PRACTICAL REINFORCED CONCRETE STANDARDS

FOR THE DESIGN OF REINFORCED CONCRETE BUILDINGS

BY

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FIRST EDITION
FIRST THOUSAND

PUBLISHED BY
SIMPSON BROS. CORPORATION
BOSTON

PREFACE

Among the many publications relating to reinforced concrete, there seem to be few that answer the requirements of the architectural designer.

The majority of architects are men who studied for their profession before any thorough investigation of reinforced concrete construction had been made. They are now called upon by their clients to design in a material requiring special and intimate study of its characteristics, and the solution of intricate formulæ to determine the proper composition, arrangement, and dimensions of its component parts.

Many theories have been advanced by many authorities during the progress of scientific research and experiment. Revisions in these theories have been made from time to time until they now tend to converge toward a common focus, but as yet these theories have not been put in practical working shape, and as a result many structures for which reinforced concrete is specially adapted are built of other material.

It is therefore the purpose of the author to publish information of reinforced concrete in the shape of standard sections, tables, and specifications, that will enable designs to be made in this material as rapidly and as intelligently as in wood or steel.

The tables contained herein have been in practical use in designing and constructing several large buildings in the City of Boston and elsewhere, and the work designed has been approved by conservative concrete specialists.

The need of a standard form of construction with standard specifications is often brought forcibly to mind by the failure of reinforced concrete structures through no fault of the materials entering therein, but through the lack of knowledge by the architect, inspector, or contractor of the design or handling of the materials which enter into the work.

This work is divided into five chapters:—

1. A Brief Theory of Reinforced Concrete Construction, including original formulæ by the author for moments of resistance of T-beams and tables of standard sections.
2. Miscellaneous Tables.
3. A Reinforced Concrete Code.
4. Standard Specifications.
5. Foundations.

It is the author's purpose to make this book as valuable as possible for practical designing and building, and to that end will invite suggestions from all interested so that use can be made of them, if found practical, for future editions.

H. B. Andrews.

Boston, January, 1908.

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PRACTICAL REINFORCED CONCRETE STANDARDS

CHAPTER I

STANDARD SECTIONS

DESIGN OF REINFORCED CONCRETE BEAMS

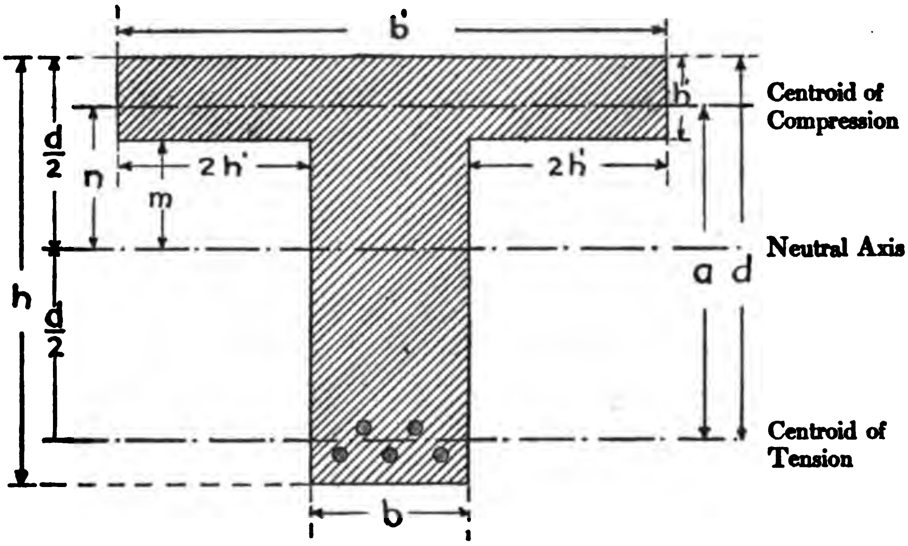


Fig. 1

NOTATION

b = breadth of web.
$b' = b + 4h'$ = breadth of flange.
d = effective depth of beam.
$\frac{d}{2}$ = distance from top of beam to neutral axis.
h = full depth of beam.
h' = depth of flange.
$m = \frac{d}{2} - h'$ = distance from lower side of flange to neutral axis.
n = distance between centroid of compression and neutral axis.
a = distance between centroid of compression and centroid of tension = Moment arm.
c = unit compression in concrete at top of flange.
c' = unit compression in concrete at bottom of flange.
s = unit stress in steel.
C = Total compression in concrete = S, total stress in steel.

FORMULÆ

The following assumptions are made in obtaining formulæ: —

I. A uniform horizontal compression in flange for a distance of twice the depth of flange each side of web. Making this the maximum width of flange tends to avoid the danger of shear along the web.

II. That the compression in the concrete varies uniformly from the neutral axis to the top of the flange.

III. That under working loads, and until the steel is stressed beyond its elastic limit, the neutral axis will lie approximately midway between the top of the beam and the centre of tension. This assumption has been corroborated by tests made to destruction of several T-beams, reinforced with different percentages of steel, at the Massachusetts Institute of Technology, the location of the neutral axis being carefully determined at each increment of load.

IV. That the total compression in the concrete will be balanced by an equal tension in the steel.

V. No allowance is made for tensile strength of concrete.

In Fig. 1 consider first a rectangular section of width b' and of depth d, then the theoretical compression due to any load

$$= \frac{b'd}{2} \times \frac{c}{2} = \frac{cb'd}{4}. \qquad (1)$$

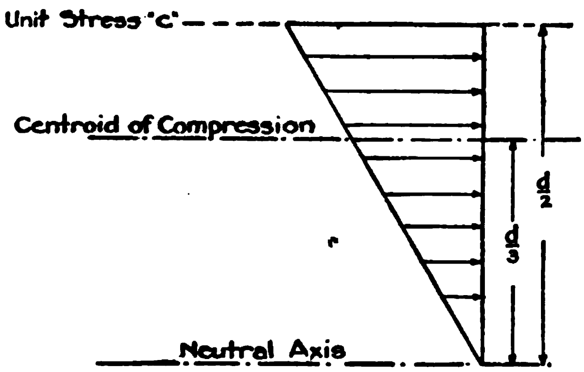


FIG. 2

This can be represented by a triangle as shown by Fig. No. 2, where it is shown that the centre of compression will be at the centre of gravity of the triangle or two thirds of the distance $\frac{d}{2} = \frac{d}{3}$ above the neutral axis.

The resistance moment about the neutral axis

$$= \frac{cb'd}{4} \times \frac{d}{3} = \frac{cb'd^2}{12}. \qquad (2)$$

Considering next the two areas bounded by m and $2h'$, the theoretical compression

$$= \frac{4c'h'm}{2} = 2c'h'm, \qquad (3)$$

and its moment about the neutral axis

$$= 2c'h'm \cdot \frac{2m}{3} = \frac{4c'h'm^2}{3}. \qquad (4)$$

The actual compression in the T-section equals the difference between formulæ (1) and (3)

$$= \frac{cb'd}{4} - 2c'h'm = C = S, \qquad (5)$$

and the resultant resistance moment about the neutral axis equals the difference between formulæ (2) and (4)

$$= \frac{cb'd^2}{4} - \frac{4\,c'h'm^2}{3}. \tag{6}$$

The quotient of the resultant resistance moment divided by the total compression is the resultant moment arm, or

$$n = \frac{\dfrac{cb'd^2}{12} - \dfrac{4\,c'h'm^2}{3}}{\dfrac{cb'd}{4} - 2\,c'h'm} = \frac{cb'd^2 - 16\,c'h'm^2}{3\,cb'd - 24\,c'h'm}, \tag{7}$$

$c' = \frac{2\,cm}{d}$; eliminating c' by substitution in equation (7) and dividing both members by c it becomes

$$n = \frac{b'd^3 - 32\,h'm^3}{3\,b'd^2 - 48\,h'm^2}. \tag{8}$$

To determine the moment of resistance of a beam when the tension in the steel is known, take moments around the centre of compression in the concrete with a moment arm

$$a = \frac{d}{2} + n, \text{ then } Mr = aS. \tag{9}$$

S must never exceed the value of C obtained by assuming the maximum unit stress c; it may, however, be less than this value, and the moment of resistance obtained by using the maximum value of c will be decreased in proportion to the decreased value of S.

SHEAR

The diagonal tension existing in the web of a concrete beam may be resolved into vertical and horizontal components, each of which equals the vertical shear due to load at the section considered. The horizontal component will be taken care of by the horizontal beam rods. The vertical component will be taken care of by the concrete, provided it is not stressed over 60 lbs. per sq. inch of effective cross-section,[1] i. e. the area included in the web between the centroid of compression in the concrete and the centroid of tension in the steel, or distance "a" in the tables. If stressed beyond this, the full vertical component must be taken care of by stirrups of steel, in a horizontal distance equal to "a".

The stirrups should not be farther apart than $\frac{3}{4}$ "a," as with any wider spacing they would lose part of their value.

Let V = total external vertical shear at cross section considered,

v = shear per sq. in. cross-section,

a = effective depth between centroid of compression in concrete and centroid of tension in steel; then

$$v = \frac{V}{ab}. \tag{10}$$

[1] This assumption is made on the basis of using a 1-2-4 mixture of concrete.

If v exceeds 50, provide stirrups spaced so that their tensile strength in a length of beam not exceeding a is equal to V.

If beam rods are trussed, the value of the vertical component of the trussed rods may be utilized.

This value we will call W.

$$W = A \times s \times \frac{a}{.3\,l}. \tag{11}$$

Where A = sectional area of steel in trussed rods,

s = working stress of steel,

a = effective depth,

$.3\,l$ = horizontal length trussed portion; all dimensions being used as inches.

If T represents tensile strength of stirrups in length of beam = "a," then

$$T = V - W. \tag{12}$$

To locate the section where the vertical shear is just 60 lbs. per sq. inch, let x = distance of this section from point of support, l = span in feet, d and b as already used in previous formulæ, and W the load per linear foot of beam or girder; then

$$x = \frac{l}{2} - \frac{30\,db}{W} \tag{13}$$

ILLUSTRATIONS OF USE OF DIAGRAMS AND TABLES

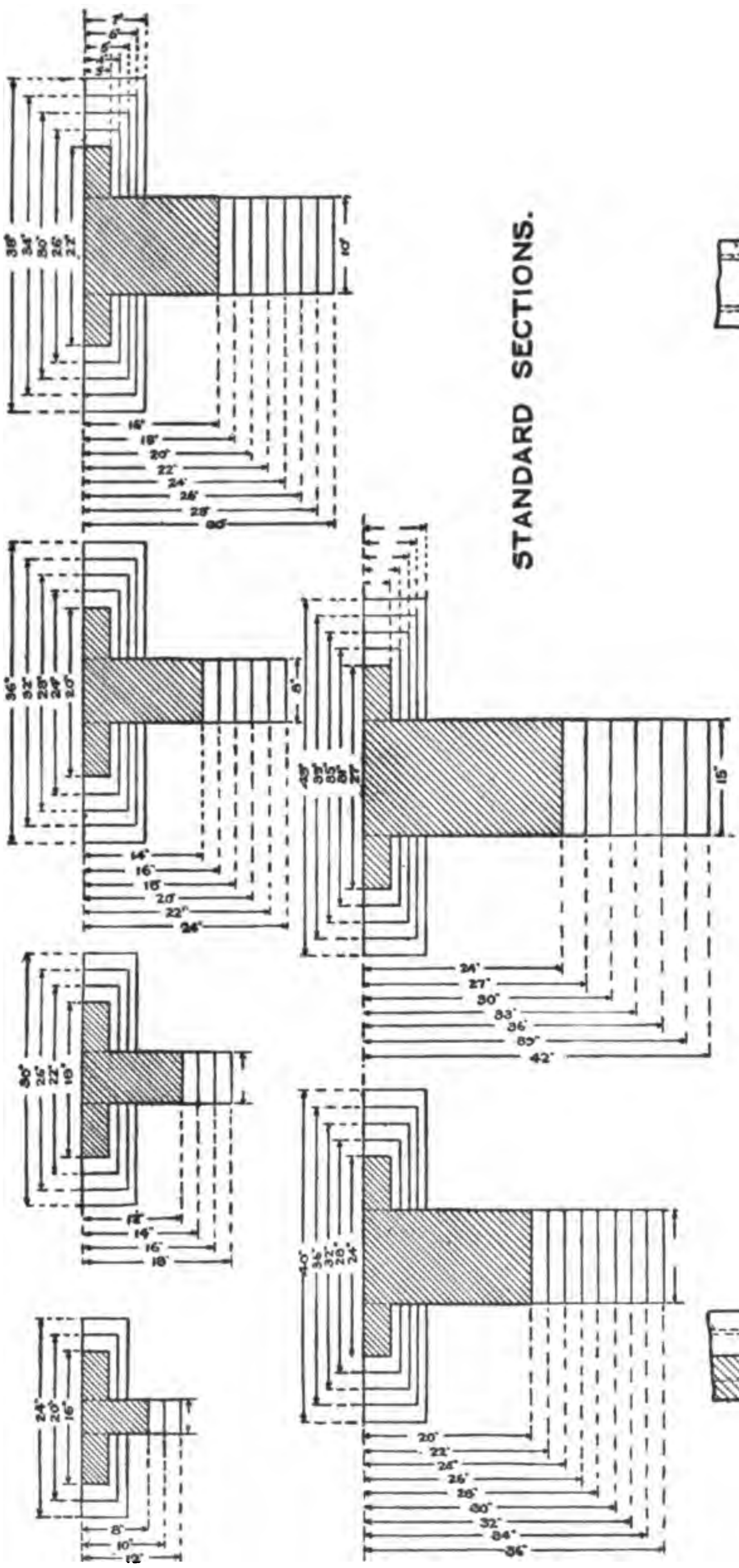
The diagram shown on page 9 is for use in obtaining graphically the thickness and reinforcement of floor slabs. For illustration, assume a superimposed load of 125 lbs. per sq. ft. and a dead load which includes the weight of the slab, approximated, of 75 lbs. per sq. ft., making a total load of 200 lbs. per sq. ft. to be carried on a span of, say 12 feet.

The horizontal lines measure the span in feet and the curved diagonal lines the bending moment in foot pounds. Follow the vertical line from the figure 12 to the point where it intersects the diagonal line marked 200 lbs. per sq. ft., and thence horizontally left to the columns marked "Thickness of slab in inches." The thickness of slab may be selected from one of these columns, and the amount of reinforcement to be used with it is shown by the figures in the column, remembering, as a general rule, that the minimum thickness of slab and the maximum amount of reinforcement is the most economical. For the example given the thickness of slab would be 6″ and the reinforcement about .53 sq. inch in sectional area for one foot in width of slab. Interpolation can be made in both the diagram and figures for any of the factors entering into the problem.

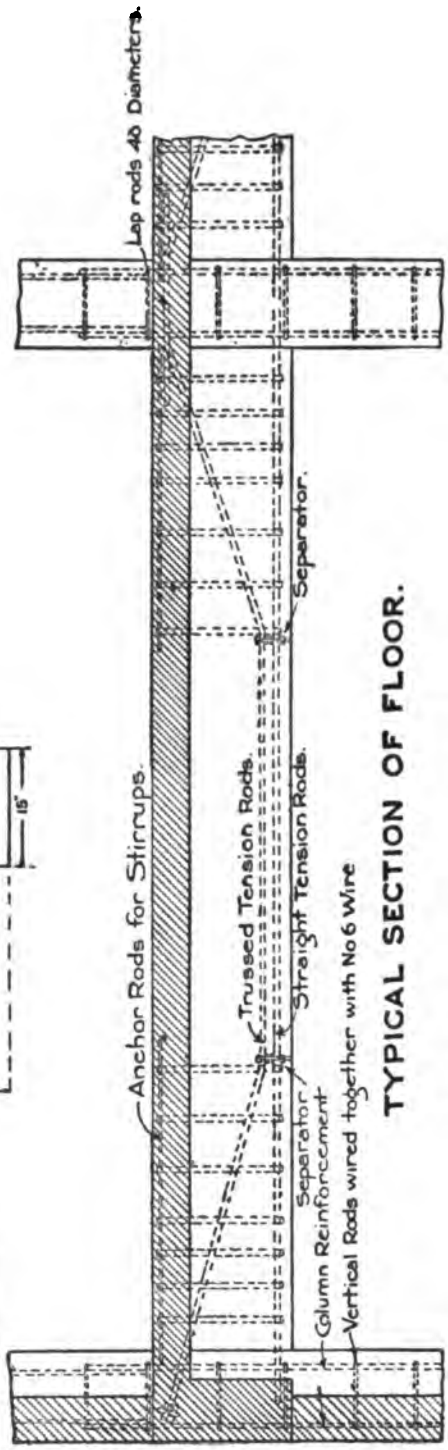
The diagram shown on page 10 is used similarly for obtaining the bending moments due to combined live and dead loads for beams. After the bending moment due to the load is obtained, a section of beam whose moment of resistance is equal to this bending moment may be selected from the tables marked "Elements of reinforced concrete beams."

