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Govt. of Madras.
PUBLIC WORKS.

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Dated

Recd.

Emd.

G.O. 1/3 1895 No. 480W

Indents for rolled joists

Circular from the Govt.
of India issuing revised
instructions for the pre-
paration of ^{together with} ~~the~~ tables
for calculation of loads,
communicated to officers of
the P.W.D.

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GOVERNMENT OF MADRAS.

PUBLIC WORKS DEPARTMENT.

General.
Account.

READ—the following paper :—

Circular from the Government of India, Public Works Department (Railway Stores), dated Calcutta, 25th January 1895, No. 2 Ry.

Revised suggestions for the preparation of indents for rolled joists.
Tables for calculation of loads, &c.

The undermentioned papers are forwarded to the Local Governments and Admini-

The Governments of Madras, Bombay, Bengal, the North-Western Provinces and Oudh, and the Punjab, Public Works Department.
The Chief Commissioners of the Central Provinces, Burma, Assam and Coorg.
The Resident at Hyderabad.
The Resident in Mysore.
The Agents to the Governor-General for Rajputana, Central India, and Baluchistan.
The Accountant-General, Public Works Department.
The Director-General of Railways.
The Consulting Engineers to the Government of India for Railways, Calcutta, Lucknow and Assam.
The Superintendent of Port Blair and Chief Commissioner, Andaman and Nicobar Islands.
The Director-General of Telegraphs.

strations and to the officers noted in the margin, for information and guidance, in supersession of Government of India circular No.11 Ry. of 31st July 1891.

2. These revised instructions are applicable to all branches of the Public Works Department.

(By Order.)

(Signed) F. B. HEBBERT,
Under Secretary.

To the Secretary to the Government of Madras,
Public Works Department.

ENCLOSURES.

Suggestions for the preparation in India of Indents for Rolled Joists.

Revised, June 1894.

Difficulty is sometimes experienced in procuring rolled joists of the exact sections demanded. It is therefore recommended that a detailed statement, giving limits of variation and other particulars for each item, should be furnished on the form shown on page 3.

2. Joists are tested with central loads and must show no permanent set after test. The loads are arranged so as to produce limiting stresses of 5 and 7½ tons per square inch for iron and steel respectively.

ROLLED IRON JOISTS.

PARTICULARS of sections and constants for load and deflection with a limiting stress of 5 tons per square inch.

Case I.

Condition of joist ... Supported at both ends.
Arrangement of load ... Dead, uniformly distributed, weight of joist included.

Section.	Weight per lineal foot.	Thickness of web.	Moment of inertia.	Constants.	
				For load.	For deflection.
INCHES.	LB.	INCHES.	QUARTIC INCHES.		
16 × 6	62	.62	713.02	297.09	.0844
14 × 6	60	.625	542.55	258.35	.0964
12 × 6	56	.625	374.81	208.23	.1125
12 × 5	42	.45	291.27	161.82	.1125
10 × 6	43	.62	199.14	132.76	.135
10 × 5	36	.7	175.51	117.01	.135
10 × 4½	32	.7	150.99	100.66	.135
9½ × 3¾	24	.375	95.39	68.75	.146
8 × 6	34	.50	107.54	89.62	.169
8 × 5	29	.39	93.07	77.56	.169
8 × 4	22	.375	67.05	55.88	.169
7 × 3½	19	.32	45.34	43.18	.1928
7 × 2½	14	.3	30.11	28.68	.1928
6½ × 3½	16	.32	29.73	31.71	.216
6½ × 2	11	.30	18.23	19.45	.216
6 × 5	29	.7	51.31	57.01	.225
5 × 4½	23	.375	28.28	37.70	.270
5 × 3	13	.25	16.18	21.57	.270
4½ × 2	8	.25	8.12	11.40	.2842
4 × 3	12	.25	9.47	15.78	.3375
4 × 2	7	.25	5.07	8.45	.3375
3½ × 1½	5½	.3	2.51	5.35	.432
3 × 3	10	.25	4.37	9.71	.450

For method of using this table, see the notes following the table of steel joists.

ROLLED STEEL JOISTS.

PARTICULARS of sections and constants for load and deflection with a limiting stress of 7.5 tons per square inch.

Case I.

Condition of joist ... Supported at both ends.
Arrangement of load ... Dead, uniformly distributed, weight of joist included.

