p. 223	85	WHITE LEAD, powder	86
TUNG OIL	59	paste in drums	174
TUNGUM	533	paint	175
TUNGSTEN	1200	— METAL	460
TURNIPS	33	WHITENING (WHITING), casks	56
— SEED	39	WHITEWOOD	29
TURPENTINE	54	WILLOW, American	36
barrels	37	English	28
TYPE METAL, varies	650	WILMIL	170
TYRES, rubber	11–16	WINE, bulk	61
		bottles in cases	37
		casks	28
UNIONMELT POWDER	97	WINTERGREEN, OIL OF	74

Table 93—*Continued.*

Material	lb./cu. ft.	Material	lb./cu. ft.
WILLEMITE	250	XYLONITE	84
WIRE p. 13			
Iron, coils	74		
Nails, bags	75		
Rod, coils	50	Y ALLOY	174
Rope, coils	90	YARN, bales	25
WITHERITE	270	YELLOW METAL, sheets or bars	
WOLFRAM (WOLFRAMITE)	460	packed	56
WOLLASTONITE	175	YEW	42–50
WOOD BLOCK PAVING p. 67	56	YORK STONE	140
WOOD WASTE, pressed bales	30		
WOOL, compressed bales	48		
piece goods, cases	27		
uncompressed	13	ZINC, cast	427
WORSTEDS, piece goods, cases	27	rolled	449
WULFENITE	430	sheets packed pp. 4, 13	56
		ZINCBLENDE	255
		ZINCITE	330–360
XYLENE (XYLOL)	54	ZIRCON	290

BEAMS

TABLES 94—124

BEAMS

SUPERIMPOSED LOADING ON BEAMS

See loading regulations on slabs. The following table gives the *L.C.C.* requirements for beams and references to the *Institution of Structural Engineers Report No.* 8. Every beam must be capable of supporting the load given in the 4th column, uniformly distributed along its length but not acting with the floor load. For timber joists see Tables 115–124.

TABLE 94

Class	Type of Building or Floor	Lb./sq. ft. of Floor Area	Uniform Load
1	Rooms used for residential purposes ; and corridors, stairs and landings within the curtilage of a flat or residence	40	1 ton
★	Bedrooms, dormitories and wards in hotels, hospitals, infirmaries, workhouses and sanatoria. For public corridors spaces and stairs see below	As Class 1	1 ton
2	Offices, floors above entrance floor	50	2 ton
★	Restaurants, cafés, theatres, cinemas ; concert and assembly halls with permanent seating accommodation ; churches ; classrooms and lecture rooms in schools ; reading and writing rooms in libraries, clubs and hotels ; art galleries, showrooms	70	2 ton
3	Offices, entrance floor and floors below ; retail shops ; garages for cars not over 2¼ tons weight	80	2 ton
4	Corridors, stairs and landings not provided for in Class 1 (Report No. 8 gives 80 lb. for corridors to offices on entrance floor and floors below, and 50 lb. on floors above.)	Not less than 100	2 ton
★	Assembly, auction and concert halls without permanent seating accommodation ; dance and drill halls ; grandstands, gymnasia, light workshops	As Class 4	2 ton
5	Workshops and factories ; and garages for motor vehicles other than those in Class 3	Not less than 120	See footnotes
★	Storage rooms, retail shops, bookshops and libraries where the average load does not exceed 120 lb./sq. ft. (The L.C.C. require 200 lb. in warehouses and libraries.)	As Class 5	2 ton
6	Warehouses, bookstores, stationery stores and the like	Not less than 200	2 ton
★	Pavements surrounding buildings but not adjoining a roadway	As Class 6	2 ton
	Report No. 8 requires corridors and stairs in Class 6 to be designed for 200 lb. loading ; and requires the loading on retail shops (see Class 3) to be ascertained and the floor placed in Class 4 or 5 if necessary. B.S. 449 is substantially in agreement with the above provisions.		

*** These cases are not specifically covered by the *L.C.C.* by-laws, but District Surveyors and local authorities will normally accept the class loading stated.**

The actual loading on floors in Classes 4 to 6 is to be ascertained, and is not to be taken as less than the above figures.

Class 5. The uniform load stipulated is 2 tons for workshops and factories ; for garages a loading equal to 1·5 times the maximum possible combination of wheel loads shall be taken. *Report No.* 8 gives a more elaborate regulation for garages.

BENDING FORMULÆ

For reinforced concrete see page 89.
For timber see page 161.

Symbols :—

- *A* Cross-sectional area of member, sq. in.
- *b* Breadth of member, in.
- *d* Depth of member, in.
- *E* Young's Modulus, tons/sq. in.
- *f* Fibre stress, tons/sq. in.
- *I* Moment of Inertia, in.^{4}
- *k* Radius of gyration, in.
- *l* Span, in.
- *z* Section Modulus, in.^{3}
- *M* Bending moment, inch-tons.
- *q* Shear stress, tons/sq. in.
- *R* Radius of curvature, in.
- *S* Total shearing force at section.
- *W* Total load distributed along the span, tons.
- *y* Dist. from neutral axis to extreme fibres, in.

$$\frac{f}{y} = \frac{M}{I} = \frac{E}{R}\,; \quad M = \frac{fI}{y} = fz\,; \quad z = \frac{I}{y}\,; \quad I = Ak^2$$

For rectangular sections, $I = \dfrac{bd^3}{12}\,; \quad z = \dfrac{bd^2}{6}\,; \quad q_{max} = 1{\cdot}5\dfrac{S}{bd}$

TABLE 95

Deflections of Beams (in inches)

Type of Beam	Distributed Load W	Central Load W
Simply supported	$\frac{5}{384} \cdot \frac{Wl^3}{EI}$	$\frac{1}{48} \cdot \frac{Wl^3}{EI}$
Fixed both ends	$\frac{1}{384} \cdot \frac{Wl^3}{EI}$	$\frac{1}{192} \cdot \frac{Wl^3}{EI}$
One end fixed, the other simply supported	$\frac{1}{185} \cdot \frac{Wl^3}{EI}$	$\frac{2}{215} \cdot \frac{Wl^3}{EI}$
Cantilever	$\frac{1}{8} \cdot \frac{Wl^3}{EI}$	Load W at end : $\frac{1}{3} \cdot \frac{Wl^3}{EI}$

Combined Bending and Direct Stress

P Direct load acting at distance e from *c.g.*

$$f \text{ Max. fibre stress} = \frac{P}{A} + \frac{Pey}{Ak^2}$$

$$= \frac{P}{A} + \frac{Pey}{I}$$

$$= \frac{P}{A} + \frac{Pe}{z} \text{ for symmetrical section.}$$

BENDING MOMENTS IN CONTINUOUS BEAMS

Approximate positive and negative design BM's in beams subjected to uniformly distributed loads may be obtained from the next table which is derived from data in the *Institution of Structural Engineers Report No.* 10. These values make allowance for unloaded spans.

More exact calculations are to be made unless the following conditions are fulfilled :—

The ratio of adjacent beam lengths shall not exceed 1·20.
The ratio of imposed to dead load shall not exceed 2.

w = imposed plus dead load, in lb. per foot run.
For support moments, l = mean of the effective spans adjacent to the support, in feet.
For mid-span moments, l = effective length of span concerned, in feet.

TABLE 96. Bending Moments, lb. feet.

Beams continuous over	EACH SPAN			
	Positive near Centre		Negative at Support	
TWO SPANS	$\frac{wl^2}{10.7}$ $\left(\frac{wl^2}{10}\right)$		$\frac{wl^2}{8}$	
	INTERIOR SPANS		END SPANS	
	Pos. near centre	Neg. at support	Pos. near centre	Neg. at support
THREE SPANS	$\frac{wl^2}{13.3}$ $\left(\frac{wl^2}{12}\right)$	$\frac{wl^2}{10}$	$\frac{wl^2}{10}$	
FOUR SPANS	$\frac{wl^2}{12.6}$ $\left(\frac{wl^2}{12}\right)$		$\frac{wl^2}{10}$	
Centre support		$\frac{wl^2}{12}$		
Support next to end support				$\frac{wl^2}{10}$
FIVE or more SPANS				
End span			$\frac{wl^2}{10}$	$\frac{wl^2}{10}$
Span next to end span	$\frac{wl^2}{12.6}$ $\left(\frac{wl^2}{12}\right)$	$\frac{wl^2}{12}$		
Other spans	$\frac{wl^2}{12}$	$\frac{wl^2}{12}$		

L.C.C. values are given in brackets where they differ from *Report No.* 10.

The by-law constants on the previous page are adequate to cover the worst possible incidence of loading which, according to the position considered, will be either when two adjacent spans are loaded and all others unloaded, or when alternate spans are loaded and the others unloaded.

The total load, i.e. self-weight plus imposed load, used in conjunction with the constants gives results on the safe side since the self-weight cannot be arranged in the manner stated above. It is sometimes worth while to separate the effects of dead and imposed loading, and for this purpose the two following tables derived from data in *Report No.* 10 are convenient. The ratio of adjoining span lengths must not exceed 1·20.

w = uniformly distributed dead load, in lb./ft.
w_1 = uniformly distributed imposed load, in lb./ft.
W = concentrated dead load at each point named, in lb.
W_1 = concentrated imposed load at the same points, in lb.

TABLE 97. TWO SPANS (End Supports Free)

Bending Moments in lb. ft.

Nature and Position of Load	Each Span			
	Positive near Centre		Neg. at Internal Support	
	Dead Load	Imposed Load	Dead Load	Imposed Load
Uniformly distributed	$\frac{wl^2}{14 \cdot 25}$	$\frac{w_1l^2}{10}$	$\frac{wl^2}{8}$	$\frac{w_1l^2}{8}$
Concentrated loads at middle points	$\frac{Wl}{6 \cdot 25}$	$\frac{W_1l}{5}$	$\frac{Wl}{5 \cdot 25}$	$\frac{W_1l}{5 \cdot 25}$
Concentrated loads at third points	$\frac{Wl}{4 \cdot 5}$	$\frac{W_1l}{3 \cdot 5}$	$\frac{Wl}{3}$	$\frac{W_1l}{3}$
Concentrated loads at middle and quarter points	$\frac{Wl}{3 \cdot 75}$	$\frac{W_1l}{2 \cdot 75}$	$\frac{Wl}{2}$	$\frac{W_1l}{2}$

TABLE 98. THREE OR MORE SPANS (End Supports Free)

Bending Moments in lb. ft.

Nature and Position of Load	Intermediate Spans				End Spans			
	Positive near Centre		Negative at Support		Positive near Centre		Negative at Support	
	Dead Load	Imposed Load	Dead Load	Imposed Load	Dead Load	Imposed Load	Dead Load	Imposed Load
Uniformly distributed	$\frac{wl^2}{24}$	$\frac{w_1l^2}{12}$	$\frac{wl^2}{12}$	$\frac{w_1l^2}{12}$	$\frac{wl^2}{12}$	$\frac{w_1l^2}{10}$	$\frac{wl^2}{10}$	$\frac{w_1l^2}{10}$
Concentrated loads at middle points	$\frac{Wl}{7\cdot5}$	$\frac{W_1l}{5\cdot25}$	$\frac{Wl}{8\cdot25}$	$\frac{W_1l}{6\cdot25}$	$\frac{Wl}{5\cdot75}$	$\frac{W_1l}{4\cdot75}$	$\frac{Wl}{6\cdot25}$	$\frac{W_1l}{5\cdot5}$
Concentrated loads at third points	$\frac{Wl}{8\cdot25}$	$\frac{W_1l}{4\cdot25}$	$\frac{Wl}{4\cdot75}$	$\frac{W_1l}{3\cdot5}$	$\frac{Wl}{4}$	$\frac{W_1l}{3\cdot5}$	$\frac{Wl}{3\cdot5}$	$\frac{W_1l}{3\cdot25}$
Concentrated loads at middle and quarter points	$\frac{Wl}{5\cdot25}$	$\frac{W_1l}{3}$	$\frac{Wl}{3\cdot25}$	$\frac{W_1l}{2\cdot5}$	$\frac{Wl}{3}$	$\frac{W_1l}{2\cdot5}$	$\frac{Wl}{2\cdot5}$	$\frac{W_1l}{2\cdot25}$

CONTINUOUS BEAMS OR SLABS WITH CANTILEVER ENDS

Uniformly distributed loads w lb./ft.
Effective length of cantilever l_1 ft.
Effective length of inner spans l ft.

TABLE 99. Bending Moments in lb. ft.

Ratio $\frac{l_1}{l}$	Negative Moments			Positive Moments
	At Support next to Cantilever	At next adjacent Support	At other internal Supports	Near middle of end Span*
·225	$\frac{wl_1^2}{2}$	$\frac{wl^2}{10}$	$\frac{wl^2}{12}$	$\frac{wl^2}{10\cdot7}$
·25	,,	$\frac{wl^2}{10\cdot2}$	,,	$\frac{wl^2}{10\cdot8}$
·30	,,	$\frac{wl^2}{10\cdot6}$	,,	$\frac{wl^2}{11\cdot1}$
·35	,,	$\frac{wl^2}{11\cdot0}$	,,	$\frac{wl^2}{11\cdot5}$
·40	,,	$\frac{wl^2}{11\cdot5}$	,,	$\frac{wl^2}{12}$
·45	,,	$\frac{wl^2}{12}$	,,	$\frac{wl^2}{12\cdot6}$

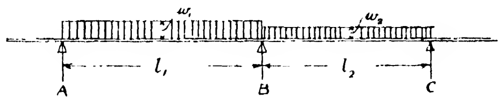
* This column is calculated in accordance with the provisions of *Report No. 10* which allow the fixing moments at the ends of the span to be taken at one-half of the values tabulated in columns 2 and 3 above.

CONTINUOUS BEAMS

Bending moments, shear forces and deflections for various conditions of loading and arrangements of beams are also given in the steel manufacturers' handbooks.

Other cases of continuous beams may be worked out by Clapeyron's Theorem of Three Moments, applicable to any number of continuous spans and any loading. With the signs given in the three cases following the fixing moments are negative; this is the usual designer's convention although the opposite of that given in many text-books.

(i) Distributed loads:—



If w_1 and w_2 are the evenly distributed loads (lb./ft. run) on the spans of length l_1 and l_2 ft., the moments M_A, M_B and M_C at A, B and C respectively, in lb. ft., are given by

$$M_A.l_1 + 2M_B(l_1 + l_2) + M_C l_2 = -\tfrac{1}{4}(w_1 l_1^3 + w_2 l_2^3)$$

This expression enables M_B to be found only if A and C are simple supports and the beam does not continue beyond them, so that $M_A = M_C = 0$. When there are several spans $l_1\ l_2\ l_3$ etc. similar equations can be written for the pairs $l_2\ l_3$, $l_3\ l_4$ and so on. Thus n equations are available for $n + 1$ spans, i.e. $n + 2$ supports, and the moments at the end supports must be found separately.

If one end overhangs, say at A, M_A can be found by calculation of the cantilever.

If the beam is built in at A so that its slope is zero,

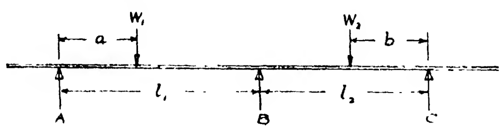
$$2M_A + M_B = -\frac{w_1 l_1^2}{4}\cdot$$

If the end C is similarly built in

$$M_B + 2M_C = -\frac{w_2 l_2^2}{4}$$

and from these simultaneous equations all the fixing moments can be obtained.

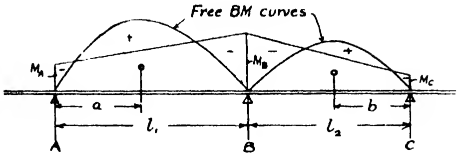
(ii) Concentrated loads:—



$$M_A l_1 + 2M_B(l_1 + l_2) + M_C l_2 = -\frac{W_1 a}{l_1}(l_1^2 - a^2) - \frac{W_2 b}{l_2}(l_2^2 - b^2)$$

If there are several loads on a span, a similar term involving either W_1 and a or W_2 and b is written down for each load on the right-hand side of the equation. If the beam is fixed at A or C additional equations are found by the method given in (iii).

(iii) Any loading:—



Draw the B.M. curves for the loading concerned, as for simply supported spans. If A_1 and A_2 are the areas under these curves and the centroids of the areas are distant a and b from the left and right-hand supports respectively,

$$M_A l_1 + 2M_B (l_1 + l_2) + M_C l_2 = -\frac{6A_1 a}{l_1} - \frac{6A_2 b}{l_2}$$

The areas A_1 and A_2 are positive for the B.M. signs shown in the figure.
If the end A is fixed and horizontal,

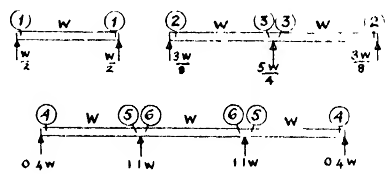
$$2M_A + M_B = -\frac{6A_1 (l_1 - a)}{l_1^2}$$

If the end C is fixed and horizontal

$$M_B + 2M_C = -\frac{6A_2 (l_2 - b)}{l_2^2}$$

Shears and Reactions in Continuous Spans (equal spans and equal loads) :—

Section	Shear
1	$\frac{W}{2}$
2	$\frac{3W}{8}$
3	$\frac{5W}{8}$
4	·4W
5	·6W
6	·5W



PORTALS OR BENTS

The increasing employment of welding in steelwork is encouraging the replacement of braced frames by bents, which depend for their stability on the stiffness of the members and the rigidity of the connections between them.

A collection of the cases most commonly met is given in the following pages ; it includes examples of rectangular frames such as are encountered in basements and deep culverts.

The moment of inertia of each member is constant along the length.

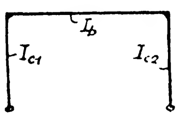
BENDING MOMENTS, THRUSTS AND REACTIONS IN PORTALS

Symbols :

A = Area of free B.M. diagram of loaded member.
E.D. = Evenly distributed.
F_{AB} = Axial thrust in member AB, etc.
H = Horizontal thrust at feet.
I = Moment of inertia of section of member.
I_b = ,, ,, ,, ,, ,, ,, beam or rafter.
I_c = ,, ,, ,, ,, ,, ,, each column if columns equal
I_{c1} = ,, ,, ,, ,, ,, ,, L.H. ,, ,, ,, unequal
I_{c2} = ,, ,, ,, ,, ,, ,, R.H. ,, ,, ,, ,,
K = Stiffness coefficient of member $= \dfrac{I}{\text{Length}}$ [Length in inches if I in in^4.]
K_b K_c K_{c1} K_{c2} correspond to I_b I_c I_{c1} I_{c2}

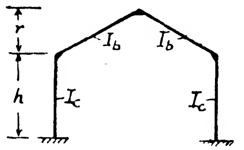
$K_b = \dfrac{I_b}{l}$ for beams $= \dfrac{I_b}{s}$ for rafters
$K_c = \dfrac{I_c}{h}$ for columns
For l, s and h see the figures concerned.

l_1, l_2 see page 124.
M = External moment applied to portal.
M_A M_B M_C M_D M_E = Bending moments induced at A B C D and E.
(Where only one value is given the moment is the same in both the members at the point considered. Where an external moment M is applied at the point, two values are given and they differ by M.)
N N_1 N_2 N_3 see below.
P = Concentrated side load.
R_A R_B = Vertical reactions at A and B.
W = Concentrated load or total distributed load.
w = Distributed load per unit length.
μ = Free B.M. in loaded member, e.g. $\dfrac{wl^2}{8}$ for load w on length l.



Feet Hinged, Columns Unequal :—

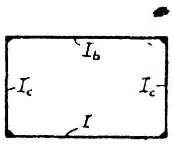
$$N = \frac{K_b}{K_{c1}} + 3 + \frac{K_b}{K_{c2}}$$



Feet Fixed :—

$$N_1 = \frac{K_b}{K_c}\left(\frac{K_b}{K_c} + 4\right) + \frac{2K_b\phi}{K_c}(3 + 2\phi) + \phi^2$$

where $\phi = \frac{r}{h}$

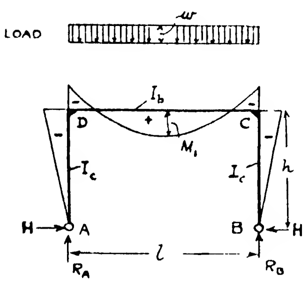


$$N_2 = \frac{I_b}{I}\left(\frac{2K_b}{K_c} + 3\right) + \frac{K_b}{K_c}\left(\frac{K_b}{K_c} + 2\right)$$

$$N_3 = 1 + \frac{I_b}{I} + \frac{6K_b}{K_c}$$

RECTANGULAR PORTALS—FEET HINGED

E.D. LOAD ON BEAM (i) Columns Equal



$$R_A = R_B = \frac{wl}{2} \quad H = \frac{wl^2}{4h} \cdot \frac{K_c}{2K_b + 3K_c}$$

$$M_C = M_D = -Hh$$

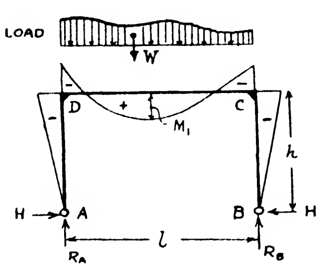
$$M_1 = \mu + M_c = \frac{wl^2}{8} \cdot \frac{2K_b + K_c}{2K_b + 3K_c}$$

(ii) Columns Unequal

$$H = \frac{wl^2}{4hN} \qquad M_1 = \mu + M_c$$

Other values as above

IRREGULAR DISTRIBUTED LOAD ON BEAM (i) Columns Equal



$$R_A = \frac{\text{Moment of load about } B}{l} = W - R_B$$

$$R_B = \frac{\text{Moment of load about } A}{l} = W - R_A$$

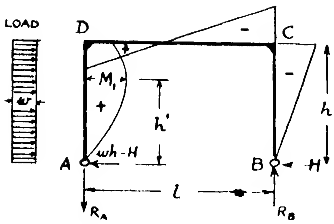
$$H = \frac{3}{lh} \cdot \frac{K_c}{2K_b + 3K_c} \cdot \left(\begin{array}{c}\text{Area of free B.M.}\\ \text{diagram}\end{array}\right)$$

$$M_C = M_D = -Hh \qquad M_1 = \mu + M_c$$

(ii) Columns Unequal

$$H = \frac{3}{lhN} \cdot (\text{Area of free B.M. diagram})$$

Other values as above



E.D. SIDE LOAD (i) Columns Equal

$$R_A = R_B = \frac{wh^2}{2l}$$

$$H = \frac{wh}{8} \cdot \frac{5K_b + 6K_c}{2K_b + 3K_c}$$

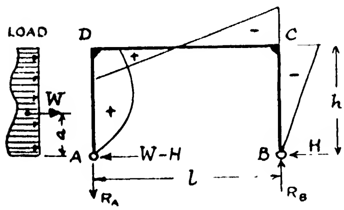
$$M_C = -Hh \quad M_D = \frac{wh^2}{2} - Hh = \frac{wh^2}{8} \cdot \frac{3K_b + 6K_c}{2K_b + 3K_c}$$

$$h' = h - \frac{H}{w} \qquad M_1 = \frac{(wh - H)^2}{2w}$$

(ii) Columns Unequal

$$H = \frac{wh}{8} \cdot \frac{5K_b + 6K_{c1}}{N \cdot K_{c1}} \qquad M_D = \frac{wh^2}{2} - Hh$$

Other values as above



IRREGULAR DISTRIBUTED SIDE LOAD

(i) Columns Equal

$$R_A = R_B = \frac{\text{Moment of load about } A}{l} = \frac{Wa}{l}$$

$$H = \frac{Wa}{l} + \frac{3K_b}{2h^2(2K_b + 3K_c)} \cdot$$

(Area of free B.M. diagram)

$M_C = -Hh \quad M_D =$ (Moment of load about A) $- Hh$

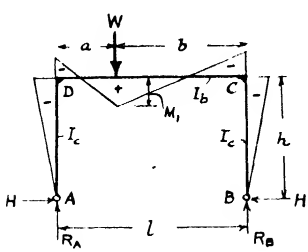
(ii) Columns Unequal

$$H = \frac{1}{2hNK_{c1}} \left\{ (2K_b + 3K_{c1}) \text{ (Moment of load about } A) + \frac{6K_b}{h^2} \cdot \text{(Moment of free B.M. diagram about } A) \right\}$$

Other values as above

CONCENTRATED LOAD ON BEAM

Columns Equal



$$R_A = \frac{Wb}{l} \qquad R_B = \frac{Wa}{l}$$

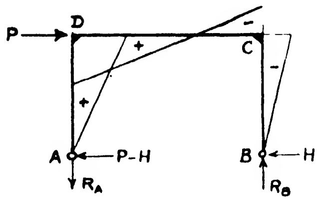
$$H = \frac{Wab}{lh} \cdot \frac{3K_c}{4K_b + 6K_c}$$

$$M_C = M_D = -Hh$$

$$M_1 = \frac{Wab}{l} + M_C = \frac{Wab}{l} \cdot \frac{4K_b + 3K_c}{4K_b + 6K_c}$$

RECTANGULAR PORTALS—FEET HINGED—*Continued.*

SIDE LOAD AT BEAM



(i) Columns Equal

$$R_A = R_B = \frac{Ph}{l} \qquad H = \frac{P}{2}$$

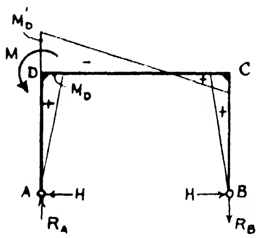
$$M_C = -\frac{Ph}{2} \qquad M_D = \frac{Ph}{2}$$

(ii) Columns Unequal

$$R_A = R_B = \frac{Ph}{l} \qquad H = \frac{P}{2N}\left(\frac{2K_b}{K_{c1}} + 3\right)$$

$$M_C = -Hh \qquad M_D = (P - H)h$$

EXTERNAL MOMENT AT BEAM



(i) Columns Equal

$$R_A = R_B = \frac{M}{l} \qquad H = \frac{3M}{2h} \cdot \frac{K_c}{2K_b + 3K_c}$$

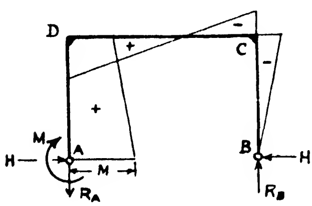
$$M_C = M_D = Hh$$

$$M'_D = M_D - M$$

(ii) Columns Unequal

$$H = \frac{3M}{2hN}$$ Other values as above

EXTERNAL MOMENT AT HINGE



(i) Columns Equal

$$R_A = R_B = \frac{M}{l} \qquad H = \frac{3M}{2h} \cdot \frac{K_b + K_c}{2K_b + 3K_c}$$

$$M_C = -Hh$$

$$M_D = M - Hh$$

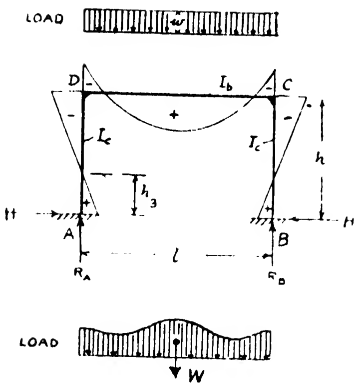
(ii) Columns Unequal

$$H = \frac{3M}{2hN} \cdot \left(\frac{K_b}{K_{c1}} + 1\right)$$

Other values as above

RECTANGULAR PORTALS—FEET FIXED

E.D. LOAD ON BEAM



$$R_A = R_B = \frac{wl}{2} \qquad H = \frac{wl^2}{4h} \cdot \frac{K_c}{K_b + 2K_c}$$

$$M_A = M_B = -\frac{M_D}{2} = \frac{Hh}{3} = \frac{wl^2}{12} \cdot \frac{K_c}{K_b + 2K_c}$$

$$M_C = M_D = -2M_A = -\frac{wl^2}{6} \cdot \frac{K_c}{K_b + 2K_c}$$

ANY SYMMETRICAL DISTRIBUTED LOAD ON BEAM

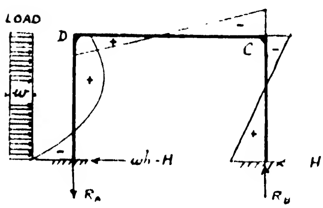
$$R_A = R_B = \frac{W}{2}$$

$$H = \frac{3}{lh} \cdot \frac{K_c}{K_b + 2K_c} \cdot \left(\begin{array}{c}\text{Area of free B.M.}\\ \text{diagram}\end{array}\right)$$

$$M_A = M_B = -\frac{M_D}{2} = \frac{Hh}{3} = \frac{K_c}{K_b + 2K_c} \cdot \left(\frac{\text{Area of free B.M. diagram}}{l}\right)$$

$$M_C = M_D = -2M_A$$

E.D. SIDE LOAD



$$R_A = R_B = wh^2 \frac{K_b}{6K_b + K_c} \qquad H = \frac{wh}{8} \cdot \frac{2K_b + 3K_c}{K_b + 2K_c}$$

$$M_A = -\frac{wh^2}{4} \cdot \left(\frac{4K_b + K_c}{6K_b + K_c} + \frac{K_b + 3K_c}{6K_b + 12K_c}\right)$$

