the concrete it may be termed reinforcement. In this case the steel is figured in the same way as vertical bars and the stresses determined from formula (60), page 491. If, for example, the allowable stress on the concrete is 450 pounds per square inch and a ratio of 15 is used, the steel can be figured only for a compressive stress of 6750 pounds per square inch.

To utilize the full working strength of the steel, the plan has sometimes been followed of separating the structural steel core from the concrete so that they will work independently, and designing the columns in the lower stories so that the steel will take the entire weight of the upper stories while the concrete surrounding the steel supports the weight of the lower stories.

Structural steel reinforcement is sometimes in the form of a cross in the center of the column, or, as in the case of the McGraw building,* channels connected by riveted latticing are placed and concrete poured within the reinforcement as well as providing a protective layer around it. Stresses for this type are suggested on page 528.

Tests† of columns reinforced with structural steel shapes frequently show lower ultimate strength than similar columns reinforced with the same quantity of steel in the form of vertical round bars. This probably is due in part to the difficulty in properly placing the concrete around the structural steel.

COLUMN EXAMPLES.

Example 15: What size of square column reinforced with 2 per cent of longitudinal bars without bands will be required to support a load of 94 000 pounds?

Solution: By paragraph (a), page 527, the allowable compression on 2000 pounds concrete is limited to 450 pounds per square inch. For this allowable stress, using 2% of longitudinal reinforcement and a ratio of moduli of elasticity of 15, the area of column from formula (62), page 491, is

$$A = \frac{94\ 000}{450\ (1 + 14 \times 0.02)}$$

= 163 square inches, corresponding to 12.8 inches square. The denominator of this expression may be obtained directly from table on page 492. Allowing 2 inches for protective covering gives 14.8 inches, or, say, 15 inches square.

Example 16: Find the diameter of a round column reinforced by 1 per cent of hooping only, designed to support a load of 120 000 pounds. Assume the allowable pressure on plain concrete as 450 pounds and a ratio of moduli of elasticity, $n = 15$.

Solution: The allowable unit compression on hooped columns may be increased 20 per cent over that on plain concrete (see paragraph (b), page 527),

* William H. Burr, Transactions American Society of Civil Engineers Vol. LX, 1908, p. 443.
†M. O. Withey in Engineering Record, July 10, 1909, p. 41

hence $f = 450 + 20\% = 540$. The area of section from formula (63) is

$$A = \frac{120\ 000}{540}$$

= 222 square inches, giving an effective diameter of 16.8 inches. Adding 3 inches for protective covering gives a total diameter of 20 inches.

Example 17: What sectional area of vertical steel will be required for a square column limited to 36 inches diameter, which has to bear 1 000 000 pounds with pressure in plain concrete limited to 450 pounds per square inch?

Solution: By paragraph (c), page 528, in a column reinforced with vertical bars and 1% of bands or hoops, the allowable pressure on the concrete may be increased 45% over that on plain concrete, hence $f_c = 450 + 45\% = 652$ pounds per square inch. Considering the area within hooping equal to $33^2 =$ 1090 square inches as effective, the unit pressure from page 491, will be

$$f = \frac{1\ 000\ 000}{1090}$$

= 918 pounds per square inch. Assume $n = 15$, then from formula (61), page 491,

$$p = \frac{918 - 652}{14 \times 652}$$

= 0.029, and area of steel, $A = 1090 \times 0.029 = 31.6$ square inches. From table on page 507, it is found that 18 round rods 1½ inches diameter will give the required area.

Example 18: What should be the area of a column 10 feet high supporting 1 000 000 pounds, reinforced with 3.5 % of longitudinal reinforcement and 1% of hooping for $n = 15$ and an allowable compression in plain concrete limited to 450 pounds?

Solution: Since the column is reinforced with longitudinal and hooping reinforcement, the unit compression on concrete may be taken as $f_c = 450 + 45\% = 652$ pounds per square inch (paragraph c, page 528). Then from formula (62), page 491, the column area is

$$A = \frac{1\ 000\ 000}{652\ (1 + 14 \times 0.035)}$$

= 1030 square inches. The denominator of this expression may be obtained directly from table on page 492.

REINFORCEMENT FOR TEMPERATURE AND SHRINKAGE STRESSES

All masonry is subject to temperature cracks, but when they are distributed in the many joints between bricks or stones they do not show so plainly as on the smooth surface of concrete.