Section.	Weight per lineal foot.	Thickness of web.	Moment of inertia.	Constants.	
				For load.	For deflection.
INCHES.	LB.	INCHES.	QUARTIC INCHES.		
19½ × 7½	96	1½	1715.48	868.60	.091
18 × 7	75	.55	1153.00	640.55	.10
17½ × 6½	80	.625	1163.05	655.21	.101
16 × 6	64.5	.64	731.02	456.88	.1125
16 × 5	50	.51	556.01	347.50	.1125
15½ × 6½	62	.7	704.58	447.33	.114
15 × 6	61	.72	621.36	414.24	.12
15 × 5½	56.5	.6	572.64	381.76	.12

Section.	Weight per lineal foot.	Thickness of web.	Moment of inertia.	Constants.	
				For load.	For deflection.
INCHES.	LB.	INCHES.	QUARTIC INCHES.		
15 × 5	42	.45	416.56	277.70	.12
14 × 6	57	.59	513.76	366.97	.1286
14 × 6	45	.435	418.45	298.89	.1286
13½ × 5½	46	.5	419.63	299.73	.13
13 × 5	40	.51	291.79	224.45	.138
12 × 6	54	.60	358.89	299.07	.15
12 × 6	42	.42	296.02	246.68	.15
12 × 5	43	.58	271.71	226.43	.15
12 × 5	32	.48	183.60	153.00	.15
11½ × 5	37	.42	242.46	205.25	.152
10 × 6	45.5	.58	215.14	215.14	.18
10 × 5	35	.52	156.99	156.99	.18
10 × 5	29	.47	127.05	127.05	.18
10 × 5	31.5	.41	149.07	149.07	.18
9½ × 6	41	.42	200.23	202.76	.182
9½ × 5	27	.36	125.90	127.50	.182
9½ × 4½	37	.516	160.84	163.91	.184
9½ × 4	22	.33	80.54	88.87	.198
9 × 7	58	.79	218.48	242.75	.20
9 × 3¾	24.25	.44	85.50	95.00	.20
8 × 6	36	.48	114.14	142.67	.225
8 × 6	32	.4	101.25	126.56	.225
8 × 5	31.25	.45	96.58	121.07	.225
8 × 4	25	.42	74.17	92.97	.225
8 × 4	18	.329	52.90	66.13	.225
8 × 4	27	.375	82.48	104.74	.2286
7½ × 4	19	.4	56.16	71.31	.2286
7 × 3½	20	.41	44.61	63.72	.257
7 × 3½	16	.25	33.80	55.43	.257
7 × 3½	18	.36	33.11	52.97	.288
6½ × 3	9.5	.25	15.81	25.29	.288
6½ × 5½	24	.5	40.47	66.40	.294
6 × 5	26	.54	43.84	73.06	.30
6 × 4½	19	.434	30.04	50.06	.30
6 × 3½	13	.25	26.79	44.65	.30
6 × 3	16	.34	26.69	44.48	.30
6 × 3	13	.322	20.89	34.81	.30
6 × 2	12.25	.39	17.12	28.53	.30
5½ × 2	11	.36	13.41	24.35	.327
5½ × 1½	9	.368	8.79	16.75	.327
5½ × 4½	17.5	.49	23.14	45.15	.351
5 × 5	25.5	.49	30.49	60.98	.36
5 × 4½	23.75	.43	27.32	54.64	.36
5 × 4½	17	.44	19.59	39.18	.36
5 × 3	15.25	.40	17.17	34.34	.36
5 × 3	13	.35	14.68	29.36	.36
5 × 3	10	.25	11.93	23.86	.36
4½ × 1¾	9.25	.37	8.08	17.01	.379
4½ × 1¾	6.5	.298	5.25	11.05	.379
4½ × 2½	7.5	.21	7.67	16.36	.384
4½ × 3	14	.42	13.35	28.86	.39
4½ × 3	10	.23	8.42	20.41	.436
4 × 3	12.75	.39	9.32	23.3	.45
4 × 2	5.5	.3	4.23	10.6	.45
4 × 1¾	8.5	.37	5.48	13.7	.45
3½ × 3	10.75	.30	6.26	17.88	.514
3½ × 1½	6	.28	3.04	8.68	.514
3½ × 1½	4	.17	1.80	5.76	.576
3½ × 3½	8	.25	3.67	11.98	.588
3 × 3	10.25	.30	4.34	14.46	.60
3 × 1½	5	.31	1.74	5.80	.60

To use the Tables.

(i) To find the load and corresponding deflection for a given section of joist with a given span—

- (a) Divide the constant for load by the distance in feet from centre to centre of bearing; * the quotient is the total distributed load in tons including the weight of the joist.†
- (b) Multiply the constant for deflection by the square of the distance in feet from centre to centre of bearings * and divide the result by 100; the quotient is the deflection in inches.

(ii) To select a joist for a given external load (i.e., load exclusive of weight of joist) and given span—

Multiply the load in tons by the distance in feet from centre to centre of bearings * and take a section against which the constant for load is slightly higher than the result. The weight of the joist † should then be added to the external load and the section tried as in (i) for load and deflection.

Cases II to VIII.

(iii) To ascertain loads, &c., for joists under different conditions and with different arrangements of loads, the constants in the tables must be multiplied by the factors given below for each particular case before proceeding as in (i) or (ii) above.