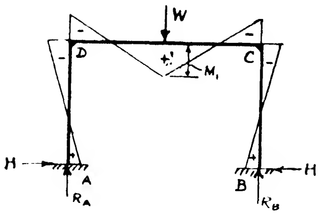
$$M_B = M_C + Hh = \frac{wh^2}{4} \cdot \left(\frac{4K_b + K_c}{6K_b + K_c} - \frac{K_b + 3K_c}{6K_b + 12K_c}\right)$$

$$M_C = M_B - Hh = -\frac{wh^2}{4} \cdot \left(\frac{2K_b}{6K_b + K_c} + \frac{K_b}{6K_b + 12K_c}\right)$$

$$M_D = \frac{wh^2}{4}\left(\frac{2K_b}{6K_b + K_c} - \frac{K_b}{6K_b + 12K_c}\right)$$

RECTANGULAR PORTALS—FEET FIXED—*Continued.*

CENTRAL CONCENTRATED LOAD ON BEAM



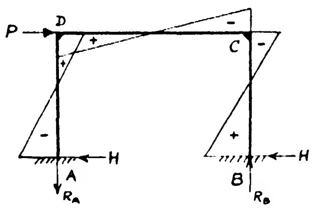
$$R_A = R_B = \frac{W}{2} \qquad H = \frac{3Wl}{8h} \cdot \frac{K_c}{K_b + 2K_c}$$

$$M_A = M_B = \frac{Hh}{3} = \frac{Wl}{8} \cdot \frac{K_c}{K_b + 2K_c}$$

$$M_C = M_D = -\frac{Wl}{4} \cdot \frac{K_c}{K_b + 2K_c}$$

$$M_1 = M_C + \frac{Wl}{4} = \frac{Wl}{4} \cdot \frac{K_b + K_c}{K_b + 2K_c}$$

CONCENTRATED SIDE LOAD

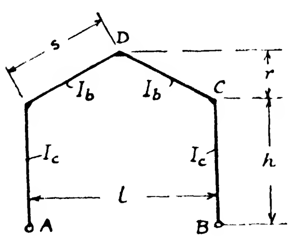


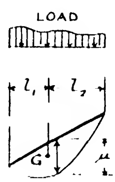
$$R_A = R_B = \frac{Ph}{2l} \cdot \frac{6K_b}{6K_b + K_c} = \frac{2M_D}{l} \qquad H = \frac{P}{2}$$

$$M_A = -\frac{Ph}{2} \cdot \frac{3K_b + K_c}{6K_b + K_c} \qquad M_B = -M_A$$

$$M_C = M_B - \frac{Ph}{2} = -\frac{Ph}{2} \cdot \frac{3K_b}{6K_b + K_c} \qquad M_D = -M_C$$

PITCHED BENTS—FEET HINGED. EQUAL COLUMNS, EQUAL RAFTERS





General Note :—

W = Total load

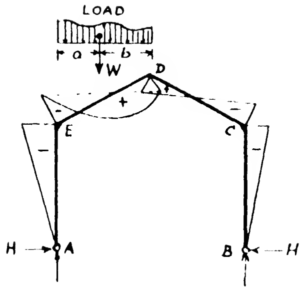
A = Area of free B.M. diagram on loaded member

G = Centroid of free B.M. diagram

l_1 = Distance of G from L.H. end

l_2 = Distance of G from R.H. end

$$\phi = \frac{r}{h}$$



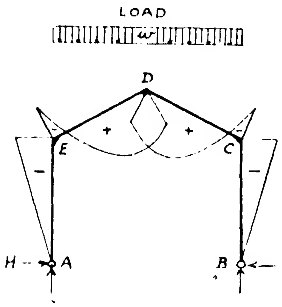
IRREGULAR DISTRIBUTED VERTICAL LOAD

$$R_A = W - R_B \qquad R_B = \frac{W \cdot a}{l}$$

$$H = \frac{Wa(3 + 2\phi) + \dfrac{6Al_2}{(\frac{1}{2}l)^2} + \dfrac{6Al_1}{(\frac{1}{2}l)^2}(1 + \phi)}{4h\left(\dfrac{K_b}{K_c} + 3 + 3\phi + \phi^2\right)}$$

$$M_C = M_E = -Hh$$

$$M_D = \frac{Wa}{2} - Hh(1 + \phi)$$



E.D. VERTICAL LOAD

$$\mu = \text{Max. free B.M.} = \frac{w}{8}\left(\frac{l}{2}\right)^2 \text{ and A}$$

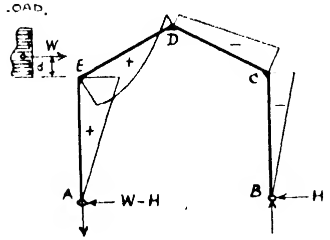
$$= \frac{2}{3} \cdot \frac{l}{2} \cdot \frac{w}{8}\left(\frac{l}{2}\right)^2 = \frac{wl^3}{96} \text{ for each rafter}$$

$$R_A = R_B = \frac{wl}{2}$$

$$H = \frac{wl^2}{32h} \cdot \frac{8 + 5\phi}{\dfrac{K_b}{K_c} + 3 + 3\phi + \phi^2}$$

$$M_C = M_E = -Hh$$

$$M_D = \frac{wl^2}{8} - Hh(1 + \phi)$$



IRREGULAR DISTRIBUTED HORIZONTAL LOAD

$$R_A = R_B = \frac{\text{Moment of load about A}}{l} = \frac{W(h + a)}{l}$$

$$H = \frac{Wh\left(\dfrac{2K_b}{K_c} + 6 + 3\phi\right) + Wa(3 + 2\phi) + \dfrac{6Al_2}{r^2} + \dfrac{6Al_1}{r^2}(1 + \phi)}{4h\left(\dfrac{K_b}{K_c} + 3 + 3\phi + \phi^2\right)}$$

$$M_C = -Hh$$

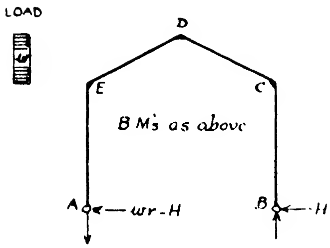
$$M_D = \frac{W(h + a)}{2} - Hh(1 + \phi)$$

$$M_E = (W - H)h$$

PITCHED BENTS—FEET HINGED. EQUAL COLUMNS, EQUAL RAFTERS—*Continued.*

See notes on p. 124.

E.D. HORIZONTAL LOAD



$$\mu = \text{Max. free B.M.} = \frac{wr^2}{8}$$

$$A = \frac{2}{3} \cdot r \cdot \frac{wr^2}{8} = \frac{wr^3}{12}$$

$$R_A = R_B = \frac{wr}{l}\left(h + \frac{r}{2}\right)$$

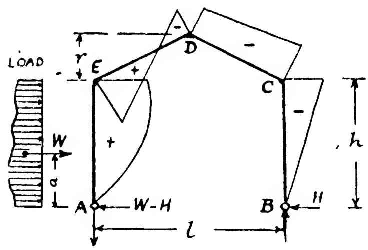
$$H = \frac{wr}{16} \cdot \frac{\frac{8K_b}{K_c} + 24 + 20\phi + 5\phi^2}{\frac{K_b}{K_c} + 3 + 3\phi + \phi^2}$$

$$M_C = - Hh$$

$$M_D = \frac{R_A \cdot l}{2} - Hh(1 + \phi)$$

$$M_E = (wr - H)h$$

IRREGULAR DISTRIBUTED HORIZONTAL LOAD



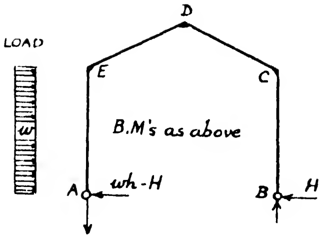
$$R_A = R_B = \frac{W \cdot a}{l} \qquad \phi = \frac{r}{h}$$

$$H = \frac{Wa\left(\frac{2K_b}{K_c} + 6 + 3\phi\right) + \frac{K_b}{K_c} \cdot \frac{6Al_1}{h^2}}{4h\left(\frac{K_b}{K_c} + 3 + 3\phi + \phi^2\right)}$$

$$M_C = - Hh$$

$$M_D = \frac{Wa}{2} - Hh(1 + \phi)$$

$$M_E = Wa - Hh$$



E.D. HORIZONTAL LOAD

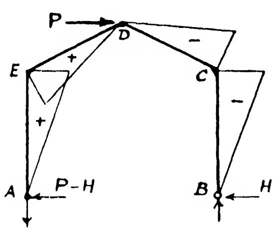
$$R_A = R_B = \frac{wh^2}{2l}$$

$$H = \frac{wh}{16} \cdot \frac{\frac{5K_b}{K_c} + 12 + 6\phi}{\frac{K_b}{K_c} + 3 + 3\phi + \phi^2}$$

$$M_C = -Hh$$

$$M_D = \frac{wh^2}{4} - Hh(1 + \phi)$$

$$M_E = \frac{wh^2}{2} - Hh$$



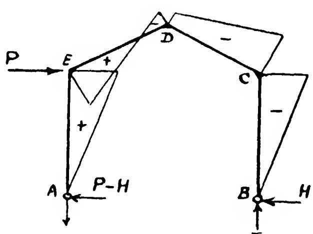
CONCENTRATED LOAD

$$R_A = R_B = \frac{Ph}{l}(1 + \phi)$$

$$H = \frac{P}{2}$$

$$M_C = -\frac{Ph}{2} \qquad M_D = 0$$

$$M_E = \frac{Ph}{2}$$



CONCENTRATED LOAD

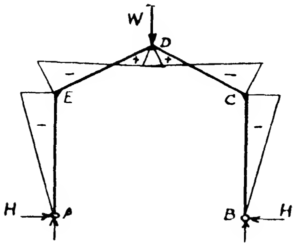
$$R_A = R_B = \frac{Ph}{l}$$

$$H = \frac{P}{4} \cdot \frac{\frac{2K_b}{K_c} + 6 + 3\phi}{\frac{K_b}{K_c} + 3 + 3\phi + \phi^2}$$

$$M_C = -Hh$$

$$M_D = \frac{Ph}{2} - Hh(1 + \phi) \qquad M_E = (P - H)h$$

PITCHED BENTS—FEET HINGED. EQUAL COLUMNS, EQUAL RAFTERS—*Continued.*

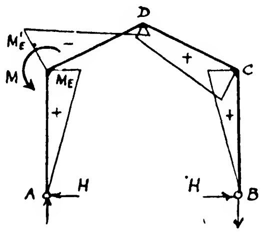


CONCENTRATED LOAD

$$R_A = R_B = \frac{W}{2}$$

$$H = \frac{Wl}{8h} \cdot \frac{3 + 2\phi}{\frac{K_b}{K_c} + 3 + 3\phi + \phi^2}$$

$$M_C = M_E = -Hh \qquad M_D = \frac{Wl}{4} - Hh(1 + \phi)$$



EXTERNAL MOMENT

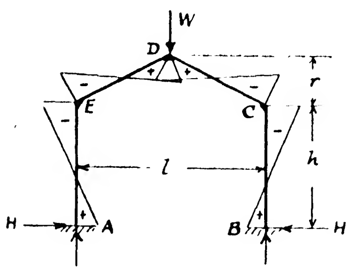
$$R_A = R_B = \frac{M}{l}$$

$$H = \frac{3M}{4h} \cdot \frac{2 + \phi}{\frac{K_b}{K_c} + 3 + 3\phi + \phi^2}$$

$$M_C = Hh \qquad M_D = -\frac{M}{2} + Hh(1 + \phi)$$

$$M_E = Hh \qquad M'_E = -M + Hh$$

PITCHED BENTS—FEET FIXED. EQUAL COLUMNS, EQUAL RAFTERS



CONCENTRATED LOAD

$$R_A = R_B = \frac{W}{2} \qquad \phi = \frac{r}{h}$$

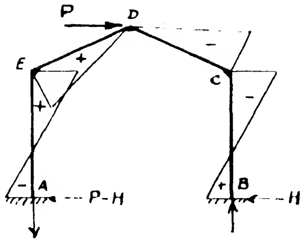
$$H = \frac{Wl}{4hN_1} \cdot \left(\frac{3K_b}{K_c} + \frac{4K_b\phi}{K_c} + \phi\right)$$

$$M_A = M_B = \frac{Wl}{4N_1}\left(\frac{K_b}{K_c} + \frac{2K_b\phi}{K_c} + \phi\right)$$

$$M_C = M_E = -Hh + M_A$$

$$M_D = \frac{Wl}{4} + M_A - Hh(1 + \phi)$$

CONCENTRATED LOAD



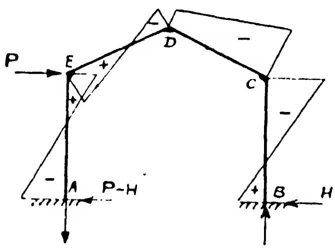
$$R_A = R_B = \frac{Ph}{l}(1+\phi) + \frac{2M_A}{l}$$

$$H = \frac{P}{2} \qquad M_E = -M_C = \frac{Ph}{2} + M_A$$

$$M_A = -\frac{Ph}{4}\cdot\frac{3K_b + 2K_c}{3K_b + K_c} \qquad M_B = -M_A$$

$$M_C = -\frac{Ph}{2} + M_B \qquad M_D = 0$$

CONCENTRATED LOAD



$$R_A = R_B = \frac{Ph}{l} - \frac{M_E - M_A}{l}$$

$$H = \frac{P}{2N_1}\cdot\frac{K_b}{K_c}\left(\frac{K_b}{K_c} + 4 + 3\phi\right)$$

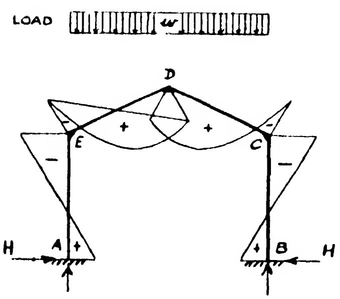
$$\left.\begin{matrix} M_A \\ M_B \end{matrix}\right\} = \frac{Ph}{4}\left\{-\frac{2\phi\left(\frac{K_b}{K_c} + \frac{2K_b\phi}{K_c} + \phi\right)}{N_1} \mp \frac{3K_b + 2K_c}{3K_b + K_c}\right\}$$

$$M_C = -Hh + M_E$$

$$M_D = \frac{Ph + M_A + M_E}{2} - Hh(1+\phi)$$

$$M_E = (P - H)h + M_A$$

E.D. LOAD



$$R_A = R_B = \frac{wl}{2}$$

$$H = \frac{wl^2}{8h}\cdot\frac{\frac{4K_b}{K_c} + \frac{5K_b\phi}{K_c} + \phi}{N_1}$$

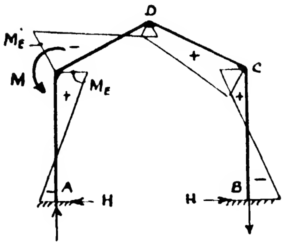
$$M_A = M_B = \frac{wl^2}{48N_1}\left\{\frac{K_b}{K_c}(8 + 15\phi) + \phi(6 - \phi)\right\}$$

$$M_C = M_E = -Hh + M_A$$

$$M_D = \frac{wl^2}{8} + M_A - Hh(1+\phi)$$

PITCHED BENTS—FEET FIXED. EQUAL COLUMNS, EQUAL RAFTERS—*Continued.*

EXTERNAL MOMENT



$$R_A = R_B = \frac{3M.K_b}{l(3K_b + K_c)} \qquad H = \frac{3M}{hN_1} \cdot \frac{K_b}{K_c}(1 + \phi)$$

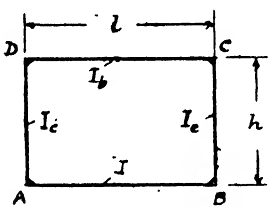
$$\left.\begin{array}{l} M_A \\ M_B \end{array}\right\rangle = - \frac{M}{2N_1} \cdot \left(\frac{2K_b}{K_c} + \frac{3K_b\phi}{K_c} - \phi^2\right) \pm \frac{M.K_c}{6K_b + 2K_c}$$

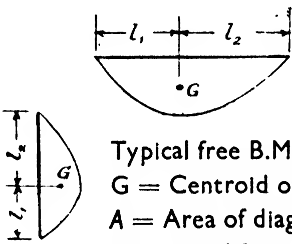
$$M_C = M_B + Hh$$

$$M_D = \frac{-M + M_A + M_B}{2} + Hh(1 + \phi)$$

$$M_E = Hh + M_A \qquad M_E' = -M + M_E$$

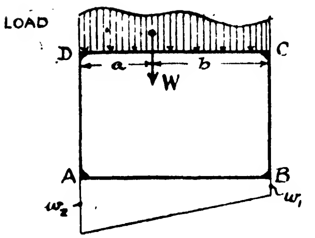
RECTANGULAR FRAMES. COLUMNS OF EQUAL K.

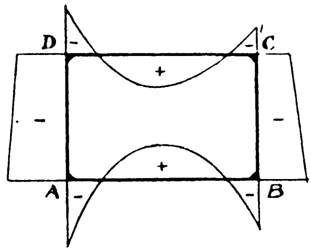




Typical free B.M. diagrams
G = Centroid of diagram
A = Area of diagram
F_{AB} = Axial force in AB, etc.
For N_2 and N_3 see page 120.

IRREGULAR DISTRIBUTED LOAD ON BEAM





$$w_1 = \frac{2W(2a - b)}{l^2}$$

$$w_2 = \frac{2W(2b - a)}{l^2}$$

($w_1 = o$ if $b = 2a$
w_1 negative if $b > 2a$)

$$\left.\begin{array}{l} M_A \\ M_D \end{array}\right\rangle = -\frac{Wl\frac{I_b}{I}\left(\frac{2K_b}{K_c} + 3\right) - \frac{12A}{l}\cdot\frac{K_b}{K_c}}{12N_2} \mp \frac{W(b - a)\frac{I_b}{I} + \frac{60A}{l^2}(l_2 - l_1)}{20N_3}$$

$$\left.\begin{array}{l} M_B \\ M_C \end{array}\right\rangle = -\frac{\frac{12A}{l}\left(\frac{3I_b}{I} + \frac{2K_b}{K_c}\right) - Wl\frac{I_b}{I}\cdot\frac{K_b}{K_c}}{12N_2} \mp \frac{W(b - a)\frac{I_b}{I} + \frac{60A}{l^2}(l_2 - l_1)}{20N_3}$$

$$F_{AD} = \frac{Wb}{l} + \frac{W(b - a)\frac{I_b}{I} + 60\frac{A}{l^2}(l_2 - l_1)}{10lN_3}$$

$$F_{BC} = \frac{Wa}{l} - \frac{W(b - a)\frac{I_b}{I} + 60\frac{A}{l^2}(l_2 - l_1)}{10lN_3}$$

$$\left.\begin{array}{l} F_{DC} \\ F_{AB} \end{array}\right\rangle = \pm\frac{M_A - M_D}{h} = \pm\frac{M_B - M_C}{h} = \pm\frac{l}{4hN_2}\cdot\left\{\frac{12A}{l}\left(\frac{I_b}{I} + \frac{K_b}{K_c}\right) - Wl\cdot\frac{I_b}{I}\left(\frac{K_b}{K_c} + 1\right)\right\}$$

RECTANGULAR FRAMES. COLUMNS OF EQUAL K.—*Continued.*

SYMMETRICAL DISTRIBUTED LOAD ON BEAM

$a = b$ $\qquad w_1 = w_2 = \dfrac{W}{l}$

B.M. diagram as before, but symmetrical about vertical C.L.

$$M_A - M_D = M_B - M_C$$

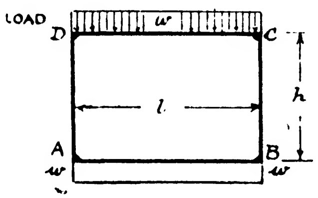
$$M_A = M_B = -\frac{1}{12N_2}\cdot\left\{Wl\frac{I_b}{I}\left(\frac{2K_b}{K_c}+3\right) - \frac{12A}{l}\cdot\frac{K_b}{K_c}\right\}$$

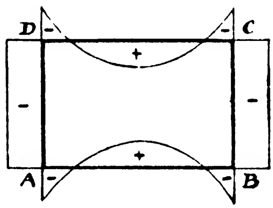
$$M_C = M_D = -\frac{1}{12N_2}\cdot\left\{\frac{12A}{l}\left(\frac{3I_b}{I}+\frac{2K_b}{K_c}\right) - Wl\cdot\frac{I_b}{I}\cdot\frac{K_b}{K_c}\right\}$$

$$F_{AD} = F_{BC} = \frac{W}{2} \qquad F_{DC} = \frac{M_A - M_D}{h} \qquad F_{AB} = -\frac{M_A - M_D}{h} = -F_{DC}$$

Note.—The loads in most of these cases are assumed to be resisted by distributed loads, e.g. w_1, w_2 such as would be caused by earth pressure ; in some cases a concentrated reaction is shown.

E.D. LOAD ON BEAM





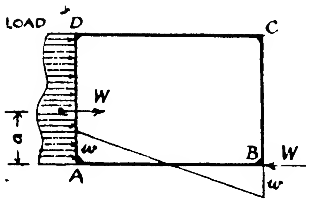
$$M_A = M_B = -\frac{wl^2}{12N_2}\cdot\left(\frac{3I_b}{I}+\frac{2I_b}{I}\cdot\frac{K_b}{K_c}-\frac{K_b}{K_c}\right)$$

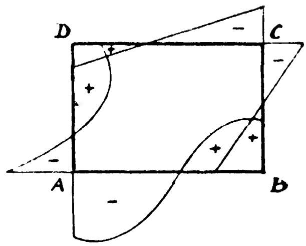
$$M_C = M_D = -\frac{wl^2}{12N_2}\cdot\left(\frac{3I_b}{I}-\frac{I_b}{I}\cdot\frac{K_b}{K_c}+\frac{2K_b}{K_c}\right)$$

$$F_{AD} = F_{BC} = \frac{wl}{2} \qquad F_{DC} = F_{AB} = 0$$

IRREGULAR DISTRIBUTED SIDE LOAD

resisted at base





$$w = \frac{6Wa}{l^2}$$

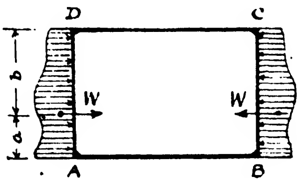
$$\left.\begin{matrix} M_A \\ M_B \end{matrix}\right\rangle = -\frac{K_b}{6K_cN_2}\cdot\left\{\frac{6Al_2}{h^2}\left(\frac{2K_b}{K_c}+3\right)-\frac{6Al_1}{h^2}\cdot\frac{K_b}{K_c}\right\}$$
$$\mp\frac{1}{2N_3}\cdot\left\{Wa\left(\frac{3K_b}{K_c}+1-\frac{I_b}{5I}\right)+\frac{6A}{h}\cdot\frac{K_b}{K_c}\right\}$$

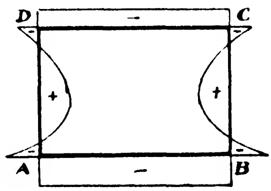
$$\left.\begin{matrix} M_C \\ M_D \end{matrix}\right\rangle = -\frac{K_b}{6K_cN_2}\cdot\left\{\frac{6Al_1}{h^2}\left(\frac{3I_b}{I}+\frac{2K_b}{K_c}\right)-\frac{6Al_2}{h^2}\cdot\frac{K_b}{K_c}\right\}$$
$$\mp\frac{1}{2N_3}\cdot\left\{Wa\left(\frac{6I_b}{5I}+\frac{3K_b}{K_c}\right)-\frac{6A}{h}\cdot\frac{K_b}{K_c}\right\}$$

$$\left.\begin{matrix} F_{AD} \\ F_{BC} \end{matrix}\right\rangle = \mp\frac{M_D-M_C}{l} \qquad F_{DC} = \frac{M_B-M_C}{h} \qquad F_{AB} = -\frac{M_B-M_C}{h} = -F_{DC}$$

RECTANGULAR FRAMES, COLUMNS OF EQUAL K.—*Continued.*

EQUAL IRREGULAR DISTRIBUTED SIDE LOADS



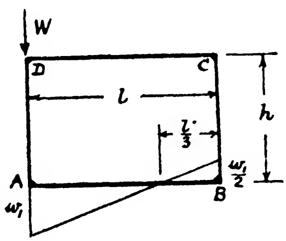


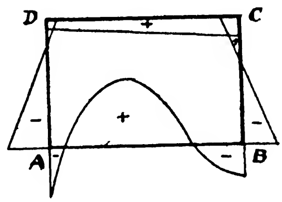
$$M_A = M_B = -\frac{K_b}{3K_cN_2}\cdot\left\{\frac{6Al_2}{h^2}\left(\frac{2K_b}{K_c}+3\right)-\frac{6Al_1}{h^2}\cdot\frac{K_b}{K_c}\right\}$$

$$M_C = M_D = -\frac{K_b}{3K_cN_2}\cdot\left\{\frac{6Al_1}{h^2}\left(\frac{3I_b}{I}+\frac{2K_b}{K_c}\right)-\frac{6Al_2}{h^2}\cdot\frac{K_b}{K_c}\right\}$$

$$F_{AD} = F_{BC} = 0 \qquad F_{DC} = \frac{Wa}{h}+\frac{M_A-M_D}{h} \qquad F_{AB} = \frac{Wb}{h}+\frac{M_D-M_A}{h}$$

CONCENTRATED VERTICAL LOAD





$$w_1 = \frac{4W}{l}$$

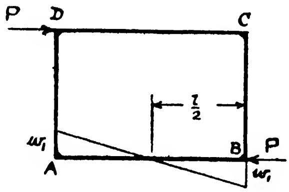
$$\left.\begin{matrix}M_A\\M_B\end{matrix}\right\rangle = \frac{WlI_b}{4I}\left\{-\frac{2K_b+3K_c}{3K_cN_2}\mp\frac{1}{5N_3}\right\}$$

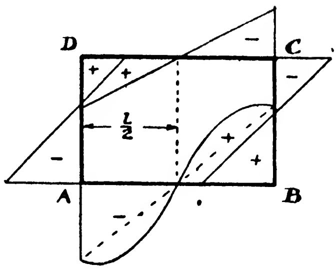
$$\left.\begin{matrix}M_C\\M_D\end{matrix}\right\rangle = \frac{WlI_b}{4I}\left\{\frac{K_b}{3K_cN_2}\pm\frac{1}{5N_3}\right\}$$

For concentrated loads between C and D use the expressions for Irregular Distributed Load on Beam.

$$F_{AD} = \frac{WI_b}{10IN_3} \qquad F_{BC} = -F_{AD} = -\frac{WI_b}{10IN_3} \qquad \left.\begin{matrix}F_{DC}\\F_{AB}\end{matrix}\right\rangle \mp \frac{WlI_b}{4hIN_2}\left(\frac{K_b}{K_c}+1\right)$$

CONCENTRATED SIDE LOAD





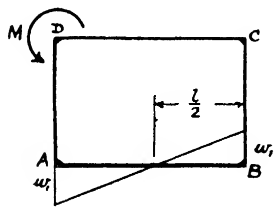
$$W_1 = \frac{6Ph}{l^2}$$

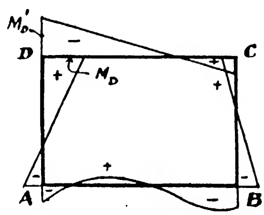
$$\left.\begin{matrix} M_A \\ M_B \end{matrix}\right\rangle \mp \frac{Ph}{2N_3}\left\{\frac{3K_b}{K_c} + 1 - \frac{I_b}{5I}\right\}$$

$$\left.\begin{matrix} M_C \\ M_D \end{matrix}\right\rangle = \mp \frac{Ph}{2N_3}\left\{\frac{6I_b}{5I} + \frac{3K_b}{K_c}\right\}$$

$$F_{BC} = -\frac{2M_c}{l} \qquad F_{AD} = \frac{2M_c}{l} \qquad F_{DC} = F_{AB} = \frac{P}{2}$$

EXTERNAL MOMENT





$$W_1 = \frac{6M}{l^2}$$

$$\left.\begin{matrix} M_A \\ M_B \end{matrix}\right\rangle = -\frac{M.K_b}{2K_cN_2} \pm \frac{M}{2N_3}\left(1 - \frac{I_b}{5I}\right)$$

$$\left.\begin{matrix} M_C \\ M_D \end{matrix}\right\rangle = \frac{M}{2N_2}\left(\frac{3I_b}{I} + \frac{2K_b}{K_c}\right) \mp \frac{M}{2N_3}\left(1 - \frac{I_b}{5I}\right)$$

$$M_D' = -M + M_D$$

$$F_{AD} = \frac{M}{lN_3}\left(\frac{6I_b}{5I} + \frac{6K_b}{K_c}\right) \qquad F_{BC} = -F_{AD}$$

$$F_{AB} = \frac{3M}{2hN_2}\left(\frac{I_b}{I} + \frac{K_b}{K_c}\right) \qquad F_{DC} = -F_{AB}$$

WORKING STRESSES IN STRUCTURAL STEEL

For steel reinforcement stresses see page 88.