For illustration, if the combined live and dead loads on a beam with a span of

20 feet is 3000 lbs. per lin. ft. of beam, then the bending moment of 150,000 foot lbs. is obtained at the left hand side of the diagram. Referring to the tables, it is found that beams *E*-10-26, *F*-10-26, *G*-10-26, *D*-10-28, *D*-10-30, *E*-12-24, *F*-12-24, *G*-12-24, and *E*-12-26 with moments of resistance varying from 140,750 to 157,609 foot lbs. will practically fill the requirements. Take, for example, the beam *E*-12-26. The letters from *C* to *G* represent thickness of the slab on flange of the T-beam of from 3″ to 7″. The letter *E*, therefore, represents a thickness of 5″. The first figure, 12, is the thickness of the stem, and the last figure, 26, the total depth of beam including slab. The first column in the table shows the maximum *unit* compressive stress in the concrete; the second column, the *total* compressive stress in concrete or tensile stress in steel; the third, the moment arm or distance between centroids of compression and tension; the fourth, the moment of resistance of beam in foot pounds; the fifth and sixth, the size of straight and trussed round rods used for reinforcement; the seventh, the sectional area of reinforcement; the eighth, the weight of reinforcement per lin. ft., and the ninth, the sectional area of concrete under the slab.



STANDARD SECTIONS.



TYPICAL SECTION OF FLOOR.

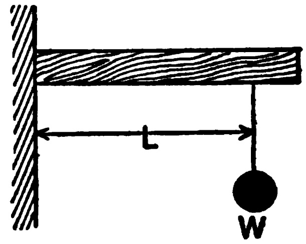
BENDING MOMENTS

FORMULÆ FOR BENDING MOMENTS

(1)

Beam fixed at one end, with concentrated load.

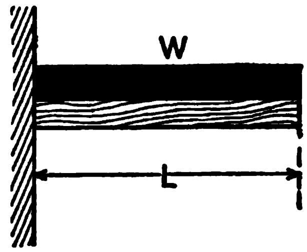
$$B.M. = WL.$$



(2)

Beam fixed at one end, with uniformly distributed load.

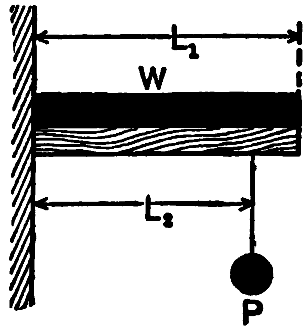
$$B.M. = \frac{WL}{2}.$$



(3)

Beam fixed at one end, with combination of uniformly distributed and concentrated loads.

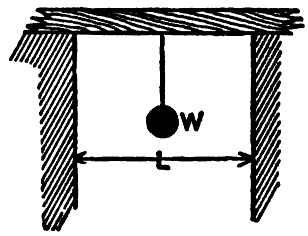
$$B.M. = PL_2 + \frac{WL_1}{2}.$$



(4.)

Beam supported at both ends, with concentrated load in middle.

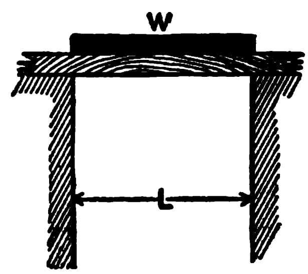
$$B.M. = \frac{WL}{4}.$$



(5.)

Beam supported at both ends, with uniformly distributed load.

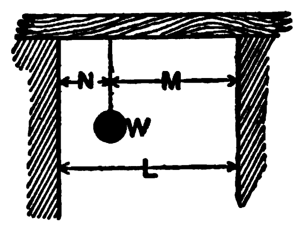
$$B.M. = \frac{WL}{8}.$$

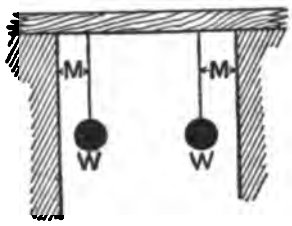


(6.)

Beam supported at both ends, with concentrated load not at centre.

$$B.M. = \frac{WMN}{L}.$$





(7)

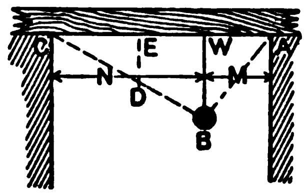
Beam supported at both ends, with equal and symmetrical concentrated loads.

$$B.M. = WM.$$

GRAPHICAL METHOD OF DETERMINING BENDING MOMENTS.

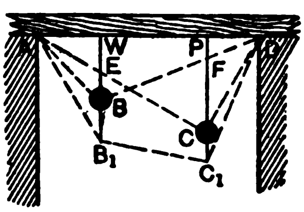
(1) ***Beam supported at both ends, with one concentrated load; to find the bending moment at any part of the beam.***

Let W be the weight as shown; then, as previously given, the bending moment at $W = \frac{WMN}{L}$. Plot the beam and the location of W to some convenient scale, then to this, or some other scale, measure the line WB equal to the bending moment already found. Connect B with each end of the beam. Then if we wish to find the bending moment at some point, as E, draw DE vertically to line CB. Measure DE with same scale used in measuring WB. The result will be the bending moment at E.



(2) ***Beam with two concentrated loads.***

Let W and P be the two concentrated loads as shown. Plot the bending moments WB and PC due to each of these loads by formula already given. Complete the diagram for each load by drawing ABD and ACD. Now the total bending moment at W would be WB, due to load W, plus WE, due to load P, or WB ; and the total bending moment at P would be PC, due to load P, plus PF, due to load W, or PC_1.



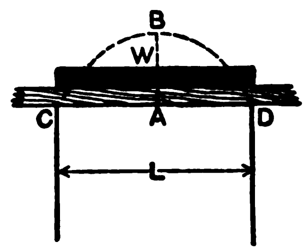
Draw the outline $ABCD$, and this will represent the bending moment due to both loads, and will be the greatest where the vertical height scales the most.

This method can be employed to find the bending moment due to any number of concentrated loads.

(3) ***Beam with uniformly distributed load.***

At the middle of the beam draw the line $AB = \frac{WL}{8}$.

Connect the points $C\ B\ D$ by a parabola and it will give the outline of the bending moments.



(4) ***Beam loaded with both distributed and concentrated loads.***

Plot the outline of the bending moments due to the concentrated loads as per Case No. 2, and for the distributed load as per Case No. 3. The vertical distance between the upper and the lower outline at any point will be the bending moment at that point.

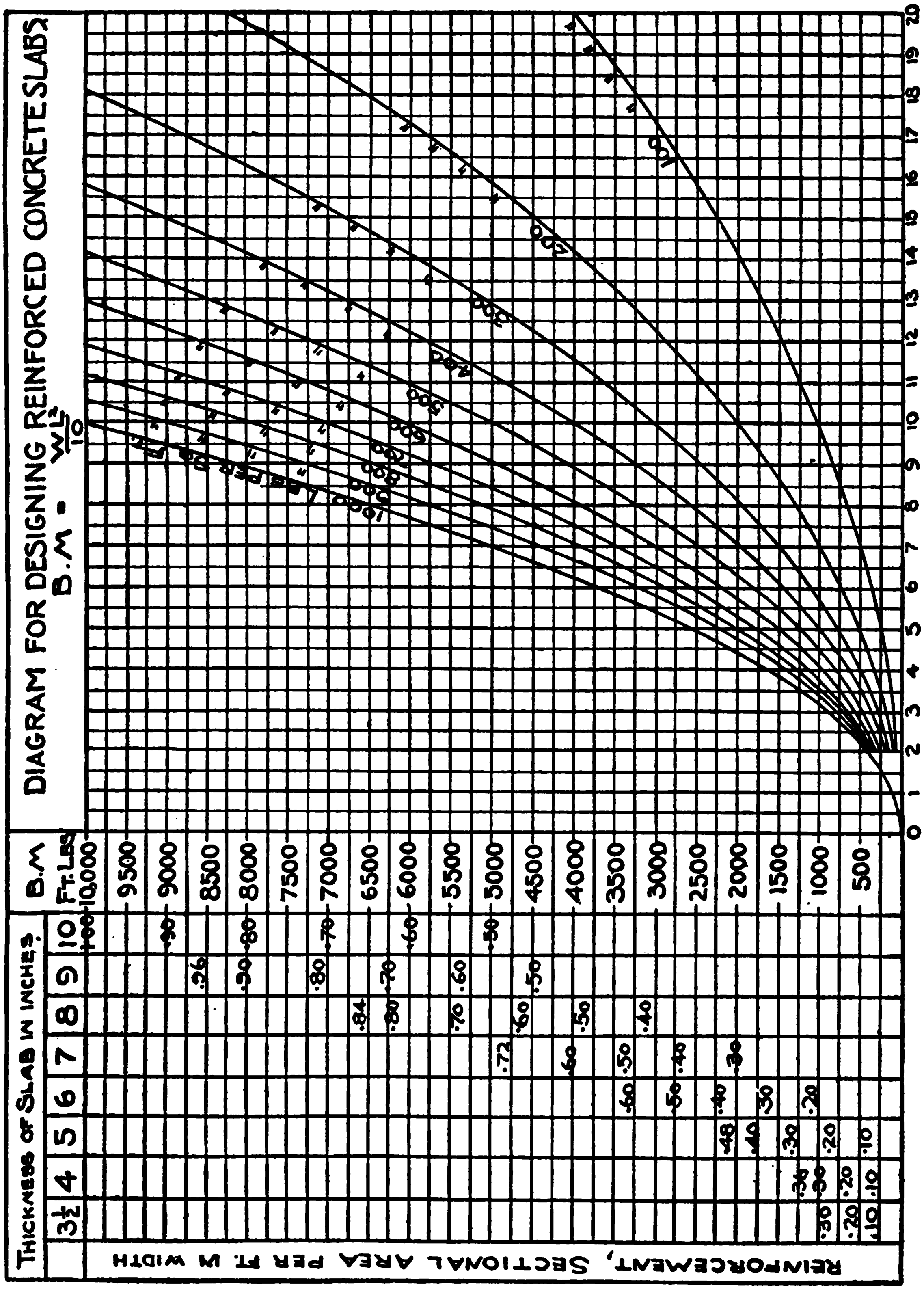
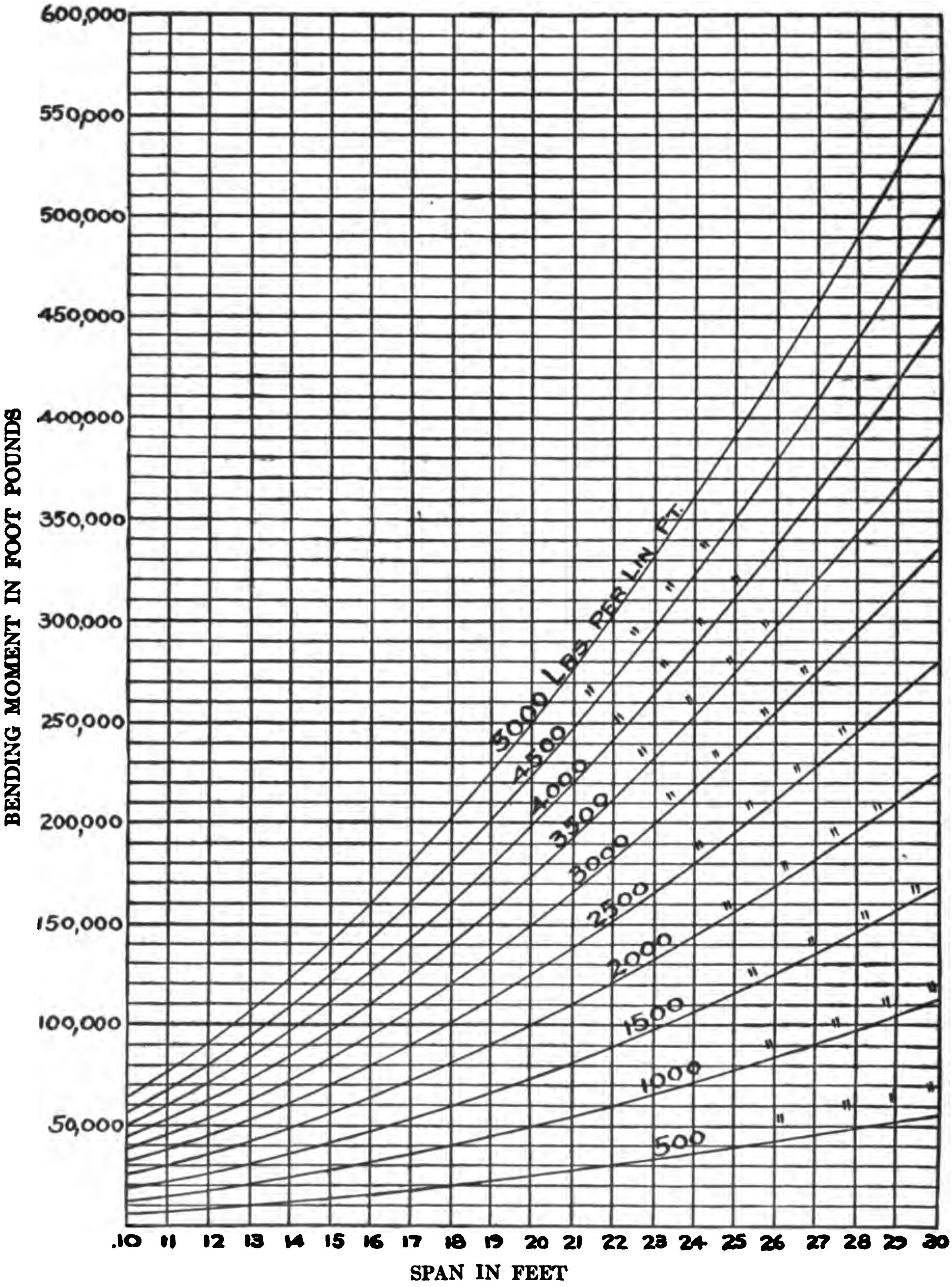


DIAGRAM FOR DESIGNING REINFORCED CONCRETE SLABS
B.M = WL²/10
SPAN IN FEET
THICKNESS OF SLAB IN INCHES
B.M FT. LBS
REINFORCEMENT, SECTIONAL AREA PER FT. W WIDTH