Case.	Condition of joist.	Arrangement of load (dead in all cases).	Factors to be applied to	
			Load constant.	Deflection constant.
II	Fixed at one end, free at the other.	Concentrated at free end ..	1	25.6
III		Uniformly distributed ..		9.6
IV	Supported both ends ..	Concentrated at centre ..	1	1.6
V		Do. do. ..		.4
VI	Fixed both ends ..	Uniformly distributed ..	1	.2
VII		Concentrated at centre ..		.7152
VIII	Fixed at one end, supported at the other.	Uniformly distributed ..	1	.4176

Notes.

(a) The constants given in the tables can readily be adapted to suit other limits of stress than those which have been used (5 and 7.5 tons per square inch for iron and steel respectively), e.g., if it be desired to limit the stress in a steel joist to 6 tons per square inch, the constants must be multiplied by $\frac{6}{7.5}$ or 0.8 before the load and deflection are determined. A higher stress than 5 tons per square inch is not recommended for iron joists.

(b) If the deflection calculated from the tables be greater than can be allowed, and if the circumstances do not permit the use of deeper section or of a heavier section of the same depth, the load calculated from the tables must be reduced in the proportion of the allowable to the calculated deflection and the number of joists increased, e.g., if the allowable deflection be 0.5 inch and the calculated deflection 0.6 inch, the load should be reduced to $\frac{5}{6}$ of the calculated load; the stress would of course be reduced in the same proportion.

(c) If the deflection be limited to $\frac{1}{16}$ of an inch per foot run of the joist, the minimum depth (with the limits of stress used in the tables) should be as follows for case I, viz. :—

For iron joists, .54 inch } for each foot of distance between centres of bearings, e.g., if
 „ steel „ .72 „ }
 the distance from centre to centre of bearings were 10 feet and the deflection were limited to $\frac{1}{16}$ or $\frac{1}{8}$ inch, the minimum depth of an iron joist, Case I, should be 5.4 inches.

* In cases II and III substitute "centre of bearing of fixed end to free end" for "centre to centre of bearing."

† In Cases II and IV, total load = external load + $\frac{1}{2}$ weight of joist.

In these four cases the whole weight of the joist is not added to the external load to make up the total load because the calculation will be made for a concentrated load, whereas the weight of the joist is uniformly distributed. The calculated deflections will in these four cases be slightly excessive.

APPENDIX.

The tabular constants have been calculated from the following data :—

Symbols.

- W = Total distributed load in tons, including the weight of the joist.
 L = Distance in feet from centre to centre of bearings.
 S = Limiting stress in tons per square inch (5 for iron, 7½ for steel).
 d = Depth of joist in inches.
 V = Deflection in inches.
 E = Modulus of elasticity in tons per square inch (11,125 for iron, 12,500 for steel).
 I = Moment of inertia of section of joists (from dimensions in inches).

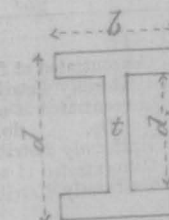
* When the thickness of the web is known as well as the depth, breadth, and weight per foot lineal, the moment of inertia for the section may be very approximately determined as follows :—

Let A = area of the section in square inches.
 „ w = weight „ „ in lb. per foot lineal.

Then for iron $A = \frac{3}{10} w$ because 1 foot lineal of wrought iron 1" × 1" weighs 3½ lb.

and for steel $A = \frac{w}{3.4}$ „ 1 „ „ steel 1" × 1" „ 3.4 lb.

Assume the flanges to be of equal thickness throughout, i.e., that the section is rectangular, as shown in figure :—



Then $I = \frac{1}{12} (bd^3 - (b-t)d_1^3)$, and d_1 is the only dimension that is not given.

From the figure, $A = bd - (b-t)d_1$

$$\text{whence } d_1 = \frac{bd-A}{b-t}$$

and as $A = \frac{3}{10} w$ for iron or $\frac{w}{3.4}$ for steel, d_1 can be found and the value of I determined.

In manufacturers' lists of joists, it is generally stated that joists can be rolled about 10 per cent. heavier than list weights; the extra weight in such cases is obtained by slightly opening the rolls and thus thickening the web, and the consequent addition to the tabular constant for load is $\frac{xd}{6}$ for an iron joist and $\frac{xd}{4.08}$ or a steel joist, x being the extra weight in lb. per foot lineal of the joist and d its depth in inches. The calculation is as follows :—

Let C = increase in area (in square inches) due to increase of x lb. in weight.

Then $\frac{C}{d}$ = increase in thickness of web.

For the rectangle $d \times \frac{C}{d}$ $\left\{ I = \frac{1}{12} d^3 \times \frac{C}{d} = \frac{Cd^2}{12} \right.$ and from equation (1) on page 8, $WL = \frac{4SI}{3d} = \frac{SCd}{9}$.