Note 1. In grillages, provided the beams are spaced not less than 3 in. apart, and have 4 in. of concrete cover all round except where they cross each other, all the stresses given in Table 100 may be increased as follows :—

	I. Struct. E Report No. 8	B.S. 449	
		Mild Steel to B.S.15	High Tensile Steel to B.S.548
Single grillage	12½%	50%	33⅓%
Other grillages : top tier .	25%	,,	,,
other tiers .	50%	,,	,,

Note 2. The tensile and compressive fibre stresses in beams encased in good concrete, with 2 in. cover on each side and with the top flange at least 1½ in. below the top level of concrete, may be increased by one-eighth (*Report No.* 8). *B.S.* 449 allows an increase of one-sixteenth.

TABLE 100. Permissible Working Stresses, tons/sq. in.

Structural Steel in Building	B.S. 449 and *Report No.* 8	
	Mild Steel to B.S.15	High Tensile Steel to B.S. 548
(*a*) **Parts in Tension**		
Axial stresses on net area of section	8	12
Extreme fibre stress in beams	8	12
Shop rivets	5	7½
Field rivets	4	6
Bolts ⅝″ and over (*B.S.* 449)	5	7½
¾″ and over (*Report No.* 8)	,,	,,
under ¾″ ,, ,, ...	4	6
(*b*) **Parts in Compression**		
Axial stress in columns, special rules	—	—
Extreme fibre stress in beams with adequate lateral support	8	12
B.S. 449 : Where the laterally unsupported length L is greater than 20 times the width b of compression flange	$*11{\cdot}0-0{\cdot}15\frac{L}{b}$	$16{\cdot}5-0{\cdot}25\frac{L}{b}$
Report No. 8 : Rule based on radius of gyration and "effective length" specified in detail.		

Table 100—*Continued.*

Structural Steel in Building	B.S.449 and *Report No. 8*	
	Mild Steel to B.S.15	High Tensile Steel to B.S. 548
(*c*) **Parts in Shear**		
On gross section of web	5	$7\frac{1}{2}$
Report No. 8 : When the distance *L* between flanges or web stiffeners exceeds for mild steel 80 or for high tensile steel 60 times the thickness *t* of web	$9{\cdot}44-\frac{L}{18t}$	$11{\cdot}5-\frac{L}{15t}$
but never to exceed, on net area . . .	6	9
B.S. 449 limits $\frac{L}{t}$ to 60		
Shop rivets and turned fitted bolts . . .	6	9
Field rivets	5	$7\frac{1}{2}$
Black bolts	4	6
(*d*) **Parts in Bearing**		
Shop rivets and turned fitted bolts . . .	12	18
Field rivets	10	15
Black bolts	8	12
Report No. 8 permits, for rivets or bolts in double shear, the bearing stress on the central thickness of metal to be taken at $2\frac{1}{2}$ times the permissible stress in shear given under (*c*).		

* These values for the standard flange widths of beams and channels are given direct in Table 111.

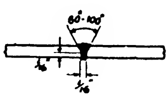
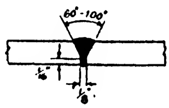
Permissible Working Stresses, tons/sq. in.

Structural Steel in Girder Bridges	B.S. 153
Tension members (on nett section)	9
Tension or compression flanges of plate girders and I beams with comp. flange and web solidly embedded	10
Compression flanges (width *b*, unsupported length *l*) in plate girders and I beams:—	
Outside edges adequately stiffened	$9\left(1-{\cdot}0075\frac{l}{b}\right)$
,, ,, unstiffened	$9\left(1-{\cdot}01\frac{l}{b}\right)$
Compression members (radius of gyration *k*, unbraced length *l*) in truss and lattice girders:—	
With riveted connections	$9\left(1-{\cdot}0038\frac{l}{k}\right)^{\dagger}$
,, pin connections	$9\left(1-{\cdot}0054\frac{l}{k}\right)^{\dagger}$
(† Not to exceed 7·65 tons/sq. in.)	

Permissible tensile stress in wrought iron is 75%, and compressive stress 85%, of values for structural steel.

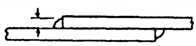
STRENGTH OF BUTT WELDS

TABLE 101

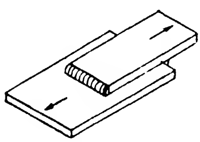
Section	Thickness of Plates	Safe Load per inch, tons.	
		Tension	Shear
	1/8"	1·00	·62
	3/16"	1·50	·94
	1/4"	2·00	1·25
	5/16"	2·50	1·56
	3/8"	3·00	1·87
	1/2"	4·00	2·50
	5/8"	5·00	3·12
	3/4"	6·00	3·75

STRENGTH OF FILLET WELDS

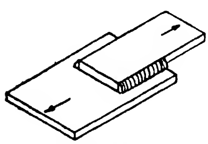
TABLE 102. In accordance with B.S. 538—*Metal Arc Welding in Mild Steel*



SPECIFIED SIZE



END FILLET



SIDE FILLET

Size of Fillet	Safe Load per inch, tons	
	End Fillets	Side Fillets
1/8"	·61	·44
3/16"	·92	·66
1/4"	1·23	·87
5/16"	1·53	1·09
3/8"	1·84	1·31
1/2"	2·45	1·75
5/8"	3·06	2·19
3/4"	3·68	2·63
7/8"	4·29	3·06
1"	4·90	3·50
Stress tons per sq. in.	7	5

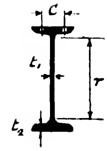
Values for butt and fillet welds usually permitted by *L.C.C.*:—

		tons/sq. in.
Butt welds:	Tension or compression	8
	Shearing in webs of plate girders and joists . .	6
	,, other than the above	5

Fillet welds: End fillets 6
Side, diagonal and T fillets 5

DIMENSIONS OF BRITISH STANDARD BEAMS

B.S. 4—*Channels and Beams for Structural Purposes*



When a size is rolled in two weights designers must specify size *and* weight.

TABLE 103. (For section moduli, see Table 112)

Size	Weight	Thickness		Distance		Area	Size
		Web t_1	Flange t_2	Clear of Root Fillets	Centres of Holes C		
in.	lb./ft.	in.	in.	r, in.	in.	sq. in.	in.
3 × 1½	4	·16	·25	2·0	¾	1·18	**3 × 1½**
3 × 3	8½	·20	·33	1·5	1½	2·52	**3 × 3**
4 × 1¾	5	·17	·24	2·9	⅞	1·47	**4 × 1¾**
4 × 3	10	·24	·35	2·5	1½	2·96	**4 × 3**
4¾ × 1¾	6½	·18	·32	3·5	⅞	1·91	**4¾ × 1¾**
5 × 3	11	·22	·38	3·4	1½	3·26	**5 × 3**
5 × 4½	20	·29	·51	2·8	2½	5·88	**5 × 4½**
6 × 3	12	·23	·38	4·4	1½	3·53	**6 × 3**
6 × 4½	20	·37	·43	4·0	2½	5·89	**6 × 4½**
6 × 5	25	·41	·52	3·7	2¾	7·37	**6 × 5**
7 × 4	16	·25	·39	5·2	2¼	4·75	**7 × 4**
8 × 4	18	·28	·40	6·2	2¼	5·30	**8 × 4**
8 × 5	28	·35	·57	5·6	2¾	8·28	**8 × 5**
8 × 6	35	·35	·65	5·2	3½	10·30	**8 × 6**
9 × 4	21	·30	·46	7·0	2¼	6·18	**9 × 4**
9 × 7	50	·40	·82	5·7	4	14·71	**9 × 7**
10 × 4½	25	·30	·50	7·8	2½	7·35	**10 × 4½**
10 × 5	30	·36	·55	7·6	2¾	8·85	**10 × 5**
10 × 6	40	·36	·71	7·1	3½	11·77	**10 × 6**
10 × 8	55	·40	·78	6·5	4¾	16·18	**10 × 8**
12 × 5	32	·35	·55	9·7	2¾	9·45	**12 × 5**
12 × 6 L	44	·40	·72	9·1	3½	13·00	**12 × 6 L**
12 × 6 H	54	·50	·88	8·8	3½	15·89	**12 × 6 H**
12 × 8	65	·43	·90	8·3	4¾	19·12	**12 × 8**
13 × 5	35	·35	·60	10·5	2¾	10·30	**13 × 5**
14 × 6 L	46	·40	·70	11·2	3½	13·59	**14 × 6 L**
14 × 6 H	57	·50	·87	10·8	3½	16·78	**14 × 6 H**
14 × 8	70	·46	·92	10·3	4¾	20·59	**14 × 8**
15 × 5	42	·42	·65	12·5	2¾	12·36	**15 × 5**
15 × 6	45	·38	·65	12·2	3½	13·24	**15 × 6**

Table 103—*Continued.*

Size in.	Weight lb./ft.	Thickness: Web t_1 in.	Thickness: Flange t_2 in.	Distance: Clear of Root Fillets r, in.	Distance: Centres of Holes, C, in.	Area sq. in.	Size in.
16 × 6 L	50	·40	·73	13·1	3½	14·71	**16 × 6 L**
16 × 6 H	62	·55	·85	12·8	3½	18·21	**16 × 6 H**
16 × 8	75	·48	·94	12·3	4¾	22·06	**16 × 8**
18 × 6	55	·42	·76	15·0	3½	16·18	**18 × 6**
18 × 7	75	·55	·93	14·5	4	22·09	**18 × 7**
18 × 8	80	·50	·95	14·2	4¾	23·53	**18 × 8**
20 × 6½	65	·45	·82	16·8	3¾	19·12	**20 × 6½**
20 × 7½	89	·60	1·01	16·2	4½	26·19	**20 × 7½**
22 × 7	75	·50	·83	18·7	4	22·06	**22 × 7**
24 × 7½	95	·57	1·01	20·2	4½	27·94	**24 × 7½**

MAXIMUM SIZE OF RIVET OR BOLT IN FLANGES OF B.S.B. AND T SECTIONS

TABLE 104

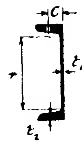
Width of Flange in.	Max. Size of Rivet or Bolt in.	Width of Flange in.	Max. Size of Rivet or Bolt in.
1½	¼	4½	¾
1¾	,,	5	,,
2	,,	5½	,,
2¼	⅜	6	⅞
2½	,,	6½	,,
3	½	7	,,
3½	,,	7½	,,
4	⅝	8	,,

For drilling centres of T sections see B.S.B.s of same flange width, in Table 103.

For weights and section modulus of T sections, see Table 108.

DIMENSIONS OF BRITISH STANDARD CHANNELS

B.S. 4—*Channels and Beams for Structural Purposes*



Each of the sections given below can also be rolled with a thicker web ; for particulars see B.S. 4. Designers should confirm that the sections chosen are readily obtainable, and should specify size *and* weight.

For dimension C and maximum rivet size, see Table 110.

TABLE 105. For section moduli see Table 113.

Size	Weight	Thickness		Distance Clear of Root Fillets r	Area
		Web t_1	Flange t_2		
in.	lb./ft.	in.	in.	in.	sq. in.
3 × 1½	4·60	·20	·28	1·8	1·35
4 × 2	7·09	·24	·31	2·5	2·09
5 × 2½	10·22	·25	·38	3·3	3·01
6 × 3	12·41	·25	·38	4·1	3·65
6 × 3	16·51	·38	·48	3·9	4·86
6 × 3½	16·48	·28	·48	3·75	4·85
7 × 3	14·22	·26	·42	5·0	4·18
7 × 3½	18·28	·30	·50	4·8	5·38
8 × 3	15·96	·28	·44	6·0	4·69
8 × 3½	20·21	·32	·52	5·7	5·94
9 × 3	17·46	·30	·44	7·0	5·14
9 × 3½	22·27	·34	·54	6·6	6·55
10 × 3	19·28	·32	·45	8·0	5·67
10 × 3½	24·46	·36	·56	7·6	7·19
11 × 3½	26·78	·38	·58	8·6	7·88
12 × 3½	26·37	·38	·50	9·7	7·76
12 × 4	31·33	·40	·60	9·3	9·21
13 × 4	33·18	·40	·62	10·3	9·76
15 × 4	36·37	·41	·62	12·3	10·70
17 × 4	44·34	·48	·68	14·2	13·04

SIZES AND WEIGHTS OF EQUAL ANGLES

B.S. 4a—*Equal Angles, Unequal Angles and Tee Bars for Structural Purposes*

TABLE 106

Size, in.	Lb./ft.	Section Modulus	Size, in.	Lb./ft.	Section Modulus
$1 \times 1 \times \frac{1}{8}$	·80	·028	$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{5}{16}$	7·11	·94
$\frac{3}{16}$	1·15	·040	$\frac{3}{8}$	8·45	1·12
$1\frac{1}{4} \times 1\frac{1}{4} \times \frac{1}{8}$	1·01	·045	$\frac{1}{2}$	11·05	1·46
$\frac{3}{16}$	1·47	·070	$4 \times 4 \times \frac{5}{16}$	8·17	1·24
$\frac{1}{4}$	1·91	·086	$\frac{3}{8}$	9·73	1·48
$1\frac{1}{2} \times 1\frac{1}{2} \times \frac{3}{16}$	1·79	·100	$\frac{1}{2}$	12·75	1·93
$\frac{1}{4}$	2·34	·128	$\frac{5}{8}$	15·68	2·36
$\frac{5}{16}$	2·85	·16	$4\frac{1}{2} \times 4\frac{1}{2} \times \frac{5}{16}$	9·24	
$1\frac{3}{4} \times 1\frac{3}{4} \times \frac{3}{16}$	2·11	·137	$\frac{3}{8}$	11·00	1·89
$\frac{1}{4}$	2·76	·180	$\frac{1}{2}$	14·45	2·47
$\frac{5}{16}$	3·39	·219	$\frac{5}{8}$	17·80	3·03
$2 \times 2 \times \frac{3}{16}$	2·43	·180	$5 \times 5 \times \frac{3}{8}$	12·28	2·35
$\frac{1}{4}$	3·19	·236	$\frac{1}{2}$	16·16	3·08
$\frac{5}{16}$	3·92	·290	$\frac{5}{8}$	19·93	3·78
$\frac{3}{8}$	4·62	·34	$\frac{3}{4}$	23·59	4·46
$2\frac{1}{4} \times 2\frac{1}{4} \times \frac{3}{16}$	2·75	·231	$6 \times 6 \times \frac{3}{8}$	14·82	3·40
$\frac{1}{4}$	3·61	·304	$\frac{1}{2}$	19·55	4·49
$\frac{5}{16}$	4·45	·374	$\frac{5}{8}$	24·17	5·54
$\frac{3}{8}$	5·26	·441	$\frac{3}{4}$	28·69	6·54
$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$	4·04	·377	$7 \times 7 \times \frac{1}{2}$	22·95	6·17
$\frac{5}{16}$	4·98	·470	$\frac{5}{8}$	28·42	7·63
$\frac{3}{8}$	5·90	·549	$\frac{3}{4}$	33·79	9·04
$3 \times 3 \times \frac{1}{4}$	4·89	·555	$8 \times 8 \times \frac{5}{8}$	32·68	10·05
$\frac{5}{16}$	6·04	·680	$\frac{3}{4}$	38·89	11·94
$\frac{3}{8}$	7·17	·812	$\frac{7}{8}$	45·00	13·77
$\frac{1}{2}$	9·35	1·05			

For drilling centres and maximum rivet size see Table 110.

SIZES AND WEIGHTS OF UNEQUAL ANGLES

B.S. 4a—*Equal Angles, Unequal Angles and Tee Bars for Structural Purposes*

TABLE 107. The section modulus is about an axis parallel to the short leg.

Size, in.	Lb./ft.	Section Modulus
$2 \times 1\frac{1}{2} \times \frac{3}{16}$	2·11	·175
$\frac{1}{4}$	2·76	·229
$2\frac{1}{2} \times 1\frac{1}{2} \times \frac{3}{16}$	2·43	·270
$\frac{1}{4}$	3·19	·350
$2\frac{1}{2} \times 2 \times \frac{3}{16}$	2·75	·280
$\frac{1}{4}$	3·61	·368
$\frac{5}{16}$	4·45	·453
$3 \times 2 \times \frac{1}{4}$	4·04	·522
$\frac{5}{16}$	4·98	·650
$\frac{3}{8}$	5·90	·761
$3 \times 2\frac{1}{2} \times \frac{1}{4}$	4·47	·541
$\frac{5}{16}$	5·51	·670
$\frac{3}{8}$	6·54	·790
$3\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$	4·89	·743
$\frac{5}{16}$	6·04	·900
$\frac{3}{8}$	7·17	1·07
$3\frac{1}{2} \times 3 \times \frac{1}{4}$	5·32	·745
$\frac{5}{16}$	6·58	·920
$\frac{3}{8}$	7·81	1·10
$\frac{1}{2}$	10·20	1·42
$4 \times 2\frac{1}{2} \times \frac{1}{4}$	5·32	·939
$\frac{5}{16}$	6·58	1·17
$\frac{3}{8}$	7·81	1·38
$4 \times 3 \times \frac{5}{16}$	7·11	1·20
$\frac{3}{8}$	8·45	1·42
$\frac{1}{2}$	11·05	1·85
$4 \times 3\frac{1}{2} \times \frac{5}{16}$	7·64	1·22
$\frac{3}{8}$	9·09	1·45
$\frac{1}{2}$	11·91	1·89
$\frac{5}{8}$	14·61	2·31

Size, in.	Lb./ft.	Section Modulus
$5 \times 3 \times \frac{5}{16}$	8·17	1·84
$\frac{3}{8}$	9·73	2·18
$\frac{1}{2}$	12·75	2·86
$\frac{5}{8}$	15·67	3·50
$5 \times 3\frac{1}{2} \times \frac{5}{16}$	8·71	1·88
$\frac{3}{8}$	10·37	2·24
$\frac{1}{2}$	13·61	2·93
$5 \times 4 \times \frac{3}{8}$	11·00	2·28
$\frac{1}{2}$	14·45	2·99
$\frac{5}{8}$	17·80	3·66
$6 \times 3 \times \frac{5}{16}$	9·24	2·59
$\frac{3}{8}$	11·00	3·09
$\frac{1}{2}$	14·45	4·05
$\frac{5}{8}$	17·80	4·97
$6 \times 3\frac{1}{2} \times \frac{5}{16}$	9·76	2·65
$\frac{3}{8}$	11·63	3·17
$\frac{1}{2}$	15·30	4·16
$\frac{5}{8}$	18·86	5·11
$6 \times 4 \times \frac{3}{8}$	12·28	3·23
$\frac{1}{2}$	16·16	4·24
$\frac{5}{8}$	19·93	5·22
$7 \times 3\frac{1}{2} \times \frac{3}{8}$	12·91	4·23
$\frac{1}{2}$	17·00	5·58
$\frac{5}{8}$	20·99	6·87
$8 \times 4 \times \frac{1}{2}$	19·55	7·34
$\frac{5}{8}$	24·17	9·06

For drilling centres and maximum rivet size see Table 110.

SIZES AND WEIGHTS OF T BARS

B.S. 4a—*Equal Angles, Unequal Angles and Tee Bars for Structural Purposes*

TABLE 108. (See also Table 104)

Size, in.	Lb./ft.	Section Modulus	Size, in.	Lb./ft.	Section Modulus
$1\frac{1}{2} \times 1\frac{1}{2} \times \frac{1}{4}$	2·36	·130	$5 \times 4 \times \frac{3}{8}$	11·06	1·49
$2 \times 2 \times \frac{1}{4}$	3·21	·237	$\frac{1}{2}$	14·50	1·96
$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$	4·07	·375	$6 \times 3 \times \frac{3}{8}$	11·08	·871
$\frac{3}{8}$	5·92	·548	$\frac{1}{2}$	14·52	1·14
$3 \times 3 \times \frac{3}{8}$	7·20	·801	$6 \times 4 \times \frac{1}{2}$	16·22	2·00
$4 \times 3 \times \frac{3}{8}$	8·49	·833	$\frac{5}{8}$	19·99	2·46
$\frac{1}{2}$	11·09	1·08	$6 \times 6 \times \frac{1}{2}$	19·62	4·36
$4 \times 4 \times \frac{3}{8}$	9·77	1·45	$\frac{5}{8}$	24·23	5·40
$\frac{1}{2}$	12·79	1·90			
$5 \times 3 \times \frac{3}{8}$	9·79	·854			
$\times \frac{1}{2}$	12·80	1·11			

The first dimension is the head or table of the Tee and the second dimension is the stalk ; the thickness applies to both.

The Section Modulus is about an axis parallel to the head of the Tee.

DEFLECTION COEFFICIENTS

for steel beams and channels carrying the full tabular loads

Mid-span deflection in inches $= cL^2$ where L is the span in feet.

Example : a beam 12 in. deep, e.g. 12 in. × 5 in. or 12 in. × 6 in. B.S.B. or 12 in. × $3\frac{1}{2}$ in. or 12 in. × 4 in. B.S.C., on 14 ft. span fully loaded, will deflect $0{\cdot}00154 \times 14^2 = {\cdot}301$ in.

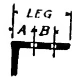
TABLE 109

Depth of Section, in.	Deflection Coeff. c.	Depth of Section, in.	Deflection Coeff. c.
3	·00615	12	·00154
4	·00461	13	·00142
$4\frac{3}{4}$	·00389	14	·00132
5	·00369	15	·00123
6	·00308	16	·00115
7	·00264	17	·00109
8	·00231	18	·00103
9	·00205	20	·000923
10	·00185	22	·000839
11	·00168	24	·000769

TABLE 110. STANDARD BACKMARKS (Drilling Centres)

For beams see Table 103 ; the values also apply to T sections.
For channels the values below for the appropriate leg length apply.

Single Row



Two Rows

Leg in.	C in.	Max. Size of Rivet or Bolt in.	Leg in.	C in.	Max. Size of Rivet or Bolt in.
1¼	¾	⅜	3	1¾	⅞
1½	⅞	½	3½	2	,,
1¾	1	,,	4	2¼	,,
2	1⅛	⅝	4½	2½	
2¼	1¼	¾	5	3	
2½	1⅜	,,	6	3½	

Leg in.	A in.	
5	2	1¾
6	2¼	2¼
7	2½	3
8	3	3
9	3	4
10	3	5

RIVET SPACING IN GIRDERS

Spacing (centres of rivets)		Diam. of Rivets			
		⅝″	¾″	⅞″	1″
Minimum pitch on line		1⅞″	2¼″	2⅝″	3″
Maximum pitch on line:—	Single line[1]	8″	8″	8″	8″
	Two lines staggered [2]	12″	12″	12″	12″
Minimum distance to sheared edge		1⅛″	1¼″	1½″	1¾″
to rolled or planed edge		1″	1⅛″	1¼″	1½″

[1] Must not exceed in tension members 16 times, or in compression members 12 times, the thickness of the thinnest outside plate or angle.

[2] If in angles, must not exceed in tension members 32 times, or in compression members 18 times, the thickness of the thinnest outside angle. If in plates, see 1.

LATERALLY UNSUPPORTED STEEL BEAMS

B.S. 449 and *L.C.C.* by-laws stipulate that when the laterally unsupported length L inches of a steel beam exceeds 20 times the breadth b inches of compression flange, the fibre stress shall not exceed $11 - \cdot 15\frac{L}{b}$ tons/sq. in., i.e. 8 tons /sq. in. when $\frac{L}{b} = 20$; further, the ratio $\frac{L}{b}$ shall not exceed 50.

TABLE III. Proportion of Tabular

Width of Flange In.	LATERALLY UNSUPPORTED										
	3	4	5	6	7	8	9	10	11	12	14
1½	·925	·775	·625	·475							
1¾		·861	·732	·605	·475						
2		·925	·813	·700	·587	·475					
2½			·925	·835	·745	·654	·565	·475			
3				·925	·850	·775	·700	·625	·550	·475	
3½				·990	·925	·861	·797	·731	·667	·603	·475
4					·981	·925	·869	·812	·756	·700	·587
4½						·974	·925	·875	·826	·775	·674
5	NO						·970	·925	·880	·835	·745
5½								·966	·925	·884	·802
6	REDUCTION								·962	·925	·850
7	NECESSARY									·898	·925
7½											·955
8											·981
10											
11											
12											

The Tables 112 to 114 are for laterally supported beams working on the full fibre stress of 8 tons/sq. in., and the table below gives the proportion of tabular loads permitted when a beam is not laterally supported, or when the distance between effective lateral supports, e.g. secondary beams, exceeds 20 times the compression flange width.

For beams solidly encased in concrete, B.S. 449 permits b to be taken as the width of the steel flange plus the least concrete cover on one side only and not exceeding 4 in. in thickness.

Loads Permitted

LENGTH IN FEET										
16	18	20	22	24	26	28	30	32	36	40
RATIO $\frac{L}{b}$ EXCEEDS 50										
·475										
·575	·475									
·654	·564	·475								
·720	·638	·557	·475							
·775	·700	·625	·550	·475						
·860	·796	·732	·666	·601	·539	·475				
·895	·835	·775	·715	·655	·595	·535	·475			
·925	·869	·812	·756	·700	·644	·587	·531	·475		
	·970	·925	·880	·835	·790	·745	·700	·654	·564	·475
		·966	·925	·887	·842	·801	·760	·721	·639	·557
			·962	·925	·887	·850	·812	·775	·700	·625

SAFE LOADS ON BRITISH STANDARD BEAMS

1. The next three tables give the total load which may be uniformly distributed along a simply supported beam. If concentrated or non-uniform loads occur the BM. must be worked out and a section chosen so that 8z (reduced if necessary according to Table 111) is not less than the BM. in inch-tons.