Expansion from a rise in temperature rarely causes trouble except at angles where the lengthening of the surface may produce a buckling or a sliding of one portion of the wall past the end of the other. In a building, the walls and floors are generally so well bonded together and free to move as a unit, that no provision need be made for expansion. In a structure like a square reservoir, the effect of expansion must be taken into account in the design to prevent failure at the corners.

Contraction is often more serious, although cracks are by no means necessarily dangerous. To prevent cracking due to the shrinkage of the concrete in hardening (see p. 287) or to the lowering of the temperature, reinforcement should be inserted or joints formed to localize the cracks. (See p. 285.)

Reinforcement properly placed distributes the contraction stresses so as to make the cracks very small, practically invisible, but it does not prevent them entirely.

The steel must be sufficient in quantity, and should be of small diameter and placed as close as practicable to the surfaces to distribute the cracks and thus make them very fine. Deformed bars, that is, bars with irregular surfaces which provide a mechanical bond with the concrete, are more effective than smooth bars, and steel of high elastic limit also is advantageous.

In practice, from $\frac{2}{10}$ of 1% to $\frac{4}{10}$ of 1% (a ratio of 0.002 to 0.004) of steel, based on the cross-section of the concrete, is commonly used as temperature or shrinkage reinforcement.

The tensile strength of concrete is so low that a small change in temperature will crack it. For example, the coefficient of expansion of concrete is 0.0000055 (see p. 287) and the modulus of elasticity is generally assumed as 2 000 000; therefore, the stress (see p. 404) per degree Fahrenheit is $0.0000055 \times 2\,000\,000 = 11$ pounds per square inch, and a fall in temperature of $\frac{300}{11} = 27°$ is sufficient to crack a concrete the tensile strength of which is 300 pounds per square inch.

It is evident, and it has been proved by experience, that there is less cracking in concrete laid in cold than in warm weather.

Longitudinal reinforcement is especially necessary in conduits which must be water-tight.

Shrinkage cracks due to the hardening of the concrete may be prevented by keeping the concrete wet. (See p. 287.)

It has been suggested by Mr. Charles M. Mills that the relation between the tensile strength of the concrete and the bond with the bars is an important factor in governing the size of the cracks, and the following analysis, based on his suggestions, gives a means of estimating the size and distance apart of the cracks so as to form a basis for judgment as to the sizes and percentages of steel to use.

The tensile stress in the steel at a crack tends to pull out the bars from

the concrete, and referring to Fig. 154, the bond stress of the bar in the length *ab* must equal the tensile stress in the whole cross-section of the concrete at *b* caused by the contraction of the concrete.

Let

x = distance apart of cracks.

D = diameter of round bar or side of square bar.

p = ratio of cross-section of steel to cross section of concrete.

Then,* if, as is sufficiently accurate for practical purposes, the strength of concrete in tension is assumed to be equal to the bond between plain steel bars and concrete, the distance apart of cracks is

$$x = \frac{D}{2p} \text{ for square or round bars.}$$

The distance apart is inversely proportional to the unit bond*, so that a deformed bar having twice the bond strength would space the cracks one-half as far apart and allow them to be only one-half as wide.

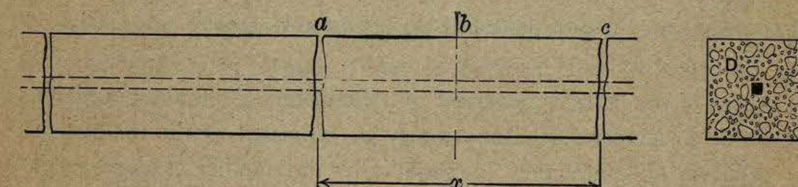


FIG. 154. Reinforcement for Temperature Stresses. (*See p.* 501.)

It is evident that the distance apart of the cracks is proportional to the diameter of the reinforcing bars, and inversely proportional to the percentage of steel.

From this formula is tabulated the estimated percentage of reinforcement for different spacing of cracks and different sizes of bars, assuming the bonding strength of the steel to the concrete to equal the tensile strength of the concrete.

* In addition to above notation, let

A_c = area of section of concrete.

A_s = area of section of steel.

o = perimeter of steel bar.

f'_c = tensile stress in concrete.

u = unit bond between plain steel and concrete.

f_s = unit tensile stress in steel.

D = diameter of bar.