For iron, $S = 5$, $C = \frac{3}{10} x$, and $WL = \frac{xd}{6}$.

For steel, $S = 7.5$, $C = \frac{x}{3.4}$, and $WL = \frac{xd}{4.08}$.

Formulae.

For distributed loads, ends of joists supported (case I)—

$$\frac{1}{8} WL \times 12 = \frac{SI \times 2}{d}$$

* or $WL = \frac{4SI}{3d}$ (1) which is constant for each section for any fixed value of S.

$$\text{and } W = \frac{4SI}{3dL} \text{ (2).}$$

$$V = \frac{5}{384} \times \frac{WL^3 \times 12^3}{EI} \text{ (3).}$$

From (2) and (3) $\frac{V}{L^2} = \frac{30S}{dE}$ (4) which is constant for each depth of joist for any fixed values of S and E.

For iron S = 5. E = 11125—

$$\text{From (1) } WL = \frac{20I}{3d}. \text{ (Tabular constant for load.)}$$

$$\text{From (4) } \frac{+100V}{L^2} = \frac{1.35}{d}. \text{ (Tabular constant for deflection.)}$$

For steel S = 7.5. E = 12,500.

$$\text{From (1) } WL = \frac{10I}{d}. \text{ (Tabular constant for load.)}$$

$$\text{From (4) } \frac{+100V}{L^2} = \frac{1.8}{d}. \text{ (Tabular constant for deflection.)}$$

* When the only particulars available are those generally given in manufacturers' lists, viz., depth, breadth, and weight in lb. per foot lineal, the constant for load may be approximately calculated from the following formula:—
 $WL = 0.11 (w - 0.3 \text{ bd}) Sd$, the values of the symbols being as given in the text. In part IV of "Notes on Building Construction" (Longmans, 1891), it is stated that this formula "will be found on trial to give fairly good results."

† The object of multiplying by 100 is to save long decimals in the tabular constants for deflection.

ORDER—dated 1st March 1895, No. 480 W., Public Works.

Communicated to officers of the Public Works Department for information and guidance in continuation of G.O., No. 2348 W., dated 3rd September 1891.

(True Extract.)

(Signed) J. PENNYCUICK, Colonel, R.E.,
 Secretary to Govt., P.W.D.

To the Chief Engineer for Irrigation.
 „ the Consulting Engineer for Railways.
 „ Superintending Engineers.
 „ the Consulting Architect to Government.
 „ the Superintendent of Works, Periyár Project.

GENERAL.
ACCOUNT.

Govt. of {1895} Madras.

PUBLIC WORKS.

Dated March, 1st.

Recd.

Encl.

G.O., 1st Mar. 1895, No. 480 W.

MARCH.

Indents for rolled joists

Circular from the Government of India issuing revised instructions for the preparation of — together with tables for calculation of loads, &c., communicated to officers of the Public Works Department.

Suggestions for the preparation in India of Indents for Rolled Joists.

REVISED, JUNE 1894.

1. Difficulty is sometimes experienced in procuring rolled joists of the exact sections demanded. It is therefore recommended that a detailed statement, giving limits of variation and other particulars for each item, should be furnished on the Form shown on page 2.

2. Joists are tested with central loads and must show no permanent set after test. The loads are arranged so as to produce limiting stresses of 5 and $7\frac{1}{2}$ tons per square inch for iron and steel respectively.

3. Steel joists are now procured more readily than iron joists, because mild steel has so largely supplanted wrought iron. There is very little difference in the prices of the two descriptions. For instance, in May 1894, actual contract prices were as follows:—

For steel joists, 13 inches $\times$ 5 inches, 5*l.* 17*s.* 6*d.* per ton.

For iron joists, 12 inches $\times$ 5 inches, 6*l.* 7*s.* 6*d.* per ton.

The tensile tests are as follows:—

Iron, 21 tons per square inch, with a reduction of area of 15 per cent.

Steel, 27 to 32 tons per square inch, with an elongation of 20 per cent. in a length of 8 inches.

4. Taking the modulus of elasticity for steel at 12,500* tons per square inch, and that for iron at 11,125† tons per square inch, the deflection of a steel joist with a limiting stress of 5.62 tons per square inch is the same as that of an iron joist of the same section, and under the same conditions with a limiting stress of 5 tons. With higher limits of stress as $7\frac{1}{2}$ tons the deflection is, of course, increased.

5. The annexed tables give particulars of various sections, together with constants for each, from which loads and deflections can be easily ascertained. The sections enumerated are all stated in published lists to be "stock" sections, and should therefore be readily obtainable, but special rolling and consequent delay are generally found necessary, probably because contractors will not cut stock lengths to waste.