2. The load shown at the left-hand end of each line is the maximum load which may be distributed on the corresponding beam ; no increase of load on shorter spans is permissible unless the web is stiffened.

3. The self-weight of beams has *not* been deducted.

TABLE 112. Safe Uniformly Distributed

Size of Joist in.	Weight lb. per ft.	Section Modulus z	EFFECTIVE SPANS								
			3	4	5	6	7	8	9	10	11
3×1½	4	1·11	1·9	1·4	1·1	·98					
4×1¾	5	1·83	3·2	2·4	1·9	1·6	1·3	1·2			
3×3	8½	2·54	4·3	3·3	2·7	2·2	1·9				
							1·6	1·2			
4¾×1¾	6½	2·83	5·0	3·7	3·0	2·5	2·1	1·8	1·6		
4×3	10	3·89	6·9	5·1	4·1	3·4	2·9	2·6	2·3		
									2·0		
5×3	11	5·47	8·4	7·2	5·8	4·8	4·1	3·6	3·2	2·9	2·6
											2·4
6×3	12	7·00	10·7	9·3	7·4	6·2	5·3	4·6	4·1	3·7	3·3
5×4½	20	10·01			10·5	8·8	7·6	6·6	5·9	5·3	4·8
											4·4
7×4	16	11·29		13·5	12·0	10·0	8·6	7·5	6·6	6·0	5·4
6×4½	20	11·57	17·7	15·4	12·3	10·2	8·8	7·7	6·8	6·1	5·6
8×4	18	13·91		17·4	14·8	12·3	10·5	9·2	8·2	7·4	6·7
6×5	25	14·56		19·0	15·5	12·9	11·0	9·7	8·6	7·7	7·0
9×4	21	18·03		20·8	19·2	16·0	13·7	12·0	10·6	9·6	8·7
8×5	28	22·42			21·6	19·9	17·0	14·9	13·2	11·9	10·8
10×4½	25	24·47			22·6	21·7	18·6	16·3	14·4	13·0	11·8
8×6	35	28·76					21·0	19·1	17·0	15·3	13·9
10×5	30	29·25			27·9	26·0	22·2	19·5	17·3	15·6	14·1

Arranged in ascending order of section modulus. The values are taken by permission from Messrs. Redpath Brown & Co. Ltd.'s Steel Handbook.

(B.S.B.) (1932 Revision) **8 tons/sq. in.**

4. Loads to the right of the thick lines must be multiplied by the appropriate factor in Table 111 if the beam is not laterally supported by cross-beams, floor slab or otherwise.

5. Where two loads are tabulated at the right hand end of the line, the higher figure is the maximum safe load and the lower figure is the load which will produce a deflection of $\frac{1}{325}$th of the span. Under *L.C.C.* by-laws and B.S. 449 the span of a steel beam shall not exceed 24 times its depth unless the deflection is less than $\frac{1}{325}$th of the span.

6. For beams continuous over a support see notes on p. 117.

Loads in Tons

IN FEET												
12	14	16	18	20	22	24	26	28	30	32	36	40
2·4												
2·0												
3·1												
4·4												
3·7												
5·0	4·3	3·8										
		3·2										
5·1	4·4	3·9										
	3·7	2·8										
6·1	5·2	4·6										
6·4	5·5	4·9										
	4·7	3·6										
8·0	6·8	6·0										
9·9	8·5	7·4	6·6									
			5·9									
10·8	9·3	8·1	7·2									
12·7	10·9	9·5	8·5									
			7·5									
13·0	11·1	9·7	8·6	7·8								

Continued overleaf.

General dimensions of these sections are given in Table 103.

British Standard Beams—*Continued.*

TABLE 112.—*Continued.*

See notes on previous page. Safe Uniformly Distributed

Size of Joist in.	Weight lb. per ft.	Section Modulus z	EFFECTIVE SPANS								
			3	4	5	6	7	8	9	10	11
12×5	32	36·84				31·7	28·0	24·4	21·8	19·6	17·8
10×6	40	40·96						26·9	24·2	21·8	19·8
13×5	35	43·62				33·5	33·2	29·0	25·8	23·2	21·0
9×7	50	46·25							26·3	24·6	22·4
12×6L	44	52·79					36·3	35·0	31·2	28·1	25·4
15×5	42	57·13				47·4	43·4	38·0	33·8	30·4	27·6
10×8	55	57·74								29·6	27·9
12×6H	54	62·63					46·1	41·6	37·0	33·4	30·2
14×6L	46	63·22						41·7	37·4	33·7	30·6
15×6	45	65·59						41·3	38·8	34·9	31·8
14×6H	57	76·19					53·8	50·6	45·0	40·6	36·8
16×6L	50	77·26						46·1	45·6	41·2	37·4
12×8	65	81·30									38·0
16×6H	62	90·63					68·4	60·4	53·6	48·3	43·8
18×6	55	93·53							53·5	49·8	45·2
14×8	70	100·8									47·8
16×8	75	121·7									59·0
20×6½	65	122·6								62·9	59·4
18×7	75	127·9							75·0	68·2	62·0
18×8	80	143·6									69·6
22×7	75	152·4								77·5	73·8
20×7½	89	167·3							90·7	89·2	81·0
24×7½	95	211·1									97·6

8 tons/sq. in.

Loads in Tons

IN FEET

12	14	16	18	20	22	24	26	28	30	32	36	40
16·3	14·0	12·2	10·9	9·8								
18·2	15·6	13·6	12·1	10·9	9·9							
					9·0							
19·3	16·6	14·5	12·9	11·6								
20·5	17·6	15·4	13·7	12·3								
				11·1								
23·4	20·1	17·5	15·6	14·0	12·7	11·7	10·8	10·0				
							9·9	8·6				
25·3	21·7	19·0	16·9	15·2	13·8	12·6	11·7	10·8	10·1			
25·6	21·9	19·2	17·1	15·3	14·0							
					12·7							
27·8	23·8	20·8	18·5	16·7	15·1	13·9	12·8	11·9				
							11·8	10·2				
28·0	24·0	21·0	18·7	16·8	15·3	14·0	12·9	12·0	11·2	10·5		
									10·4	9·2		
29·1	24·9	21·8	19·4	17·4	15·9	14·5	13·4	12·4	11·6	10·9	9·7	
										10·2	8·0	
33·8	29·0	25·3	22·5	20·3	18·4	16·9	15·6	14·5	13·5	12·7		
									12·6	11·1		
34·3	29·4	25·7	22·8	20·6	18·7	17·1	15·8	14·7	13·7	12·8	11·4	10·3
											10·1	8·2
36·1	30·9	27·0	24·0	21·6	19·7	18·0	16·7	15·5				
							15·3	13·2				
40·2	34·5	30·2	26·8	24·1	21·9	20·1	18·5	17·2	16·1	15·1	13·5	12·1
											11·9	9·6
41·5	35·6	31·1	27·7	24·9	22·6	20·7	19·1	17·8	16·6	15·5	13·8	12·5
												11·2
44·7	38·3	33·5	29·8	26·8	24·4	22·3	20·6	19·1	17·9	16·8		
									16·7	14·7		
54·1	46·3	40·5	36·0	32·4	29·5	27·0	24·9	23·1	21·6	20·2	18·0	16·2
											16·0	12·9
54·4	46·7	40·8	36·3	32·6	29·7	27·2	25·1	23·3	21·7	20·4	18·1	16·3
56·8	48·7	42·6	37·8	34·1	31·0	28·4	26·2	24·3	22·7	21·3	18·9	17·0
												15·3
63·8	54·6	47·8	42·5	38·2	34·8	31·9	29·4	27·3	25·5	23·9	21·2	19·1
												17·2
67·7	58·0	50·8	45·1	40·6	36·9	33·8	31·2	29·0	27·0	25·4	22·5	20·3
74·3	63·7	55·7	49·5	44·6	40·5	37·1	34·3	31·8	29·7	27·8	24·7	22·3
93·8	80·4	70·3	62·5	56·2	51·1	46·9	43·2	40·2	37·5	35·1	31·2	28·1

SAFE LOADS ON BRITISH STANDARD

See notes 1 to 4 on page 148.

TABLE 113. Safe Distributed

Size in.	Weight * lb./ft.	Section Modulus Z	EFFECTIVE SPANS								
			3	4	5	6	7	8	9	10	11
3×1½	4·60	1·22	2·1	1·6	1·3	1·0	·79	·61			
4×2	7·09	2·53	4·4	3·3	2·6	2·2	1·9	1·6	1·3	1·0	
5×2½	10·22	4·75	8·4	6·3	5·0	4·2	3·6	3·1	2·8	2·5	2·0
6×3	12·41	7·09		9·4	7·5	6·3	5·4	4·7	4·2	3·7	3·4
6×3	16·51	8·76	15·5	11·6	9·3	7·7	6·6	5·8	5·1	4·6	4·2
7×3	14·22	9·36		12·4	9·9	8·3	7·1	6·2	5·5	4·9	4·5
6×3½	16·48	9·63			10·2	8·5	7·3	6·4	5·7	5·1	4·6
8×3	15·96	11·68		15·5	12·4	10·3	8·8	7·7	6·9	6·2	5·6
7×3½	18·28	12·24			13·0	10·8	9·3	8·1	7·2	6·5	5·9
9×3	17·46	13·89							8·2	7·4	6·7
8×3½	20·21	15·14			16·1	13·4	11·5	10·0	8·9	8·0	7·3
10×3	19·28	16·53							9·6	8·8	8·0
9×3½	22·27	18·36							10·8	9·7	8·9
10×3½	24·46	21·90							12·8	11·6	10·6
11×3½	26·78	25·80							15·2	13·7	12·4
12×3½	26·37	26·62							15·6	14·1	12·8
12×4	31·33	33·35							19·6	17·7	16·0
13×4	33·18	37·98							22·4	20·2	18·4
15×4	36·37	46·55							27·4	24·8	22·4
17×4	44·34	61·20							36·2	32·6	29·6

* Each of the sections tabulated above is also rolled in a heavier weight by raising the rolls to give a thicker web. The user should confirm that a section is available.

CHANNELS (B.S.C.) 1932 Revision

8 tons/sq. in.

Loads in Tons.

IN FEET											
12	14	16	18	20	22	24	26	28	30	32	36
1·7											
3·1	2·3	1·7									
3·8	2·8	2·1									
4·1	3·5	2·7	2·1								
4·2	3·1	2·4									
5·1	4·4	3·8	3·0	2·4							
5·4	4·6	3·5	2·8								
6·1	5·2	4·6	4·1	3·3	2·7						
6·7	5·7	5·0	3·9	3·2							
7·3	6·2	5·5	4·8	4·4	3·6	3·0					
8·1	6·9	6·1	5·4	4·4	3·6						
9·7	8·3	7·3	6·4	5·8	4·9	4·0					
11·4	9·8	8·6	7·6	6·8	6·2	5·2	4·4				
11·8	10·1	8·8	7·8	7·0	6·4	5·9	5·0	4·3			
14·8	12·7	11·1	9·8	8·8	8·0	7·4	6·3	5·4			
16·8	14·4	12·6	11·2	10·1	9·2	8·4	7·7	6·7	5·8		
20·6	17·7	15·5	13·7	12·4	11·2	10·3	9·5	8·9	8·2	7·2	5·7
27·2	23·3	20·4	18·1	16·3	14·8	13·6	12·5	11·6	10·8	10·2	8·5

Arranged in ascending order of section modulus. The values are taken by permission from Messrs. Redpath Brown & Co. Ltd.'s Steel Handbook. General dimensions of these sections are given in Table 105.

SAFE LOADS ON BROAD

See notes 1 to 4 on page 148. The thick vertical lines below show the limit of spans equal to 20 times flange width ; the widths and depths of these beams are less than the nominal dimensions.

The deflections do not exceed $\frac{1}{325}$th of span for the loads tabulated.

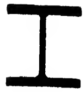
TABLE 114. Safe Distributed

Nominal Size * in.	Approx. Weight * lb./ft.	Depth of web clear of Root Fillets in.	Section Modulus z	EFFECTIVE SPANS				
				6	7	8	9	10
5 × 5	13	3·0	6·4	5·7	4·9	4·3	3·8	
5½ × 5½	16½	3·6	9·3	8·3	7·1	6·2	5·5	5·0
6 × 6	18	4·0	10·9	9·7	8·3	7·3	6·5	5·8
7 × 7	25	4·9	18·5		14·1	12·3	10·9	9·9
8 × 8	30	5·4	24·9		16·8	16·6	14·8	13·3
10 × 10	44	7·1	46·7					23·3
11 × 11	51½	8·0	61·0					
12 × 12	59	8·8	75·8					
14 × 12	76	10·6	114					
16 × 12	85	12·0	142					
18 × 12	96	13·7	179					
20 × 12	108	15·4	221					
24 × 12	124	19·1	299					
30 × 12	145	24·7	424					
40 × 12	188	34·2	700					

The above values have been extracted from Handbook 22 by permission of Messrs. R. A. Skelton & Co., Steel and Engineering Ltd., who marketed these sections in Great Britain until 1939. The sections were rolled in Luxembourg and it is expected that they will become available again in due course.

* The exact sizes and weights are metric figures. Each size is rolled in 4 weights of which the lightest (D.I.E. series) is tabulated above.

FLANGED BEAMS (Grey Process)



8 tons/sq. in.

Loads in Tons

IN FEET											
12	14	16	18	20	22	24	26	28	30	32	36
8·2											
11·0	9·5										
21	18	16	14								
26·9	23	20	18	16							
31	29	25	22	20	18	17					
45	43	38	34	30	28	25	23	22			
	53	47	42	38	34	32	29	27	25		
	65	60	53	48	43	40	37	34	32	30	
	78	74	65	59	54	49	45	42	39	37	33
	102	100	89	80	72	66	61	57	53	50	44
		137	126	113	103	94	87	81	75	71	63
		210	207	187	170	156	144	133	124	117	104

Broad flanged beams have advantages as columns, since the radius of gyration about the *YY* axis is greater than in a B.S.B. of similar weight. When used as beams they are less efficient than B.S.B.'s, the ratio of section modulus to weight being smaller ; they are useful in some circumstances, e.g. for lintols where the broad flange forms a wide bearing for brickwork, in cases where lateral rigidity is necessary, and where they may replace compound girders, i.e. joists with riveted flange plates.

TIMBER FLOOR CONSTRUCTION

The *L.C.C.* by-laws permit alternative methods of determining the size and spacing of timber joists and binders.

(*a*) Provided that the construction is of normal weight, e.g. does not include concrete pugging between the joists, the size and spacing of timbers may be obtained by the use of a table of spacing factors.

The following tables have been calculated to give this information direct ; they are based on the *L.C.C.* factors for " non-graded " timber (working fibre stress in bending 800 lb./sq. in.).

The alternative (*b*) is referred to at the end of the timber tables.

Cantilevers may project clear of support by a distance not exceeding ¼ of the supported span for which the timber would be permitted.

Non-graded timbers, supported at each end

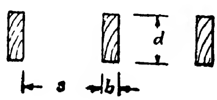
[(iv) JOISTS AND BINDERS TO RESIDENTIAL FLOORS, see Table 35]

(v) JOISTS TO OFFICES, ABOVE ENTRANCE FLOOR

TABLE 115. Clear Spacing S in inches

Joist Size $d \times b$ in.	Clear Span in Feet									
	6	7	8	9	10	11	12	13	14	15
6 × 1¾	17	12	8	7[1]				Max. span :—		
6 × 2	20	14	10	9[2]				[1] 8′-6″		
7 × 2	25	20	14	10	9[3]			[2] 8′-6″		
8 × 2		25	20	14	12	9		[3] 9′-11″		
8 × 2¼			22	16	13	10		[4] 12′-9″		
8 × 2½			25	17	15	11				
9 × 2				20	14	12	10	9[4]		
9 × 2½				25	17	15	12	11[4]		
9 × 3					21	18	15	13[4]		
11 × 2½						25	21	15	12	11
11 × 3							25	18	15	13

[1] Refer to the table inset, which gives the calculated maximum permitted span.



(vi) BINDERS TO OFFICES, ABOVE ENTRANCE FLOOR

TABLE 116. Clear Spacing S in inches

Joist Size d × b in.	Clear Span in Feet 8	9	10	11	12	13	14	15
9 × 3	57	48						
9 × 4	76	64	46					
10 × 4	94	76	64	46				
11 × 3	88	70	57	48				
11 × 4	118	94	76	64	54			
12 × 4	134	118	94	76	64	54	46	
12 × 6	201	177	141	114	96	81	69	60

(vii) JOISTS TO OFFICES ON AND BELOW ENTRANCE FLOOR, RETAIL SHOPS, GARAGES FOR CARS NOT OVER 2¼ TONS

TABLE 117. Clear Spacing S in inches

Joist Size d × b in.	Clear Span in Feet 6	7	8	9	10	11	12	13	14	15
6 × 1¾	16	11	8	7[1]				Max. span :—		
6 × 2	18	13	9	8[1]				[1] 8′-6″		
7 × 2	22	18	13	9	8[2]			[2] 9′-11″		
8 × 2	35	22	18	13	11	9		[3] 12′-9″		
8 × 2¼		26	20	15	12	10				
8 × 2½			22	16	14	11				
9 × 2			22	18	13	11	9	8[3]		
9 × 2½				22	16	14	11	10[3]		
9 × 3					19	16	13	12[3]		
11 × 2½						22	18	14	11	10
11 × 3							22	16	13	12

(viii) BINDERS TO OFFICES ON AND BELOW ENTRANCE FLOOR, RETAIL SHOPS, GARAGES FOR CARS NOT OVER 2¼ TONS

TABLE 118. Clear Spacing S in inches

Joist Size d × b in.	Clear Span in Feet 8	9	10	11	12	13	14	15
9 × 3	37							
9 × 4	50	40						
10 × 4	60	50						
11 × 3	57	45						
11 × 4	76	60	50	40				
12 × 4	88	76	60	50				
12 × 6	132	114	90	75	60	51	42	

(ix) JOISTS AND BINDERS TO CORRIDORS AND LANDINGS

Note. If within the curtilage of a flat or residence, a waiver may be sought to work on Table 35.

TABLE 119. Clear Spacing S in inches

Joist Size $d \times b$ in.	Clear Span in Feet									
	6	7	8	9	10	11	12	13	14	15
$6 \times 1\frac{3}{4}$	9	6								
6×2	10	7								
7×2	13	10	7							
8×2	21	13	10	7						
$8 \times 2\frac{1}{4}$	23	14	11	8						
$8 \times 2\frac{1}{2}$	26	16	12	9						
9×2	24	16	13	10	7					
$9 \times 2\frac{1}{2}$	30	20	16	12	9					
9×3	36	24	19	15	10					
$11 \times 2\frac{1}{2}$	34	30	26	20	16	12	10	9		
11×3	40	36	31	24	19	15	12	10		

(x) JOISTS TO WORKSHOPS, FACTORIES, GARAGES FOR MOTOR VEHICLES OTHER THAN THOSE IN CLASS (viii)

TABLE 120. Clear Spacing S in inches

Joist Size $d \times b$ in.	Clear Span in Feet							
	6	7	8	9	10	11	12	13
$6 \times 1\frac{3}{4}$	9	6						
6×2	10	7					Max. span [1] 12′-10″	
7×2	13	10	7					
8×2	21	13	10	7				
$8 \times 2\frac{1}{4}$	23	14	11	8				
$8 \times 2\frac{1}{2}$	26	16	12	9				
9×2	24	16	13	10	7			
$9 \times 2\frac{1}{2}$		20	16	12	9			
9×3		24	19	15	10			
$11 \times 2\frac{1}{2}$			26	20	16	12	10	9[1]
11×3				24	19	15	12	10[1]

(xi) BINDERS TO WORKSHOPS, FACTORIES, GARAGES FOR MOTOR VEHICLES OTHER THAN THOSE IN CLASS (viii)

TABLE 121. Clear Spacing S in inches

Joist Size d × b in.	Clear Span in Feet					
	8	9	10	11	12	13
10 × 4	40					
11 × 3	37					
11 × 4	50	40				
12 × 4	58	50	40			
12 × 6	86	75	. 60	48	39	

(xii) JOISTS AND BINDERS TO WAREHOUSES, BOOK AND STATIONERY STORES AND THE LIKE

TABLE 122. Clear Spacing S in inches

Joist Size d × b in.	Clear Span in Feet						
	6	7	8	9	10	11	12
8 × 2	15	9	7				
8 × 3	22	13	10				
9 × 2	18	12	9	7			
9 × 3	27	18	13	10			
9 × 4	36	24	18	14			
10 × 4	- -	- -	24	18	14		
11 × 3	30	27	22	18	13	10	
11 × 4	40	36	30	24	18	14	
12 × 4	—	—	36	30	26	18	14
12 × 6	—	—	54	44	36	27	21

(*b*) The alternative to using the foregoing tables is to determine the size and spacing of timber by calculation, in which case the following superimposed loadings are specified by the *L.C.C.* and in *B.S.* 1018—*Timber in Building Construction*, respectively.

Both specifications state that floor boards shall be not less than $\frac{5}{8}$ in. thick, and shall be calculated on a superimposed loading of not less than 200 lb./sq. ft. ; but B.S. 1018 allows grooved and tongued boards to be designed on not less than twice the loading for joists (see next table).

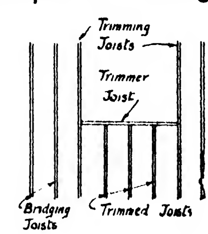
The *M.O.H.* Model by-laws give rules for timber rafter and joist thickness, and specify that a trimmer joist carrying not more than 6 common joists, or carrying one trimmer joist not more than 3 ft. from its end, should be $1\frac{1}{2}$ in. thicker than a common joist of the same span. The common joists specified for warehouses are not deep enough to be efficient, but timber is no longer likely to be permitted in warehouses.

TABLE 123. Superimposed Loading. Lb./sq. ft.

Class	Type of Building or Floor	On Joists between Binders or other Supports.		On binders and other Supporting Constructions.	
		L.C.C.	BS.1018	L.C.C.	BS.1018
1	Rooms used for residential purposes ; and corridors, stairs and landings within the curtilage of a flat or residence	40	40	40	40
★	Hotel bedrooms, hospital rooms and wards (for public spaces see below)	As Class 1	40	As Class 1	40
2	Offices, floors above entrance floor	80	80	50	50
3	Offices, entrance floor and floors below ; retail shops ; garages for cars not over $2\frac{1}{2}$ tons, L.C.C. (2 tons, B.S. 1018)	90	80	80	80
★	Churches, schools, reading rooms, art galleries	As Class 3	80	As Class 3	70
4	Corridors, stairs and landings not provided for in Class 1	100	100	100	100
★	Assembly, dance and drill halls, restaurants, cafés, theatres, cinemas, grandstands, gymnasia, light workshops, public spaces in hotels and hospitals	As Class 4	100	As Class 4	100
5	Workshops and factories, garages for motor vehicles other than those described in Class 3	Not less than 150	—	Not less than 120	—
5a	Garages for motor vehicles exceeding 2 tons in weight	—	200	—	200
6	Warehouses, book stores, stationery stores and the like	Not less than 200	200	Not less than 200	200

★ These cases are not specifically covered by the *L.C.C.* by-laws, but District Surveyors and local authorities will normally accept the class loading stated. The actual loading on floors in Classes 5 and 6 and for any purpose not specified is to be ascertained, and is not to be taken as less than the figures given where they apply.

The minimum breadth of a joist or binder is $1\frac{3}{8}$ in.—*B.S.* 1018 or $1\frac{3}{4}$ in.—*L.C.C.* Both specifications limit the deflection under the specified loading to $\frac{1}{360}$th of the span. *B.S.* 1018 stipulates that if the depth of a member exceeds 3 times the breadth and the length exceeds 50 times the breadth, lateral restraint (such as would be provided by floor boards) is necessary.



B.S. 1018 gives definitions of the various types of joist in floor construction, as shown in the sketch plan. A plate is a member supported throughout its length, as on a wall, and used to spread the load from other parts of the construction, e.g. joists or rafters.

The following formulæ are given for checking the bending moment, shear and deflection of timber beams. They may be derived from the expressions given on page 112.

TABLE 124

Bridging Joists and Trimmed Joists, simply supported.	Bridging Joists, Trimmed Joists, Binders, continuing over Supports and adequately cantilevered.
$Wl = \frac{4}{3} . b.d^2f$	$Wl = \frac{1}{3} . bd^2f$
$q = \frac{3}{4} \frac{W}{bd}$	$q = \frac{3}{2} \frac{W}{bd}$
$bd^3 = \frac{225}{4} . \frac{Wl^2}{E}$	$bd^3 = 540 \frac{Wl^2}{E}$

where W is the total load in lb. distributed over the span.
l is the span in inches.
b and d are in inches.
E is the Elastic Modulus in lb./in.^{2} units.
q is the maximum shear stress, lb./in.^{2}

FOUNDATIONS

TABLES 125—130

FOUNDATIONS

SOIL DEFINITIONS AND SAFE LOADS

TABLE 125

Agricultural Definitions

Sandy soil, containing not more than	5% clay
Sandy Loam	5–8% ,,
Loam	8–15% ,,
Clay Loam	15–30% ,,
Clay	over 30% ,,
Marl	5–50% lime

TABLE 126

Soil Classification

(Massachusetts Institute of Technology)

Designation	Grain Size mm.
Gravel	above 2·0
Coarse sand	0·6–2·0
Medium sand	0·2–0·6
Fine sand	·06–0·2
Coarse silt	·02–·06
Medium silt	·006–·02
Fine silt	·002–·006
Clay	below ·002

FOUNDATION PRESSURES ON GROUND

Any list such as this can only be a rough indication of the permissible load. The decision should be made after consulting the local authority, who may require tests. Excavation in clay should always be taken below frost level.

TABLE 127

Nature of Ground	Safe Load tons/sq. ft.
Natural bed of silt, peat, recent made ground	Less than ¼ or requires piling
Alluvial soil, very wet sand, made ground well compacted or tipped several years.	Up to ½
Natural bed of soft clay, wet sand	1
Natural bed of fairly dry clay, fine dry sand or loam	2
Natural bed of firm dry clay, medium boulder clay, gravel	3
Compact sand or gravel, London blue clay, hard boulder or similar compact clay, in deep foundations	4
Hard solid chalk	6
Shale and soft rock	Up to 10
Very hard rock	Up to 40

TABLE 128. COMPARATIVE WEIGHTS OF EARTH, GRAVEL, etc.

Material (see Tables 125 and 126 for Definitions)		Lb. per cu. ft.
Alluvial ground	undisturbed	100
Ballast	loose, graded	100
	undisturbed	120
Chalk		100–170
Clay fill	dry, lumps	65
	dry, compact	90
	damp, compact	110
	wet, compact	130
,, undisturbed		120
do.	gravelly	130
,, China	compact	140
Fuller's Earth	natural	110–150
Gravel	loose	100
	undisturbed	120–135
Kaolin	compact	140
Loam (sandy clay)	dry, loose	75
	dry, compact	100
	wet, compact	120
Loess	dry	90
Marl (limey clay)	compact	110–120
Mud, river	wet	110–120
Peat	dry, stacked	35
	sandy, compact	50
	wet, compact	85
Sand fill	damp when filled	80
	dry when filled	100
	saturated	120
,, undisturbed	dry	105
	saturated	125
Shingle	fine, dry	100
	,, saturated	130
	coarse, graded, dry	115
	,, ,, saturated	140
Silt	wet	110–120
Soil, common	loose	90
	compact	130

For the weights of building stones see page 64. A number of minerals are included in the table of Densities, page 94.

ANGLES OF REPOSE

The angle of repose of granular materials varies with the size of the particles, being steeper as the size increases, but the presence of damp fine material in broken stone or ballast increases the angle.

In fine granular materials, dampness increases the angle, but water, above a certain proportion, acts as a lubricant and the angle flattens.

The angle of repose of material like clay is very indefinite. Hard lumps can be stacked to an almost vertical face, but weathering will eventually break them down to a slope which depends on the nature of the clay. The presence of clay in sand and of sand in clay increases the angle of repose.