DIAGRAM OF BENDING MOMENTS

B. M. = WL² + 8



ELEMENTS OF REINFORCED CONCRETE BEAMS

No. of Beam	*c*	*C=S*	*a*	*Mr* in ft. lbs.	Size of Rods		Sec. Area of Steel	Wt. of Steel per lin. ft.	Cu. ft. of Concrete under Slab
					Bent	Straight			
4–8	663	3976	5	1657		One 9–16"	.2485	.845	.222
C–4–8	401	9621	5	4009		" 7–8"	.6013	2.044	.138
D–4–8	321	9621	5	4009		" 7–8"	.6013	2.044	.111
E–4–8	267	9621	5	4009		" 7–8"	.6013	2.044	.083
4–10	614	4909	6.67	2729		" 5–8"	.3068	1.043	.278
C–4–10	422	12566	6.76	7329		" 1"	.7854	2.670	.194
D–4–10	314	12566	6.67	6985		" 1"	.7854	2.670	.166
E–4–10	262	12566	6.67	6985		" 1"	.7854	2.670	.139
4–12	707	7069	8.33	4907		" 3–4"	.4418	1.502	.333
C–4–12	485	15904	8.66	11477		" 1 1–8"	.9940	3.379	.250
D–4–12	334	15904	8.43	11173		" 1 1–8"	.9940	3.379	.222
E–4–12	265	15904	8.33	11040		" 1 1–8"	.9940	3.379	.194
F–4–12	227	15904	8.33	11040		" 1 1–8"	.9940	3.379	.166
6–12	641	9621	8.33	6679		" 7–8"	.6013	2.044	.500
C–6–12	509	19242	8.57	13742	One 7–8"	" 7–8"	1.2026	4.088	.375
D–6–12	366	19242	8.41	13485	" 7–8"	" 7–8"	1.2026	4.088	.333
E–6–12	296	19242	8.33	13357	" 7–8"	" 7–8"	1.2026	4.088	.291
F–6–12	257	19242	8.33	13357	" 7–8"	" 7–8"	1.2026	4.088	.255
6–14	698	12566	10.00	10472	" 1"	" 1"	.7854	2.670	.583
C–6–14	620	25132	10.40	21781	" 1"	" 1"	1.5708	5.340	.459
D–6–14	433	25132	10.23	21425	" 1"	" 1"	1.5708	5.340	.417
E–6–14	333	25132	10.08	21111	" 1"	" 1"	1.5708	5.340	.375
F–6–14	280	25132	10.00	20943	" 1"	" 1"	1.5708	5.340	.333
6–16	673	14138	11.67	13749	" 3–4"	" 3–4"	.8836	3.005	.667
C–6–16	607	28862	11.45	27539	" 7–8"	Two 7–8"	1.8039	6.133	.542
D–6–16	448	28862	11.34	27275	" 7–8"	" 7–8"	1.8039	6.133	.500
E–6–16	352	28862	11.10	26697	" 7–8"	" 7–8"	1.8039	6.133	.458
F–6–16	293	28862	11.03	26529	" 7–8"	" 7–8"	1.8039	6.133	.416
6–18	589	14138	13.33	15705	" 3–4"	One 3–4"	.8836	3.005	.750
C–6–18	672	34754	13.26	38403	" 7–8"	Two 1"	2.1721	7.385	.625
D–6–18	497	34754	13.19	38200	" 7–8"	" 1"	2.1721	7.385	.583
E–6–18	386	34754	13.00	37650	" 7–8"	" 1"	2.1721	7.385	.541
F–6–18	316	34754	12.80	37071	" 7–8"	" 1"	2.1721	7.385	.500

ELEMENTS OF REINFORCED CONCRETE BEAMS

No. of Beam	e	C=S	a	Mr in ft. lbs.	Size of Rods		Sec. Area of Steel	Wt. of Steel per lin. ft.	Sec. Area Concrete under Slab
					Bent	Straight			
8-14	589	14138	10.00	11782	One 3-4"	One 3-4"	.8836	3.005	.777
C-8-14	652	31808	9.66	25605	" 1"	Two 7-8"	1.9880	6.759	.611
D-8-14	547	34753	9.48	27455	" 7-8"	" 1"	2.1721	7.385	.555
E-8-14	447	34753	9.36	27107	" 7-8"	" 1"	2.1721	7.385	.500
F-8-14	388	34753	9.33	27020	" 7-8"	" 1"	2.1721	7.385	.445
G-8-14	345	34753	9.33	27020	" 7-8"	" 1"	2.1721	7.385	.390
8-16	687	19242	11.67	18713	" 7-8"	One 7-8"	1.2026	4.089	.888
C-8-16	695	37698	11.44	35939	" 1"	Two 1"	2.3562	8.011	.722
D-8-16	531	37698	11.34	35625	" 1"	" 1"	2.3562	8.011	.667
E-8-16	426	37698	11.16	35059	" 1"	" 1"	2.3562	8.011	.612
F-8-16	360	37698	11.04	34682	" 1"	" 1"	2.3562	8.011	.557
G-8-16	318	37698	11.00	34556	" 1"	" 1"	2.3562	8.011	.500
8-18	697	21207	12.67	22391	" 3-4"	Two 3-4"	1.3254	4.506	1.000
C-8-18	636	37698	13.22	41531	" 1"	" 1"	2.3562	8.011	.833
D-8-18	616	47712	13.14	52245	" 1 1-8"	" 1 1-8"	2.9820	10.139	.778
E-8-18	490	47712	12.98	51608	" 1 1-8"	" 1 1-8"	2.9820	10.139	.722
F-8-18	406	47712	12.81	50933	" 1 1-8"	" 1 1-8"	2.9820	10.139	.666
G-8-18	351	47712	12.69	50455	" 1 1-8"	" 1 1-8"	2.9820	10.139	.610
8-20	691	23759	14.33	28372	" 7-8"	" 3-4"	1.4849	5.049	1.111
C-8-20	692	44374	14.99	55430	" 1"	" 1 1-8"	2.7734	9.430	.944
D-8-20	623	50264	14.60	61154	Two 1"	" 1"	3.1416	10.681	.888
E-8-20	492	50264	14.43	60442	" 1"	" 1"	3.1416	10.681	.833
F-8-20	402	50264	14.27	59772	" 1"	" 1"	3.1416	10.681	.778
G-8-20	346	50264	14.12	59144	" 1"	" 1"	3.1416	10.681	.722
8-22	685	26311	16.00	35081	" 7-8"	One 3-4"	1.6444	5.591	1.222
C-8-22	693	47712	16.78	70061	One 1 1-8"	Two 1 1-8"	2.9820	10.139	1.056
D-8-22	662	56940	16.42	77913	Two 1"	" 1 1-8"	3.5588	12.100	1.000
E-8-22	522	56940	16.27	77201	" 1"	" 1 1-8"	3.5588	12.100	.944
F-8-22	425	56940	16.10	76394	" 1"	" 1 1-8"	3.5588	12.100	.888
G-8-22	358	56940	15.94	75635	" 1"	" 1 1-8"	3.5588	12.100	.833
8-24	681	28863	17.67	42501	One 7-8"	" 7-8"	1.8039	6.133	1.333
C-8-24	690	50264	18.22	76317	Two 1"	" 1"	3.1416	10.681	1.167
D-8-24	682	63616	18.24	96696	" 1 1-8"	" 1 1-8"	3.9760	13.518	1.111
E-8-24	541	63616	18.11	96007	" 1 1-8"	" 1 1-8"	3.9760	13.518	1.056
F-8-24	442	63616	17.93	95053	" 1 1-8"	" 1 1-8"	3.9760	13.518	1.000
G-8-24	371	63616	17.75	94099	" 1 1-8"	" 1 1-8"	3.9760	13.518	.944

ELEMENTS OF REINFORCED CONCRETE BEAMS

No. of Beam	c	C=S	a	Mr in ft. lbs.	Size of Rods				Sec. Area of Steel	Wt. of Steel per lin. ft.	Sec. Area Concrete under Slab
					Bent		Straight				
10–16	676	23759	11.67	23106	One	7–8"	Two	3–4"	1.4849	5.049	1.111
C–10–16	620	37698	11.39	35782	"	1"	"	1"	2.3562	8.011	.903
D–10–16	.661	50264	10.92	45740	Two	1"	"	1"	3.1416	10.681	.833
E–10–16	541	50264	10.78	45154	"	1"	"	1"	3.1416	10.681	.763
F–10–16	463	50264	10.67	44693	"	1"	"	1"	3.1416	10.681	.693
G–10–16	413	50264	10.62	44484	"	1"	"	1"	3.1416	10.681	.623
10–18	658	26311	13.33	29227	One	3–4"	Two	7–8"	1.6444	5.591	1.250
C–10–18	663	44374	13.16	48664	"	1"	"	1 1–8"	2.7734	9.430	1.042
D–10–18	675	56940	12.91	61258	Two	7–8"	Three	1"	3.5588	12.100	.972
E–10–18	547	56940	12.77	60594	"	7–8"	"	1"	3.5588	12.100	.903
F–10–18	460	56940	12.62	59882	"	7–8"	"	1"	3.5588	12.100	.833
G–10–18	401	56940	12.52	59407	"	7–8"	"	1"	3.5588	12.100	.763
10–20	642	28863	15.00	36079	One	7–8"	Two	7–8"	1.8039	6.133	1.390
C–10–20	657	47712	14.91	59282	"	1 1–8"	"	1 1–8"	2.9820	10.139	1.181
D–10–20	687	62830	14.72	77072	Two	1"	Three	1"	3.9270	13.352	1.111
E–10–20	599	66561	14.50	80379	Three	7–8"	"	1"	4.1601	14.144	1.042
F–10–20	493	66561	14.33	79486	"	7–8"	"	1"	4.1601	14.144	.972
G–10–20	424	66561	14.18	78653	"	7–8"	"	1"	4.1601	14.144	.903
10–22	695	34754	16.67	48279	One	7–8"	Two	1"	2.1721	7.385	1.528
C–10–22	698	53995	16.36	73613	Two	1"	Three	7–8"	3.3747	11.474	1.320
D–10–22	677	66561	16.66	91159	Three	7–8"	"	1"	4.1601	14.144	1.250
E–10–22	592	72844	16.56	100525	Two	1"	"	1 1–8"	4.5528	15.480	1.181
F–10–22	498	72844	16.37	99371	"	1"	"	1 1–8"	4.5528	15.480	1.111
G–10–22	424	72844	16.20	98340	"	1"	"	1 1–8"	4.5528	15.480	1.042
10–24	686	37698	18.33	57584	One	1"	Two	1"	2.3562	8.011	1.667
C–10–24	683	56940	18.25	86588	Two	7–8"	Three	1"	3.5588	12.100	1.460
D–10–24	693	66561	18.14	100618	Three	7–8"	"	1"	4.1601	14.144	1.390
E–10–24	575	79520	18.17	120406	Two	1 1–8"	"	1 1–8"	4.9700	16.898	1.320
F–10–24	514	79520	18.01	119346	"	1 1–8"	"	1 1–8"	4.9700	16.898	1.250
G–10–24	436	79520	17.83	118154	"	1 1–8"	"	1 1–8"	4.9700	16.898	1.181
10–26	628	37698	20.00	62830	One	1"	Two	1"	2.3562	8.011	1.806
C–10–26	708	62830	20.00	104717	Two	1"	Three	1"	3.9270	13.352	1.598
D–10–26	659	72844	20.10	122014	"	1"	"	1 1–8"	4.5528	15.480	1.528
E–10–26	663	90686	20.15	152277	"	1 1–8"	"	1 1–4"	5.6678	19.270	1.460
F–10–26	553	90686	19.93	150614	"	1 1–8"	"	1 1–4"	5.6678	19.270	1.390
G–10–26	468	90686	19.75	149254	"	1 1–8"	"	1 1–4"	5.6678	19.270	1.320

ELEMENTS OF REINFORCED CONCRETE BEAMS

No. of Beam	*c*	*C*=*S*	*a*	M_r in ft. lbs.	Size of Rods		Sec. Area of Steel	Wt. of Steel per lin. ft.	Sec. Area Concrete under Slab
					Bent	Straight			
10–28	683	44374	21.67	80132	One 1"	Two 1 1-8"	2.7734	9.430	1.944
C–10–28	667	62830	21.74	113827	Two 1"	Three 1"	3.9278	13.352	1.736
D–10–28	684	79520	21.88	144991	" 1 1-8"	" 1 1-8"	4.9700	16.898	1.667
E–10–28	674	95424	21.72	172717	Three 1 1-8"	" 1 1-8"	5.9640	20.278	1.598
F–10–28	558	95424	21.60	171755	" 1 1-8"	" 1 1-8"	5.9640	20.278	1.528
G–10–28	471	95424	21.52	171127	" 1 1-8"	" 1 1-8"	5.9640	20.278	1.460
10–30	682	47712	23.33	92760	One 1 1-8"	Two 1 1-8"	2.9820	10.139	2.084
C–10–30	670	66561	23.38	129683	Three 1"	Three 7-8"	4.1601	14.144	1.875
D–10–30	653	79520	23.55	156058	Two 1 1-8"	" 1 1-8"	4.9700	16.898	1.806
E–10–30	644	95424	23.52	187031	Three 1 1-8"	" 1 1-8"	5.9640	20.278	1.736
F–10–30	596	106590	23.45	208295	" 1 1-8"	" 1 1-4"	6.6618	22.550	1.669
G–10–30	503	106590	23.27	206696	" 1 1-8"	" 1 1-4"	6.6618	22.550	1.598
12–20	698	37698	15.00	47122	One 1"	Two 1"	2.3562	8.011	1.667
C–12–20	706	56940	14.63	69419	Two 7-8"	Three 1"	3.5588	12.100	1.417
D–12–20	668	66561	14.59	80927	Three 7-8"	" 1"	4.1601	14.144	1.333
E–12–20	657	79520	14.47	95888	Two 1 1-8"	" 1 1-8"	4.9700	16.898	1.250
F–12–20	554	79520	14.31	95328	" 1 1-8"	" 1 1-8"	4.9700	16.898	1.167
G–12–20	480	79520	14.18	93966	" 1 1-8"	" 1 1-8"	4.9700	16.898	1.083
12–22	628	37698	16.67	52369	One 1"	Two 1"	2.3562	8.011	1.833
C–12–22	654	56940	16.36	77628	Two 7-8"	Three 1"	3.5588	12.100	1.583
D–12–22	679	72844	16.40	99554	" 1"	" 1 1-8"	4.5528	15.480	1.500
E–12–22	696	90686	16.30	123182	" 1 1-8"	" 1 1-4"	5.6678	19.270	1.417
F–12–22	585	90686	16.15	122132	" 1 1-8"	" 1 1-4"	5.6678	19.270	1.333
G–12–22	503	90686	15.98	120764	" 1 1-8"	" 1 1-4"	5.6678	19.270	1.250
12–24	672	44374	18.33	67781	One 1"	Two 1 1-8"	2.7734	9.430	2.000
C–12–24	683	62830	18.12	94873	Two 1"	Three 1"	3.9270	13.352	1.750
D–12–24	695	79520	18.15	120274	" 1 1-8"	" 1 1-8"	4.9700	16.898	1.667
E–12–24	690	95424	18.00	143136	Three 1 1-8"	" 1 1-8"	5.9640	20.278	1.583
F–12–24	579	95424	17.85	141943	" 1 1-8"	" 1 1-8"	5.9640	20.278	1.500
G–12–24	496	95424	17.70	140750	" 1 1-8"	" 1 1-8"	5.9640	20.278	1.417
12–26	663	47712	20.00	79520	One 1-1-8"	Two 1 1-8"	2.9820	10.139	2.167
C–12–26	695	69506	19.81	114743	Two 1-1-8"	Three 1"	4.3450	14.773	1.918
D–12–26	654	79520	19.94	132136	" 1-1-8"	" 1 1-8"	4.9700	16.898	1.833
E–12–26	651	95424	19.82	157609	Three 1-1-8"	" 1 1-8"	5.9640	20.278	1.750
F–12–26	611	106590	19.70	174985	" 1-1-8"	" 1 1-4"	6.6618	22.650	1.667
G–12–26	522	106590	19.52	173386	" 1-1-8"	" 1 1-4"	6.6618	22.650	1.583