6. In estimates of weight 2 per cent. should be added to list weights of joists to allow for variations in rolling.

* Professor T. A. Hearson, M.I.C.E.
† Molesworth's Pocket Book.

Item of Indent.	Section re-quired.		Maximum and Minimum Limits of Dimensions of Section which may be allowed in case the exact Section cannot be procured.						Lengths.	Clear span.	Number required.			Dead Load, including Weight of Joist.	* Arrange-ment of Load.	† Condi-tion of Joist.	Stress in Tons per Square Inch not to exceed —	REMARKS. State whether built up plate girders may be substituted for joists, and, if so, whether they must be of uniform section throughout or may be of uniform strength.
	Depth.		Depth.		Width.		Lengths.	Clear span.	In Dead Length, <i>i.e.</i> , both Ends machin-ed.	With one End machin-ed.	With neither End machin-ed.	Dead Load, including Weight of Joist.	* Arrange-ment of Load.	† Condi-tion of Joist.	Stress in Tons per Square Inch not to exceed —	REMARKS. State whether built up plate girders may be substituted for joists, and, if so, whether they must be of uniform section throughout or may be of uniform strength.		
			Max.	Min.	Max.	Min.												
In.	Dep't.	Width.	In.	In.	In.	In.	Ft. in.	Ft. in.	Tons.	Tons.	Tons.							

* i.e., Distributed. Central, etc.

† i.e., Fixed both ends. Supported, ditto, etc.

ROLLED IRON JOISTS.

Particulars of Sections, and Constants for Load and Deflection, with a limiting Stress of 5 tons per square inch.

Case I.

Condition of Joist . . . Supported at both ends.

Arrangement of Load . . . Dead, uniformly distributed, weight of joist included.

Section.	Weight per Lineal Foot.	Thickness of Web.	Moment of Inertia.	CONSTANTS.	
				For Load.	For Deflection.
Inches.	Lbs.	Inches.	Quartic Inches.		
16 × 6	62	•62	713.02	297.09	•0844
14 × 6	60	•625	542.55	258.35	•0964
12 × 6	56	•625	374.81	208.23	•1125
12 × 5	42	•45	291.27	161.82	•1125
10 × 6	43	•62	199.14	132.76	•135
10 × 5	36	$\frac{7}{16}$	175.51	117.01	•135
10 × 4½	32	$\frac{7}{16}$	150.99	100.66	•135
9½ × 3½	24	•375	95.39	68.75	•146
8 × 6	34	•50	107.54	89.62	•169
8 × 5	29	•39	93.07	77.56	•169
8 × 4	22	•375	67.05	55.88	•169
7 × 3½	19	•32	45.34	43.18	•1928
7 × 2½	14	$\frac{5}{16}$	30.11	28.68	•1928
6½ × 3½	16	•32	29.73	31.71	•216
6½ × 2	11	•30	18.23	19.45	•216
6 × 5	29	$\frac{7}{16}$	51.31	57.01	•225
5 × 4½	23	•375	28.28	37.70	•270
5 × 3	13	•25	16.18	21.57	•270
4½ × 2	8	•25	8.12	11.40	•2842
4 × 3	12	•25	9.47	15.78	•3375
4 × 2	7	•25	5.07	8.45	•3375
3½ × 1½	5½	$\frac{3}{16}$	2.51	5.35	•432
3 × 3	10	•25	4.37	9.71	•450

For method of using this table, see the notes following the Table of Steel Joists.

ROLLED STEEL JOISTS.

Particulars of Sections, and Constants for Load and Deflection, with a limiting Stress of 7.5 tons per square inch.

Case I.

Condition of Joist . . . Supported at both ends.
Arrangement of Load . . . Dead, uniformly distributed, weight of Joist included.