Then $A_c f'_c = \frac{1}{2} uox$, or $x = \frac{2 A f'_c}{u o}$. If $f'_c = u$, $x = \frac{2 A_c}{o}$, and since $p = \frac{A_s}{A_c}$

$x = \frac{2 A_s}{o p}$. Also, $\frac{A_s}{o} = \frac{D}{4}$ for both round and square bars, hence $x = \frac{1}{2} \frac{D}{p}$.

Estimated Percentage of Reinforcement for Different Spacing of Cracks

DISTANCE APART OF CRACKS WITH							
PLAIN BARS		12″	18″	24″	36″	48″	60″
DEFORMED BARS *		8″	12″	16″	24″	32″	40″
		%	%	%	%	%	%
Diameter of round or side of square bar	¼″	1.04	0.70	0.52	0.35	0.26	0.21
	⅜″	1.56	1.04	0.78	0.52	0.39	0.31
	½″	2.08	1.39	1.04	0.69	0.52	0.41
	⅝″	2.60	1.74	1.30	0.87	0.65	0.52
	¾″	3.12	2.08	1.56	1.04	0.78	0.62
	⅞″	3.65	2.44	1.82	1.22	0.91	0.73
	1″	4.17	2.78	2.08	1.39	1.04	0.83

NOTE: To express the steel as the ratio of area of cross-section of steel to cross-section of concrete, divide the percentages by 100; thus 1.04 becomes $p = 0.0104$.

* Assuming the bond of deformed bars to be 50% greater than plain.

The size of the crack is governed by the amount of shrinkage and for cracks due to temperature changes may be estimated as the product of the coefficient of contraction (0.0000055) by the number of degrees fall in temperature by the distance between cracks.

Estimated Width of Cracks for Different Distances Apart

WIDTH FOR DIFFERENT TEMPERATURE CHANGES	DISTANCE APART					
	12″	18″	24″	36″	48″	60″
30° Fahr.	0.0020	0.0030	0.0040	0.0059	0.0079	0.0099
50° "	0.0033	0.0050	0.0066	0.0099	0.0132	0.0165
70° "	0.0046	0.0069	0.0092	0.0139	0.0185	0.0232

From this, if it can be determined how large a crack will be allowable, the corresponding spacing can be obtained.

To avoid large cracks it may be necessary to use enough steel to prevent its passing its elastic limit. If the bars are continuous for such a length that the ends are practically immovable, as in a long retaining wall, a drop

* 30° corresponds to a shrinkage of 0.017%; 50° to 0.028%; 70° to 0.038%.

in temperature, tending to shorten them, produces a tensile stress which is independent of the distance between the restrained ends. Assuming the coefficient of expansion of steel the same as concrete and the modulus of elasticity of steel as 30 000 000, this stress is 30 000 000 × 0.0000055 = 165 pounds per square inch per degree of temperature, or for 50° Fahr. is 8250 pounds per square inch. This is well within the elastic limit of the steel and would not, of itself, cause the steel to take a permanent set. However, since the concrete surrounding the steel will be continuous except at certain cracks, the stretch in the steel may be unevenly distributed and largely confined to the immediate vicinity of the cracks. If cracks occur while steel is unstressed, through the concrete shrinking, the steel tends to resist the shrinkage by tension at the crack and compression at the center of the block of concrete, and the tensile stress will be equal to the compressive and each equal to one-half the tensile strength of the concrete. This may be expressed by the following formula, using the foregoing notation:*

$$f_s' = \frac{1}{2p} f_c'$$

Since the tensile stress in the concrete is liable to be low at the time shrinkage cracks are formed, it may be assumed, for illustration, as 200 pounds per square inch making

$$f_s' = \frac{100}{p}$$

This represents the stress due to local cracks which is additional to the temperature stresses above described. The total stress is, therefore, for 50° change of temperature $8250 + f_s'$ or $8250 + \frac{100}{p}$. If the elastic limit of the steel is 40 000 pounds per square inch, and we must keep below this,

$$40\,000 = 8250 + \frac{100}{p} \text{ and } p = 0.0031$$

For steel, the elastic limit of which is 50 000 pounds per square inch,

$$50\,000 = 8250 + \frac{100}{p} \text{ and } p = 0.0024$$

These values of p represent the lowest theoretical ratio of area of cross-section of steel to area of cross-section of concrete which can be used without the steel passing its elastic limit at certain of the cracks when the ends are restrained or the length is so great that intermediate parts are practically restrained.