The figures below can only be regarded as typical.

TABLE 129

Material	Angle	Material	Angle
Alluvial ground	25°	Hæmatite, loose	35°
Ballast	45°	Marl	45°
Cement, clinker	33°	Pyrites, ground	40°
ground	concave	Rock filling	45°
Clay	15°–45°	Sand, coarse	35°–40°
,, typical construction :		fine	30°–35°
Embankment, water face	1 in 3 = 18°	saturated	25°
downstream face	1 in $2\frac{1}{2}$ = 22°	Shale, colliery dirt	35°
Cutting	1 in $1\frac{1}{2}$ = 33°	Shingle, crushed	40°
Coal, broken	35°–45°	smooth	30°
10 mesh	34°	Slag filling	35°
100 mesh	16°	Stone, broken, up to 2″	35°–40°
slurry	0–20°		
Coke	25°–30°		
Grain	25°		
Gravel	35°–45°		

INCREASE IN BULK OF EXCAVATED MATERIAL

TABLE 130

Chalk	$\frac{1}{3}$–$\frac{1}{2}$
Clay	$\frac{1}{3}$
Gravel	$\frac{1}{10}$
Rock	$\frac{1}{3}$–$\frac{1}{2}$
Sand, dry	$\frac{1}{8}$
damp	$\frac{1}{3}$
saturated	$\frac{1}{12}$

METER PITS

The *Metropolitan Water Board* specify the minimum dimensions of meter pits when not in the line of wheeled traffic as below.

TABLE 131

Size of Meter	Internal Dimensions of Pit, and Clear Opening of Cover	Depth of Frame of Cover
3/8" to 1½"	24" × 24"	4¼"
2" to 3"	36" × 24"	,,
4" to 8"	42" × 24"	,,

MANHOLE COVERS AND FRAMES (CAST IRON)

B.S. 497 for light manhole covers and frames gives the dimensions and weights below.

TABLE 132

Nominal Size = Clear Opening In.	Overall Size of Frame In.	Depth of Frame* In.	Minimum Weight	
			Frame lb.	Cover lb.
18 × 18	21¼ × 21¼	1 7/32	13½	28½
24 × 18	27¾ × 21¼	,,	18	38
,,	28 × 22	1½	27	57
,,	28½ × 22½	1⅞	36	76
24 × 24	28 × 28	1½	31	81

* The cover chequer pattern projects 3/32 in. above the rim of the frame.

STEEL CHEQUERED AND PLAIN PLATES
Weights and Safe Loads

TABLE 133.

Thickness In.	Weight per sq. ft.		Safe uniformly Distributed Load, lb./sq. ft.				
	Chequer	Plain	Span 1	2	3	4	5 ft.
½	22	20·4	5970	1490	660	370	240
7/16	19¼	17·9	4570	1140	510	280	180
⅜	16¾	15·3	3360	840	370	210	130
5/16	14¼	12·8	2330	580	260	140	93
¼	11¾	10·2	1490	370	160	93	59
3/16	9¼	7·7	840	210	93	52	—

DIMENSIONS FOR PLANNING

In general these dimensions should be regarded as minima.

Stairs. Rise $7\frac{1}{2}$ in. max. Run or tread $8\frac{1}{2}$ in. Width 3 ft. (Public buildings: Rise 6 in., tread 11 in., width 4 ft. 6 in.) Headroom from nose of stair 6 ft. 6 in. vertically. Height of handrail from nose of stair 2 ft. 6 in. vertically. Ditto on landings 3 ft. 0 in.

Windows. 10% of floor area (*L.C.C.*), half to open.

P.W.B.S. No. 12 recommends 15% for large bedrooms and large living rooms and 20% for kitchens. Measurement of area is inside the fixed framework. The glass line should be not more than 2 ft. 9 in. above floor level and the lintel not less than 7 ft. 6 in. above floor level.

Fittings

Bath		5 ft. 6 in. × 2 ft. 4 in. in plan
★Sink	10 in. deep ×	2 ft. 0 in. × 1 ft. 6 in. ,,
Linen and clothes cupboard not less than 20 in. deep.		
Lavatory basin		25 in. wide by 18 in. front to back
★Gas oven vertical type		2 ft. 6 in. × 2 ft. 0 in. ,, ,,
★	horizontal type	3 ft. 6 in. × 2 ft. 0 in. ,, ,,
★Copper, gas or electric		1 ft. 9 in. × 1 ft. 9 in. in plan

* These items are becoming standardised at 3 ft. 0 in. in height above floor and 1 ft. 9 in. front to back.

Roads and paths

Access road 16 ft. Cul de sac 13 ft. Private drive 9 ft.

Public path 6 ft. The minimum width of carriage-way usually permitted in local by-laws is 20 ft.

Minimum turning circles : 10 ton lorry 60–65 ft. diameter.
30 H.P. car 45 ft. diameter.

Vehicles

Cars range from 4 ft. 3 in. to 6 ft. 0 in. wide, 5 ft. 1 in. to 6 ft. 5 in. high, 10 ft. 7 in.–16 ft. 7 in. long.

All cars not over 14 H.P. will go in a garage 14 ft. 6 in. long.

Garage for cars :
door opening (straight approach) 7 ft. Height to lintel 6 ft. 6 in.
width inside 11 ft.

Garage for large lorries :
door opening 10 ft. Height to lintel 14 ft.
track width outside tyres 7 ft.
wheel load single tyre 2·1 tons, double tyre 3·6 tons.

Loading dock level above road 3 ft. 0 in.

Railways

Standard gauge between running faces of rails .	4 ft. 8½ in.
Clearance from running face of rail to structure .	4 ft. 9¾ in.
Height clear above rail level to structure . .	15 ft. 0 in.
Centre of buffer stop above rail level . .	3 ft. 6 in.
Wagon floor above rail level	4 ft. 0 in.
Loading dock above rail level	3 ft. 3 in.
Large loco. wheel loads 8 tons at 5 ft. 3 in. centres.	
Width of widest rolling stock	8 ft. 4 in.
Dimensions of timber sleepers . 10 in. × 5 in. ×	9 ft. 0 in.
Height of rail top above top of sleeper	
90 lb. bullhead rails	7½ in.
90 lb. flat bottom rails	6¼ in.

DIMENSIONS OF PIPES

The main purpose of these pipe tables is to show conveniently the overall diameters and effective lengths, which are required in planning. In the British Standard specifications, the outside diameters of sockets must be obtained by adding other dimensions which are often in fractions to $\frac{1}{32}$ in. The present tables give these dimensions directly, in decimals to the nearest tenth of an inch, so that the figures are sufficiently accurate for determining clearances and easier to handle than small fractions.

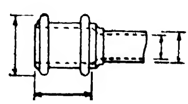
When pipes are cast with ears, the face of the ears is practically tangential to the outside of the socket.

It will be noticed that the standard lengths are in some cases "effective," i.e. exclusive of the depth of socket, and in other cases overall, i.e. inclusive of the socket. The depth of socket for the latter cases is tabulated so that the effective length may be derived.

Summary of Cast Iron Spigot and Socket Pipes

B.S. 40. *Cast Iron Low Pressure Heating Pipes.*
41. *Cast Iron Flue or Smoke Pipes.*
78. *Cast Iron Pipes (Vertically Cast) for Water, Gas and Sewage.*
416. *Cast Iron Soil, Waste, Ventilating and Heavy Rainwater Pipes.*
437. *Cast Iron Drain Pipes.*
460. *Cast Iron Light Rainwater Pipes (Cylindrical).*

DIMENSIONS OF CAST IRON PIPES



B.S. 40. *Heating Pipes (Low Pressure)* in standard lengths 3 ft., 6 ft. and 9 ft. *overall.*

B.S. 41. *Flue or Smoke Pipes* in standard lengths 3 ft. and 6 ft. *overall.*

TABLE 134. Dimensions in inches

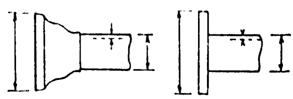
Nominal Internal Diam.	B.S. 40				B.S. 41			
	Outside Diam.	Diam. over Socket	Depth of Socket	Weight of 6 ft. Pipe lb.	Outside Diam.	Diam. over Socket	Depth of Socket	Weight of 6 ft. Pipe lb.
2	2·4	4·0	3	27	—	—	—	—
3	3·5	5·3	3·5	45	—	—	—	—
4	4·5	6·5	4	61	4·3	5·4	3	33
4½	—	—	—	—	4·8	5·9	3	36
5	5·6	7·7	4	94	5·3	6·4	3·25	46
6	6·6	9·0	4·5	125	6·3	7·6	3·5	63
7	7·7	10·1	4·5	160	7·4	8·8	3·5	86
8	8·8	11·5	5	201	8·5	10·1	4	112
9	9·8	12·6	5	243	9·5	11·4	4	144
10	—	—	—	—	10·6	12·6	4·25	176
12	—	—	—	—	12·6	14·8	4·25	245

Dimensions of Cast Iron Pipes—*Continued.*

In accordance with *B.S.* 78—*Cast Iron Pipes for Water, Gas and Sewage.*

Four classes are included in this specification, which covers straight pipes and bends and other specials, with joints either spigot and socket, turned and bored, or flanged.

Class	Purpose	Tested Pressure
A	Gas	200 ft.
B	Water sewage	400 ft.
C	,, ,,	600 ft.
D	,, ,,	800 ft.



(i) Spigot & socket (ii) Turned & bored *(iii) Flanged*

For the weights see next table.

TABLE 135. Dimensions in inches

Nominal Internal Diam. in.	Pipe Thickness in.			Outside Diam. in.		Diam. over Socket in.		Flange Diam. A, B & C In.	Nominal Internal Diam. In.
	A	B	C	A & B	C	A & B	C		
1½	·35	As Class A	As Class A	2·20	As Classes A & B	4·86	As Classes A & B	5¼	1½
2	·36	,,	,,	2·72	,,	5·42	,,	6	2
2½	·37	,,	,,	3·24	,,	6·00	,,	6½	2½
3	·38	,,	,,	3·76	,,	6·60	,,	7¼	3
4	·39	,,	·40	4·80	,,	7·74	,,	8½	4
5	·41	,,	·45	5·90	,,	8·88	,,	10	5
6	·43	,,	·49	6·98	,,	10·0	,,	11	6

TABLE 135—*Continued.*

Nominal Internal Diam. in.	Pipe Thickness in.			Outside Diam. in.		Diam. over Socket in.		Flange Diam. A, B & C in.	Nominal Internal Diam. in.
	A	B	C	A & B	C	A & B	C		
7	·45	,,	·53	8·06	,,	11·2	,,	12	**7**
8	·47	,,	·57	9·14	,,	12·4	,,	13¼	**8**
9	·49	,,	·60	10·20	,,	13·5	,,	14½	**9**
10	·52	,,	·63	11·3	,,	14·6	,,	16	**10**
12	·55	·57	·69	13·1	13·6	16·7	17·6	18	**12**
14	·57	·61	·75	15·2	15·7	19·0	20·0	20¾	**14**
15	·59	·63	·77	16·3	16·8	20·1	21·1	21¾	**15**
16	·60	·65	·80	17·3	17·8	21·2	22·3	22¾	**16**
18	·63	·69	·85	19·4	20·0	23·6	24·7	25¼	**18**
21	·67	·75	·92	22·5	23·1	26·9	28·1	29	**21**
24	·71	·80	·98	25·6	26·3	30·3	31·6	32½	**24**

Other sizes are also listed. Class D is only used for very high pressures.

The *Metropolitan Water Board* stipulates that water service pipes shall be at least Class C. For fraction-decimal equivalents see Table 188.

LENGTHS AND WEIGHTS OF C.I. PIPES (spigot and socket)

In accordance with *B.S.* 78. The length is exclusive of depth of socket. For the dimensions see previous page.

TABLE 136. Weight per pipe, lb.

Internal Diam. in.	Class A			Class B		Class C	
	6 ft.	9 ft.	12 ft.	9 ft.	12 ft.	9 ft.	12 ft.
1½	47			★		★	
2	60			★		★	
2½		105		As		As	
3		129		Class A		Class A	
4		171	221	,,	As	175	226
5		222	286	,,	Class A	239	310
6		276	357	,,	,,	307	399
7		334	433	,,	,,	383	498
8		403	520	,,	,,	473	614
9		468	605	,,	,,	555	721
10		546	707	,,	,,	642	835
12		677	876	697	904	868	1125
14			1066		1131		1425
15			1179		1248		1563
16			1278		1371		1727
18			1505		1629		2056
21			1860		2055		2132
24			2266		2516		3147

* 6 ft. lengths only; weights as Class A.

Dimensions and Weights of typical spun Cast Iron Pipes (spigot and socket)

The length is exclusive of the depth of socket. Tested pressure 400 ft.

TABLE 137. Weight per pipe, lb.

Internal Diameter In.	Class B			
	Thickness In.	9 ft.	12 ft	18 ft.
4	·30	135	175	255
5	·31	180	231	334
6	·33	228	294	426
7	·34	267	343	497
8	·36	322	413	596
9	·37	377	483	696
10	·39	436	560	808
12	·43	556	714	1032
14	·46		896	1312
15	·47		980	1413
16	·49		1085	1565
18	·52		1281	2163

B.S. 416—*Soil, Waste, Ventilating and Heavy Rainwater Pipes,* in standard lengths 6 ft. *overall.*

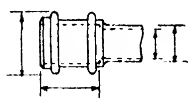


TABLE 138. Dimensions in inches

Nominal Size = Internal Diam.	Outside Diam.	Diameter over Socket	Depth of Socket	Weight of Pipe lb.
Extra Heavy Grade				
3½	4	5·8	3	55
4	4½	6·3	3	60
5	5½	7·5	3·25	78
6	6½	8·5	3·5	92
Heavy Grade				
3	3·4	5·1	2·75	40
3½	3·9	5·75	3	48
4	4·4	6·25	3	54

Dimensions of Cast Iron Pipes—*Continued.*

TABLE 138—*Continued.*

Nominal Size = Internal Diam.	Outside Diam.	Diameter over Socket	Depth of Socket	Weight of Pipe lb.
Medium Grade				
1½	1·9	3·4	2·25	22
2	2·4	3·9	2·5	24
2½	2·9	4·4	2·75	30
3	3·4	5·1	2·75	35
3½	3·9	5·8	3	41
4	4·4	6·3	3	46
5	5·4	7·5	3·25	59
6	6·4	8·5	3·5	71

B.S. 437.—*Drain Pipes*, in standard lengths 9 ft. exclusive of socket (*2 in. diam., 6 ft. only)

TABLE 139. Dimensions in inches

Nominal Size = Internal Diam.	Outside Diam.	Diameter over Socket	Weight of Pipe lb.
2	2·6	4·4	42*
3	3·6	5·75	98
4	4·75	7·1	157
5	5·75	8·25	186
6	6·75	9·25	225
7	7·9	10·9	316
8	8·9	11·9	370
9	9·9	12·9	441

B.S. 460—*Light Rainwater Pipes* (*Cylindrical*) in standard lengths 6 ft. *overall*

TABLE 140. Dimensions in inches

Nominal Size †	Outside Diam.	Diameter over Socket	Depth of Socket	Weight of Pipe lb.
2	⅛″ more than nominal size	3	2½	17
2½		3·5	2⅝	19
3		4	2¾	23
3½		4·6	2⅞	28
4	,,	5·1	3	34
4½	,,	5·7	3⅛	40
5	,,	6·2	3¼	45
6	,,	7·25	3⅜	58

† The internal diameter in each case is approximately ⅛ in. less than the Nominal Size.

DIMENSIONS OF ASBESTOS CEMENT PIPES

See remarks on page 173.
The following specifications refer to asbestos cement pipes :—

B.S. 567. *Flue Pipes for Gas Fired Appliances.*
Standard lengths 1 ft., 2 ft., 3 ft., 4 ft., 5 ft., 6 ft. effective.
Test pressure 6 lb./sq. in.

B.S. 569. *Rain Water Pipes* (includes gutters, rainwater heads, etc.).
Standard length 6 ft. effective.

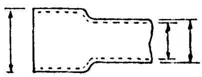
B.S. 582. *Soil, Waste and Ventilating Pipes.*
Standard length 6 ft. effective. See Table 141 for test pressures.

B.S. 835. *Flue Pipes for Domestic Heating Stoves.*
Standard lengths 1 ft., 2 ft., 3 ft., 4 ft., 5 ft., 6 ft. effective.
Test pressure 6 lb./sq. in.

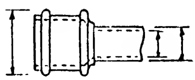
B.S. 486. *Pressure Pipes*, see Table 142.

The year of the latest specification referred to is given in the list at the end of the book.

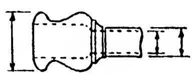
B.S. 567
B.S. 835



B.S. 569



B.S. 582



B.S. 486

TABLE 141. Dimensions in inches

Internal Diam. = Nominal Diam.	B.S. 567 Outside Diam.	B.S. 567 Diam. over Socket	B.S. 569 Outside Diam.	B.S. 569 Diam. over Socket	B.S. 582 Outside Diam.	B.S. 582 Diam. over Socket	B.S. 582 Min. Test Pressure	B.S. 835 Outside Diam.	B.S. 835 Diam. over Socket
2	$2\frac{3}{8}$	3	$2\frac{1}{2}$	$3\frac{3}{4}$	$2\frac{1}{2}$	4·1	300		
$2\frac{1}{2}$	$2\frac{7}{8}$	$3\frac{1}{2}$	3	$4\frac{1}{4}$	3	4·6	240		
3	$3\frac{3}{8}$	4	$3\frac{5}{8}$	5	$3\frac{5}{8}$	5·4	250	$3\frac{5}{8}$	$4\frac{1}{2}$
$3\frac{1}{2}$	$3\frac{7}{8}$	$4\frac{1}{2}$	$4\frac{1}{8}$	$5\frac{1}{2}$	$4\frac{1}{8}$	6·0	215	$4\frac{1}{4}$	$5\frac{1}{4}$
4	$4\frac{3}{8}$	5	$4\frac{5}{8}$	6	$4\frac{5}{8}$	6·5	190	$4\frac{3}{4}$	$5\frac{3}{4}$
$4\frac{1}{2}$	5	$5\frac{3}{4}$	$5\frac{1}{4}$	$6\frac{3}{4}$	—	—	—	$5\frac{1}{4}$	$6\frac{1}{4}$
5	$5\frac{1}{2}$	$6\frac{1}{4}$	$5\frac{3}{4}$	$7\frac{1}{4}$	$5\frac{3}{4}$	7·9	180	$5\frac{3}{4}$	$6\frac{3}{4}$
$5\frac{1}{2}$	6	$6\frac{3}{4}$	$6\frac{3}{4}$	$8\frac{1}{4}$	$6\frac{3}{4}$	8·9	150	$6\frac{1}{4}$	$7\frac{1}{4}$
6	$6\frac{1}{2}$	$7\frac{1}{4}$					lb./	$6\frac{3}{4}$	$7\frac{3}{4}$
7	$7\frac{3}{4}$	9					sq. in.	$7\frac{3}{4}$	9
8	$8\frac{3}{4}$	10						$8\frac{3}{4}$	10
9	$9\frac{3}{4}$	11						$9\frac{3}{4}$	11
10	$10\frac{3}{4}$	12						$10\frac{3}{4}$	12
11	$11\frac{3}{4}$	13						$11\frac{3}{4}$	13
12	13	$14\frac{1}{2}$						13	$14\frac{1}{2}$

B.S. 486—Asbestos Cement Pressure Pipes

These pipes have plain ends, to be jointed by sleeves which are not covered in the specification. The pipes will fit in the sockets of the corresponding cast iron pipes of *B.S.* 78.

TABLE 142. Dimensions and Weights per foot

	CLASS	A		B		C		D	
	Working Pressure	100 ft.		200 ft.		300 ft.		400 ft.	
Nom. Internal Diam. in.	Outside Diameter (all classes) in.	Int. Diam. in.	Wt. per ft., lb.	Int. Diam. in.	Wt. per ft., lb.	Int. Diam. in.	Wt. per ft., lb.	Int. Diam. in.	Wt. per ft., lb.
2	2·76	1·98	3	1·98	3	1·98	3	1·86	$3\frac{1}{2}$
3	3·76	2·96	$4\frac{1}{2}$	2·96	$4\frac{1}{2}$	2·76	$5\frac{1}{2}$	2·66	6
4	4·80	3·96	6	3·86	7	3·58	$8\frac{1}{2}$	3·48	9
5	5·90	4·98	8	4·80	10	4·50	12	4·34	13
6	6·98	6·00	10	5·76	13	5·42	16	5·18	18
7	8·06	7·00	13	6·74	16	6·32	20	6·00	24
8	9·14	8·00	16	7·70	20	7·22	26		
9	10·2	9·00	18	8·62	23	8·10	30		
10	11·26	9·98	21	9·58	27	8·94	37		

TABLE 142—*Continued.*

CLASS		A		B		C		D	
Working Pressure		100 ft.		200 ft.		300 ft.		400 ft.	
Nom. Internal Diam. in.	Outside Diameter (all classes) in.	Int. Diam. in.	Wt. per. ft., lb.	Int. Diam. in.	Wt. per. ft., lb.	Int. Diam. in.	Wt. per. ft., in.	Int. Diam. in.	Wt. per. ft., lb.
	Class A / Classes B C D								
12	13·14 / 13·60	11·78	27	11·60	39	11·26	46		
14	15·22 / 15·72	13·64	36	13·42	53				
15	16·26 / 16·78	14·58	41	14·32	60				
18	19·38 / 19·98	17·38	58	17·02	85				
20	21·46 / 22·06	19·26	71	18·82	102				
21	22·50 / 23·12	20·18	78	19·72	115				
24	25·60 / 26·26	23·00	99						

Other sizes are listed up to 40 in.
100 ft. of head = 43·35 lb./sq. in.

SALT-GLAZED WARE PIPES

Formerly known as "stoneware." The trade designation "Best Quality" is appreciably cheaper than goods marked "British Standard." *B.S.* 65 covers taper pipes, bends and junctions in addition to straight pipes. The dimensions given below are calculated from data in *B.S.* 65.

The standard length is exclusive of depth of socket.

TABLE 143

Internal Diameter in.	Outside Diameter in.	Diam. over Socket in.	Standard Lengths	Approx. Wt. per 2ft. Pipe, lb.	Wt. of 6" of barrel lb.
3	3⅞	5·5	2′	11	—
4	5	6·9	,,	19	—
5	6⅛	8·3	,,	25	—
6	7¼	9·5	,,	30	—
7	8⅜	10·8	2′, 2′ 6″	37	8
8	9⅜	11·9	,,	45	9
9	10½	13·2	2′, 2′ 6″, 3′	55	11
10	11⅝	14·7	,, ,,	66	13
12	14	17·4	,, ,,	100	20
13	15⅛	18·7	,, ,,	115	23
14	16⅜	20·2	,, ,,	139	28
15	17½	21·4	,, ,,	157	31
18	21	25·4	,, ,,	239	45
21	24¼	29·2	,, ,,	304	56
24	27½	32·7	,, ,,	372	69
27	30¾	36·2	,, ,,	460	83
30	34	39·7	,, ,,	540	98
36	41	48·2	,, ,,	820	147

Pipes to British Standard Specification must withstand an internal hydraulic pressure of 20 lb./sq. in. for 5 seconds.

WROUGHT IRON AND STEEL TUBES FOR GAS, WATER AND STEAM

In accordance with *B.S.* 788—*Wrought Iron Tubes and Tubulars*
and *B.S.* 789—*Steel Tubes and Tubulars*

The three grades are also known as Light, Medium and Heavy, Medium being one size and Heavy two sizes thicker on the S.W.G. than Light. The outside diameter is controlled by the screw gauges, and the actual bore therefore depends on the wall thickness but is within $\frac{1}{16}$ in. of the nominal, for sizes up to 2″ and within $\frac{1}{8}$ in. for larger sizes.

TABLE 144

Nominal Bore in.	Approx. Outside Diameter in.	Wall Thickness, in. Gas	Water	Steam	Weight per ft. lb.* Gas	Water	Steam	Diam. over Socket
$\frac{1}{8}$	$\frac{13}{32}$	·080	·092	·104	·274	·303	·329	·60
$\frac{1}{4}$	$\frac{17}{32}$	,,	,,	,,	·378	·423	·465	·75
$\frac{3}{8}$	$\frac{11}{16}$	·092	·104	·116	·574	·636	·695	·91
$\frac{1}{2}$	$\frac{27}{32}$	·104	·116	·128	·806	·885	·960	1·10
$\frac{3}{4}$	$1\frac{1}{16}$	·116	·128	·144	1·150	1·253	1·385	1·34
1	$1\frac{11}{32}$	·128	·144	·160	1·630	1·810	1·983	1·66
$1\frac{1}{4}$	$1\frac{11}{16}$	·144	·160	·176	2·327	2·559	2·786	2·03
$1\frac{1}{2}$	$1\frac{29}{32}$	·160	·176	·192	2·926	3·189	3·447	2·28
2	$2\frac{3}{8}$	,,	,,	,,	3·711	4·053	4·389	2·78
$2\frac{1}{2}$	3	·176	·192	·212	5·205	5·646	6·190	3·44
3	$3\frac{1}{2}$	,,	,,	,,	6·126	6·651	7·300	4·0
$3\frac{1}{2}$	4	,,	,,	,,	7·048	7·656	8·410	4·5
4	$4\frac{1}{2}$	,,	,,	,,	7·970	8·662	9·520	5·06
5	$5\frac{1}{2}$	,,	,,	,,	9·813	10·67	11·74	6·12
6	$6\frac{1}{2}$	,,	,,	,,	11·66	12·68	13·96	7·25

The weights given are for wrought iron ; add 2% for mild steel.

War Emergency *B.S.* 789A—1940 substitutes Light and Heavy Weights for the three grades of *B.S.* 789; Light Weight is one gauge lighter in each size than Gas, and Heavy Weight is the same as Water or Medium grade.

The properties of useful sizes of tubes are given below, calculated on the nominal thickness and *minimum* permitted outside diameter. The steel is 22–30 tons/sq. in. tensile, and may be stressed in bending to 10 tons/sq. in. for scaffolding. Tubes of $\frac{1}{2}$ in. bore and upwards are supplied in random lengths of 15 to 23 ft.

Steel Tubes—*B.S.* 789 Water or *B.S.* 789A Heavy Weight

Trade Name	Nominal Bore in.	Approx. Outside Diam. in.	Wall Thickness in.	Weight lb./ft.	Minimum Properties: Section Area sq. in.	*I* in.^{4}	*k* in.	*z* in.^{3}
2″	$1\frac{1}{2}$	$1\frac{29}{32}$	·176	3·253	·949	·353	·610	·372
$2\frac{1}{2}$″	2	$2\frac{3}{8}$	,,	4·134	1·206	·724	·774	·614
3″	$2\frac{1}{2}$	3	·192	5·759	1·675	1·626	·985	1·095

PIPE HOOKS

A table of standard dimensions of pipe hooks suitable for fixing the above tubes is given in *B.S.* 31—*Electric Conduits.*

COPPER TUBES

Ministry of Health Model Specification agrees with *B.S.* 659 for Light Gauge Copper Tubes, suitable for compression or capillary joints or bronze welding. For screwed joints *B.S.* 61—*Copper Tubes and their Screw Threads* gives three classes, viz., Low Pressure, 50 lb./sq. in. working, Medium Pressure 125 lb., High Pressure 200 lb./sq. in.

t = thickness in inches (specified as S.W.G.) of the wall.