Section.	Weight per Lineal Foot.	Thickness of Web.	Moment of Inertia.	CONSTANTS.	
				For Load.	For Deflection.
Inches.	Lbs.	Inches.	Quartie inches.		
19 $\frac{1}{2}$ x 7 $\frac{1}{2}$	96	$\frac{11}{16}$	1715.48	868.60	.091
18 x 7	75	$\frac{5}{8}$	1153.00	640.55	.10
17 $\frac{1}{2}$ x 6 $\frac{3}{4}$	80	.625	1163.05	655.21	.101
16 x 6	64.5	.64	731.02	456.88	.1125
16 x 5	50	.51	556.01	347.50	.1125
15 $\frac{1}{2}$ x 6 $\frac{1}{2}$	62	$\frac{9}{16}$	704.58	417.33	.114
15 x 6	61	$\frac{7}{8}$	621.36	414.24	.12
15 x 5 $\frac{7}{8}$	56.5	$\frac{9}{16}$	572.64	381.76	.12
15 x 5	42	.45	416.56	277.70	.12
14 x 6	57	.59	513.76	366.97	.1286
14 x 5	45	.435	418.45	298.89	.1286
13 $\frac{1}{2}$ x 5 $\frac{1}{2}$	46	$\frac{7}{8}$	419.63	299.73	.13
13 x 5	40	.51	291.79	224.45	.138
12 x 6	54	.60	358.89	299.07	.15
12 x 5	42	.42	296.02	246.63	.15
12 x 4	43	.58	271.71	226.43	.15
12 x 3	32	.48	183.60	153.00	.15
11 $\frac{1}{2}$ x 5	37	.42	242.46	205.25	.152
10 x 6	45.5	.58	215.14	215.14	.18
10 x 5	35	.52	156.99	156.99	.18
10 x 4	29	.47	127.05	127.05	.18
10 x 3	31.5	.41	148.07	149.07	.18
9 $\frac{1}{2}$ x 5	41	.42	200.23	202.76	.182
9 $\frac{1}{2}$ x 4	27	.36	125.90	127.50	.182
9 $\frac{1}{2}$ x 3	37	.516	160.84	163.91	.184
9 $\frac{1}{2}$ x 2	22	.33	80.54	88.87	.198
9 x 4	58	.79	218.48	242.75	.20
9 x 3	24.25	.44	85.50	95.00	.20
8 x 6	36	.48	114.14	142.67	.225
8 x 5	32	$\frac{7}{8}$	101.25	126.56	.225
8 x 4	31.25	.45	96.58	121.07	.225
8 x 3	25	.42	74.17	92.97	.225
7 $\frac{1}{2}$ x 5	18	.329	52.90	66.13	.225
7 $\frac{1}{2}$ x 4	27	.375	82.48	104.74	.2286
7 $\frac{1}{2}$ x 3	19	$\frac{5}{8}$	56.16	71.31	.2286
7 x 5	20	.41	44.61	63.72	.257
7 x 4	16	.25	38.80	55.43	.257
7 x 3	18	.36	33.11	52.97	.288
6 $\frac{1}{2}$ x 5	9.5	.25	15.81	25.29	.288
6 $\frac{1}{2}$ x 4	24	$\frac{7}{8}$	40.47	66.40	.294
6 $\frac{1}{2}$ x 3	26	.54	43.84	73.06	.30
6 x 5	19	.434	30.04	50.06	.30
6 x 4	13	.25	26.79	44.65	.30
6 x 3	16	.34	26.69	44.48	.30
6 x 2	13	.322	20.89	34.81	.30
5 $\frac{1}{2}$ x 4	12.25	.39	17.12	28.53	.30
5 $\frac{1}{2}$ x 3	11	.36	13.41	24.35	.327

Section.	Weight per Lineal Foot.	Thickness of Web.	Moment of Inertia.	CONSTANTS.	
				For Load.	For Deflections.
Inches.	Lbs.	Inches.	Quartie Inches.		
5 $\frac{1}{2}$ x 1 $\frac{1}{2}$	9	.368	8.79	16.75	.327
5 $\frac{1}{2}$ x 1 $\frac{1}{4}$	17.5	$\frac{5}{8}$	23.14	45.15	.351
5 x 5	25.5	.49	30.49	60.98	.36
5 x 4 $\frac{1}{2}$	23.75	.43	27.32	54.64	.36
5 x 4 $\frac{3}{8}$	17	.44	19.59	39.18	.36
5 x 3	15.25	.40	17.17	34.34	.36
5 x 3	13	.35	14.68	29.36	.36
5 x 3	10	.25	11.93	23.86	.36
4 $\frac{3}{4}$ x 1 $\frac{3}{4}$	9.25	.37	8.08	17.01	.379
4 $\frac{3}{4}$ x 1 $\frac{1}{2}$	6.5	.298	5.25	11.05	.379
4 $\frac{1}{2}$ x 1 $\frac{3}{4}$	7.5	.21	7.67	16.36	.384
4 $\frac{1}{2}$ x 1 $\frac{1}{2}$	14	.42	13.35	28.86	.39
4 $\frac{1}{2}$ x 1	10	.23	8.42	20.41	.436
4 x 3	12.75	.39	9.32	23.3	.45
4 x 2	5.5	$\frac{3}{8}$	4.23	10.6	.45
4 x 2	8.5	.37	5.48	13.7	.45
4 x 1 $\frac{3}{4}$	10.75	.30	6.26	17.88	.514
3 $\frac{1}{2}$ x 3	6	.28	3.04	8.68	.514
3 $\frac{1}{2}$ x 1 $\frac{1}{2}$	4	.17	1.80	5.76	.576
3 $\frac{1}{2}$ x 1	8	.25	3.67	11.98	.588
3 x 3	10.25	.30	4.34	14.46	.60
3 x 1 $\frac{1}{2}$	5	.31	1.74	5.80	.60

To use the Tables:—

(i) To find the Load and corresponding Deflection for a given section of joist with a given span:—

(a) Divide the constant for Load by the distance in feet from centre to centre of bearings*; the quotient is the total distributed load in tons, including the weight of the joist†.