ELEMENTS OF REINFORCED CONCRETE BEAMS

No. of Beam	c	C=S	a	Mr in ft. lbs.	Size of Rods		Sec. Area of Steel	Wt. of Steel per lin. ft.	Sec. Area Concrete under Slab
					Bent	Straight			
12–28	644	48100	20.75	83173	Two 7–8"	Three 7–8"	3.0065	10.222	2.333
C–12–28	685	72844	21.55	130816	" 1"	" 1 1–8"	4.5528	15.480	2.083
D–12–28	706	90686	21.67	163764	" 1 1–8"	" 1 1–4"	5.6678	19.270	2.000
E–12–28	691	106590	21.63	192128	Three 1 1–8"	" 1 1–4"	6.6618	22.550	1.917
F–12–28	641	117756	21.52	211176	" 1 1–4"	" 1 1–4"	7.3596	25.023	1.833
G–12–28	548	117756	21.38	209802	" 1 1–4"	" 1 1–4"	7.3596	25.023	1.750
12–30	703	56940	22.50	106762	Two 7–8"	" 1"	3.5588	12.100	2.500
C–12–30	705	79520	23.27	154202	" 1 1–8"	" 1 1–8"	4.9700	16.898	2.250
D–12–30	671	90686	23.45	177216	" 1 1–8"	" 1 1–4"	5.6678	19.270	2.167
E–12–30	659	106590	23.31	207051	Three 1 1–8"	" 1 1–4"	6.6618	22.550	2.083
F–12–30	613	117756	23.27	228348	" 1 1–4"	" 1 1–4"	7.3596	25.023	2.000
G–12–30	523	117756	23.13	226975	" 1 1–4"	" 1 1–4"	7.3596	25.023	1.917
12–32	654	56940	24.17	114687	Two 7–8"	" 1"	3.5588	12.100	2.667
C–12–32	667	79520	25.00	165667	" 1 1–8"	" 1 1–8"	4.9700	16.898	2.417
D–12–32	674	95424	25.13	199833	Three 1 1–8"	" 1 1–8"	5.9640	20.278	2.333
E–12–32	697	117756	25.18	247091	" 1 1–4"	" 1 1–4"	7.3596	25.023	2.250
F–12–32	587	117756	25.15	246797	" 1 1–4"	" 1 1–4"	7.3596	25.023	2.167
G–12–32	502	117756	25.08	246110	" 1 1–4"	" 1 1–4"	7.3596	25.023	2.083
12–34	689	63830	25.75	136968	Two 1"	" 1"	3.9270	13.352	2.833
C–12–34	694	86964	26.71	193567	" 1 1–4"	" 1 1–8"	5.4352	18.480	2.583
D–12–34	644	95424	26.88	213750	Three 1 1–8"	" 1 1–8"	5.9640	20.278	2.500
E–12–34	668	117756	26.98	264755	" 1 1–4"	" 1 1–4"	7.3596	25.023	2.417
F–12–34	565	117756	26.97	264657	" 1 1–4"	" 1 1–4"	7.3596	25.023	2.333
G–12–34	483	117756	26.86	263577	" 1 1–4"	" 1 1–4"	7.3596	25.023	2.250
12–36	673	66561	27.38	124162	Three 7–8"	" 1"	4.1601	14.144	3.000
C–12–36	690	90686	28.43	214850	Two 1 1–8"	" 1 1–4"	5.6678	19.270	2.750
D–12–36	689	106590	28.62	254209	Three 1 1–8"	" 1 1–4"	6.6618	22.650	2.667
E–12–36	643	117756	28.77	282320	" 1 1–4"	" 1 1–4"	7.3596	25.023	2.583
F–12–36	545	117756	28.79	282516	" 1 1–4"	" 1 1–4"	7.3596	25.023	2.500
G–12–36	466	117756	28.71	281731	" 1 1–4"	" 1 1–4"	7.3596	25.023	2.417
15–24	690	56940	18.67	88589	Two 1"	Two 1 1–8"	3.5588	12.100	2.500
C–15–24	683	75396	18.31	115042	Three 1"	Three 1"	4.7124	16.022	2.188
D–15–24	674	87962	18.16	133116	" 1"	Four 1"	5.4978	18.693	2.084
E–15–24	649	100528	17.93	150206	Four 1"	" 1"	6.2832	21.363	1.980
F–15–24	631	113880	17.79	168827	" 1"	" 1 1–8"	7.1376	24.268	1.876
G–15–24	548	113880	17.67	167888	" 1"	" 1 1–8"	7.1376	24.268	1.772

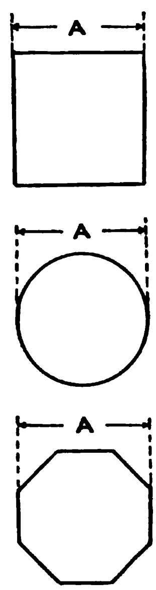
ELEMENTS OF REINFORCED CONCRETE BEAMS

No. of Beam	*c*	*C=S*	*a*	*Mr* in ft. lbs.	Size of Rods		Sec. Area of Steel	Wt. of Steel per lin. ft.	Sec. Area Concrete under Slab
					Bent	Straight			
15-27	678	63616	20.83	110427	Two 1 1-8"	Two 1 1-8"	3.9960	13.586	2.812
C 15-27	671	82072	20.84	143365	" 1 1-8"	Four 1"	5.1296	17.441	2.500
D 15-27	662	95424	20.96	166674	Three 1 1-8"	Three 1 1-8"	5.9640	20.278	2.396
E 15-27	658	111328	20.81	193045	" 1 1-8"	Four 1 1-8"	6.9580	23.657	2.292
F 15-27	639	126216	20.62	216881	" 1 1-8"	" 1 1-4"	7.8884	26.821	2.178
G 15-27	573	137382	20.51	234809	" 1 1-4"	" 1 1-4"	8.5862	29.193	2.074
15-30	670	67347	22.42	125825	Three 7-8"	Four 7-8"	4.2691	14.311	3.124
C 15-30	662	87962	23.14	169620	" 1"	" 1"	5.4978	18.693	2.812
D 15-30	649	100528	23.23	194605	Four 1"	" 1"	6.2832	21.363	2.708
E 15-30	694	126216	23.35	245595	Three 1 1-8"	" 1 1-4"	7.8884	26.821	2.604
F 15-30	669	142120	23.27	275594	Four 1 1-8"	" 1 1-4"	8.8824	30.200	2.500
G 15-30	640	157008	23.15	302895	" 1 1-4"	" 1 1-4"	9.8128	33.364	2.396
15-33	670	75396	25.00	157075	Three 1"	Three 1"	4.7124	16.022	3.436
C 15-33	698	100528	25.64	214795	Four 1"	Four 1"	6.2832	21.363	3.124
D 15-33	681	113880	25.86	245411	" 1"	" 1 1-8"	7.1376	24.268	3.020
E 15-33	647	126216	25.96	273047	Three 1 1-8"	" 1 1-4"	7.8884	26.821	2.916
F 15-33	635	142120	25.90	306742	Four 1 1-8"	" 1 1-4"	8.8824	30.200	2.812
G 15-33	586	157008	25.86	338352	" 1 1-4"	" 1 1-4"	9.8128	33.364	2.708
15-36	663	82072	27.50	188082	Two 1 1-8"	Four 1"	5.1296	17.441	3.752
C 15-36	645	100528	28.18	236073	Four 1"	" 1"	6.2832	21.363	3.440
D 15-36	636	113880	28.45	266657	" 1"	" 1 1-8"	7.1376	24.268	3.336
E 15-36	684	142120	28.60	338719	" 1 1-8"	" 1 1-4"	8.8824	30.200	3.228
F 15-36	652	157008	28.64	374726	" 1 1-4"	" 1 1-4"	9.8128	33.364	3.124
G 15-36	566	157008	28.59	374072	" 1 1-4"	" 1 1-4"	9.8128	33.336	3.020
15-39	652	87962	30.00	219905	Three 1"	" 1"	5.4978	18.693	4.062
C 15-39	681	113880	30.72	291533	Four 1"	" 1 1-8"	7.1376	24.268	3.752
D 15-39	660	126216	31.03	326373	Three 1 1-8"	" 1 1-4"	7.8884	26.821	3.648
E 15-39	646	142120	31.22	369749	Four 1 1-8"	" 1 1-4"	8.8824	30.200	3.544
F 15-39	618	157008	31.34	410053	" 1 1-4"	" 1 1-4"	9.8128	33.364	3.440
G 15-39	538	157008	31.32	409791	" 1 1-4"	" 1 1-4"	9.8128	33.364	3.336
15-42	652	95424	32.50	258440	Three 1 1-8"	Three 1 1-8"	5.9640	20.278	4.375
C 15-42	637	113880	33.27	315732	Four 1"	Four 1 1-8"	7.1376	24.268	4.064
D 15-42	700	126216	33.62	398173	" 1 1-8"	" 1 1-4"	8.8824	30.200	3.960
E 15-42	675	142120	33.86	443024	" 1 1-4"	" 1 1-4"	9.8128	33.364	3.856
F 15-42	588	157008	34.02	445118	" 1 1-4"	" 1 1-4"	9.8128	33.364	3.752
G 15-42	513	157008	34.04	445379	" 1 1-4"	" 1 1-4"	9.8128	33.364	3.648

WORKING LOADS FOR REINFORCED CONCRETE COLUMNS

	500 Lbs. per Sq. In. 1-2-4 Concrete			600 Lbs. per Sq. In. 1-1½-3 Concrete		
Dim. "A"	Square	Round	Octagonal	Square	Round	Octagonal
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
12 ins.	72000	56500	59600	86400	67900	71600
13	84500	66400	69600	101400	79600	83900
14	98000	77000	81200	117600	92400	97400
15	112500	88400	93100	135000	106000	111800
16	128000	100500	106100	153600	120600	127300
17	144500	113500	119700	173400	136200	143600
18	162000	127200	134300	194400	152700	161100
19	180500	141800	149500	216600	170100	179400
20	200000	157100	165600	240000	188500	198700
21	220500	173200	182700	264600	207800	219200
22	242000	190100	200400	290400	228100	240500
23	264500	207700	219200	317400	249300	263000
24	288000	226200	238600	345600	271400	286300
25	312500	245400	259000	375000	294500	310800
26	338000	265500	280000	405600	318600	336000
27	364500	286300	301900	437400	343500	362300
28	392000	307900	324800	470400	369500	389800
29	420500	330300	348300	504600	396300	417900
30	450000	353400	372900	540000	424100	447500

Add for each Steel Rod		
	In 1-2-4 Conc.	In 1-1½-3 Conc.
	Lbs.	Lbs.
3-4" Dia.	1988	2386
7-8" "	2485	2982
1" "	3534	4241
1 1-8" "	4473	5368
1 1-4" "	5516	6619
3-4" Sq.	2531	3037
7-8" "	3164	3799
1" "	4500	5400
1 1-8" "	5698	6834
1 1-4" "	7031	8437



CHAPTER II

WEIGHTS AND AREAS OF SQUARE AND ROUND STEEL RODS, WELDED AND EXPANDED METAL

Weights and Areas of Round and Square Steel Rods

Dia. in 16ths	Area □ Sq. Ins.	Weight □ Lbs.	Area ○ Sq. Ins.	Weight ○ Lbs.
0– 1	.0039	.013	.0031	.010
2	.0156	.053	.0123	.042
3	.0352	.119	.0276	.094
4	.0625	.212	.0491	.167
5	.0977	.333	.0767	.261
6	.1406	.478	.1104	.375
7	.1914	.651	.1503	.511
8	.2500	.850	.1963	.667
9	.3164	1.076	.2485	.845
10	.3906	1.328	.3068	1.043
11	.4727	1.608	.3712	1.262
12	.5625	1.913	.4418	1.502
13	.6602	2.245	.5185	1.763
14	.7656	2.603	.6013	2.044
15	.8789	2.989	.6903	2.347
1– 0	1.0000	3.400	.7854	2.670
1	1.1289	3.838	.8866	3.014
2	1.2656	4.303	.9940	3.379
3	1.4102	4.795	1.1075	3.766
4	1.5625	5.312	1.2272	4.173
5	1.7227	5.857	1.3530	4.600
6	1.8906	6.428	1.4849	5.049
7	2.0664	7.026	1.6230	5.518
8	2.2500	7.650	1.7671	6.008

Welded Metal

Size Longitudinal Wires W. and M. Gauge Sq. Ins.		Area Per Foot in Width		
		2 in. Centres Sq. Ins.	3 in. Centres Sq. Ins.	4 in. Centres Sq. Ins.
No. 0	.0738	.4427	.2951	.2213
1	.0613	.3680	.2453	.1840
2	.0541	.3247	.2165	.1624
3	.0466	.2798	.1866	.1399
4	.0399	.2392	.1595	.1196
5	.0335	.2013	.1342	.1006
6	.0289	.1737	.1158	.0868
7	.0246	.1477	.0984	.0738
8	.0206	.1237	.0826	.0618

Expanded Metal

Designation			Section sq. in. per ft. width	Wt. per sq. ft.	Size of Standard Sheets	No. of Sheets in a Bundle	No. sq. ft. in Bundle of 8-ft. Lengths
Mesh	Gauge (Stubs)	Standard or Extra					
1-2″	No. 18	Stand.	.209	.74	4′ or 5′ × 8′	5	
3-4″	" 13	"	.225	.80	6′ ×8′ or 12′	5	240
1 1-2″	" 12	"	.207	.70	4′ ×8′ or 12′	5	160
2″	" 12	"	.166	.56	5′ ×8′ or 12′	5	200
3″	" 16	"	.083	.28	6′ ×8′ or 12′	10	480
3″	" 10	Light	.148	.50	6′ ×8′ or 12′	5	240
3″	" 10	Stand.	.178	.60	6′ ×8′ or 12′	5	240
3″	" 10	Heavy	.267	.90	4′ ×8′ or 12′	5	160
3″	" 10	Ex. Heavy	.356	1.20	6′ ×8′ or 12′	3	144
3″	" 6	Stand.	.400	1.38	5′ ×8′ or 12′	3	120
3″	" 6	Heavy	.600	2.07	5′ ×8′ or 12′	3	120
4″	" 16	Old Style	.093	.42	4½′ ×8′ or 9′	6	216
6″	" 4	Stand.	.245	.84	5′ ×8′ or 12′	5	200
6″	" 4	Heavy	.368	1.26	5′ ×8′ or 12′	3	120