* $\frac{A_c f_c'}{2} = A_s f_s'$ or $f_s' = \frac{A_c}{2A_s} f_c'$ hence $f_s' = \frac{1}{2p} f_c'$

In view of the very slight stretch required to relieve the stress in the bars when the elastic limit is exceeded, and the probability of its distribution by the restraint to movement by the mass, it is not always essential to consider the elastic limit.

SYSTEMS OF REINFORCEMENT

One of the earliest recorded examples of the application of reinforced concrete is a boat of concrete and iron, built by Mr. L. J. Lambot in France, and shown at the Paris International Exhibition in 1855.* In 1861 Mr. Coignet began his investigations, and in 1866 Mr. Monier, to whom the invention of reinforced concrete is often attributed, applied the combination of concrete and iron to various structures, and laid the foundation for its future widespread applications.

As long ago as 1877, Mr. W. E. Ward,† at Port Chester, N. Y., built a house entirely of concrete, reinforced with iron I-beams and round rods.

The rapid development of reinforced concrete has resulted in the introduction of numerous systems, many of them covered by patents, for arranging the metal in the concrete, or for special forms of metal. These systems are fully described in the various French works on reinforced concrete.‡

A few of the systems, representing both the arrangement and the form of the metal, are described below, and forms of metal extensively used in the United States are illustrated in Fig. 155.

Systems of Reinforcement

Bonna. Metal of cruciform cross-section.

Bertini. Girder Frame. Horizontal tension members with vertical stirrups shrunk on to them.

Chaudy and Degon. Cross rods passing under bearing rods, but looped up between them.

Coignet. Round bars in top and bottom of beam connected by diagonal wire lacing.

Columbian. Vertical steel plates with horizontal ribs.

Cottacin. Round rods interlaced in the same manner as in wire netting.

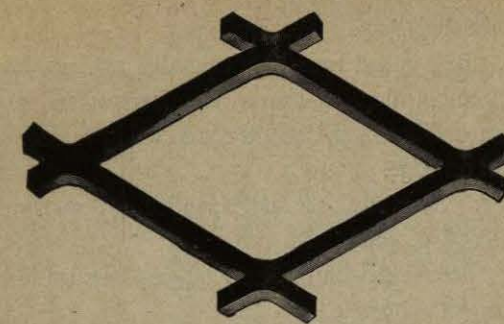
Cummings. Bars of different lengths having their ends bent to an incline and formed into a loop to resist internal stresses.

Cup Bar. Special rolled section with longitudinal ribs connected at frequent intervals by cross ribs forming cup depressions.

* Christophe's Beton Armé, 1902, p. 1.

† Transactions American Society Mechanical Engineers, Vol. IV, p. 388.

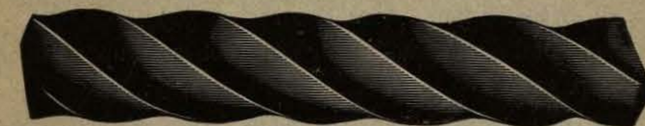
‡ See among others Christophe's Beton Armé, 1902, pp. 10–71, and Morel's Ciment Armé, 1902, pp. 88 to 152.



Expanded Metal.

Kahn Trussed Bar.

Thacher Bulb Bar.



Ransome Twisted Bar.

Johnson Corrugated Bar.

De Man Undulated Bar.

FIG. 155.—Types of Reinforcing Steel. (*See pp.* 504 *and* 506.

De Man. Undulated Bars. (See Fig. 155.)

Diamond Bar. Bars rolled round with parallel ribs passing along and around the bar forming diamond-shaped shoulders on its surface.

Donath. Inverted T-beams or I-beams connected by horizontal diagonals of light, flat metal on edge.

Expanded Metal. Sheet steel, slit and expanded, so as to form a diamond mesh. (See Fig. 155, p. 505.)

Ferroinclave. Sheet steel with inversely tapered corrugations to be covered on both sides with concrete.

Gabriel. Deformed tension members with trussing of hard drawn wire.

Habrich and Düsing. Flat metal twisted hot.

Hennebique. A combination of alternate straight bars and bars with ends bent up at an angle, with vertical U-bars, or stirrups, of flat iron passing around the straight bars and reaching nearly to the top of the beam.

Herringbone Frame. Horizontal tension member with special attachments for stirrups.