(b) Multiply the constant for deflection by the square of the distance in feet from centre to centre of bearings* and divide the result by 100; the quotient is the deflection in inches.

(ii) To select a joist for a given external load (i.e., load exclusive of weight of joist) and given span:—

Multiply the load in tons by the distance in feet from centre to centre of bearings* and take a section against which the constant for load is slightly higher than the result. The weight of the joist† should then be added to the external load, and the section tried as in (i) for load and deflection.

CASES II TO VIII.

(iii) To ascertain loads, etc., for joists under different conditions and with different arrangements of loads, the constants in the tables must be multiplied by the factors given below for each particular case before proceeding as in (i) or (ii) above.

Case.	Condition of Joist.	Arrangement of Load (dead in all cases).	Factors to be applied to	
			Load constant	Deflection constant.
II	Fixed at one end, free at the other	Concentrated at free end	$\frac{1}{2}$	25.6
III		Uniformly distributed	$\frac{1}{2}$	9.6
IV	Supported both ends	Concentrated at centre	1	1.6
V		Ditto	$\frac{1}{2}$	.4
VI	Fixed both ends	Uniformly distributed	$\frac{1}{2}$	.2
VII	Fixed at one end, supported at the other	Concentrated at centre	$\frac{3}{4}$	.7152
VIII		Uniformly distributed	1	.4176

* In cases II and III, substitute "centre of bearing of fixed end to free end" for "centre to centre of bearing."

† In Cases II and IV, Total load = External load + $\frac{1}{2}$ weight of joist.

In these four cases the whole weight of the joist is not added to the external load to make up the total load because the calculation will be made for a concentrated load, whereas the weight of the joist is uniformly distributed. The calculated deflections will in these four cases be slightly excessive.

Notes.

(a) The constants given in the tables can readily be adapted to suit other limits of stress than those which have been used (5 and 7.5 tons per square inch for iron and steel respectively), *e. g.*, if it be desired to limit the stress in a steel joist to 6 tons per square inch, the constants must be multiplied by $\frac{6}{7.5}$ or 0.8 before the load and deflection are determined. A higher stress than 5 tons per square inch is not recommended for iron joists.

(b) If the deflection calculated from the tables be greater than can be allowed, and if the circumstances do not permit the use of deeper section or of a heavier section of the same depth, the load calculated from the tables must be reduced in the proportion of the allowable to the calculated deflection and the number of joists increased, *e. g.*, if the allowable deflection be 0.5 inch and the calculated deflection 0.6 inch the load should be reduced to $\frac{5}{6}$ ths of the calculated load; the stress would of course be reduced in the same proportion.

(c) If the deflection be limited to $\frac{1}{40}$ th of an inch per foot run of the joist, the minimum depth (with the limits of stress used in the Tables) should be as follows for Case 1, *viz.* :—

For iron joists, 5.4 inch } for each foot of distance between centres of bearings;
 „ steel „ 7.2 „ }
e. g., if the distance from centre to centre of bearings were 10 feet and the deflection were limited to $\frac{10}{40}$ or $\frac{1}{4}$ inch, the minimum depth of an iron joist, Case 1, should be 5.4 inches.

APPENDIX.

The tabular constants have been calculated from the following data :—

Symbols.

W = Total distributed load in *tons*, including the weight of the joist.
 L = Distance in *feet* from centre to centre of bearings.
 S = Limiting stress in *tons* per square inch (5 for iron; 7.5 for steel).
 d = Depth of joist in *inches*.
 V = Deflection in *inches*.
 E = Modulus of elasticity in *tons* per square inch (11125 for iron; 12500 for steel).
 *I = Moment of inertia of section of joist (from dimensions in inches).

* When the thickness of the web is known as well as the depth, breadth, and weight per foot lineal, the Moment of Inertia for the section may be very approximately determined as follows :—

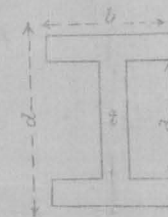
Let A = area of the section in square inches.

„ w = weight „ „ in lb. per foot lineal.

Then for Iron $A = \frac{3}{10}w$ because 1 foot lineal of wrought iron 1" x 1" weighs $3\frac{1}{2}$ lb.

and for Steel $A = \frac{w}{3.4}$ „ 1 „ „ steel „ „ 3.4 lb.

Assume the flanges to be of equal thickness throughout, *i.e.*, that the section is rectangular, as shown in figure,—



Then $I = \frac{1}{12} (bd^3 - (b-t)d_1^3)$, and d_1 is the only dimension that is not given.