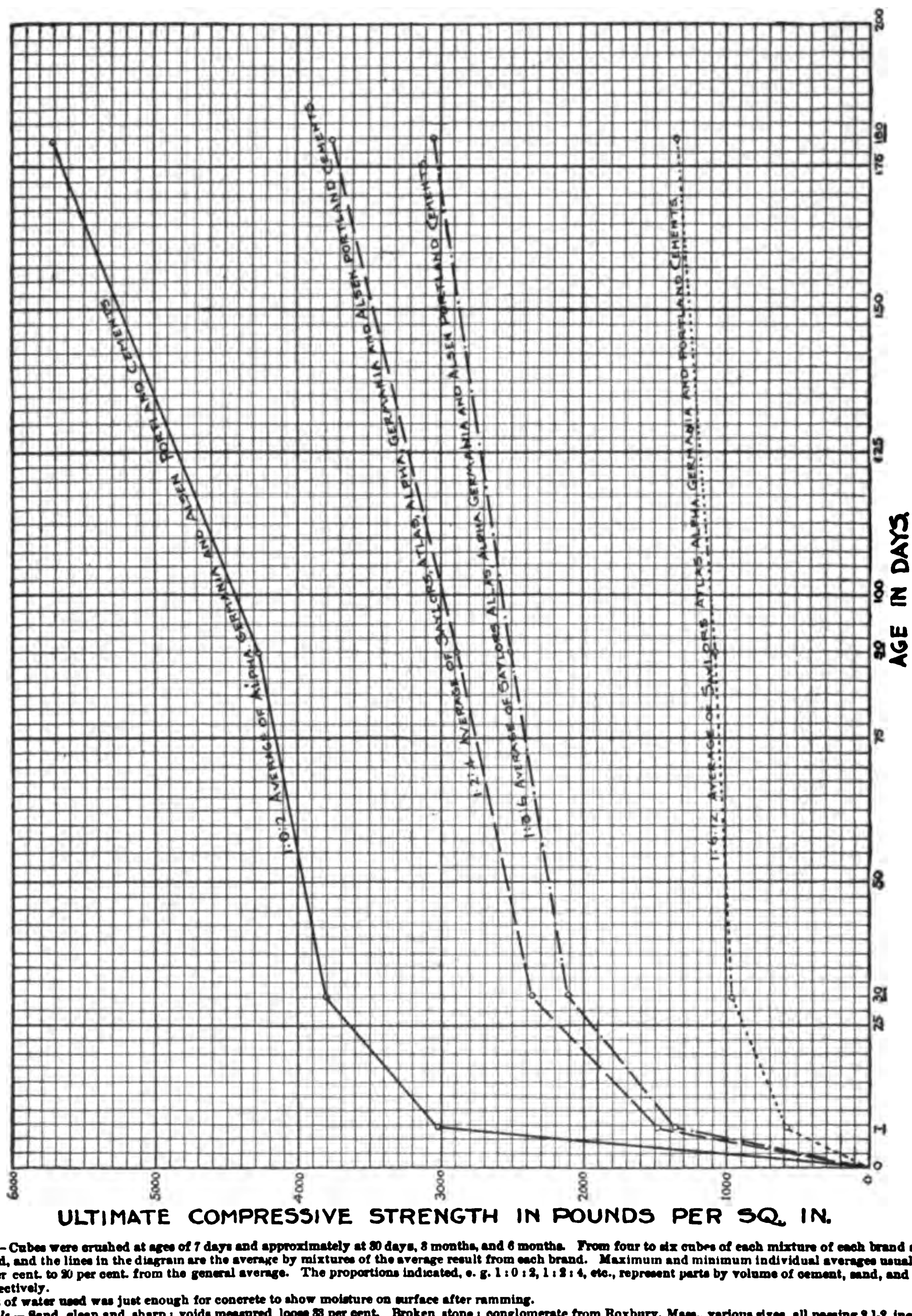
PROPORTIONS OF CONCRETE AGGREGATES

Mortars with No. 3 Sand								
Parts of sand with 1 part cement		1.0	1.5	2.0	2.5	3.0	3.5	4.
Required for 1 cub. yd. wet mortar	Cement Bbls.	4.70	3.70	3.04	2.58	2.21	1.94	1.72
	Sand cub. yds.	0.71	0.84	0.92	0.98	1.01	1.03	1.05
Required for 1 cub. yd. dry mortar	Cement Bbls.	5.40	4.18	3.41	2.88	2.49	2.20	1.96
	Sand cub. yds.	0.82	0.95	1.04	1.10	1.14	1.17	1.20

Concrete			Materials Required for 1 Cubic Yard								
Proportions of Mixture			With Hazelnut Stone			2½-in. Stone and Under			¾-in. Stone and Under		
Cement	Sand	Stone	Barrels Cement	Cu. Yds. Sand	Cu. Yds. Stone	Barrels Cement	Cu. Yds. Sand	Cu. Yds. Stone	Barrels Cement	Cu. Yds. Sand	Cu. Yds. Stone
1	1	2	2.57	0.39	0.78	2.63	0.40	0.80	2.33	0.35	0.75
1	1	2.5	2.29	0.35	0.87	2.34	0.36	0.89	2.10	0.32	0.80
1	1	3	2.06	0.31	0.94	2.10	0.32	0.96	1.89	0.29	0.86
1	1.5	2.5	2.05	0.47	0.78	2.09	0.48	0.80	1.85	0.42	0.73
1	1.5	3	1.85	0.42	0.84	1.90	0.43	0.87	1.71	0.39	0.78
1	1.5	3.5	1.72	0.39	0.91	1.74	0.40	0.93	1.57	0.36	0.83
1	1.5	4	1.57	0.36	0.96	1.61	0.37	0.98	1.46	0.33	0.88
1	2	3.5	1.57	0.48	0.83	1.61	0.49	0.85	1.44	0.44	0.77
1	2	4	1.46	0.44	0.89	1.48	0.45	0.90	1.34	0.41	0.81
1	2	4.5	1.36	0.42	0.93	1.38	0.42	0.95	1.26	0.38	0.86
1	2	5	1.27	0.39	0.97	1.29	0.39	0.98	1.17	0.36	0.89
1	2.5	4	1.35	0.52	0.82	1.38	0.53	0.84	1.24	0.47	0.75
1	2.5	4.5	1.27	0.48	0.87	1.29	0.49	0.88	1.16	0.44	0.80
1	2.5	5	1.19	0.46	0.91	1.21	0.46	0.92	1.10	0.42	0.83
1	2.5	5.5	1.13	0.43	0.94	1.15	0.44	0.96	1.03	0.39	0.86
1	2.5	6	1.07	0.41	0.97	1.07	0.41	0.98	0.98	0.37	0.89
1	3.0	5	1.11	0.51	0.85	1.14	0.52	0.87	1.03	0.47	0.78
1	3.0	5.5	1.06	0.48	0.89	1.07	0.49	0.90	0.97	0.44	0.81
1	3.0	6	1.01	0.46	0.92	1.02	0.47	0.93	0.92	0.42	0.84
1	3.0	6.5	0.96	0.44	0.95	0.98	0.44	0.96	0.88	0.40	0.87
1	3.0	7	0.91	0.42	0.97	0.92	0.42	0.98	0.84	0.38	0.89
1	3.5	6	0.95	0.50	0.87	0.97	0.51	0.89	0.88	0.46	0.80
1	3.5	6.5	0.92	0.49	0.91	0.93	0.49	0.92	0.83	0.44	0.82
1	3.5	7	0.87	0.47	0.93	0.89	0.47	0.95	0.80	0.43	0.85
1	3.5	7.5	0.84	0.45	0.96	0.86	0.45	0.98	0.76	0.41	0.87
1	3.5	8	0.80	0.42	0.97	0.83	0.43	1.00	0.73	0.39	0.89
1	4	6	0.90	0.55	0.82	0.92	0.56	0.84	0.83	0.51	0.76
1	4	7	0.83	0.51	0.89	0.84	0.51	0.90	0.77	0.47	0.80
1	4	8	0.77	0.47	0.93	0.78	0.48	0.95	0.71	0.43	0.83
1	4	9	0.71	0.43	0.97	0.72	0.45	1.00	0.65	0.40	0.86

STRENGTH OF PORTLAND CEMENT CONCRETE

AVERAGE ACCORDING TO MIXTURE, FROM TESTS OF 12-IN. CUBES, MADE UNDER THE DIRECTION OF GEORGE A. KIMBALL CHIEF ENGINEER, BOSTON ELEVATED RAILWAY CO., BY THE U. S. GOVERNMENT AT WATERTOWN ARSENAL, MASS., DECEMBER, 1898, TO JULY, 1899



NOTES.— Cubes were crushed at ages of 7 days and approximately at 30 days, 3 months, and 6 months. From four to six cubes of each mixture of each brand and age were tested, and the lines in the diagram are the average by mixtures of the average result from each brand. Maximum and minimum individual averages usually vary from 10 per cent. to 20 per cent. from the general average. The proportions indicated, e. g. 1 : 0 : 2, 1 : 2 : 4, etc., represent parts by volume of cement, sand, and broken stone respectively.

Amount of water used was just enough for concrete to show moisture on surface after ramming.

Materials.— Sand, clean and sharp; voids measured loose 33 per cent. Broken stone: conglomerate from Roxbury, Mass., various sizes, all passing 2 1-2 inch ring. Voids measured loose 49.5 per cent. Method of mixing: cement and sand turned twice dry, then moistened, mortar turned on wet stone and concrete turned twice before ramming into molds.

Cubes taken out of molds 3 to 4 days after making, and, except the 7 day cubes, buried in wet ground until about a week before testing.

Voids, broken corners, or other defects in cubes not plastered or patched in any way.

MATERIAL FOR 100 SQ. FT. CONCRETE SIDEWALK OR FLOOR

	Base						Wearing Surface						
	Proportions 1-2½-5			Proportions 1-3-6				Proportions 1-1		Proportions 1-1½		Proportions 1-2	
Thickness in Inches	Cement Barrels	Sand Cu. Yds.	Stone Cu. Yds.	Cement Barrels	Sand Cu. Yds.	Stone Cu. Yds.	Thickness in Inches	Cement Barrels	Sand Cu. Yds.	Cement Barrels	Sand Cu. Yds.	Cement Barrels	Sand Cu. Yds.
2½	1.10	0.39	0.78	0.94	0.40	0.80	½	0.85	0.12	0.68	0.14	0.56	0.16
3	1.33	0.47	0.94	1.13	0.48	0.96	¾	1.28	0.18	1.02	0.21	0.85	0.24
3½	1.55	0.55	1.10	1.32	0.56	1.12	1	1.70	0.24	1.36	0.29	1.13	0.32
4	1.77	0.63	1.25	1.51	0.64	1.28	1¼	2.13	0.30	1.70	0.36	1.41	0.40
4½	1.99	0.70	1.41	1.70	0.72	1.44	1½	2.56	0.36	2.04	0.43	1.69	0.47
5	2.21	0.78	1.56	1.89	0.80	1.60	2	3.41	0.48	2.72	0.57	2.26	0.63

HARD PINE BEAMS (Kidder)

Table of safe quiescent loads for horizontal rectangular beams of Georgia yellow pine one inch broad, supported at both ends, load uniformly distributed. For concentrated load at centre divide by two. For permanent loads (such as masonry) reduce by 10 per cent.

HARD-PINE BEAMS

Depth of Beam	Span in Feet												
	6	8	10	12	14	15	16	18	20	22	24	25	27
Ins.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
6	1,200	900	720	600	514	480							
7	1,633	1,225	980	816	700	653	612						
8	2,133	1,600	1,280	1,066	914	853	800						
9	2,700	2,025	1,620	1,350	1,157	1,080	1,012	900					
10	3,333	2,500	2,000	1,666	1,428	1,333	1,250	1,111	1,000				
12	4,800	3,600	2,880	2,400	2,056	1,920	1,800	1,600	1,440				
14	6,533	4,900	3,920	3,266	2,800	2,613	2,450	2,177	1,960	1,782	1,633	1,568	1,450
15	7,500	5,633	4,500	3,750	3,214	3,000	2,816	2,500	2,250	2,045	1,875	1,800	1,666
16	8,533	6,400	5,120	4,266	3,656	3,412	3,200	2,844	2,560	2,327	2,133	2,048	1,896

Loads above and to the right of heavy line will crack plastered ceilings.

SPRUCE BEAMS (Kidder)

Table of safe quiescent loads for horizontal rectangular beams one inch broad, supported at both ends, load uniformly distributed. For concentrated load at centre divide by two. For permanent loads (such as masonry) reduce by 10 per cent.

SPRUCE BEAMS

Depth of Beam	Span in Feet												
	6	8	10	12	14	15	16	17	18	20	22	24	25
Ins.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
6	840	630	504	420	360	336							
7	1,143	857	686	572	490	457	428						
8	1,493	1,120	896	746	640	597	560	527					
9	1,890	1,417	1,134	945	810	756	708	667	630				
10	2,333	1,750	1,400	1,166	1,000	933	875	824	777	700			
12	3,360	2,520	2,016	1,680	1,440	1,344	1,260	1,086	1,120	1,018			
14	4,573	3,430	2,744	2,286	1,960	1,828	1,715	1,614	1,524	1,372	1,247	1,143	1,097
15	5,250	3,937	3,150	2,625	1,875	2,100	1,968	1,853	1,750	1,575	1,431	1,312	1,260
16	5,973	4,480	3,584	2,986	2,540	2,388	2,240	2,108	1,991	1,792	1,629	1,493	1,433

Loads above and to the right of heavy line will crack plastered ceilings.

CHAPTER III

CODE USED FOR THE DESIGN OF STANDARD REINFORCED CONCRETE SECTIONS

1. THE bond between concrete and steel is sufficient to make the two materials act as a homogeneous solid aggregate.

2. The design shall be based on the assumption of the total live and dead load producing a stress of 16,000 pounds per square inch in the reinforcement, and a corresponding stress in the concrete of not over 700 pounds per square inch at the extreme fibre.

3. The stress in any fibre is directly proportional to the distance of that fibre from the neutral axis.

4. The modulus of elasticity of concrete remains constant within the limits of the working stresses.

5. The dimensions of all weight-bearing members submitted to transverse stresses shall be so proportioned that the strength of the metal in tension shall determine the strength of the member.

6. The tensile strength of concrete shall not be considered.

7. No metal shall be added to the compression side of a member to assist it in compression.

8. In the design of structures involving reinforced concrete beams and girders in connection with slabs, the beams and girders shall be treated as T-sections, with a portion of the slab acting as a flange. This portion of the slab shall be assumed to have a width equal to four times its thickness plus the width of the beam.

9. For all working loads, the neutral axis of any slab, beam, or girder shall be assumed midway between the centroid of compression of the steel in tension and the top of the member.

10. The ultimate shearing strength of concrete shall be assumed as one tenth its compressive strength.

11. All reinforced concrete girders acting as T-sections must be reinforced against shearing stress along the plane of junction of the rib and the flange.

12. Concrete in direct compression shall be assumed to have the following working values:—

1-3-6	mix,	400	lbs.	per	sq.	in.
1-2½-5	"	450	"	"	"	"
1-2-4	"	500	"	"	"	"
1-1½-3	"	600	"	"	"	"
1-1-2	"	700	"	"	"	"

Reinforced concrete columns shall be designed with the assumption that the stress in the concrete shall be simultaneous with ten times the stress per square inch in the steel.

13. In carrying out work in the field, special care must be taken that the ribs of all girders and beams shall be monolithic with the floor slab for a distance of twice the depth of slab each side of rib.

14. Care must be taken to introduce steel enough to prevent cracks developing from tensile stresses due to the continuity of the members.

15. In the determination of bending moments, beams and girders shall be considered as supported at the ends, no allowance being made for continuity over supports, and the bending moment shall be figured as $\frac{Wl}{8}$.

16. Floor slabs when constructed continuous, and when provided with reinforcement at the top of slab over supports, may be treated as continuous beams, the bending moment being taken as $\frac{Wl}{10}$ for uniformly distributed loads, or in case of slabs supported on four sides and reinforced in each direction, as $\frac{Wl}{20}$.

17. Where concrete is exposed to extreme changes of temperature it should be reinforced to the extent of .005 of 1 per cent. of sectional area of concrete for every degree of estimated variation of temperature, to prevent cracks developing.

18. When the shearing stresses developed in any part of a reinforced concrete structure exceed the shearing strength of concrete, as fixed, a sufficient amount of steel shall be introduced in such a position as to take care of the full shearing stress.

19. The full estimated strength of plain or reinforced concrete columns shall not be used where the length is more than 15 times the least side or diameter.

DISCUSSION OF REINFORCED CONCRETE CODE

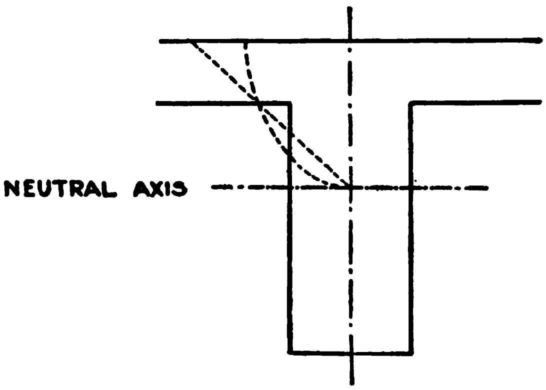
Bond. In order to develop the bond between concrete and steel, all trussed rods over columns, or rods where the stress is transmitted from one to another, shall have a lap of at least 40 diameters.