Outside diam. = Internal diam. + $2t$

TABLE 145

Internal Diam. In.	B.S. 659		B.S. 61 Low Pressure		B.S. 61 Medium Pressure		B.S. 61 High Pressure	
	t	lb./ft.	t	lb./ft	t	lb./ft.	t	lb./ft.
⅛	·040	·08	·064	·15	·064	·15	·080	·20
¼	·048	·17	·072	·28	·080	·32	·092	·38
⅜	,,	·25	,,	·39	,,	·44	,,	·52
½	,,	·32	,,	·50	,,	·56	·104	·76
⅝			,,	·61	,,	·68	·116	1·04
¾	,,	·46	,,	·72	·092	·94	,,	1·21
⅞			,,	·82	,,	1·08	,,	1·39
1	·056	·71	·080	1·04	·104	1·39	·128	1·75
1¼	,,	·88	,,	1·29	,,	1·70	·144	2·43
1½	,,	1·05	,,	1·53	,,	2·02	,,	2·86
1¾			·092	2·05	,,	2·33	,,	3·30
2	·064	1·60	,,	2·33	,,	2·65	,,	3·73
2½	,,	1·98	,,	2·88	·116	3·67	·176	5·70
3	·072	2·68	·104	3·90	·128	4·84	·192	7·42
3½	·080	3·46	·116	5·07	·144	6·25	·212	9·55
4	·092	4·55	·128	6·39	·160	7·93	·232	11·88

LEAD PIPES

The *Metropolitan Water Board* define pipes as follows :—

A *service pipe* is any pipe subject to pressure from the main ; the portion from the main to the stopvalve in the street, or if no stopvalve to the boundary of the street or where the pipe enters the premises in or under the street (whichever of these points is nearer to the main), is called a *communication pipe* and the remainder of the service pipe is called a *supply pipe.* A *distributing pipe* is any pipe under pressure from a storage cistern, feed cistern or hot water apparatus.

There are several conflicting specifications relating to lead pipes.

(i) *B.S.* 602—*Lead Pipes,* specifies the following weights per lineal yard (the figures in brackets are the weights stipulated for B.N.F. Ternary Alloy No. 2 lead pipes specified in *B.S.* 603, for pipes laid above ground) :—

TABLE 146. Minimum Weight, lb./lin. yd.

Internal Diameter :	⅜″	½″	¾″	1″	1¼″	1½″	2″
Working Pressure	**Supply and Distributing Pipes**						
Not exceeding 150 ft. head (65 lb./sq. in.)	4½ (3)	6 (4)	9 (6)	12½ (9)	16 (12)	20 (15)	28 (21)
Exceeding 150 ft. and not exceeding 250 ft. head (108 lb./sq. in.)	5 (3½)	7 (5)	11 (8)	16 (13)	21 (18)	27 (24)	38[1] (38[1])
Exceeding 250 ft. and not exceeding 350 ft. head (152 lb./sq. in.)	6 (4)	9 (6)	15 (12)	21 (21)	28 (28)	35[2] (35[2])	
	Flushing and Warning Pipes						
		3 (2½)	5 (4)	7 (5½)	9 (7½)	12 (10)	16 (13)

[1] Not exceeding 225 ft. head.
[2] ,, ,, 325 ,,

The *M.W.B.* by-laws differentiate between service and distributing pipes, and between hot and cold water in the latter.

The *M.O.H.* Model Specification also makes these distinctions but differs from both the other authorities in the recommended weights.

(ii) *M.W.B.* by-laws. (The figures in brackets are the weights stipulated for ternary alloy lead pipes fixed above ground.)

TABLE 147. Minimum Weight, lb./lin. yd.

Internal Diam. :	⅜″	½″	¾″	1″	1¼″	1½″	2″	2½″	3″
Pressure	**Service Pipes**								
Not exceeding 250 ft. head	5 (3½)	7 (5)	11 (7½)	16 (11)	21 (14)	27 (18)	38 (25½)	59 (40)	85 (57)
Exceeding 250 ft. and not exceeding 400 ft.	6 (4)	9 (6)	15 (10)	21 (14)	28 (19)	35 (23½)	48 (32)	— —	— —
	Distributing Pipes								
For cold water	4	5	8	11	14	18	24	38	54
For hot water	4½	6	9	12½	16	20	28	44	63
Hot or cold, alloy	(3)	(4)	(6)	(8½)	(11)	(13½)	(19)	(29½)	(42)
	Flushing and Warning Pipes								
Lead or ternary alloy	2	3	5	7	9	12	16		

(iii) *Ministry of Health* Model Specification

TABLE 148. Minimum Weight, lb./lin. yd.

Internal Diameter:	⅜″	½″	¾″	1″	1¼″	1½″	2″
Pressure	**Supply Pipes**						
Not exceeding 110 ft. head	4	6	9	12	16	18	24
Exceeding 110 ft. and not exceeding 250 ft.	5	7	12	16	21	27	33
Exceeding 250 ft.	5½	9	16	21	28	36	48
	Distributing Pipes						
For cold water	4	5	8	11	14	18	24
For hot water	4	6	9	12	16	18	24
	Flushing and Warning Pipes						
			5	7	9	11	14

APPROXIMATE DIMENSIONS OF LEAD PIPES

This table gives the wall thickness *t* and outside diameter O.D. of the lead pipes mentioned in the foregoing specifications; the sizes are not necessarily obtainable. Lead pipe should be specified by the internal diameter (bore) and weight per yard. The usual length of coil is 60 ft. for bores up to 1 in. and 30 ft. for larger sizes.

TABLE 149. Dimensions in inches.

⅜″ bore			½″ bore			¾″ bore			1″ bore		
lb./yd.	*t*	O.D.	lb./yd.	*t*	O.D.	lb./yd.	*t*	O.D.	lb./yd.	*t*	O.D.
	in.	in.		in.	in.		in.	in.		in.	in.
2	·09	·56	3	·11	·71	5	·12	1·00	7	·13	1·23
3	·13	·63	4	·14	·77	6	·14	1·04	8½	·16	1·31
3½	·14	·66	5	·16	·83	7½	·17	1·10	11	·20	1·39
4	·16	·70	6	·19	·87	8	·18	1·12	12½	·22	1·44
4½	·17	·73	7	·21	·92	9	·20	1·16	14	·24	1·48
5	·19	·76	9	·26	1·01	10	·22	1·19	16	·27	1·54
6	·22	·81				11	·24	1·23	21	·34	1·68
						15	·31	1·36			

TABLE 149—*Continued.*

1¼" bore			1½" bore			2" bore			2½" bore		
lb./yd.	t	O.D.	lb./yd.	t	O.D.	lb./yd.	t	O.D.	lb./yd.	t	O.D.
	in.	in.		in.	in.		in.	in.		in.	in.
9	·14	1·53	12	·15	1·81	16	·16	2·32	38	·30	3·09
11	·17	1·58	13½	·18	1·85	19	·19	2·38	44	·34	3·18
14	·21	1·66	18	·22	1·95	24	·23	2·46	59	·43	3·37
16	·23	1·71	20	·24	1·99	25½	·24	2·49			
19	·27	1·79	23½	·28	2·06	28	·27	2·54			
21	·29	1·84	27	·32	2·14	32	·30	2·60			
28	·37	2·00	35	·40	2·30	38	·35	2·70			
						48	·43	2·86			

B.N.F. Ternary alloy lead may be taken as having the same weight as lead.

TABLE 150

PLUMBERS' WIPED JOINTS

Diam. of pipe	½	¾	1	1¼	1½	2	3	4	in.
Length of joint	2½	2¾	3	3	3	3¼	3½	3½	in.
Weight of solder	¾	1	1¼	1½	1¾	2¾	3½	4¼	lb.

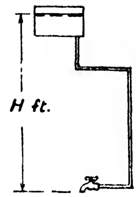
B.S. 617—Identification of Pipes, etc., in Buildings

The specification recommends painting with the appropriate colour either the whole line, or a 12-in. length on each pipe in positions readily seen, in each compartment of the building and next to valves, switches, etc. A list of identification marks to distinguish individual lines is also given. A separate specification is issued for Chemical Factories.

TABLE 151

Service	Colour	Service	Colour
Air	White	Water :—	
Drainage	Black	Cold fresh	Azure blue
Electricity	Orange	Hydraulic power	,, ,,
Gas	Deep cream	Hot fresh	Sky blue
Oil	Light brown	Central heating	Brilliant green
Refrigeration	French grey	Fire service	Signal red
Steam	Crimson	Salt	Sea green

HEAD REQUIRED BY SMALL WATER PIPES



Add to the length of pipe 2 ft. for each bend and obtain the head required by proportion from the table; for example actual length 40 ft. plus 5 bends = 50 ft., so take $\frac{50}{100}$ of value in table. Then, if the discharge required is 10 gals. per minute, a head of 8 ft. is needed for a 1 in. bore pipe, $2\frac{1}{2}$ ft. for $1\frac{1}{4}$ in. bore and so on.

A flow of 10 gals./minute will supply sufficient for a bath in 3–4 minutes or fill a normal bucket in 10 seconds.

TABLE 152. Head H in feet required per 100 ft. of pipe

Internal Diam. of Pipe	Discharge in Gals. per minute.											
	2	4	6	8	10	12	14	20	40	60	80	100
$\frac{1}{2}''$	20		Veloc	ities								
$\frac{5}{8}''$	8	28		Exce	ssive							
$\frac{3}{4}''$		11	26									
1″		3	6	10	16	23						
$1\frac{1}{4}''$			2	4	5	7	10					
$1\frac{1}{2}''$			1	1·5	2	3	4	7				
2						0·6	1	1·5	6			
$2\frac{1}{2}$								0·5	2	4·4	7·8	
3								0·2	0·8	1·8	3·1	4·7

HYDRAULIC DATA

1 cu. ft. of fresh water weighs 62·3 lb. at 60° F.

,, ,, sea ,, (av.) ,, 64·0 lb.

1 gallon of fresh water weighs 10·0 lb.

1 cu. ft. = 6·23 gals.

1 cu. ft. per second (cusec) = 60 cu. ft. per minute (c.f.m.) = 374 gals. per minute (g.p.m.) = 28,430 gals. per hour (g.p.h.)

1 ft. of head = ·433 lb./sq. in.

1 lb./sq. in. = 2·30 ft. of head.

1 in. on mercury manometer = 0·49 lb./sq. in.

1 atmosphere = 14·7 lb./sq. in. = 29·9 in. of mercury.
= 33·9 ft. of water.

DISCHARGE OF SMALL DRAINS AND SEWERS OF CONCRETE OR SALT-GLAZED WARE

Calculated from Barnes' Formula for Slimy Sewers :

$$Q = 31{\cdot}85 \times 60 \times d^{2.70} \times i^{.50} \text{ c.f.m.}$$

TABLE 153. Discharge, cu. ft./minute

Hydraulic Gradient*	Diameter of Pipe				
	4″	6″	9″	12″	15″
1 in 40	16	46	139	302	552
1 in 60	13	38	114	247	451
1 in 80		33	98	213	390
1 in 100		29	88	191	349
1 in 120			80	174	318
1 in 140			74	161	295
1 in 160			69	151	276
1 in 180			66	144	263
1 in 200				135	247
1 in 250				121	221
1 in 300				110	201
Usual minimum gradient	1 in 60	1 in 90	1 in 180	1 in 380	1 in 500

DISCHARGE OF UN-PLANED WOOD FLUMES

Calculated from Barnes' formula :

$$Q = Av = A \times 182{\cdot}5\, m^{.666}\, i^{.569} \times 60 \text{ c.f.m.}$$

TABLE 154. Discharge, cu. ft./minute

Hydraulic Gradient*	Internal Section of Flume, Breadth × Depth, in.						
	12″ × 12″ 24 × 6	24 × 12	24 × 18 36 × 12	36 × 6	36 × 18	36 × 24 48 × 18	48 × 12
1 in 100	383	1000	1700	622	2960		
1 in 200	258	677	1150	419	2000	2910	1640
1 in 300	205	538	910	333	1580	2310	1300
1 in 400	174	456	773	282	1340	1960	1110
1 in 500	153	402	681	249	1180	1730	970

* The hydraulic gradient is not necessarily equal to the gradient of the channel. It is defined as the drop in free water level (e.g. at manhole chambers) divided by the distance measured along the line of flow.

COVERING POWER OF PAINTS AND COATINGS

TABLE 155

	Yards super per gallon
Ironwork :	
Red lead oil paint, priming	80
second coat	110
White lead oil paint on undercoat	130
Bituminous solution	100–130
Wrought Woodwork :	
Knotting	800
Linseed oil	80
Stain	100
Tar	20
White lead oil paint, priming	90
second coat	110
third coat	120–130
Enamel finish paint, undercoat	100
finish coat	70
Enamel, first coat	70
second coat	80
Varnish, first coat	60
second coat	80
Carbolineum or sideroleum	40
Rough Woodwork :	
Creosote	20
Tar	10
Plaster :	
Oil paint, priming	70
second coat	100
	Yards super per lb.
Water paints, distempers, first coat	4
second coat	8
Size (dry weight)	30
Whitening, first coat	7
second coat	10
Stucco or Concrete :	
Water paints, distempers, first coat	3
second coat	6

ELECTRICAL DATA

$$\text{Ampères} = \frac{\text{Volts}}{\text{Ohms}}. \quad \text{Watts} = \text{ampères} \times \text{volts} = (\text{ampères})^2 \times \text{Ohms}.$$

The above relations apply to direct current supply. In alternating current circuits the effect of inductance and capacity must be included, but on ordinary systems for the lighting and heating of building these factors may be ignored.

1 Kilowatt (KW) = 1000 watts = 1·34 horsepower.
1 " Unit " or Board of Trade Unit (B.T.U.) = 1 kilowatt-hour.
1 Horsepower = 746 watts = 550 ft. lb./second.

When converting horsepower to watts, etc., the efficiency of the plant must be taken into account.

For thermal and gas equivalents see page 199.

DOMESTIC ELECTRIC CONSUMPTION

TABLE 156

Appliance	Watts
Boiling ring, to boil 1 qt. in 15 mins.	1000
Flat iron, 3 lb.	350
Griller, per sq. in of surface	12
Hot plate	150–300
Kettle, to boil 1 qt. in. 10 mins.	700
Oven 12″ × 12″ × 15″	2000
16″ × 16″ × 18″	3000
Radiator, per 1000 cu. ft. of space	1000
Toaster	350
Vacuum cleaner	150
Water boiler, small, per gal.	500–600

The next two tables are based, in part, on data in the *Institution of Electrical Engineers*' Regulations for the Electrical Equipment of Buildings, reproduced by permission of the Institution.

The second column of Table 157 gives average values for 250 volt cables: the sizes vary slightly among different manufacturers. The diameters of 600 volt cables are somewhat greater.

VULCANISED-RUBBER-INSULATED CABLES

TABLE 157

Conductor Size	Nominal Outside Diameter in.	Current Rating when in Conduit, amp.			Resistance per 1000 yds. at 60° F, ohms
		Not more than 2 Single Cables	Not more than 4 Single Cables	Not more than 8 Single Cables	
1/·044	·155		5	5	15·79
3/·029	·180		5	5	12·36
3/·036	·200		10	8	8·019
7/·029	·210		15	12	5·281
7/·036	·235	29	23		3·427
7/·044	·270	38	30		2·294
7/·052	·300	45	36		1·643
7/·064	·345	56	45		1·084
19/·044	·380	65	52		0·847
19/·052	·425	78	62		0·606

ELECTRIC CONDUITS

Weight, thickness and radius in accordance with *B.S.* 31.

Cable capacity in accordance with Regulations for the Electrical Equipment of Buildings.

TABLE 158

Outside Diam. of Conduit	½"	⅝"	¾"	1"	1¼"	1½"	2"	2½"
Nominal thickness :	in.							
Class A (plain) . .	·040	·040	·048	·048	·056	·064	·064	·072
Class B (screwed) . .	·056	·064	·072	·072	·072	·080	··092	·092
Weight per 100 ft., lb. A	20	26	37	50	73	100	135	191
Weight per 100 ft., lb. B	27	39	53	73	93	124	192	242
Min. radius on C.L. :								
Elbow or tee . .	½	⅝	¾	1	1¼	1½	2	2½
Normal or ½ normal bend	1½	1 9/16	1⅞	2½	3⅛	3¾	5	6¼

Conductor Size	½" S	½" B	⅝" S	⅝" B	¾" S	¾" B	1" S	1" B	1¼" S	1¼" B	1½" S	1½" B	2" S	2" B	2½" S	2½" B
	Maximum Number of Cables															
1/·044	2	2	5	4	7	6	13	10	20	14						
3/·029			4	3	7	5	12	10	20	14						
3/·036			3	2	5	4	10	8	18	12						
7/·029			2	2	5	4	8	6	12	10						
7/·036					3	2	6	5	10	8						
7/·044					2		5	4	8	7						
7/·052					2		4	3	6	5	8	6				
7/·064							3	2	4	4	7	6				
19/·044							2		4	3	6	5	10	7	12	8
19/·052									3	2	5	4	8	6	9	7

Conduit is ordered by the outside diameter and class (A or B). Pipe hooks for fixing conduit to walls, and standard connector boxes, etc., are covered by *B.S.* 31. A normal bend turns through 90° and a half-normal bend through 45°. The cables referred to are 250 v. grade vulcanised-rubber-insulated in accordance with *B.S.* 7. Column S applies to runs not exceeding 14 ft. between draw-in boxes and not deflecting from the straight more than 15° ; column B to runs which deflect more than 15°. ·

Electric conduits must not be allowed to touch gas or water pipes, but may be earthed to water pipes.

DIMENSIONS AND WEIGHT OF GALVANISED OPEN CISTERNS

TABLE 159

Gals.	Typical Dimensions				Weight of		Minimum Thickness of Sheet,
	Size on Plan	Depth of Water	Size on Plan	Depth of Water	Cistern lb.	Water lb.	BG.
20	2′ × 1′ 4″	1′ 3″	1′ 8″ × 1′ 8″	1′ 3″	19	200	20
30	2′ × 1′ 6″	1′ 7″	2′ × 2′	1′ 4″	24	300	,,
40	2′ 3″ × 1′ 8″	1′ 8″	2′ × 2″	1′ 8″	30	400	,,
50	2′ 5″ × 1′ 10″	1′ 10″	2′ 1″ × 2′ 1″	1′ 10″	35	500	,,
60	2′ 6″ × 1′ 11″	2′	2′ 3″ × 2′ 3″	1′ 11″	40	600	,,
80	3′ × 2′ 2″	2′	2′ 6″ × 2′ 6″	2′ 1″	63	800	18
100	3′ × 2′ 6″	2′ 2″	2′ 9″ × 2′ 9″	2′ 1″	71	1000	,,
150	3′ 7″ × 2′ 10″	2′ 5″	3′ × 3′	2′ 8″	130	1500	16
200	4′ × 3′	2′ 8″	3′ 6″ × 3′ 6″	2′ 7″	160	2000	,,
300	4′ 6″ × 3′ 7″	3′ 0″	4′ 0″ × 4′	3′	200	3000	,,

DIMENSIONS OF HOT WATER CYLINDERS

Suitable for 30 ft. working head

TABLE 160

Gallons	Diameter	Height over Dome	Weight, lb.	
			Cylinder	Water
19	1′ 6″	2′ 0″	50	190
25	,,	2′ 6″	59	250
30	,,	3′ 0″	66	300
37	1′ 8″	,,	76	370
44	,,	3′ 6″	85	440
62	1′ 10″	4′ 10″	145	620
83	2′ 0″	4′ 6″	152	830
100	,,	5′ 4″	172	1000

HEATING DATA

The heating requirements of normal small brick buildings, in which no effort has been made to reduce heat losses by the incorporation of insulating materials, may be estimated by rule of thumb methods. For thermal units and equivalents see page 199.

HEATING AND RADIATOR AREA REQUIRED PER 1000 CU. FT. OF SPACE

TABLE 161

Temperature maintained in Excess over Outside Air	B.Th.U. per hour	Area of Radiator plus Exposed Piping	
		Low Pressure Hot Water at 160° F.	Low Pressure Steam, 5 lb. gauge
20° F.	1600	12 sq. ft.	7 sq. ft.
25°	2150	16	9
30°	2700	20	12
35°	3400	25	15
40°	4200	31	19

Additions to the above should be made separately for the particular circumstances listed below.

For exceptionally high or unsheltered sites		15%
When heating is cut off during the night		15%
For rooms facing north to east		10%
For each external wall of room above one		10%
In lofty rooms :	12 ft. up to 15 ft.	5%
	15 ft. to 25 ft.	10%
	over 25 ft.	15%

In *Post-War Building Studies, No. 1—House Construction*, desirable standards of insulation for walls of houses are given. For large buildings it is necessary to make accurate estimates of heat loss so as to secure the best balance between capital expenditure on insulation and annual cost of heating. See the notes following Table 165.

RADIATION FROM HORIZONTAL PIPES TO AIR AT 60° F.

TABLE 162. B.Th.U./hour/lineal foot

Internal Diamter of Pipe	Temperature in Pipe		
	160° F.	212° F.	226° F. (5 lb. gauge)
$\frac{3}{4}$	63	96	104
1	77	117	128
$1\frac{1}{4}$	96	146	159
$1\frac{1}{2}$	105	160	174
2	124	188	206
$2\frac{1}{2}$	146	222	242
3	175	266	290
4	218	332	358

HOT WATER SERVICE

The following amounts of storage in hot tank are usually recommended :

Per bath		16 gallons
Per sink :	hotel, etc.	40 ,,
	commercial	10–20 ,,
	domestic	7 ,,
Per lavatory basin		3 ,,

The boiler should be capable of raising the hot tank contents through 100° F. in $1\frac{1}{2}$ to 2 hours. For dimensions of hot tanks, see Table 160.

To heat 100 gallons of water through 100° F. in 2 hours requires $\frac{100 \times 10 \times 100}{2} = 50{,}000$ B.Th.U./hr., to which should be added 20% for loss in exposed circulation in small installations, i.e. about 600 B.Th.U./hr./gallon stored.

1 cu. ft. of town gas gives about 500 B.Th.U.

Heating Data—*Continued.*

SMALL BOILERS BURNING SOLID FUEL

In accordance with the recommendations of *B.S.* 758.

TABLE 163

Heating Surface sq. ft.	Performance B.Th.U./hour		Smoke Pipe Diameter in.	Storage Vessel gals.	Circulating Pipe Diameter, in.	
	Continuous	Short Period			Soft Water	Hard Water
2	12000	20000	4	25–30	1	1¼
2½	15000	25000	,,	25–37	1¼	,,
3	18000	30000	4½	30–45	,,	1½
4	24000	40000	,,	40–60	1¼–1½	,,
5	30000	50000	,,	50–75	1½	1½–2

For larger installations the makers should be consulted.

All pipes and fittings in heating installations should be of " steam " weight (see Table 144 (*M.W.B.*)).

The hot draw-off should be not further than 25 ft. from hot water cistern or flow pipe (*M.O.H.*) ; a maximum of 16 ft. is preferred (*M.W.B.*).

BOILER FLUE SIZES

TABLE 164. Thousands of B.Th.U./hr.

Size of Flue, in.	Height of Flue, feet.			
	20	30	40	50
9×4½	70	90	120	130
9×9	190	230	270	310
14×9	320	420	460	500
14×14	400	600	800	900

DESIRABLE AIR TEMPERATURES

TABLE 165

Accommodation	Degrees F.
Garages for storage only	40
Bedrooms, corridors in public buildings, dance halls	50
Shops, showrooms, factories for light manual work	55
Churches, lecture halls, theatres, cinemas, concert halls	58–60
Factories, workers seated	60
Offices, living and bed-sitting rooms	62
Hospitals, schoolrooms, nurseries	65
Operating theatres, drying rooms	75

Transmittance of Heat

The property often tabulated in connection with the transmittance of heat through various materials is the Thermal Conductivity, which in British units is defined as the number of British Thermal Units (B.Th.U.) transmitted through a stated thickness of the material per square foot per hour per degree Fahrenheit difference of temperature between the *faces*. When dealing with different materials in combination a more convenient unit is the Thermal Resistance, i.e. $\frac{1}{\text{Thermal Conductivity}}$, defined as the number of hours required to transmit 1 B.Th.U. through a stated thickness of the material per square foot per degree F. difference of temperature between the faces ; these units can be added algebraically.

The temperatures which interest the designer, however, are not those of the *faces* of the construction but of the air on each side of it, and the rate of loss of heat depends, for a given difference of air temperature, not only on the thermal resistance of the material but also on the readiness with which the outer surface transfers heat to the atmosphere by convection and radiation. The practical unit for heating purposes is the Heat Transmittance Coefficient U, measured in B.Th.U./sq. ft./hr./degree F. difference in *air* temperature, and it varies according to the exposure.

Table 166 gives the values of U for various constructions with normal exposure ; the values should be increased by 10%–20% for walls facing north, and on exceptionally exposed sites.

The rate of heat loss through a wall of area A sq. ft. and Transmittance Coefficient U, if the inside air temperature is maintained at $t°$ F. above the outside temperature, is $A \times U \times t$ in B.Th.U./hr., and the sum of these quantities for the walls, floor and ceiling or roof of a room or building is equal to the rate of heating required to maintain the difference of temperature assumed.* Boilers and heating appliances are rated in B.Th.U./hr. The outside temperature for maximum heating requirements may be taken as 30° F. in the south of England and 20° F. in the north. Desirable inside temperatures are given in Table 165.

* (Allowance must be made for loss due to draughts, see Table 167.)

TRANSMITTANCE COEFFICIENT U FOR TYPICAL CONSTRUCTIONS

The values of U in B.Th.U./sq. ft./hr./degree F. difference of air temperature on the two sides are tabulated below for normal exposure, see the preceding notes. The constructions are listed in order of merit for heat insulation.

TABLE 166

Wall Construction (Dry unless otherwise stated)	U
6″ foamed slag concrete 1 : 6, rendered, 1½″ wood wool lining	·15
2–4½″ skins clinker concrete 1 : 10, 2″ cavity, render and plaster	·17
,, ,, Fletton bkwk, 2″ cavity, ½″ fibreboard on battens	·18
6″ 1 : 2 : 4 ballast concrete, 1″ cavity, aluminium foil, asbestos sheet on battens	,,
4″ Bath or Portland stone, 8″ foamed slag concrete 1 : 6, plaster	·19
9″ Fletton bkwk., ½″ fibreboard on battens	·21
9″ ,, ,, ,, ,, direct against bkwk.	·23
2–3″ skins clinker concrete 1 : 10, 2″ cavity, render and plaster	·23
2–2½″ ,, ,, ,, ,, core filled ballast concrete 1 : 6, render and plaster	·25

TABLE 166—*Continued.*

Wall Construction (Dry unless otherwise stated)	*U*
7″ stone concrete 1 : 2 : 4, 1″ wood wool slab, render	,,
9″ Fletton bkwk, render, plaster on battens internally	·28
Corrugated asbestos sheeting, ½″ fibreboard on battens internally	·30
2–4½″ skins Fletton bkwk, 2″ cavity, plaster	·31
3″ stone concrete 1 : 2 : 4, 2″ cavity, 3″ clinker concrete 1 : 6, render	,,
Corrugated steel sheeting, ½″ fibreboard on battens internally	,,
9″ hollow clay tile, render and plaster	·32
5″ clinker concrete 1 : 10, rendered, papered	,,
4″ Bath or Portland stone, 9″ Fletton backing, plaster	·32
9″ London stock bkwk, dry, plaster	·36
9″ Fletton ,, ,, ,,	·37
2–4½″ skins sandlime bkwk dry, 2″ cavity, plaster	,,
9″ Fletton bkwk.	·40
10″ Stone or ballast concrete 1 : 2 : 4	·41
4″ Bath or Portland stone, 4½″ Fletton backing, plaster	·42
8″ no-fines concrete 1 : 6, stone aggregate, render and plaster	·43–·46
4″ hollow clay tiles, render and plaster	·44
9″ Sandlime bkwk, dry, plaster	·45
8″ stone or ballast concrete 1 : 2 : 4	·45
4″ studding, lath and plaster both sides	,,
4½″ hollow clay tiles, render and plaster	·46
9″ Sandlime bkwk, dry	·48
6″ stone or ballast concrete 1 : 2 : 4	·52
9″ London stock bkwk, wet, plaster	·53
4½″ Fletton bkwk.	·54
5″ stone or ballast concrete 1 : 2 : 4	·55
8″ Bath or Portland stone	·56
9″ London stock bkwk, wet	·58
4″ stone or ballast concrete 1 : 2 : 4	·59
4½″ sandlime bkwk.	·62
Corrugated asbestos sheeting, unlined	1·15
,, steel ,, ,,	1·2

The cavities are of normal construction with metal ties and unventilated.