Holzer. Metal in form of I-beams.

Hyatt. Flat plates or bars set on edge and pierced with holes through which pass small round rods to form the cross reinforcements.

Johnson. Corrugated bars. (See Fig. 155, p. 505.)

Kahn. Horizontal flanged bars with flanges sheared up at intervals. (See Fig. 155, p. 505.)

Lock-Woven Steel Fabric. Steel wire mesh, locked at intersections.

Lug Bars. Twisted bars with projecting lugs at intervals in the surface.

Melan. Steel ribs, either I-beam or 4 angles latticed, imbedded in the concrete of the arch.

Monier. Two series of round parallel bars at right angles to each other.

Mushroom. Flat floor slabs supported by columns with enlarged heads.

Parmley. Bars with bent ends, to place in the sides of a conduit or the haunches of an arch to resist tension.

Rabitz. Various combinations employing galvanized wire.

Ransome. Square steel rods twisted cold. (See Fig. 155, p. 505.)

Roebling. Flat steel bars set on edge, clamped to supporting beams, and held in alignment by flat bar separators.

Schülter. Like Monier System except rods are placed diagonally.

Scofield. An oval bar with projecting shoulders.

Thacher. Bulb bars. (See Fig. 155, p. 505.)

Triangle Mesh. Wire mesh reinforcement with transverse metal placed diagonally.

Trussit. Expanded metal or herringbone lath bent to V-shaped section.

Visintini. Beams of concrette, cored out so as to form lattice girders.

Welded Wire Fabric. Wire mesh reinforcement with wires at right angles to each other and welded at intersections.

TABLE 1. AREAS, WEIGHTS AND CIRCUMFERENCES OF BARS.

Areas and Weights of Square and Round Rods and Circumferences of Round Rods.

One cubic foot weighs 490 lb.

Thickness or Diameter in inches.	Area of Square Rod in square inches.	Area of Round Rod in square inches.	Circumference of Round Rod in inches.	Weight of Square Rod One Foot Long.	Weight of Round Rod One Foot Long.	Thickness or Diameter in inches.	Area of Square Rod in square inches.	Area of Round Rod in square inches.	Circumference of Round Rod in inches.	Weight of Square Rod One Foot Long.	Weight of Round Rod One Foot Long.
0						2	4.0000	3.1416	6.2832	13.60	10.68
1/16	0.0039	0.0031	0.1963	0.013	0.010	1/16	4.2539	3.3410	6.4795	14.46	11.36
1/8	0.0156	0.0123	0.3927	0.053	0.042	1/8	4.5156	3.5466	6.6759	15.35	12.06
3/16	0.0352	0.0276	0.5890	0.119	0.094	3/16	4.7852	3.7583	6.8722	16.27	12.78
1/4	0.0625	0.0491	0.7854	0.212	0.167	1/4	5.0625	3.9761	7.0686	17.22	13.52
5/16	0.0977	0.0767	0.9817	0.333	0.261	5/16	5.3477	4.2000	7.2649	18.19	14.28
3/8	0.1406	0.1104	1.1781	0.478	0.375	3/8	5.6406	4.4301	7.4613	19.18	15.07
7/16	0.1914	0.1503	1.3744	0.651	0.511	7/16	5.9414	4.6664	7.6576	20.20	15.86
1/2	0.2500	0.1963	1.5708	0.850	0.667	1/2	6.2500	4.9087	7.8540	21.25	16.69
9/16	0.3164	0.2485	1.7671	1.076	0.845	9/16	6.5664	5.1572	8.0503	22.33	17.53
5/8	0.3906	0.3068	1.9635	1.328	1.043	5/8	6.8906	5.4119	8.2467	23.43	18.40
11/16	0.4727	0.3712	2.1598	1.608	1.262	11/16	7.2227	5.6727	8.4430	24.56	19.29
3/4	0.5625	0.4418	2.3562	1.913	1.502	3/4	7.5625	5.9396	8.6394	25.00	20.20
13/16	0.6602	0.5185	2.5525	2.245	1.763	13/16	7.9102	6.2126	8.8357	26.90	21.12
7/8	0.7656	0.6013	2.7489	2.603	2.044	7/8	8.2656	6.4918	9.0321	28.10	22.07
15/16	0.8789	0.6903	2.9452	2.989	2.347		8.6289	6.7771	9.2284	29.34	23.04
1	1.0000	0.7854	3.1416	3.400	2.670	3 15/16	9.0000	7.0686	9.424	30.60	24.03
1/16	1.1289	0.8866	3.3379	3.838	3.014	1/16	9.3789	7.3662	9.6211	31.89	25.04
1/8	1.2656	0.9940	3.5343	4.303	3.379	1/8	9.7656	7.6699	9.8175	33.20	26.08
3/16	1.4102	1.1075	3.7306	4.795	3.766	3/16	10.160	7.9798	10.014	34.55	27.13
1/4	1.5625	1.2272	3.9270	5.312	4.173	1/4	10.563	8.2958	10.210	35.92	28.20
5/16	1.7227	1.3530	4.1233	5.857	4.600	5/16	10.973	8.6179	10.407	37.31	29.30
3/8	1.8906	1.4849	4.3197	6.428	5.049	3/8	11.391	8.9462	10.603	38.73	30.42
7/16	2.0664	1.6230	4.5160	7.026	5.518	7/16	11.816	9.2806	10.799	40.18	31.56
1/2	2.2500	1.7671	4.7124	7.650	6.008	1/2	12.250	9.6211	10.996	41.65	32.71
9/16	2.4414	1.9175	4.9087	8.301	6.520	9/16	12.691	9.9678	11.192	43.14	33.90
5/8	2.6406	2.0739	5.1051	8.978	7.051	5/8	13.141	10.321	11.388	44.68	35.09
11/16	2.8477	2.2365	5.3014	9.682	7.604	11/16	13.598	10.680	11.585	46.24	36.31
3/4	3.0625	2.4053	5.4978	10.41	8.178	3/4	14.063	11.045	11.781	47.82	37.56
13/16	3.2852	2.5802	5.6941	11.17	8.773	13/16	14.535	11.416	11.977	49.42	38.81
7/8	3.5156	2.7612	5.8905	11.95	9.388	7/8	15.016	11.793	12.174	51.05	40.10
15/16	3.7539	2.9483	6.0868	12.76	10.02	15/16	15.504	12.177	12.370	52.71	41.40