In continuous columns where the stress in the steel is assumed to be 5000 or 6000 pounds per square inch, the lap may be 15 to 18 diameters. All trussed rods ending at wall beams, or elsewhere, where the bond is not developed by the length of the rod, must have an anchorage sufficient to develop their strength. The best method of obtaining this anchorage, where round rods are used, is to thread the end of the rod, and fit it with a wrought iron or steel plate washer with an area of at least 24 times the sectional area of the rod, with two nuts, one on each side of the plate to hold it firmly in place. Tension rods should be separated by a distance of at least one and one half times their diameter, and should be no nearer the face of the concrete.

Steel must be free from paint or oil, and all rust scales must be removed before imbedding in concrete, as these will prevent the proper adhesion of the concrete to the steel.

Stirrups used for shearing stress should be anchored both at the top and the bottom of the beam.

STRESS IN STEEL AND CONCRETE. The stress of 16,000 pounds per square inch in the steel is that usually assumed for the working stress in structural steel in building construction, and there is no good reason why the same working stress should not apply to concrete reinforcement. The assumed maximum compressive stress of 700 pounds per square inch in the concrete is that obtained by the straight line theory, and is actually considerably less, as the stress strain curve will follow more nearly the line of the parabola as shown in cut.



If, however, the stress in the steel produced a maximum stress of 700 pounds per square inch in a concrete the ultimate strength of which is four times as much, then the first signs of failure in a properly designed beam would not result from compression, but from the elongation of the tension steel and the consequent cracks in the bottom of the beams resulting therefrom, which begin to show plainly when the steel is stressed to about 40,000 pounds per square inch.

MODULUS OF ELASTICITY. The ratio of the moduli of elasticity of concrete and steel is neglected in the design of transverse weight-bearing members, as this ratio is always a variable depending upon the mixture of concrete and its age. It seems as reasonable to adopt a fixed position of the neutral axis as to adopt a fixed ratio for the moduli of elasticity upon which the position of the neutral axis would depend.

Rules 3 and 4 are therefore correlative.

RELATIVE DIMENSIONS. If a beam is so proportioned that the strength of the steel determines the strength of the beam, then ample warning will be given before failure by overloading; if, on the other hand, the strength of the beam is determined by the strength of the concrete in compression, the beam will fail without warning, with possible disastrous results.

TENSILE STRENGTH OF CONCRETE. The tensile strength of concrete is neglected for the following reasons: —

The steel is undoubtedly assisted in tension by the concrete until the elastic limit of the concrete is reached, which will be when the steel is stressed to about 6000 pounds per square inch. At this point numerous microscopic cracks will occur at the bottom of the beam, which, while not visible and in no way affecting the integrity of the beam, completely eliminates the tensile strength of the concrete. These cracks will not become visible to the naked eye until after the elastic limit of the steel is reached.

NO METAL IN COMPRESSION. The exact value of metal in compression in a beam is an undetermined quantity and is also not economical in design. It therefore should be eliminated from any standard sections, and in case it is necessary to use steel in compression to reduce the size of a member, special consideration should be given its design.

Width of Flange of T-Sections. Various assumptions of the width of flange have been made by engineers. Some base the width of flange upon the span of beam, others upon the thickness of slab. While this width undoubtedly depends more or less upon both elements, the author thinks it wise to base it upon the depth of slab for standard sections, as it limits the danger of failure from longitudinal shear along the junction of web and flange, and no standard sections would be possible if the span had to be taken into consideration each time.

Location of Neutral Axis. The location of neutral axis is assumed midway between the top of the slab and the centroid of tension in the steel. Tests made to destruction, on full-sized beams reinforced with different percentages of steel in which the position of the neutral axis at each successive increment of load was carefully determined, show that there is no great variation from this location until after the elastic limit of the steel is passed. The author is of the opinion that the position of the neutral axis is more dependent on the unit stress in the concrete than on the unit stress in the steel.

Strength of Concrete in Diagonal Tension. The tensile strength of concrete is usually assumed to be equal to about one tenth its compressive strength. The working value of a 1–2–4 concrete in diagonal tension, usually called shear, may be assumed to be 60 pounds per square inch.

Referring to rule 11, floor beams are always reinforced sufficiently against shear along the junction of rib and flange by the floor slab reinforcement. This reinforcement, however, does not occur across girders, and it is good conservative practice to reinforce the top of the slab across girders to provide against this shearing action and also to transmit a part of the load on the floor slab directly to the girders by means of the cantilever action thus developed. The slab reinforcement parallel to the girder may be omitted for a little way each side of girder.

Stresses in Columns. The less steel in columns, other than that needed for flexure, tends to economy. After forms are in place we will assume that a 1–1½–3 concrete with a working value of 600 pounds per square inch may be deposited for eight dollars per yard or approximately thirty cents per cubic foot. This gives a supporting value of $144 \times 600 = 86{,}400$ pounds one foot in height for thirty cents. A sectional area of 14.4 square inches of steel weighing 49 pounds and costing in place about one dollar and a half per lineal foot would be necessary to carry the same load.

However, in high buildings with heavy loads it is often necessary to limit the size of concrete columns by the introduction of steel. Steel reinforcement may be used with economy up to 5 per cent. of the sectional area of the column, but if more steel than this is necessary, it is fully as cheap to use structural steel columns based on 12,000 pounds per square inch and fireproof them.

A 1–1½–3 concrete should be used in columns with a 1–2–4 mix in the floor slab, as the confined 1–2–4 concrete in the floor slab through which the column passes has quite as much value as the 1–1½–3 concrete midway between floors.

Hooped columns based on Considere's theory have been designed with as high a working stress as 1000 pounds per square inch, but in the light of experiments made at the Watertown Arsenal by United States Army engineers, such a working stress does not seem rational, and the author would not advise the use of excessive values in compression until further investigation sufficiently warrants it.

There is also an element of danger involved in carrying so high a compression value through the intersecting floor beams and girders with their many reinforcing rods around which it is necessary to use extreme care in the placing and tamping of concrete.

CONTINUITY OF MEMBERS. In monolithic structures stresses are developed over all supports by the negative bending moments which must be taken care of by a sufficient quantity of steel to prevent cracks developing. In beams and girders, if one half the number of tension rods are trussed over the supports and lapped for a sufficient distance to develop their strength, all necessary provision is made against cracking of concrete over supports. All concrete liable to be affected by extreme temperature changes should be reinforced with steel to prevent cracks developing.

In the case of floor slabs, the floor reinforcement should be kept down to within one inch of the bottom of the slab midway between beams and lifted to within one inch of the top of the slab over the beams.

BENDING MOMENTS. In continuous beams, the maximum bending moment when adjacent spaces are loaded occurs over the supports. T-beam sections are designed for the maximum amount of steel at the bottom of the beam, midway between supports, this steel being balanced in compression by the T-section of concrete. The amount of steel thus obtained by using the formula $\frac{Wl}{8}$ is sufficient to relieve the stress over the columns and provide for any unequal loading of bays, the internal stresses adjusting themselves to the varied position of load.

Some building ordinances allow the bending moment to be assumed $\frac{Wl}{10}$ with a maximum amount of steel over the columns. This is liable to cause a weakness in compression at the bottom of the beam next to the column before the strength of the steel is developed, unless the area of concrete at the bottom of the beam is increased by haunching the beam.

The formula $\frac{Wl}{10}$ may be used for floor slabs when the reinforcement is lifted over the beams.

CHAPTER IV

REINFORCED CONCRETE SPECIFICATIONS

CEMENT. The cement is to be stored in a suitable building and kept free from moisture before using. It is to be so placed as to admit identification and inspection of each shipment and so that the lots arriving first shall be used first. Cement shall be furnished at such periods that a seven-day test can be made on each lot before it is necessary for use. All cement shall be of a high grade American Portland, and shall comply with the specifications adopted by the American Society for Testing Materials. The cement tests shall be made as specified by persons skilled in this work, at the expense of the owner.

All necessary assistance shall be provided the representative of the owner in obtaining such samples as he requires.

SAND. The sand must be clean, sharp, and free from loam, clay, mica, or other objectionable material. Samples of the sand used shall be furnished the cement tester from time to time as required by the architect, so that the strength of a 1–3 mortar can be observed.

CRUSHED STONE OR GRAVEL. The crushed stone or gravel must be clean, hard, and free from foreign matter. Crushed slate, shale, or limestone shall not be used in reinforced concrete construction.

Dust shall be screened out of crushed stone. Sand shall be screened out of gravel, but may be remixed with it in the proper proportions, if of the specified quality.

For heavy foundations, stone which has passed through a 4-in. mesh may be used. For smaller footings and thick walls, stone which has passed through a 3-in. mesh may be used. For reinforced columns, girders, beams, slabs, and thin walls all stones shall pass through a 1-in. mesh.

MIXING. Proper boxes or gauges must be provided for measuring sand and stone. 95 pounds of cement, or one bag, shall be assumed as .95 cubic feet.

Concrete shall be mixed in an approved mixing machine, unless permission is obtained from the architect to mix by hand.

In either case all concrete shall be mixed to his entire satisfaction, and no concrete shall be placed in the work until each particle of stone is thoroughly covered with mortar.

Sufficient water is to be used to produce a " wet " mix, but not enough so that the concrete will be sloppy in the wheelbarrows with water standing at the top before depositing.

Concrete is to be mixed in the following proportions: For the lower part of footings and for foundation walls, one part cement, two and one half parts sand, and five parts broken stone or gravel. For the upper part of footings and for columns, one part cement, one and one half parts sand, and three parts broken stone. For all other reinforced work, one part cement, two parts sand, and four parts broken stone. Any variation from these materials or proportions must be with the written permission of the architect.

PLACING CONCRETE. Concrete shall be deposited wet enough so that it will require but little tamping, but care must be taken in spading next to the forms to press back the stone and bring the mortar to the surface, so as to insure a smooth finish. Spading will also be necessary to bring the air bubbles to the surface, especially in deep columns. Columns for each floor shall be filled to the height of the bottom of the deepest intersecting beam or girder in two or more operations. After columns are filled sufficient time shall elapse before work is continued on the floor to allow shrinkage of concrete in columns to take place. The beams, girders, and floor slabs are to be laid as a monolith, and on no account shall work be stopped except on such lines as are previously determined or as directed at the time by the architect. As a general rule, working joints shall be through the middle of the bay. Joints where work is stopped are to be cleaned with a wire brush, and painted with a neat cement grout before any concrete is laid against them on resuming work.

GRANOLITHIC SURFACES. Where granolithic surfaces are specified, the upper inch is to be composed of one part cement, three fourths part clean, sharp, coarse sand, and three fourths part crushed stone through a half-inch mesh with the dust screened out.

It is preferable that this surface be laid monolithic with the floor slab, and if so it shall be part of the effective depth of the floor slab. If it is impracticable to lay the granolithic surface at the same time as the floor slab, then the total thickness of floor shall be increased one inch, and the granolithic surface shall be bonded to the base in an approved manner. The contractor must guarantee that the granolithic top shall not separate from the base for a period of one year from completion of work.

FORMS. Forms shall be constructed in a thorough and substantial manner and shall be well braced to prevent any distortion. All lumber adjacent to concrete shall be planed to uniform thickness, shall be laid with tight joints to prevent cement from escaping, and shall be free from shakes and loose knots. All floor boarding shall be laid in narrow widths of 6 inches or less, and special care must be taken to prevent uneven surfaces. Chamfer all corners of beams, girders, and columns by nailing triangular strips to the forms. A trap door shall be left at the bottom of each column form to admit cleaning out dirt before concrete is deposited. No forms shall be removed until the concrete is thoroughly set, and has obtained sufficient strength to prevent any distortion or deflection. After the forms are removed the contractor is to repair any defective work upon instruction by the architect, and if in his opinion such defects are sufficient to cause undue weakness, the whole of the member affected must be removed and replaced. After the forms are removed, cut off all fins, patch up defects, and correct other irregularities.

REINFORCEMENT. The steel used for reinforcement shall consist of such shapes and sizes as are shown on the plans or approved by the architect. It shall conform to the " Manufacturers' Standard Specifications " for " Medium " steel. Under these specifications it may be either Bessemer or Open Hearth, although Open

Hearth should be given the preference. It shall have an ultimate strength of 60,000 to 70,000 pounds per square inch. It shall have an elastic limit of not less than half its ultimate strength. The percentage of elongation shall be 1,400,000 ÷ ultimate strength. It shall bend 180 degrees to a diameter equal to thickness of piece tested, without fracture on outside of bent portion.

No steel used in reinforcing concrete shall be painted or coated with any oily material, but shall be clean and free from rust scales.

Before placing, all steel shall be bent true to templates as required on the drawings. Care shall be taken in handling to preserve the shape of each piece, and in setting to place each piece or group of pieces in their proper locations.

All steel reinforcement for columns, beams, and girders shall be assembled before being placed in the forms, in such a manner as to hold all component parts rigidly in their proper locations and to prevent any change in location of steel during the placing, tamping, or spading of the concrete. Rods shall be lapped 40 diameters over supports and dead ends shall be threaded and provided with two standard nuts inclosing a 5-8 inch steel washer with an area of twenty-four times the sectional area of the rod or rods which it engages.

PROTECTION AGAINST ELEMENTS. In hot weather concrete shall be kept wet one week after placing, and if possible covered from the sun's rays.

Stone intended for use in concrete that has long been exposed to the sun shall be thoroughly wet down before using.

Concrete shall be absolutely protected from freezing. Any concrete which has been allowed to freeze within forty-eight hours from the time of depositing shall be removed immediately and replaced with new concrete.

AMERICAN SOCIETY FOR TESTING MATERIALS

REPORT OF COMMITTEE ON STANDARD SPECIFICATIONS FOR PORTLAND CEMENT

Adopted June 17, 1904

GENERAL OBSERVATIONS

1. These remarks have been prepared with a view of pointing out the pertinent features of the various requirements and the precautions to be observed in the interpretation of the results of the tests.

2. The committee would suggest that the acceptance or rejection under these specifications be based on tests made by an experienced person having the proper means for making the tests.

SPECIFIC GRAVITY

3. Specific gravity is useful in detecting adulteration or underburning. The results of tests of specific gravity are not necessarily conclusive as an indication of the quality of a cement, but when in combination with the results of other tests may afford valuable indications.

FINENESS

4. The sieves should be kept thoroughly dry.

TIME OF SETTING

5. Great care should be exercised to maintain the test pieces under as uniform conditions as possible. A sudden change or wide range of temperature in the room in which the tests are made, a very dry or humid atmosphere, and other irregularities, vitally affect the rate of setting.

TENSILE STRENGTH

6. Each consumer must fix the minimum requirements for tensile strength to suit his own conditions. They shall, however, be within the limits stated.

CONSTANCY OF VOLUME

7. The tests for constancy of volume are divided into two classes, the first normal, the second accelerated. The latter should be regarded as a precautionary test only, and not infallible. So many conditions enter into the making and interpreting of it that it should be used with extreme care.

8. In making the pats the greatest care should be exercised to avoid initial strains due to molding or to too rapid drying-out during the first twenty-four hours. The pats should be preserved under the most uniform conditions possible, and rapid changes of temperature should be avoided.

9. The failure to meet the requirements of the accelerated tests need not be sufficient cause for rejection. The cement may, however, be held for twenty-eight days, and a re-test made at the end of that period. Failure to meet the requirements at this time should be considered sufficient cause for rejection, although in the present state of our knowledge it cannot be said that such failure necessarily indicates unsoundness, nor can the cement be considered entirely satisfactory simply because it passes the tests.

STANDARD SPECIFICATIONS FOR PORTLAND CEMENT

GENERAL CONDITIONS

1. All cement shall be inspected.

2. Cement may be inspected either at the place of manufacture or on the work.

3. In order to allow ample time for inspecting and testing, the cement should be stored in a suitable weather-tight building having the floor properly blocked or raised from the ground.