Stucco, rough-cast or pebble-dash finishes may be substituted for rendering without materially altering the value of *U*. Render refers to the outside face and plaster to the inside face.

For constructions not listed see the text following the next Table.

Transmittance Coefficients—*Continued.*

TABLE 167

Pitched Roof and Ceiling Construction	U
Tiles, felt and battens. Ceiling ½″ fibreboard above ceiling joists, ½″ fibreboard ceiling	·17
Tiles, battens, boards and felt. Ceiling of plaster	·30
Slating, felt underlay, ⅞″ sarking. Ceiling of plaster	·30–·35
Corr. steel or asbestos sheets, ½″ fibreboard and air space, no ceiling	·32
Tiles, felt and battens. Ceiling of plaster	·43
Tiles, felt and boards, no ceiling	·9
Tiles, felt and battens, no ceiling	1·1
Corr. asbestos sheets unlined, no ceiling	1·4
,, steel ,, ,, ,, ,,	1·5
,, perspex ,, ,, ,, ,,	·93
Flat Roof and Ceiling Construction	
¾″ asphalt, 2″ lightweight concrete screed, 6″ concrete slab. Ceiling ½″ fibreboard on battens	·20
1½″ boards and felt, wood joists. Ceiling of plaster	·22
,, ,, ,, ,, ,, ,, No ceiling	·40
6″ concrete slab, ½″ asphalt	·56
6″ hollowtile concrete slab, ½″ asphalt	·53
As above with ½″ fibreboard lining	·33
See also wall construction, Table 166.	
Windows and Lights	
King's Glas-crete pavement lights, single construction	·43
double construction	·29
21 oz. glass in wood frames [1]	1·08
,, ,, ,, ,, double glazed	·5
Floor Construction [2]	
Wood blocks or boards on concrete direct on ground	·15
1″ t and g boarding on wood joists, ventilated below	·25

[1] For opening windows the heat loss is usually about doubled through infiltration of air. If the windows remain open special calculations must be made. 19·3 B.Th.U. will raise the temperature of 1000 cu. ft. of air by 1° F. The air in a well-ventilated room is changed twice an hour, and with a coal fire up to 10 times an hour.

[2] The exposure is less than in the case of walls and roofs, and the values of *U* here given have been adjusted so as to be suitable for calculation of heat loss.

To arrive at the value of *U* for constructions not listed, Table 168 and the graph following it may be used. Table 168 gives the Thermal Resistance per inch of thickness for various materials. The Thermal Resistance is proportional to the thickness, and from these values the total Thermal Resistance of any combination of materials may be obtained. The corresponding value of *U* for heating calculations may then be read from the graph and will be near enough for practical purposes.

Example :—

11 in. ventilated cavity wall of Fletton brickwork, with ½ in. fibreboard on wood battens inside.

			Thermal Resistance
From Table 168 :	$4\frac{1}{2}$ in. Fletton brickwork	$4\frac{1}{2} \times \cdot 16 =$	·72
	2 in. cavity and wall ties		·20
	$4\frac{1}{2}$ in. Fletton brickwork	as above	·72
	Air space at battens		·90
	$\frac{1}{2}$ in. Fibreboard	$\frac{1}{2} \times 3{\cdot}0 =$	1·50
	Total thermal resistance	=	4·04

From graph, $U = \cdot 19$
Table 166 gives ·18

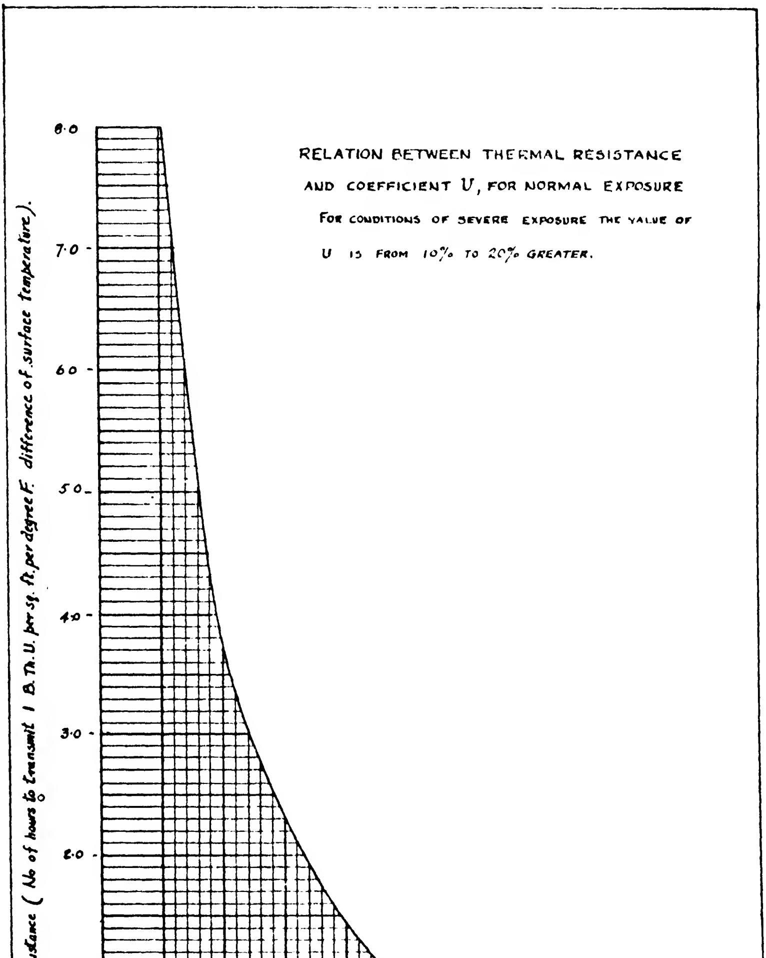
Thermal Resistance K of Materials

The unit of thermal resistance is the number of hours required to transmit 1 B.Th.U. per sq. ft. per degree F. difference of temperature between the faces, and is given below **per inch of thickness.** The figure in the first column gives the order of merit in this table.

TABLE 168

	Material	Thermal Resistance		Material	Thermal Resistance
22	Air space 2″, and ties	·20★	29	Fireclay, at 600° C.	·11
18	,, ,, ,, (unventilated)	·50★	28	Glass	·12–·14
	,, ,, between wall and		2	Glass silk	3·4
9	lining on wood battens	·90★		Hardboard	1·4–2·0
2	As above with aluminium foil	3·4★	13	Hardwood, mahogany	·7
	curtain in cavity		14	oak, teak	·6
37	Aluminium	·00067	35	Iron, cast	·0030
18	Asbestos cement sheets	·48	36	wrought	·0024
	Boards, see Hardwood, Soft-		33	Lead	·0041
	wood.		4	Magnesia pipe insulation	2·5
	Breeze, see Concrete, Clinker		31	Marble	·05
6	Brickwork, diatomaceous	1·8	8	Perspex	1·02
24	Fletton, dry	·16		Plaster	·1–·5
23	Ldn. stocks, dry	·17	17	do. partition slab	·57
30	wet	·07	10	Plasterboard	·7–·9
29	sandlimes, dry	·11		Plastics, laminated	·45–·7
	Cavity, see Air Space.		8	Plywood	1·0
	Clinker, see Concrete.			Pumice, see Concrete.	
25	Concrete, ballast 1 : 1 : 2	·15		Rendering, cement abt.	·2
26	1 : 2 : 4	·14	11	Rubber	·8
27	do., no fines	·13–·15	2	Slagwool (silicate cotton)	3·4
10	cellular	·5–1·0	30	Slate	·07
21	clinker 1 : 6	·36	8	Softwood	1·0
20	1 : 10	·44	34	Steel	·0031
19	foamed slag 1 : 6	·46		Stone, Bath or Portland	·08
16	1 : 10	·59		Stucco	·1–·5
12	pumice 1 : 6	·72		Wood, see Hardwood,	
9	1 : 10	·90	7	Softwood.	
38	Copper	·00038	32	Wood wool slab	1·7
3	Cork slab	3·3		Zinc	·013
	Diatomaceous earth, see				
	Brickwork.			For proprietary building	
1	Felt	3·8		boards see Fibreboard,	
4	Fibreboard, insulating	2·5–3·0		Hardboard, Plasterboard,	
5	laminated	1·9		etc.	

* The values for air spaces must be taken as stated and not regarded as per inch of thickness.


RELATION BETWEEN THERMAL RESISTANCE
AND COEFFICIENT U, FOR NORMAL EXPOSURE
FOR CONDITIONS OF SEVERE EXPOSURE THE VALUE OF
U IS FROM 10% TO 20% GREATER.
8·0
7·0
6·0
5·0
4·0
3·0
2·0
1·0
Thermal Resistance (No of hours to transmit 1 B.Th.U. per sq. ft. per degree F. difference of surface temperature).
·1
·2
·3
·4
·5
·6
·7
·8
·9
1·0
Overall Heat Transmittance Coefficient U
(B.Th U per sq. ft. per hour per degree F. difference in air temperature)

1 B.Th.U. (British Thermal Unit) is the quantity of heat required to raise the temperature of 1 lb. of water by 1° F. (at 63° F.).

1 c.g.s. unit of thermal conductivity is the number of gm.-calories transmitted per sq. cm. per second per cm. thickness per degree C.

1 B.Th.U. per sq. ft. per hour per degree F. per inch = 2903 c.g.s. units.

1 cu. ft. of ordinary town gas represents about 500 B.Th.U.

1 Gas Therm = 100,000 B.Th.U. = about 200 cu. ft. of town gas.
= 29·32 kilowatt-hours or "Units."

1 B.Th.U. = 0·293 watt-hours = 778 ft. lb.

1 Kilowatt-hour = 3411 B.Th.U. = 0·0341 gas therms = about 6·8 cu. ft. of town gas.

In domestic installations 1 gas therm will raise 100 gals. of water by about 150° F., and 1 B.T.U. will raise 100 gals. of water by 2–3° F.

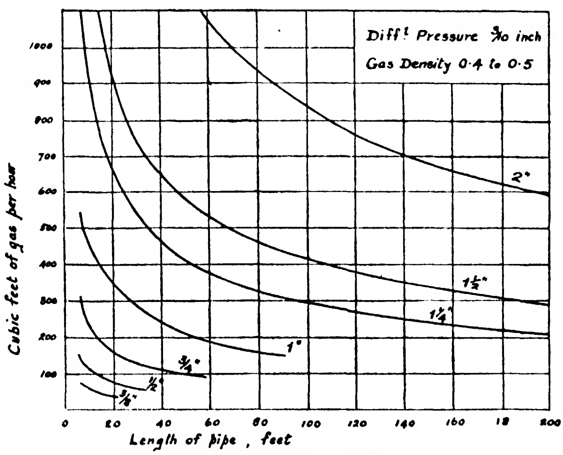
Gas Consumption

TABLE 169

	Cu. ft. per hour
Cooker (1¾ cu. ft. oven, hotplate)	90
Fire, full on : 10 in.	30
14 in.	40
21 in.	65
Geyser (2 gals. per minute)	120
Refrigerator, domestic	2
Water Heater : bath	200
storage, 20 gal.	40
wash copper, 5 gal.	25

Size of Gas Pipes

The chart below gives the flow in pipes of steam weight (see Table 144) for ordinary conditions.



FLOW OF GAS IN STRAIGHT PIPES

WHITWORTH BLACK BOLTS, NUTS, LOCKNUTS AND WASHERS HEX-ROUND-HEX (*B.S.* 28)

The length is measured to the underside of head

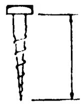
TABLE 170. Weight per bolt in lb.

Length in.	¼″	⅜″	½″	⅝″	¾″	⅞″	1″ dia.	
1	·042	·106	·222	·376	·612			
1¼	·045	·114	·236	·398	·643	·944		
1½	·049	·122	·250	·419	·675	·986	1·394	
1¾	·052	·130	·264	·441	·706	1·029	1·449	
2	·056	·138	·278	·463	·737	1·072	1·505	
2¼	·059	·145	·292	·484	·769	1·114	1·561	
2½	·063	·153	·305	·506	·800	1·157	1·616	
2¾	·065	·161	·319	·528	·831	1·999	1·672	
3	·069	·169	·333	·549	·862	1·242	1·727	
3½	·075	·185	·361	·593	·925	1·327	1·838	
4	·082	·200	·389	·637	·988	1·412	1·950	
4½	·089	·216	·417	·680	1·050	1·497	2·061	
5	·096	·232	·445	·724	1·113	1·583	2·172	
5½	·103	·247	·472	·767	1·175	1·667	2·283	
6			·500	·810	1·238	1·753	2·394	
7			·556	·897	1·363	1·923	2·617	
8			·612	·984	1·488	2·094	2·839	
9			·667	1·071	1·613	2·264	3·062	
10			·723	1·158	1·739	2·434	3·284	
11				1·245	1·863	2·605	3·507	
12					1·989	2·775	3·729	
Thickness of head	·23	·34	·45	·56	·67	·78	·89	inches
Weight of one nut	·0134	·0345	·0757	·1394	·2164	·3203	·4611	lb.
Thickness of nut	·26	·39	·51	·64	·76	·89	1·01	inches
Thickness of locknut	·18	·26	·34	·43	·51	·59	·68	inches
Thickness of washer	·064	·080	·104	·128	·144	·160	·176	inches
Wt. per 100 washers	·44	1·02	2·20	4·04	6·35	9·38	13·2	lb.
Diameter washer	⅝	⅞	1⅛	1⅜	1⅝	1⅞	2⅛	inches

COACH SCREWS

TABLE 171. Weight per gross, lb.

Length in.	Diameter $\frac{3}{8}''$	$\frac{1}{2}''$	$\frac{5}{8}''$
$1\frac{1}{2}$	11	24	
2	13	26	46
$2\frac{1}{2}$	15	30	51
3	17	34	57
$3\frac{1}{2}$	19	38	62
4	21	42	68
5	25	49	79
6	29	59	90

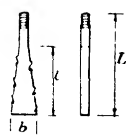


LEWIS BOLTS (RAG BOLTS)

For nuts ee Whitworth bolts

TABLE 172. Dimensions and Weight

Diam.	$\frac{1}{2}''$	$\frac{5}{8}''$	$\frac{3}{4}''$	$\frac{7}{8}''$	1″	$1\frac{1}{8}''$	$1\frac{1}{4}''$
L	5″	6″	6″	7″	8″	9″	10″
l	3″	3″	3″	$3\frac{1}{2}''$	$4\frac{1}{2}''$	5″	6″
b	$\frac{7}{8}''$	$1\frac{1}{8}$	$1\frac{1}{4}''$	$1\frac{1}{2}''$	$1\frac{5}{8}''$	$1\frac{7}{8}''$	$2\frac{1}{8}''$
Weight lb.	·40	·73	1·02	1·63	2·45	3·53	5·00

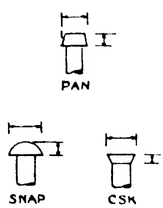


RIVET HEAD DIMENSIONS

Calculated in accordance with *B.S.* 275

TABLE 173

Nominal Diameter in.	Snap or Pan Diameter in.	Snap or Pan Projection in.	Countersunk Diameter in.	Countersunk Depth in.
$\frac{1}{2}$	·80	·35	·75	·22
$\frac{5}{8}$	1·00	·44	·94	·27
$\frac{3}{4}$	1·20	·53	1·12	·33
$\frac{7}{8}$	1·40	·61	1·31	·38
1	1·60	·70	1·50	·43



The nominal diameter is the diameter of the hole in which the rivet is driven.

COPPER ROVES

TABLE 174

Size, in.	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$
lb. per 1000	3	$3\frac{3}{4}$	5

WIRE NAILS

TABLE 175. Number in 1 lb.

S.W.G.	Length, in.									
	¾"	1"	1½"	2"	2½"	3"	3½"	4"	5"	6"
0								11	9	**8**
2						22	19	16	**13**	11
4					36	30	26	**23**	18	15
6				62	50	41	**35**	31	25	21
8				86	69	**57**	49	43	35	
10			165	124	99	83	71	62		
12			274	205	164	137	117	103		
14		710	473	350	284	236				
16		1140	761	571						
18	2760	2070	1380							

Common constructional sizes are shown in bold figures.

WOOD SCREWS

TABLE 176

Size	Diameter in.	Size	Diameter in.
0	·052	11	·206
1	·066	12	·220
2	·080	13	·234
3	·094	14	·248
4	·108	15	·262
5	·122	16	·276
6	·136	17	·290
7	·150	18	·304
8	·164	19	·318
9	·178	20	·332
10	·192		

The length of roundhead screws is measured to the underside of head, countersunk screws overall.

RAILWAY RAILS

TABLE 177. British Standard Flat Bottom

Weight lb. per yard	Dimensions in inches			Section Modulus Z in.³	B.S. No.
	Height	Width of Head	Width of Base		
14	2·125	1·156	2·125		536
20	2·5	1·375	2·5	1·37	,,
25	2·875	1·5	2·75	1·88	11
30	3·125	1·625	3·0	2·44	,,
35	3·375	1·75	3·25	3·10	,,
40	3·625	1·875	3·5	3·77	,,
45	3·875	1·969	3·75	4·55	,,
50	4·125	2·062	3·937	5·43	,,
55	4·312	2·156	4·125	6·22	,,
60	4·5	2·25	4·312	7·04	,,
65	4·687	2·312	4·437	7·79	,,
70	4·875	2·375	4·625	8·73	,,
75	5·062	2·437	4·812	9·72	,,
80	5·25	2·5	5·0	10·75	,,
85	5·437	2·562	5·187	11·61	,,
90	5·625	2·625	5·375	13·05	,,
95	5·812	2·687	5·562	14·22	,,
100	6·0	2·75	5·75	15·37	,,
110	6·25	2·875	6·0	17·41	,,
120	6·5	3·0	6·25	19·73	,,

TABLE 178. British Standard Bull Head (*B.S.* 9)

Weight lb. per yard	Dimensions, inches		Section Modulus Z in.³
	Height	Width of Head	
60	4·75	2·312	6·47
65	4·875	2·375	7·22
70	5·0	2·437	7·92
75	5·125	2·5	8·53
80	5·375	2·562	9·64
85	5·469	2·687	10·44
90	5·547	2·75	11·00
95	5·719	,,	11·77
100	5·906	,,	12·47

WEIGHT AND STRENGTH OF MANILA ROPES

In accordance with B.S. 431—*Manila Ropes for General Purposes*

TABLE 179. 3 Strand (Hawser Laid) Manila Rope

Circumference in.	Approx. Diameter in.	Safe Load in Cwt.			Weight per 100 ft. lb.
		Grade I or Special Quality.	Grade II or Standard Quality	Grade III or Merchant Quality	
1	5/16	1·8	1·6	1·4	3·6
¼		2·7	2·4	2·1	4·7
½		4·0	3·5	3·1	7·2
¾	9/16	5·3	4·7	4·1	9·6
2	5/8	7·1	6·3	5·5	13·1
¼		8·5	7·6	6·6	15·1
½	13/16	10·5	9·4	8·2	20·3
¾	7/8	12·7	11·3	9·9	23·9
3	15/16	15·0	13·3	10·7	28·6
¼		17·4	15·5	13·6	33·4
½	1⅛	20·0	17·7	15·5	39·3
¾		22·8	20·2	17·7	43·9
4	1¼	25·6	22·7	19·9	51·3
¼		28·5	25·3	22·1	57·2
½		31·9	28·3	24·8	64·3
¾	1½	35·1	31·2	27·3	71·5
5		38·8	34·4	31·8	80·0

The safe loads given above are based on a Factor of Safety of 6.
Where the rope is knotted or spliced a deduction of ⅓ should be made.

4 STRAND (shroud laid) has a central core ; the strength is 10% less than for 3 strand and the weight 5%–10% more.

SISAL has about the same strength and weight as Manila rope.

TARRED HEMP weighs 25% more and is 30% weaker than Manila.

COIR weighs 25% less and is about 70% weaker than Manila.

Cordage is always specified by the circumference.

WEIGHT AND STRENGTH OF STEEL WIRE ROPES

In accordance with B.S. 302—*Round Strand Steel Wire Rope for Cranes.*

The values below are for Best Patent Steel 80–90 tons/sq. in. For other qualities multiply the strength by :—

Special Improved Patent Steel	90–100 tons/sq. in.	1·10
Best Plough Steel	100–110 ,, ,,	1·23
Special Improved Plough Steel	110–120 ,, ,,	1·35

TABLE 180. Steel Wire Ropes—80–90 ton quality

Circumference	Approx. Diameter	Safe Load in Tons			Weight per 100 ft.
		Construction			
In.	In.	6/19	6/24	6/37	lb.
1	5/16	·46	·40	·47	18
1⅛		·55	·55	·57	21
1¼		·70	·67	·65	25
1⅜		·82	·79	·78	30
1½		1·00	·95	·96	36
1⅝	½	1·21	1·09	1·13	43
1¾		1·35	1·25	1·34	50
2	⅝	1·84	1·71	1·78	66
2⅛	11/16	2·02	1·92	2·02	74
2¼		2·32	2·13	2·29	84
2½	13/16	2·85	2·71	2·71	102
2¾	⅞	3·42	3·22	3·34	123
3	15/16	4·31	3·79	4·03	154
3¼		5·01	4·56	4·56	184
3½	1⅛	5·91	5·22	5·36	217
3¾		6·74	5·92	6·22	247
4	1¼	7·60	6·87	7·15	275
4⅜	1⅜	9·12	8·10	8·38	336
4¾	1½	10·7	9·69	10·0	392
Sheave diameter / Rope circumf.		7·5	7·0	6·0	

The safe loads given above are based on a Factor of Safety of 6, which is usually sufficient. The sheave diameters are those recommended for rope speeds up to 200 ft./minute ; the life of the rope is shortened if smaller sheaves are used.

SHORT LINK WROUGHT IRON CHAINS

The working loads given below are in accordance with the recommendations of B.S. 394—*Short Link Wrought Iron Crane Chains*, and of the Home Office, for chains of " Standard " quality (corresponding approximately to the old BBB quality).

Where a chain is subject to shock or passes over an edge or where there is any special hazard the working load is to be substantially less than the values tabulated.

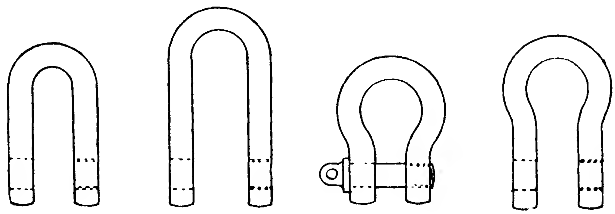
Chains become brittle in use and should be sent periodically for heat treatment.

The nominal diameter is the diameter of the material in the link ; the overall width of each link is 3¼ times the nominal diameter.

TABLE 181

Nominal Size. in.	Weight per foot. lb.	Working Load (see notes above) tons
$\frac{5}{16}$	1·25	·55
$\frac{3}{8}$	1·71	·80
$\frac{7}{16}$	2·25	1·12
$\frac{1}{2}$	2·92	1·50
$\frac{9}{16}$	3·75	1·87
$\frac{5}{8}$	4·50	2·32
$\frac{3}{4}$	6·17	3·37
$\frac{7}{8}$	8·5	4·57
1	11	6·0

A separate specification is issued covering Pitched or Calibrated chain for working over chain wheels.



STRENGTH OF SHACKLES

In accordance with *B.S. 825—Mild Steel Shackles for Lifting Purposes*

TABLE 182. D Shackles

Material Diameter in.	Small D Shackles			Large D Shackles		
	Jaw Opening in.	Pin Diameter in.	Working Load tons	Jaw Opening in.	Pin Diameter in.	Working Load tons
$\frac{3}{8}$	$\frac{5}{8}$	$\frac{1}{2}$	·6	$\frac{3}{4}$	$\frac{1}{2}$	·5
$\frac{1}{2}$	$\frac{7}{8}$	$\frac{5}{8}$	1·0	$1\frac{1}{8}$	$\frac{5}{8}$	·75
$\frac{5}{8}$	1	$\frac{3}{4}$	1·5	$1\frac{1}{4}$	$\frac{3}{4}$	1·25
$\frac{3}{4}$	$1\frac{1}{4}$	$\frac{7}{8}$	2·0	$1\frac{1}{2}$	$\frac{7}{8}$	1·75
$\frac{7}{8}$	$1\frac{3}{8}$	1	2·75	$1\frac{3}{4}$	1	2·25
1	$1\frac{1}{2}$	$1\frac{1}{8}$	3·5	2	$1\frac{1}{8}$	3·0

TABLE 183. Bow Shackles

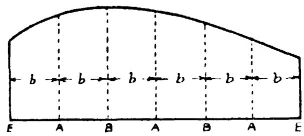
Material Diameter in.	Small Bow Shackles.			Large Bow Shackles		
	Jaw Opening in.	Pin Diameter in.	Working Load tons	Jaw Opening. in.	Pin. Diameter in.	Working Load tons
$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	·3	$\frac{5}{8}$	$\frac{1}{2}$	·35
$\frac{1}{2}$	$\frac{5}{8}$	$\frac{1}{2}$	·5	$\frac{7}{8}$	$\frac{5}{8}$	·6
$\frac{5}{8}$	$\frac{3}{4}$	$\frac{5}{8}$	·75	$1\frac{1}{8}$	$\frac{3}{4}$	1·0
$\frac{3}{4}$	$\frac{7}{8}$	$\frac{3}{4}$	1·25	$1\frac{3}{8}$	$\frac{7}{8}$	1·5
$\frac{7}{8}$	1	$\frac{7}{8}$	1·75	$1\frac{5}{8}$	1	2·0
1	$1\frac{1}{8}$	1	2·25	$1\frac{3}{4}$	$1\frac{1}{8}$	2·5

GENERAL TABLES

TABLES 184—194

GENERAL TABLES

SIMPSON'S RULE



To find the area under a curve as shown in the sketch:—

Divide the base into an even number of parts so that there is an odd number of ordinates. Then if S_E is the sum of the lengths of the end ordinates E, S_A the sum of the alternate ordinates A and S_B the sum of the remaining (even) ordinates B, then the area of the figure is approximately

$$\frac{b}{3}(S_E + 4S_A + 2S_B)$$

The greater the number of ordinates used, the more accurate will be the result.