From the figure, $A = bd - (b-t)d_1$

$$\text{whence } d_1 = \frac{bd - A}{b - t}$$

and as $A = \frac{3}{10}w$ for iron or $\frac{w}{3.4}$ for steel, d_1 can be found and the value of I determined.

In manufacturers' lists of joists, it is generally stated that joists can be rolled about 10 per cent. heavier than list weights; the extra weight in such cases is obtained by slightly opening the rolls and thus thickening the web, and the consequent addition to the tabular constant for load is $\frac{xd}{6}$ for an iron joist and $\frac{xd}{4.08}$ or a steel joist, x being the extra weight in lb. per foot lineal of the joist and d its depth in inches. The calculation is as follows :—

Let C = increase in area (in square inches) due to increase of x lb. in weight.

Then $\frac{C}{d}$ = increase in thickness of web.

For the rectangle $d \times \frac{C}{d}$ $\left\{ \begin{array}{l} I = \frac{1}{12} d^3 \times \frac{C}{d} = \frac{Cd^2}{12} \\ \text{and from equation (1) on page 8, } WL = \frac{4SI}{3d} = \frac{SCd}{9} \end{array} \right.$

For Iron, $S=5$, $C = \frac{3}{10}x$, and $WL = \frac{xd}{6}$.

For Steel, $S=7.5$, $C = \frac{x}{3.4}$, and $WL = \frac{xd}{4.08}$.

Formulae.

For distributed loads, ends of joists supported (Case I),—

$$\frac{1}{8} WL \times 12 = \frac{SI \times 2}{d}.$$

† or $WL = \frac{4SI}{3d}$ (1) which is constant for each section for any fixed value of S.

and $W = \frac{4SI}{3dL}$ (2).

$$V = \frac{5}{384} \times \frac{WL^3 \times 12^3}{EI} \quad (3).$$

From (2) and (3) $\frac{V}{L^3} = \frac{30S}{dE}$ (4) which is constant for each depth of joist for any fixed values of S and E.

For Iron S=5. E=11125,—

From (1) $WL = \frac{20I}{3d}$. (Tabular constant for load.)

From (4) $\frac{100V}{L^3} = \frac{1.35}{d}$. (Tabular constant for deflection.)

For Steel S=7.5. E=12500.

From (1) $WL = \frac{10I}{d}$. (Tabular constant for load.)

From (4) $\frac{100V}{L^3} = \frac{1.8}{d}$. (Tabular constant for deflection.)

† When the only particulars available are those generally given in manufacturers' lists, viz., depth, breadth, and weight in lb. per foot lineal the constant for load may be approximately calculated from the following formula:— $WL=0.11(w-0.36d)Sd$, the values of the symbols being as given in the text. In Part IV of "Notes on Building Construction" (Longmans, 1891), it is stated that this formula "will be found on trial to give fairly good results."

‡ The object of multiplying by 100 is to save long decimals in the tabular constants for deflection.

[For General Distribution.]

Circular No. 2 Ry.

GOVERNMENT OF INDIA.
PUBLIC WORKS DEPARTMENT.
RAILWAY STORES.

Calcutta, 25th January 1895.

Revised suggestions for the preparation of indents for rolled joists.
Tables for calculation of loads, etc.

The undermentioned papers are forwarded to the Local Governments and Administrations and to the officers noted in the margin for information and guidance in supersession of Government of India circular No. 11 Ry. of 31st July 1891.

The Governments of Madras, Bombay, Bengal, the North-Western Provinces and Oudh, and the Punjab, Public Works Department.
The Chief Commissioners of the Central Provinces, Burma, Assam and Coorg.
The Resident at Hyderabad.
The Resident in Mysore.
The Agents to the Governor General for Rajputana, Central India, and Baluchistan.
The Accountant General, Public Works Department.
The Director General of Railways.
The Consulting Engineers to the Government of India for Railways, Calcutta, Lucknow, and Assam.
The Superintendent of Port Blair and Chief Commissioner, Andaman and Nicobar Islands.
The Director General of Telegraphs.

2. These revised instructions are applicable to all Branches of the Public Works Department.

By order,

Under Secretary.

Documents referred to.

Revised rules for the preparation of indents for rolled joists, together with tables for the calculation of loads, etc.

G. I. C. P. O.—No. 1067 P. W. D.—28-1-95.—30.—J. N. D.

To The Secretary to the Government of Madras
Public Works Department
12th Feb 1895
50/20 for Ry. N. H.

3-9-91 No 2348W

Lo 480h d, 1 March 1895

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officers of the Public Works
Dept. for information and
Dept. for information and
guidance in continuation
guidance in continuation
of L.O. No 2348W dated 3rd
of L.O. No 2348 W dated 3rd
September 1891
September 1891.

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- Suptg. Engrs.
- to the Chief Architect to Govt.
- The Chief Architect to Govt.
- to the Supt. of Works, Periyar Project
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