4. The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment.

5. Every facility shall be provided by the contractor, and a period of at least twelve days allowed for the inspection and necessary tests.

6. Cement shall be delivered in suitable packages with the brand and name of manufacturer plainly marked thereon.

7. A bag of cement shall contain 94 pounds of cement net. Each barrel of Portland cement shall contain 4 bags, and each barrel of natural cement shall contain 3 bags of the above net weight.

8. Cement failing to meet the seven-day requirements may be held awaiting the results of the twenty-eight-day tests before rejection.

9. All tests shall be made in accordance with the methods proposed by the Committee on Uniform Tests of Cement of the American Society of Civil Engineers presented to the Society January 21, 1903, and amended January 20, 1904, with all subsequent amendments thereto. (See addendum to these specifications.)

10. The acceptance or rejection shall be based on the following requirements:

PORTLAND CEMENT

11. *Definition.* This term is applied to the finely pulverized product resulting from the calcination to incipient fusion of an intimate mixture of properly proportioned argillaceous and calcareous materials, and to which no addition greater than 3 per cent. has been made subsequent to calcination.

SPECIFIC GRAVITY

12. The specific gravity of the cement, thoroughly dried at 100° C., shall be not less than 3.10.

FINENESS

13. It shall leave by weight a residue of not more than 8 per cent. on the No. 100, and not more than 25 per cent. on the No. 200 sieve.

TIME OF SETTING

14. It shall develop initial set in not less than thirty minutes, but must develop hard set in not less than one hour, nor more than ten hours.

TENSILE STRENGTH

15. The minimum requirements for tensile strength for briquettes one inch square in section shall be within the following limits, and shall show no retrogression in strength within the periods specified.[1]

Age	Neat Cement	Strength
24 hours in moist air		150–200 lbs.
7 days (1 day in moist air, 6 days in water)		450–550 "
28 days (1 day in moist air, 27 days in water)		550–650 "
	One Part Cement, Three Parts Sand	
7 days (1 day in moist air, 6 days in water)		150–200 "
28 days (1 day in moist air, 27 days in water)		200–300 "

[1] For example the minimum requirements for the twenty-four hour neat cement test should be some value within the limits of 150 and 200 pounds, and so on for each period stated.

CONSTANCY OF VOLUME

16. Pats of neat cement about three inches in diameter, one half inch thick at the centre, and tapering to a thin edge, shall be kept in moist air for a period of twenty-four hours.

(*a*) A pat is then kept in air at normal temperature and observed at intervals for at least twenty-eight days.

(*b*) Another pat is kept in water maintained as near 70° F. as practicable, and observed at intervals for at least twenty-eight days.

(*c*) A third pat is exposed in any convenient way in an atmosphere of steam, above boiling water, in a loosely closed vessel for five hours.

17. These pats, to satisfactorily pass the requirements, shall remain firm and hard and show no signs of distortion, checking, cracking, or disintegrating.

SULPHURIC ACID AND MAGNESIA

18. The cement shall not contain more than 1.75 per cent. of anhydrous sulphuric acid (SO^3), nor more than 4 per cent. of magnesia (MgO).

Submitted on behalf of the committee.

George F. Swain, *Chairman.*
George S. Webster, *Vice-Chairman.*
Richard L. Humphrey, *Secretary.*

ADDENDUM

ABSTRACT OF METHODS RECOMMENDED BY THE SPECIAL COMMITTEE ON UNIFORM TESTS OF CEMENT OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

SAMPLING

1. *Selection of Sample.* The sample shall be a fair average of the contents of the package; it is recommended that, where conditions permit, one barrel in every ten be sampled.

2. All samples should be passed through a sieve having twenty meshes per linear inch, in order to break up lumps and remove foreign material; this is also a very effective method for mixing them together in order to obtain an average. For determining the characteristics of a shipment of cement, the individual samples may be mixed and the average tested; where time will permit, however, it is recommended that they be tested separately.

3. *Method of Sampling.* Cement in barrels should be sampled through a hole made in the centre of one of the staves, midway between the heads, or in the head, by means of an auger or a sampling iron similar to that used by sugar inspectors. If in bags, it should be taken from surface to centre.

CHEMICAL ANALYSIS

4. *Method.* As a method to be followed for the analysis of cement, that proposed by the Committee on Uniformity in the Analysis of Materials for the Port-

land Cement Industry, of the New York Section of the Society for Chemical Industry, and published in the *Journal* of the Society for January 15, 1902, is recommended.

SPECIFIC GRAVITY

5. *Apparatus and Method.* The determination of specific gravity is most conveniently made with Le Chatelier's apparatus. This consists of a flask (*D*, Fig. 1) of 120 cu. cm. (7.32 cu. ins.) capacity, the neck of which is about 20 cm. (7.87 ins.) long; in the middle of this neck is a bulb (*C*), above and below which are two marks, *F* and *E;* the volume between these marks is 20 cu. cm. (1.22 cu. ins.). The neck has a diameter of about 9 mm. (0.35 in.), and is graduated into tenths of cubic centimeters above the mark *F*.

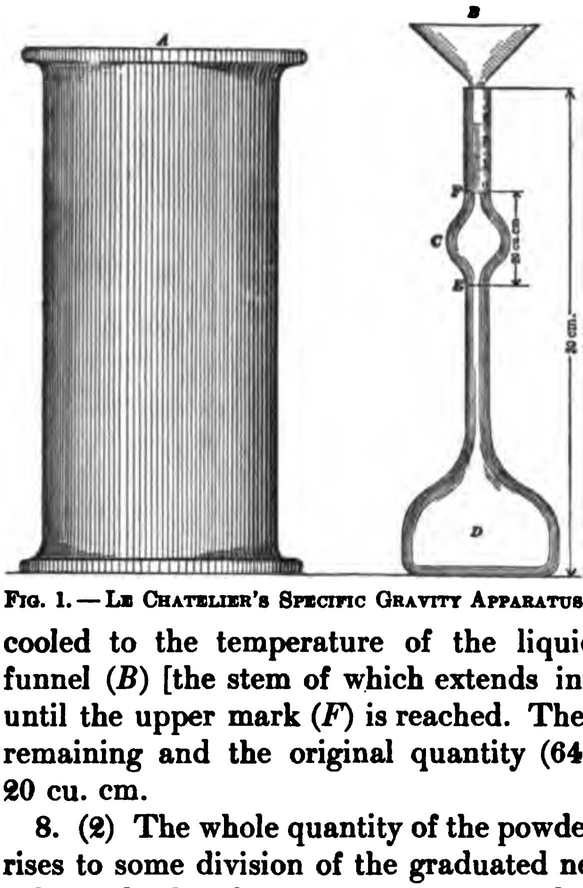


Fig. 1.—Le Chatelier's Specific Gravity Apparatus

6. Benzine (62° Baumé), naphtha, or kerosene free from water, should be used in making the determination.

7. The specific gravity can be determined in two ways: —

(1) The flask is filled with either of these liquids to the lower mark (*E*), and 64 gr. (2.25 oz.) of powder, previously dried at 100° C. (212° F.) and cooled to the temperature of the liquid, is gradually introduced through the funnel (*B*) [the stem of which extends into the flask to the top of the bulb (*C*)], until the upper mark (*F*) is reached. The difference in weight between the cement remaining and the original quantity (64 gr.) is the weight which has displaced 20 cu. cm.

8. (2) The whole quantity of the powder is introduced, and the level of the liquid rises to some division of the graduated neck. This reading plus 20 cu. cm. is the volume displaced by 64 gr. of the powder.

9. The specific gravity is then obtained from the formula: —

$$\text{Specific Gravity} = \frac{\text{Weight of Cement}}{\text{Displaced Volume}}.$$

10. The flask, during the operation, is kept immersed in water in a jar (*A*), in order to avoid variations in the temperature of the liquid. The results should agree within 0.01.

11. A convenient method for cleaning the apparatus is as follows: The flask is inverted over a large vessel, preferably a glass jar, and shaken vertically until the liquid starts to flow freely; it is then held still in a vertical position until empty; the remaining traces of cement can be removed in a similar manner by pouring into the flask a small quantity of clean liquid and repeating the operation.

FINENESS

12. *Apparatus.* The sieves should be circular, about 20 cm. (7.87 ins.) in diameter, 6 cm. (2.36 ins.) high, and provided with a pan 5 cm. (1.97 ins.) deep, and a cover.

13. The wire cloth should be woven (not twilled) from brass wire having the following diameters:

No. 100, 0.0045 in.; No. 200, 0.0024 in.

14. This cloth should be mounted on the frames without distortion; the mesh should be regular in spacing and be within the following limits:—

No. 100, 96 to 100 meshes to the linear inch.
No. 200, 188 to 200 " " " " "

15. Fifty grams (1.76 oz.) or 100 gr. (3.52 oz.) should be used for the test, and dried at a temperature of 100° C. (212° F.) prior to sieving.

16. *Method.* The thoroughly dried and coarsely screened sample is weighed and placed on the No. 200 sieve, which, with pan and cover attached, is held in one hand in a slightly inclined position, and moved forward and backward, at the same time striking the side gently with the palm of the other hand, at the rate of about 200 strokes per minute. The operation is continued until not more than one tenth of 1 per cent. passes through after one minute of continuous sieving. The residue is weighed, then placed on the No. 100 sieve and the operation repeated. The work may be expedited by placing in the sieve a small quantity of large shot. The results should be reported to the nearest tenth of 1 per cent.

NORMAL CONSISTENCY

17. *Method.* This can best be determined by means of *Vicat Needle Apparatus*, which consists of a frame (*K*), Fig. 2, bearing a movable rod (*L*), with the cap (*A*) at one end, and at the other the cylinder (*B*), 1 cm. (0.39 in.) in diameter, the cap, rod and cylinder weighing 300 gr. (10.58 oz.). The rod, which can be held in any desired position by a screw (*F*), carries an indicator, which moves over a scale (graduated to centimeters) attached to the frame (*K*). The paste is held by a conical, hard-rubber ring (*I*), 7 cm. (2.76 ins.) in diameter at the base, 4 cm. (1.57 ins.) high, resting on a glass plate (*J*) about 10 cm. (3.94 ins.) square.

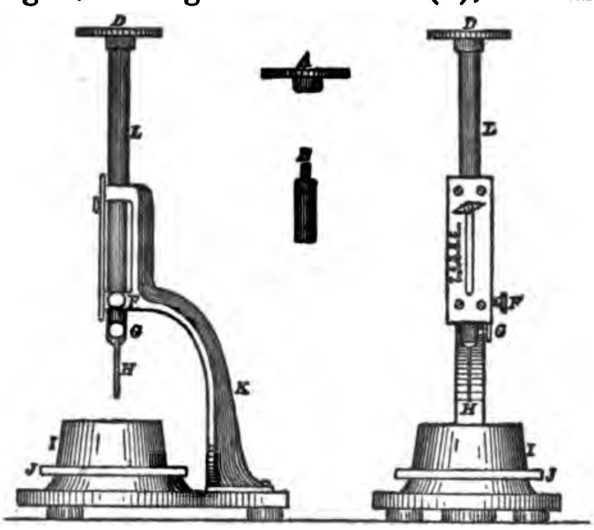


FIG. 2. — VICAT NEEDLE

18. In making the determination, the same quantity of cement as will be subsequently used for each batch in making the briquettes (but not less than 500 grams) is kneaded into a paste, as described

in paragraph 39, and quickly formed into a ball with the hands, completing the operation by tossing it six times from one hand to the other, maintained 6 ins. apart; the ball is then pressed into the rubber ring, through the larger opening, smoothed off, and placed (on its large end) on a glass plate and the smaller end smoothed off with a trowel; the paste, confined in the ring, resting on the plate, is placed under the rod bearing the cylinder, which is brought in contact with the surface and quickly released.

19. The paste is of normal consistency when the cylinder penetrates to a point in the mass 10 mm. (0.39 in.) below the top of the ring. Great care must be taken to fill the ring exactly to the top.

20. The trial pastes are made with varying percentages of water until the correct consistency is obtained.

PERCENTAGE OF WATER FOR STANDARD MIXTURES [1]

Neat	1-1	1-2	1-3	1-4	1-5	Neat	1-1	1-2	1-3	1-4	1-5
18	12.0	10.0	9.0	8.4	8.0	33	17.0	13.3	11.5	10.4	9.6
19	12.3	10.2	9.2	8.5	8.1	34	17.3	13.6	11.7	10.5	9.7
20	12.7	10.4	9.3	8.7	8.2	35	17.7	13.8	11.8	10.7	9.9
21	13.0	10.7	9.5	8.8	8.3	36	18.0	14.0	12.0	10.8	10.0
22	13.3	10.9	9.7	8.9	8.4	37	18.3	14.2	12.2	10.9	10.1
23	13.7	11.1	9.8	9.1	8.5	38	18.7	14.4	12.3	11.1	10.2
24	14.0	11.3	10.0	9.2	8.6	39	19.0	14.7	12.5	11.2	10.3
25	14.3	11.6	10.2	9.3	8.8	40	19.3	14.9	12.7	11.3	10.4
26	14.7	11.8	10.3	9.5	8.9	41	19.7	15.1	12.8	11.5	10.5
27	15.0	12.0	10.5	9.6	9.0	42	20.0	15.3	13.0	11.6	10.6
28	15.3	12.2	10.7	9.7	9.1	43	20.3	15.6	13.2	11.7	10.7
29	15.7	12.5	10.8	9.9	9.2	44	20.7	15.8	13.3	11.9	10.8
30	16.0	12.7	11.0	10.0	9.3	45	21.0	16.0	13.5	12.0	11.0
31	16.3	12.9	11.2	10.1	9.4	46	21.3	16.1	13.7	12.1	11.1
32	16.7	13.1	11.3	10.3	9.5						

	1 to 1	1 to 2	1 to 3	1 to 4	1 to 5
Cement	500	333	250	200	167
Sand	500	666	750	800	833

TIME OF SETTING

21. *Method.* For this purpose the Vicat Needle, which has already been described in paragraph 17, should be used.

22. In making the test, a paste of normal consistency is molded and placed under the rod (L), Fig. 2, as described in paragraph 18; this rod, bearing the cap (D) at one end and the needle (H), 1 mm. (0.039 in.) in diameter at the other, weighing

[1] The committee on Standard Specifications inserts this table for temporary use, to be replaced by one to be devised by the Committee of the American Society of Civil Engineers.

300 gr. (10.58 oz.). The needle is then carefully brought in contact with the surface of the paste and quickly released.

23. The setting is said to have commenced when the needle ceases to pass a point 5 mm. (0.20 in.) above the upper surface of the glass plate, and is said to have terminated the moment the needle does not sink visibly into the mass.

24. The test pieces should be stored in moist air during the test; this is accomplished by placing them on a rack over water contained in a pan and covered with a damp cloth, the cloth to be kept away from them by means of a wire screen; or they may be stored in a moist box or closet.

25. Care should be taken to keep the needle clean, as the collection of cement on the sides of the needle retards the penetration, while cement on the point reduces the area and tends to increase the penetration.

26. The determination of the time of setting is only approximate, being materially affected by the temperature of the mixing water, the temperature and humidity of the air during the test, the percentage of water used, and the amount of molding the paste receives.

STANDARD SAND

27. For the present, the Committee recommends the natural sand from Ottawa, Ill., screened to pass a sieve having 20 meshes per linear inch and retained on a sieve having 30 meshes per linear inch; the wires to have diameters of 0.0165 and 0.0112 in., respectively, i. e. half the width of the opening in each case. Sand having passed the No. 20 sieve shall be considered standard when not more than 1 per cent. passes a No. 30 sieve after one minute continuous sifting of a 500-gram sample.

28. The Sandusky Portland Cement Company, of Sandusky, Ohio, has agreed to undertake the preparation of this sand and to furnish it at a price only sufficient to cover the actual cost of preparation.