BEAM AND SLAB TABLES

Beam Tables. Tables 2, 3, and 4, pages 509, 510 and 511, give the loading and reinforcement for beams based on 1 inch of width under different conditions. For a beam 10 inches wide, for example, both the safe load per linear foot and the steel area will be ten times the values given in the tables.

The tables are for rectangular beams but may be used for T-beams which have a depth 3 or 4 times the thickness of slab by taking the width of flange as the breadth, , b.

Table 2 is for a simply supported beam and is based on a working compressive stress in concrete of 500 pounds per square inch and in steel of 14 000 pounds per square inch—lower values than are customarily used in construction, but required in many building laws. If the compression in concrete is limited to 500 pounds, while 16 000 pounds is permitted in the steel, use the same loading but reduce the steel in the ratio of 16 to 14.

Tables 3 and 4 are for ordinary design, approved by the authors and corresponding to recommendations of the Joint Committee. All tables are based on a ratio of elasticity of $n = 15$. (See p. 408.)

For other working stresses than those given, the loads may be multiplied by ratios of the values of the constant C in Table 10, page 519, since C is proportional to the load.

The uses of the tables are illustrated in Examples 12 and 13. As high steel is not recommended for ordinary work on a small scale, no table is presented for safe loads for concrete reinforced with it.

Slab Table. Table 5 is for slab design with different working stresses in the steel and concrete. Ordinarily, the series at the top of the second page of the table is used. Note that the values are based on $\frac{wl^2}{10}$. For $\frac{wl^2}{12}$, generally used where the slabs are fully continuous over the supports, add 20% to the loads, leaving the area of steel as given. For square slabs fully reinforced in both directions, the loads may be doubled, or if also fully continuous, they may be doubled and 20% added also.

Table 6 is more convenient for review of beams already designed. It is computed by using formulas (7) and (8) on page 753, and selecting the lower value of M. The most economical ratio of steel for the limiting stresses is $p = 0.0077$. For ratios lower than this the safe loads on the slabs are governed by the tensile strength of the steel, while for larger ratios they are limited by the working strength of the concrete in compression.

TABLE 2. USE FOR SIMPLY SUPPORTED BEAMS FOR EXTRA CONSERVATIVE DESIGN.

Safe Loading and Reinforcement for Rectangular Beams One inch in Width. 1 : 2 : 4 Concrete. Mild Steel.