QUADRATIC EQUATIONS

If $ax^2 + bx + c = 0$, $\qquad x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

or, if $x^2 + ax = b$, $\qquad x = -\dfrac{a}{2} \pm \sqrt{b + \left(\dfrac{a}{2}\right)^2}$

AREAS OF SMALL CIRCLES

TABLE 184. For Round Bars at different spacings see Table 88

S.W.G. or Diameter in.	Area sq. in.	Diameter in.	Area sq. in.	Diameter in.	Area sq. in.
20g	·0010	$\frac{3}{8}$	·110	$2\frac{1}{2}$	4·908
18g	·0018	$\frac{7}{16}$	·150	$2\frac{3}{4}$	5·939
16g	·0032	$\frac{1}{2}$	·196	3	7·069
14g	·0050	$\frac{9}{16}$	·248	$3\frac{1}{4}$	8·295
13g	·0066	$\frac{5}{8}$	·307	$3\frac{1}{2}$	9·621
12g	·0085	$\frac{11}{16}$	·371	$3\frac{3}{4}$	11·04
11g	·0106	$\frac{3}{4}$	·442	4	12·57
$\frac{1}{8}$	·0122	$\frac{13}{16}$	·518	$4\frac{1}{4}$	14·18
10g	·0129	$\frac{7}{8}$	·601	$4\frac{1}{2}$	15·90
9g	·0163	$\frac{15}{16}$	·690	$4\frac{3}{4}$	17·72
8g	·0201	1	·785	5	19·64
7g	·0243	$1\frac{1}{16}$	·890	$5\frac{1}{4}$	21·64
$\frac{3}{16}$	·0276	$1\frac{1}{8}$	·994	$5\frac{1}{2}$	23·75
6g	·0290	$1\frac{3}{16}$	1·107	$5\frac{3}{4}$	25·96
5g	·0353	$1\frac{1}{4}$	1·227	6	28·27
4g	·0423	$1\frac{3}{8}$	1·484	7	38·48
$\frac{1}{4}$	·0490	$1\frac{1}{2}$	1·767	8	50·27
3g	·0499	$1\frac{5}{8}$	2·073	9	63·62
2g	·0599	$1\frac{3}{4}$	2·405	10	78·54
1g	·0707	$1\frac{7}{8}$	2·761	11	95·03
$\frac{5}{16}$	·0767	2	3·142	12	113·1
0g	·0824	$2\frac{1}{4}$	3·976		

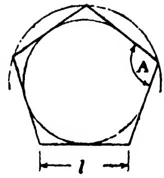
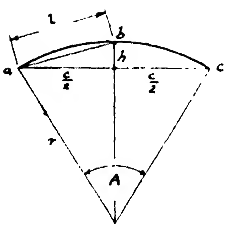


TABLE 185

REGULAR POLYGONS

Name	Number of Sides	Area $l^2 \times$	Radius of Circle		Corner Angle A
			Inside $l\times$	Outside $l\times$	
Equilateral triangle .	3	·4330	·2887	·5773	60°
Square . . .	4	1·0	·5	·7071	90°
Pentagon . . .	5	1·720	·6879	·8506	108°
Hexagon . . .	6	2·598	·8660	1·0	120°
Heptagon . .	7	3·634	1·038	1·152	128½°
Octagon . . .	8	4·828	1·207	1·307	135°
Nonagon . . .	9	6·182	1·374	1·462	140°
Decagon . .	10	7·694	1·539	1·618	144°
Undecagon . .	11	9·366	1·703	1·775	147¼°
Dodecagon . .	12	11·196	1·866	1·932	150°

PROPERTIES OF THE CIRCLE



Chord of angle A $= \frac{c}{r}$

Versed sine of angle $\frac{1}{2}A = \frac{h}{r} = 1 - \cos. \frac{1}{2}A$

Area of circle $= \pi r^2 = \cdot 7854 d^2$

For areas of small circles see Table 184.

Circumference of circle $= 2\pi r$

$\pi = 3{\cdot}141593 \quad \pi^2 = 9{\cdot}869604$

Arc length $abc = r.A$ (A in radians)

$= \frac{8l - c}{3}$ approx.

1 radian $= 57{\cdot}296°$

$$l = \sqrt{h^2 + \frac{c^2}{4}}$$

$$c = 2\sqrt{2rh - h^2}$$

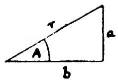
$$r = \frac{4h^2 + c^2}{8h}$$

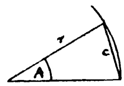
$$h = r - \sqrt{r^2 - \frac{c^2}{4}}$$

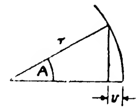
Moment of inertia about a diameter $= \frac{\pi d^4}{64} = \cdot 0491 d^4$

TRIGONOMETRICAL FUNCTIONS

See table on next page







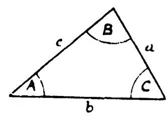
$\sin A = \dfrac{a}{r}$ $\qquad$ chord of $A = \dfrac{c}{r}$ $\qquad$ versine $A = \dfrac{v}{r} = 1 - \cos A$

$\tan A = \dfrac{a}{b}$ $\qquad$ $\dfrac{\sin A}{\cos A} = \tan A$ $\qquad$ $\sin^2 A + \cos^2 A = 1$

$\cos A = \dfrac{b}{r}$ $\qquad$ $1 + \tan^2 A = \sec^2 A = \dfrac{1}{\cos^2 A}$

PROPERTIES OF TRIANGLES

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$



$$\cos A = \frac{b^2 + c^2 - a^2}{2bc}$$

If $s = \frac{1}{2}(a + b + c)$, area of triangle $= \sqrt{s(s-a)(s-b)(s-c)}$

TRIGONOMETRICAL FUNCTIONS

TABLE 186. See diagrams on previous page

Degrees	Sine	Tan		Cos	Chord		
0	0	0	∞	1·0000	0		90
1	·01745	·01746	57·290	·99985	·01745	1·4018	89
2	·03490	·03492	28·636	·99939	·03490	1·3893	88
3	·05234	·05241	19·081	·99863	·05235	1·3676	87
4	·06976	·06993	14·301	·99756	·06980	1·3640	86
5	·08716	·08749	11·430	·99619	·08724	1·3512	85
6	·10453	·10510	9·5144	·99452	·10467	1·3383	84
7	·12187	·12278	8·1443	·99255	·12210	1·3252	83
8	·13917	·14054	7·1154	·99027	·13951	1·3121	82
9	·15643	·15838	6·3137	·98769	·15692	1·2989	81
10	·17365	·17633	5·6713	·98481	·17431	1·2856	80
11	·19081	·19438	5·1445	·98163	·19169	1·2722	79
12	·20791	·21256	4·7046	·97815	·20906	1·2586	78
13	·22495	·23087	4·3315	·97437	·22641	1·2450	77
14	·24192	·24933	4·0108	·97030	·24374	1·2313	76
15	·25882	·26795	3·7320	·96593	·26105	1·2175	75
16	·27564	·28675	3·4874	·96126	·27835	1·2036	74
17	·29237	·30573	3·2708	·95630	·29562	1·1896	73
18	·30902	·32492	3·0777	·95106	·31287	1·1756	72
19	·32557	·34433	2·9042	·94552	·33010	1·1614	71
20	·34202	·36397	2·7475	·93969	·34730	1·1471	70
21	·35837	·38386	2·6051	·93358	·36447	1·1328	69
22	·37461	·40403	2·4751	·92718	·38162	1·1184	68
23	·39073	·42447	2·3558	·92050	·39874	1·1039	67
24	·40674	·44523	2·2460	·91355	·41582	1·0893	66
25	·42262	·46631	2·1445	·90631	·43288	1·0746	65
	Cos		Tan	Sine		Chord	Degrees

TABLE 186—*Continued.*

Degrees	Sine	Tan		Cos	Chord		
26	·43837	·48773	2·0503	·89879	·44990	1·0598	64
27	·45399	·50953	1·9626	·89101	·46689	1·0450	63
28	·46947	·53171	1·8807	·88295	·48384	1·0301	62
29	·48481	·55431	1·8040	·87462	·50076	1·0151	61
30	·50000	·57735	1·7320	·86603	·51764	1·0000	60
31	·51504	·60086	1·6643	·85717	·53448	·98485	59
32	·52992	·62487	1·6003	·84805	·55127	·96962	58
33	·54464	·64941	1·5399	·83867	·56803	·95432	57
34	·55919	·67451	1·4826	·82904	·58474	·93894	56
35	·57358	·70021	1·4281	·81915	·60141	·92350	55
36	·58778	·72654	1·3764	·80902	·61803	·90798	54
37	·60181	·75355	1·3270	·79864	·63461	·89240	53
38	·61566	·78129	1·2799	·78801	·65114	·87674	52
39	·62932	·80978	1·2349	·77715	·66761	·86102	51
40	·64279	·83910	1·1917	·76604	·68404	·84524	50
41	·65606	·86929	1·1504	·75471	·70041	·82939	49
42	·66913	·90040	1·1106	·74314	·71674	·81347	48
43	·68200	·93252	1·0724	·73135	·73300	·79750	47
44	·69466	·96569	1·0355	·71934	·74921	·78146	46
45	·70711	1·0000	1·0000	·70711	·76537	·76537	**45**
	Cos		**Tan**	**Sine**		**Chord**	**Degrees**

IMPERIAL AND OTHER MEASURES
with metric and U.S. equivalents

TABLE 187

LENGTH

1 mil = ·001 in.
1 cm. = ·3937 in. = ·0328 ft.
1 in. = 25·40 mm. = 2·540 cm.
1 line (printing) = 6 points = 1·12 in.
1 nail (cloth) = 2¼ in.
1 palm = 3 in.
1 hand = 4 in.
1 link (Gunter) = 7·92 in.
1 foot = 12 in. = ·3048 m.
1 yard = 3 ft. = ·9144 m.
1 thread (yarn) = 1½ yds.
1 fathom = 6 ft.
1 rod or pole = 5½ yds.
1 knot (sashline) = 12½ yds.
1 chain (Gunter) = 22 yds. = 100 links
1 skein (yarn) = 120 yds.
1 cable = 600 or 608 ft.
1 coil (rope) = 600–720 ft.
1 furlong = 10 chains = 220 yds.
1 metre = 3·281 ft. = 39·37 in. See also Tables 188, 189.
1 mile = 8 furlongs = 1760 yds. = 5280 ft. = 1·609 km.
1 nautical mile (Admiralty) = 6080 ft. average
1 km. = ·6214 mile

AREA

1 sq. in. = 6·452 sq. cm.
1 sq. cm. = ·1550 sq. in.
1 sq. ft. = 929·0 sq. cm. = ·0929 sq. m.
1 sq. yd. = 9 sq. ft. = ·8361 sq. m.
1 sq. m. = 10·76 sq. ft.
1 square = 100 sq. ft.
1 rod, pole or perch = 30¼ sq. yds. = 272¼ sq. ft.
1 rood = 40 perches
1 acre = 4 roods = 10 sq. chains = 4840 sq. yds. = 4046·89 sq. m.
1 sq. mile = 640 acres = 2·5899 sq. km.

VOLUME (see also Liquid Measure)

1 cu. in. = 16·39 c.c.
1 c.c. = ·0610 cu. in.
1 cu. ft. = 1728 cu. in. = 28,320 c.c. = ·0283 cu. m.
1 cu. yd. = 27 cu. ft. = ·7645 cu. m. = 21·04 bushels
1 cu. m. = 1·308 cu. yds. = 35·31 cu. ft.
1 bushel = 1·2836 cu. ft. = 1·032 U.S. bushel
1 Petrograd standard = 165 cu. ft.
1 rod of brickwork = 306 cu. ft.
1 hod (bricklayer's) = ⅔ cu. ft.
1 bushel = 4 pecks = 8 gals.
1 bushel of cement weighs 1 cwt.
1 sack = 2 or 4 bushels
1 quarter = 8 bushels

WEIGHT

1 grain = ·0648 gm. = ·0001429 lb.
1 oz. = 16 drams = 28·350 gm. 1 gm. = ·0353 oz.
1 lb. = 16 oz. = 453·59 gm. = 7000 grains
1 stone = 14 lb. 1 Smithfield stone = 8 lb.
1 quarter = 28 lb. 1 cental = 100 lb. 1 centner = 50 kgm.
1 cwt. = 4 quarters = 112 lb.
1 ton = 20 cwt. = 2240 lb. 1 U.S. ton (short ton) = 2000 lb.
1 ton = 1·0160 tonnes = 1016·0 kgm. 1 tonne = ·9842 ton
1 kgm. = 1000 gm. = 2·204 lb. 1 tonne = 1000 kgm. = 2204 lb.

Imperial Measures and Equivalents—*Continued.*

PRESSURE

1 lb./sq. in. = ·0643 ton/sq. ft. = ·0703 kgm./sq. cm.
1 ton/sq. ft. = 15·55 lb./sq. in. = 1·094 kgm./sq. cm.
1 kgm./sq. cm. = 14·22 lb./sq. in. = ·9141 ton/sq. ft.

For atmospheric and hydraulic equivalents see page 186.

DENSITY

1 lb./cu ft. = ·0160 gm./c.c. 1 gm./c.c. = 62·43 lb./cu. ft.
100 lb./cu. ft. = 1·205 tons/cu. yd. = 0·05787 lb./cu. in.
1 ton/cu. yd. = 82·96 lb./cu. ft. = 1329 kgm./cu. m.

TEMPERATURE

1° C. = $1\frac{4}{5}$° F. 1° F. = $\frac{5}{9}$° C.
Freezing point = 32° F. = 0° C.

LIQUID MEASURE

60 minims = 1 fluid drachm = ·222 cu. in.
8 fl. dr. = 1 fl. oz. = 1·732 cu. in.
20 fl. oz. = 1 pint = 4 gills = 34·68 cu. in. = 568·3 c.c.
1 quart = 2 pints. 1 pottle = 2 quarts
1 gallon = 4 quarts = 8 pints = 277·463 cu. in. = ·1605 cu. ft.
1 cu. ft. = 6·230 gallons
1 litre = 1000 c.c. = ·2200 Imperial gallons = 1·76 Imp. pints
1 U.S. gallon = ·833 Imp. gallons
1 Imp. gallon = 1·196 U.S. gals. = 4·546 litres
1 Imp. gallon of pure water weighs 10 lb.
1 Reputed quart = 0·60 Imp. quart.

BEER AND WINE MEASURES

1 Pin		= $4\frac{1}{2}$ gals.
1 Firkin or $\frac{1}{4}$ barrel		= 9 gals.
1 Anker		= 10 gals.
1 Aum		= 30 gals.
1 Barrel		= 36 gals.
1 Tierce		= 42 gals.
1 Hogshead,	beer and sherry	= 54 gals.
	brandy	= 46–60 gals.
1 Puncheon,	beer	= 72 gals.
	brandy and rum	= 120 gals.
1 Butt, beer and sherry		= 108 gals.
1 Pipe		= 92–115 gals.

DECIMAL AND METRIC EQUIVALENTS FOR EACH 1/32 INCH

TABLE 188

Fraction	Decimal	Milli-metres	Fraction	Decimal	Milli-metres
1/32	·03125	·79	17/32	·53125	13·49
1/16	·0625	1·59	9/16	·5625	14·29
3/32	·09375	2·38	19/32	·59375	15·08
1/8	·125	3·17	5/8	·625	15·87
5/32	·15625	3·97	21/32	·65625	16·67
3/16	·1875	4·76	11/16	·6875	17·46
7/32	·21875	5·56	23/32	·71875	18·26
1/4	·25	6·35	3/4	·75	19·05
9/32	·28125	7·14	25/32	·78125	19·84
5/16	·3125	7·94	13/16	·8125	20·64
11/32	·34375	8·73	27/32	·84375	21·43
3/8	·375	9·52	7/8	·875	22·22
13/32	·40625	10·32	29/32	·90625	23·02
7/16	·4375	11·11	15/16	·9375	23·81
15/32	·46875	11·91	31/32	·96875	24·62
1/2	·5	12·70	1		25·40

TABLE 189

MM. AND CM. EQUIVALENTS IN INCHES

MM.	Inch	MM.	Inch	MM.	Inch	CM.	Inches
1	·03937	11	·4330	21	·8268	1	·3937
2	·07874	12	·4724	22	·8662	2	·7874
3	·1181	13	·5118	23	·9055	3	1·181
4	·1575	14	·5512	24	·9449	4	1·575
5	·1968	15	·5905	25	·9842	5	1·968
6	·2362	16	·6299	25·4	1·0000	6	2·362
7	·2755	17	·6693			7	2·755
8	·3149	18	·7087			8	3·149
9	·3543	19	·7480			9	3·543
10	·3937	20	·7874			10	3·937

SIZES FOR DRAWINGS

The following sizes are recommended as standards in *B.S.* 308—*Engineering Drawing Office Practice*, which also gives a list of standard abbreviations for use on drawings.

The more common commercial sizes of paper corresponding to these dimensions have been added.

TABLE 190

Commercial Size	Dimensions, inches	
	Outside Edges of Sheet	Maximum Border Size
	72 × 40	70 × 38
	60 × 40	58 × 38
Antiquarian	53 × 30	52 × 29
	40 × 30	39 × 29
Double Elephant	40 × 27	39 × 26
	40 × 15	39 × 14
Imperial	30 × 22	29 × 21
	27 × 20	26 × 19
Demy	20 × 15	19 × 14
	15 × 10	$14\frac{1}{4}$ × $9\frac{1}{4}$
Foolscap	13 × 8	$12\frac{1}{4}$ × $7\frac{1}{4}$
Quarto	10 × 8	$9\frac{1}{4}$ × $7\frac{1}{4}$

PROPERTIES OF METALS

The physical properties of some metals vary widely according to the conditions of manufacture, e.g. the proportions of constituent metals, rate of cooling, subsequent heat treatment and working, and the size of the specimen.

Table 191 gives the **Density, Ultimate Tensile Stress, Yield Stress** (tensile), **Young's Modulus** and the **Elongation** of the most commonly used metals.

For metals for which the density and no other information is given, see Table 93.

The relative densities of certain common metals are also given on page 13 in connection with the weight of sheets.

The Ultimate Compressive Stress of ductile materials is uncertain, but may be taken as approximately equal to the tensile *Yield* Stress ; in brittle materials the compressive strength is generally higher than the tensile, and for grey cast iron is from 3 to 4 times as great.

The **Yield Stress in Compression** is generally the same as in tension, but in cast iron is higher (10–12 tons/sq. in.).

The **Elastic Modulus in Compression** is about the same as in tension ; in shear it may be taken at 0·4 of the values tabulated.

The **Ultimate Shear Stress** is generally 0·8 to 0·85 of the ultimate tensile stress.

For representative values of **Temperature Coefficient of Expansion, Brinell Hardness** and **Melting Point,** see Table 192.

The **Working Stress** in metals is usually taken at about 0·3 of the ultimate stress, whether tensile or shear. For working stresses in structural steel, see page 136.

A few representative light alloys are included in the tables; for further information the reader is referred to the numerous D.T.D. specifications and to an article by Hardy and Watson in the *Structural Engineer*, February, 1946.

PROPERTIES OF METALS

For composition of the alloys mentioned, see Table 193.

For other properties see the preceding Notes.

Elongation is measured on 2″ specimen for the aluminium alloys and on 8″ specimen for other metals.

TABLE 191

Metal	Weight lb./cu. ft.	Ultimate Tensile Stress	Yield Stress	Young's Modulus	Elongation
		tons per sq. in.			%
ALPAX die cast	164	13–15	7	4820	2–5
sand cast	,,	10–12	6	,,	
ALUMINIUM, cast	159	5·5	2·2	4000	20
rolled	167			4560	
hard-rolled	,,	10·8		,,	7
do. annealed	,,	6·1		,,	39
5–20% Zn.		5–13	3–12		3–16
ALUMINIUM BRONZE	471	Up to 42	20–25		8–19
BA/29, cast	164	16		4800	7
BERYLLIUM BRONZE quenched and heat treated	512	76–82	67		3–5
BIRMABRIGHT, various alloys	167	11–25			3–18
BRASS (*a*) cartridge :					
chill cast	520	16	6		60–70
rolled sheet	533–536	30–40	20	5800	10–15
do. annealed	,,	20–23	6	,,	65–75
wire	,,				
(*b*) Admiralty :					
drawn tube	530	42			9
do. reheated	,,	21			79
rolled plate ½″	,,	26			20
(*c*) Naval, annealed	,,	24–30		5800	20–50
BRONZE (see also Aluminium, Beryllium, Manganese and Phosphor Bronzes)					
90/10 cast	520	15	9	5400	10
cold drawn	549	38	26		12
quenched, 400° C.	,,	12	6·6		14
,, 800° C.	,,	13	4·5		30
CERALUMIN "C" chill cast	170	24		4500	1
CHROMADOR, see Steel.					

TABLE 191—*Continued.*

Metal	Weight lb./cu. ft.	Ultimate Tensile Stress	Yield Stress	Young's Modulus	Elongation
		tons per sq. in.			%
COPPER, cast	547	11	3·6	6700	
hammered or sheet	558	16		7600	
wire, annealed	555	19			25
do. hard-drawn	,,	27			4
CUPRO-NICKEL 80/20	558	23		8000	40–45
60/40	,,	30		9200	45
DELTA METAL, see Manganese Bronze.					
DURALUMIN "E"	174	26–36	16	4800	8
ELEKTRON, cast	108–113	9	7	2850	5
forged	,,	20	9	,,	18
rolled, annealed	,,	21	,,	,,	15
GUNMETAL, Admiralty, cast	528	8			
rolled	549	14			10
HIDUMINIUM "Du"	175	26–27		4800	15
INCONEL	533	45–55			15–18
IRON, cast, grey*	450	5–18	3	5–10000	slight
malleable :					
Blackheart	460	22–25		11000	12–18
Whiteheart	468	22–28		,,	5–7
spun		15–18		7000	
wrought, sheet	480	20–27	12–18	12000	25–30
wire :					
annealed	,,	30			
hard-drawn	,,	38			
LEAD (see also Ternary alloy)	707	0·8–1·0		320	20–65
MANGANESE BRONZE	537	25–27	11–13		46–48
MONEL, cast	548	19–23	14·5	10000	12
hot rolled sheets and rods		30–34	21–24	,,	30–35
MUNTZ METAL					
cast	524	24			
hot rolled and cold drawn	557	25·8	6·5		48
extruded and cold drawn		28·4	13·9		31
NITRALLOY, see Steel.					

TABLE 191—*Continued.*

Metal	Weight lb./cu. ft.	Ultimate Tensile Stress	Yield Stress	Young's Modulus	Elongation
		tons per sq. in.			%
NITRICAST-IRON					
sand cast		25		8500	
centrifugal cast		28		9800	
NORAL 26ST	174	28–32			8
PHOSPHOR-BRONZE					
malleable cast	540	16–18	8		17
hard drawn wire	550	55–58		7–8000	10
STEEL, see also pp. 136, 137					
cast, annealed	489	30–35		13500	30
Chromador	,,	37–43	23	,,	
·8% C oil quenched	492	80	54	,,	2
·6% Cr 1·2% Ni	,,	69	56	,,	14
·4% C 3·5% Ni, oil quenched	,,	127	71	,,	5
Nitralloy		35–76	32–69		12–37
structural :—					
B.S. 15 plates and sections	489	28–33		,,	16–20
,, rivets	,,	25–30		,,	26–30
,, rounds and squares	,,	28–33		,,	16–24
B.S. 548 high tensile	,,	37–43	19–23	,,	14–18
TERNARY ALLOY LEAD No. 2	707	1·69			62
TUNGUM					
cold forged	533	45		6900	13
hard rolled	,,	46		8000	17
sand cast		20	10		51
Y ALLOY, quenched and aged	174	14		4500	2
ZINC, rolled	449	7–10		6000	45

* See *B.S.* 991 for details of various grades of cast iron.

HARDNESS, EXPANSION AND MELTING POINT OF SELECTED METALS

The temperature coefficient gives the change of length with change of temperature, thus: Change of length in inches = length of specimen (inches) × change of temperature in degrees F. × coefficient tabulated, divided by 1 million.

TABLE 192

Metal	Brinell Hardness	Temperature Coefficient per °F	Melting Point °F.
		Parts per million	
Aluminium, rolled	45	14	1215
Brass, cartridge :			
chill cast	60	10-11	1650
hard rolled	150–200		
Copper		9·5	1949
Duralumin	114	12·6	1170
Invar		− ·17 to + 1·4	
Iron, grey cast	100–200	6·0	2770
do. chilled	400–500	,,	,,
malleable		6·2	
wrought		6·6	
Lead (see also below)		16	621
Monel, hot-rolled sheets	120–140	25·2	2460
Muntz metal ditto	116		
Phosphor-bronze	100–130	9·3	1800
Steel, cast	150–200		2800 (casting temperature)
cobalt alloys	1250–1400		
mild structural	115–150	6·0	
nickel chrome hardened	400–700		
Ternary alloy lead No. 2	5·7	14·6	
Tin		12·1	449
Tungum		10·5	2088
Y alloy	114	12·6	
Zinc		14·5	787

COMPOSITION OF COMMON ALLOYS

List of symbols :—

Al	Aluminium	Cu	Copper	Pb	Lead
Be	Beryllium	Fe	Iron	Sb	Antimony
C	Carbon	Mg	Magnesium	Si	Silicon
Cd	Cadmium	Mn	Magnanese	Sn	Tin
Ce	Cerium	Ni	Nickel	Zn	Zinc
Cr	Chromium	P	Phosphorus		

TABLE 193

Metal	Composition of Alloy when referred to in Table 192.
Alpax	Si 8–13, Al 87–92
Aluminium bronze	Cu 92, Al or Zn 8
Babbitt's metal	Sn 10, Cu 1, Sb 1
Beryllium bronze	Be 2·4, Cu 97·6
Birmabright	Similar to duralumin
Brass	Cartridge Cu 70, Zn 30 ; Admiralty Cu 70, Zn 29, Sn 1 ; Naval ,, 62 ,, 37 ,, 1
Bronze	Cu 90, Sn 10, some Zn
Ceralumin "C"	Similar to duralumin, with ·15% Ce
Chromador	Proprietary chrome steel
Cupro-nickel	Cu 80, Ni 20 ; Cu 60, Ni 40 ; and other proportions
Delta metal	Proprietary manganese bronze Cu 55, Zn 40, Fe and Mn
Duralumin, typical	Cu 4·0, Mn ·5, Mg ·5, Si 1·0, Al 94, some Fe
Elektron	Proprietary aluminium-magnesium alloy
Everdur	Cu 96, Si 3, Mn 1
German silver	Cu 60, Ni 15, Zn 25
Gunmetal, Admiralty	Cu 86–88, Sn 10–12, Zn 2·5 max.
Hiduminium	Similar to duralumin with Ni, Fe
Inconel	Ni 80, Cr 12–14, Fe 6–8
Lead-bronze	Cu 70, Pb 30
Magnalium	Al 70–86, Mg 13–30
Manganese bronze	Cu 55, Zn 40, Fe + Mn 4 ; varies
Monel	Ni 65–70, Cu 30–35
Muntz metal	Cu 60, Zn 40, trace Pb
Nickel silver	Cu 60–65, Ni 20, Zn 15–20
Nitralloy steels	C ·2–·4, Mn ·5–·6, Si ·2–·4, Cr 1·4–1·7, Al ·9–1·1, Fe 96
Nitricast-iron	C 2·6, Si 2·6, Al 1·7, Cr 1·4, Mn ·6, Fe 91
Pewter	Sn 86, Sb 14 ; varies
Phosphor-bronze	Cu 92, Sn 7·4, P ·3–·6
Ternary alloy lead No. 2	Sb 1·5, Cd ·25, Pb 98·25
Tungum	Proprietary copper alloy Cu 84, Zn 13, Al 1, Si 1
Y alloy	Similar to duralumin

PROPERTIES OF PLASTICS

The list below gives the characteristics of some well-known plastics; the properties can be varied over a wide range by the inclusion of filler materials and changing the conditions of manufacture, and the figures given are typical only. The figures are largely derived from Warburton Brown's *Handbook of Engineering Plastics.*

TABLE 194

Typical Trade Name		Weight lb./cu. ft.	Ultimate Stress lb./sq. in. Tensile	Ultimate Stress lb./sq. in. Comp.ve	Young's Modulus lb./sq. in.	Temperature Coefficient per °F.
					Millions	Parts per million
Bakelite	1	80	6–9000		·7–1·0	
Cellomold	2	78–85	6–11000	4–16000	·10–·13	80–90
Celluloid	3	84–100	5–10000		·2–·4	66–90
Diakon	4	74	7–9000	11–13000	·4–·6	44
Improved wood	5	50	22000	11000		
		80	29000	20000		
Ivorine	6	84	7500		·5–·6	44
Jicwood "138"		86	45000	25000		
,, "87"		54	30000	16500		
Perspex	7	75–84	8–10000		·35–·4	38
Tufnol	8	84–86	10–16000		1·0–1·5	
Trolitol	9	66	6–8500	6–8000	1·2–1·5	40–45
Resin-bonded sheet for gears		82–86				

Type of plastic :—

1. Phenol formaldehyde.
2. Cellulose acetate.
3. ,, nitrate.
4. Methyl methacrylate.
5. (Impregnated Canadian birch.)
6. Casein.
7. Polyvinyl chloride acetate.
8. Urea formaldehyde.
9. Polystyrene.

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INDEX TO PAGES

Note.—The densities of a large number of materials are given in Table 93. The names of these materials will not be found in the Index unless other information is given elsewhere in the book.

The weights of a large number of substances are given in Table 93 ; these substances will not be found in the Index unless other information is included in the book.