Based on $M = \frac{wl^2}{8}$ $n = 15$. $f_c = 500$. $f_s = 14000$. (*See p. 508 and item 8, p. 519.*)

For $M = \frac{wl^2}{10}$ add 25% to the safe loads using same steel area. For $M = \frac{wl^2}{12}$ add 50% to the safe loads using same steel area.

Depth of Beam.	Total Safe Load (w) per Linear Foot for Beam One Inch Wide including Weight of Beam. *For safe live load deduct weight of beam in column* (22) (See important footnotes.) Span in Feet (l).																			Weight of Beam One Inch Wide per Linear Foot.	Depth to Steel.	Depth below Steel.	Steel Area in a Beam One Inch Wide.*	Safe Moment of Resistance. (*See p. 753.*)
(h) in.	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	25	30	35	lb.	(d) in.	(e) in.	sq. in.	(M) in. lb.
																				(22)	(23)	(24)	(25)	(26)
5	33	23	17	13	10	8														5.4	4.0	1.0	0.024	1230
6	51	36	26	20	16	13	10	9												6.4	5.0	1.0	0.030	1925
7	74	51	38	29	23	18	15	13	11	9										7.5	6.0	1.0	0.037	2770
8	101	69	51	39	31	25	21	17	15	13	11									8.6	7.0	1.0	0.043	3770
9	123	86	63	48	38	31	25	21	18	16	14	10								9.6	7.75	1.25	0.047	4620
10	157	109	80	61	48	39	32	27	23	20	17	15								10.7	8.75	1.25	0.053	5890
11	195	135	99	76	60	49	40	34	29	25	22	19	17							11.8	9.75	1.25	0.059	7310
12	237	165	121	93	73	59	49	41	35	30	26	23	20							12.8	10.75	1.5	0.066	8900
13	274	188	138	106	84	68	56	47	40	35	30	26	23	21						13.9	11.50	1.5	0.070	10100
14	321	223	164	125	99	80	66	56	47	41	36	31	28	25						15.0	12.50	1.5	0.076	12030
15	374	260	191	146	115	93	77	65	55	48	41	36	32	29	26					16.0	13.50	1.5	0.082	14030
16	431	300	220	168	132	108	89	75	64	55	48	42	37	33	30					17.1	14.50	1.5	0.088	16170
17	493	342	251	193	152	123	102	86	73	63	55	48	43	38	34					18.1	15.50	1.5	0.094	18500
18	557	388	285	218	172	139	115	97	83	71	62	54	48	43	39					19.2	16.50	1.5	0.101	20960
19	593	411	303	232	183	148	122	103	88	77	66	58	51	46	41	37				20.3	17.00	2.0	0.104	22250
20		462	339	260	205	166	137	115	98	85	74	65	57	51	46	41				21.4	18.00	2.0	0.110	24940
22			419	321	253	205	169	142	121	104	91	80	71	63	57	51	33			23.6	20.00	2.0	0.122	30800
24			506	388	306	248	205	172	147	127	111	97	86	77	69	62	40			25.7	22.00	2.0	0.134	37260
26				462	365	295	244	205	175	151	131	115	102	91	82	74	47	33		27.9	24.00	2.0	0.146	44350
28				532	428	346	287	241	205	177	154	135	120	107	96	87	55	38		30.0	26.00	2.0	0.159	52020
30					496	402	332	279	238	205	179	157	139	124	111	100	64	45		32.1	28.00	2.0	0.171	60360
36						576	476	400	340	293	256	225	199	178	159	144	92	64	46	38.5	33.50	2.5	0.220	86400
42						800	661	556	473	408	355	312	277	247	222	200	128	89	64	44.9	39.50	2.5	0.240	120100
48							876	736	627	540	471	414	367	327	294	265	169	118	85	51.4	45.50	2.5	0.278	159400

RULES.
1. **For safe load of any width of beam** multiply by width in inches.
2. **For area of cross-section of steel** for any width of beam multiply column (25) by width in inches.
3. **Total loads for other spans** (l) and the same depth of steel are inversely proportional to the squares of the spans.
4. **Total loads for other depths of steel** (d) and the same span are proportional to the squares of the depths of steel.
5. The values in this table may apply to a very carefully graded 1 : 2½ : 5 mixture.

* This is for a ratio of steel $p = 0.0062$ (0.62 per cent) which is required for the given working stresses