FORM OF BRIQUETTE

29. While the form of the briquette recommended by a former committee of the Society is not wholly satisfactory, this committee is not prepared to suggest any change, other than rounding off the corners by curves of ½-in. radius, Fig. 3.

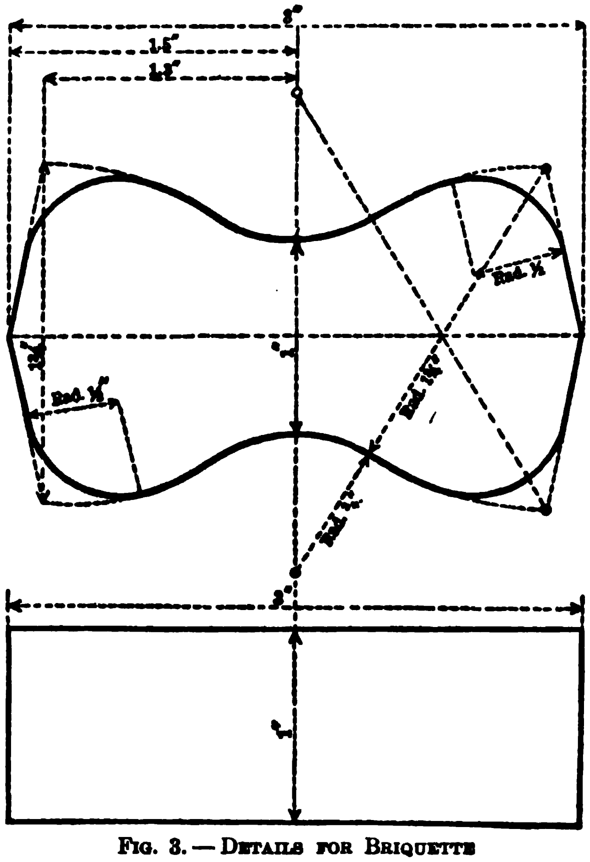


FIG. 3. — DETAILS FOR BRIQUETTE

MOLDS

30. The molds should be made of brass, bronze, or some equally non-corrodible material, having sufficient metal in the sides to prevent spreading during molding.

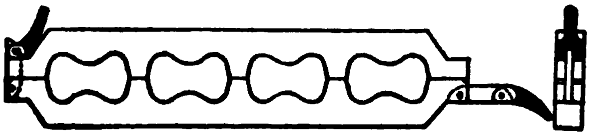


Fig. 4. — Details for Gang Flank

31. Gang molds, which permit molding a number of briquettes at one time, are preferred by many to single molds; since the greater quantity of mortar that can be mixed tends to produce greater uniformity in the results. The type shown in Fig. 4 is recommended.

32. The molds should be wiped with an oily cloth before using.

MIXING

33. All proportions should be stated by weight; the quantity of water to be used should be stated as a percentage of the dry material.

34. The metric system is recommended because of the convenient relation of the gram and the cubic centimeter.

35. The temperature of the room and the mixing water should be as near 21° C. (70° F.) as it is practicable to maintain it.

36. The sand and cement should be thoroughly mixed dry. The mixing should be done on some non-absorbing surface, preferably plate glass. If the mixing must be done on an absorbing surface it should be thoroughly dampened prior to use.

37. The quantity of material to be mixed at one time depends on the number of test pieces to be made; about 1000 gr. (35.28 oz.) makes a convenient quantity to mix, especially by hand methods.

38. *Method.* The material is weighed and placed on the mixing table, and a crater formed in the centre, into which the proper percentage of clean water is poured; the material on the outer edge is turned into the crater by the aid of a trowel. As soon as the water has been absorbed, which should not require more than one minute, the operation is completed by vigorously kneading with the hands for an additional 1½ minutes, the process being similar to that used in kneading dough. A sand-glass affords a convenient guide for the time of kneading. During the operation of mixing, the hands should be protected by gloves, preferably rubber.

MOLDING

39. Having worked the paste or mortar to the proper consistency, it is at once placed in the molds by hand.

40. *Method.* The molds should be filled at once, the material pressed in firmly with the fingers and smoothed off with a trowel without ramming; the material should be heaped up on the upper surface of the mold, and in smoothing off, the trowel should be drawn over the mold in such a manner as to exert a moderate pressure on the excess material. The mold should be turned over and the operation repeated.

41. A check upon the uniformity of the mixing and molding is afforded by weighing the briquettes just prior to immersion, or upon removal from the moist closet. Briquettes which vary in weight more than 3 per cent. from the average should not be tested.

STORAGE OF THE TEST PIECES

42. During the first twenty-four hours after molding, the test pieces should be kept in moist air to prevent them from drying out.

43. A moist closet or chamber is so easily devised that the use of the damp cloth should be abandoned, if possible. Covering the test pieces with a damp cloth is objectionable, as commonly used, because the cloth may dry out unequally, and in consequence the test pieces are not all maintained under the same condition. Where a moist closet is not available, a cloth may be used and kept uniformly wet by immersing the ends in water. It should be kept from direct contact with the test pieces by means of a wire screen or some similar arrangement.

44. A moist closet consists of a soapstone or slate box, or a metal-lined wooden box — the metal lining being covered with felt and this felt kept wet. The bottom of the box is so constructed as to hold water, and the sides are provided with cleats for holding glass shelves on which to place the briquettes. Care should be taken to keep the air in the closet uniformly moist.

45. After twenty-four hours in moist air, the test pieces for longer periods of time should be immersed in water maintained as near 21° C. (70° F.) as practicable; they may be stored in tanks or pans, which should be of non-corrodible material.

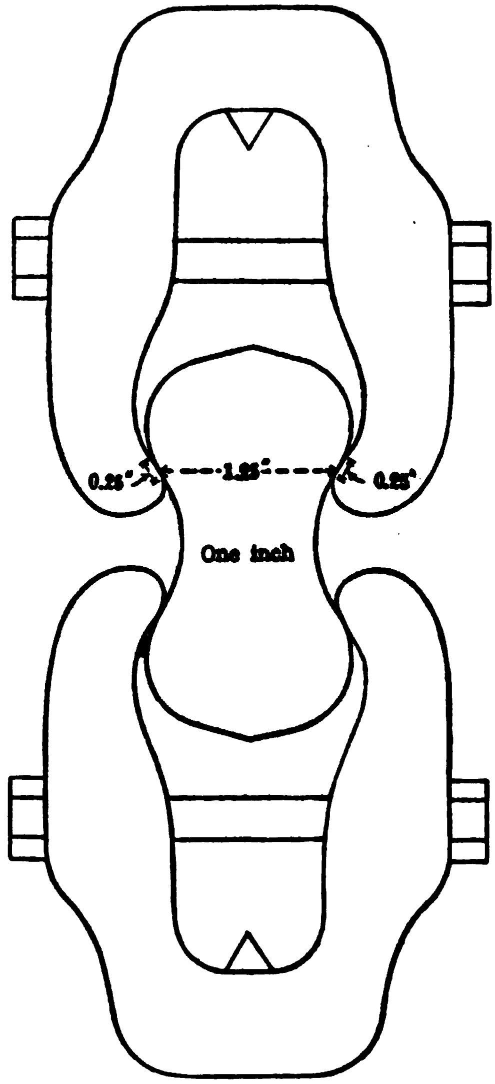


Fig. 5. — Form of Clip

TENSILE STRENGTH

46. The tests may be made on any standard machine. A solid metal clip, as shown in Fig. 5, is recommended. This clip is to be used without cushioning at the points of contact with the test specimen. The bearing at each point of contact should be ¼ in. wide, and the distance between the centre of contact on the same clip should be 1¼ in.

47. Test pieces should be broken as soon as they are removed from the water. Care should be observed in centring the briquettes in the testing machine, as cross-strains, produced by improper centring, tend to lower the breaking strength. The load should not be applied too suddenly, as it may produce vibration, the shock from which often breaks the briquette before the ultimate strength is reached. Care must be taken that the clips and the sides of the briquette be clean and free from grains of sand or dirt, which would prevent a good bearing. The load should be applied at the rate of 600 lbs. per minute. The average of the briquettes of each sample tested should be taken as the test, excluding any results which are manifestly faulty.

CONSTANCY OF VOLUME

48. *Methods.* Tests for constancy of volume are divided into two classes: (1) normal tests, or those made in either air or water maintained at about 21° C. (70° F.), and (2) accelerated tests, or those made in air, steam, or water at a temperature of 45° C. (115° F.) and upward. The test pieces should be allowed to remain twenty-four hours in moist air before immersion in water or steam, or preservation in air.

49. For these tests, pats about 7½ cm. (2.95 ins.) in diameter, 1¼ cm. (0.49 ins.) thick at the centre, and tapering to a thin edge, should be made, upon a clean glass plate [about 10 cm. (3.94 ins.) square], from cement paste of normal consistency.

50. *Normal Test.* A pat is immersed in water maintained as near 21 C. (70° F.) as possible for twenty-eight days, and observed at intervals. A similar pat is maintained in air at ordinary temperature and observed at intervals.

51. *Accelerated Test.* A pat is exposed in any convenient way in an atmosphere of steam, above boiling water, in a loosely-closed vessel.

52. To pass these tests satisfactorily, the pats should remain firm and hard, and show no signs of cracking, distortion, or disintegration.

53. Should the pat leave the plate, distortion may be detected best with a straight-edge applied to the surface which was in contact with the plate.

CHAPTER V

FOUNDATIONS

LOADING

THE floor slabs, beams, and girders throughout a building should be designed for full dead and live load.

It is considered safe by many architects and engineers to make reductions from column loading from floor to floor, on the assumption that the entire space of any one floor will not be loaded to its full capacity. The recommendation for floor loads by a committee of Boston engineers acting as a commission on the revision of the building laws is as follows: "All new or renewed floors shall be so constructed as to carry safely the weight to which the proposed use of the building will subject them, and every permit granted shall state for what purpose the building is designed to be used; but the least capacity per superficial square foot, exclusive of materials shall be: —

"For floors of houses for habitation, fifty pounds.

"For office floors and for public rooms of hotels and houses exceeding five hundred square feet, one hundred pounds.

"For floors of retail stores and public buildings, except schoolhouses, one hundred and twenty-five pounds.

"For floors of schoolhouses, other than floors of assembly rooms, eighty pounds, and for floors of assembly rooms, one hundred and twenty-five pounds.

"For floors of drill rooms, dance halls, and riding schools, two hundred pounds.

"The floors of warehouses and mercantile buildings, at least two hundred and fifty pounds.

"The loads for floors not included in this classification or for galleries shall be determined by the commissioner.

"The full floor load specified in this section shall be included in proportioning all parts of buildings designed for warehouses, or for heavy mercantile and manufacturing purposes. In other buildings, however, certain reductions may be allowed as follows: In girders carrying more than one hundred square feet of floor, the live load may be reduced ten per cent. In columns, piers, walls, and other parts carrying two floors, a reduction of fifteen per cent. of the total live load may be made; where three floors are carried the total live load may be reduced by twenty per cent.; four floors, twenty-five per cent.; five floors, thirty per cent.; six floors, thirty-five per cent.; seven floors, forty per cent.; eight floors, forty-five per cent.; nine or more floors, fifty per cent.

"The platforms, landings, and stairways of every fire escape shall be strong enough to carry a load of seventy pounds to the square foot in addition to the weight of material."

The foundations should be so designed as to carry the load transmitted to them by the columns, with an equal loading per square foot of bearing area for both interior and exterior footings, in order to prevent cracks that might be occasioned by any unequal settlements.

CLASSES OF FOUNDATIONS

Foundations are usually supported in two ways, either directly upon the soil or upon piles.

Borings or test pits should be made for every job of any importance, to determine the character of the soil, as there often may be strata of soft material underlying a hard surface material.

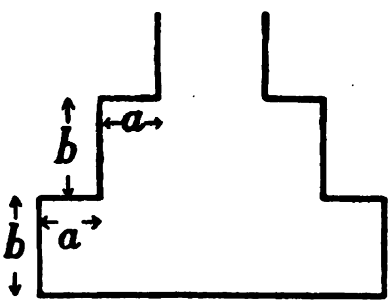
Pile foundations should be used wherever there is any question as to the bearing value of the soil being inadequate to the load.

The foundation of any structure is the last place to apply economy.

The cost of pile foundations will not average four per cent. of the cost of any ordinary building, and it would seem unwise to jeopardize ninety-six per cent. to save four per cent.

FOUNDATIONS DIRECTLY UPON THE SOIL. These are divided into two classes, plain foundations and grillage foundations.

The plain foundations do not generally require any great amount of engineering. The area of the footing should be such as to conform to the bearing value of the soil, which should be predetermined, and the depth should be at least one and one half times the projection from side of bearing area above, or $b = \frac{3a}{2}$ (see cut).



Footings may be built up in successive steps or in the shape of a truncated pyramid. The first method is the more economical owing to the simplicity of forms. It is difficult to keep the forms in position for the second method, as a mass of wet concrete deposited in them is liable to float them.

The concrete in the lower part of the footing should not be weaker than 1–3–6, and the upper portion must be of the same mixture as a supported concrete column. Where an iron bearing plate is used under a cast iron or steel column, its area must be such that the safe working strength of the concrete directly under it is not exceeded.

Whenever eccentricity of loading occurs, it should be properly taken care of in the design and the error should be guarded against of assuming the maximum load per square foot over the full bearing area.

When a great amount of excavation is necessary to carry footings to a satisfactory foundation, an economical method is to excavate inside a steel shell driven into the ground as the excavation progresses,—this excavation to be enlarged at the bottom of the shell to obtain the required bearing area. The full size of excavation is filled with concrete as soon as the excavation is completed.

FOUNDATIONS WITH STEEL GRILLAGE. The advantages of this type of foundation are in the saving of excavation, and in many cases shoring and pumping, also in obtaining a large bearing area on a poor soil. There is a considerable saving in labor and concrete materials with this method, but this saving in cost is usually balanced by the cost of the steel grillage..

Grillage foundations are especially adapted for chimneys, where it is desirous to obtain a uniform distribution of stress over a large area.

Mr. E. L. Ransome has published formulæ for this type of foundation which have been extensively used and are reprinted with his permission.

WALL AND PIER FOOTINGS

Figures 1 and 2 illustrate the general form and arrangement of tension bars in our standard wall and pier footings.

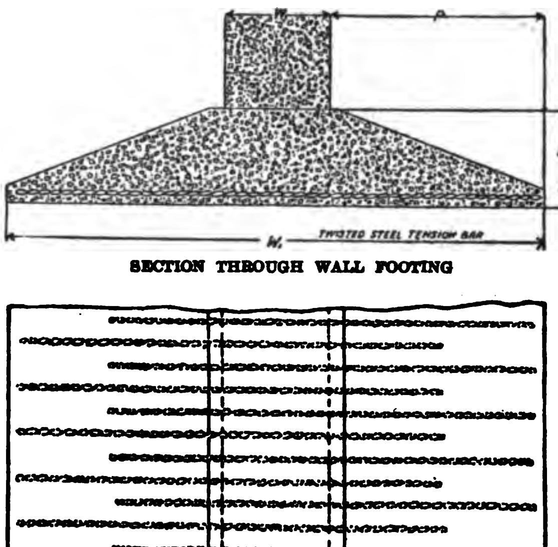
FORMULA FOR WALL FOOTINGS

We have given in all cases the width of the wall (W), the load per linear foot (L), and the width of the footing (W_1). The total stress in the tension bars or the total compression in the concrete per linear foot is

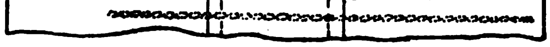
$$\text{Stress} = \frac{2\,LP}{7\,D},$$

in which L equals the total load in tons, P equals the projection in inches, and D equals the distance in inches from the top of the footing to the centre of the bars.

We have two unknown quantities, Stress and D. It is therefore unnecessary to impose another condition, and it is that when the safe compressive strength of the concrete equals 35 tons per square foot there shall be 16 square inches of concrete in the area above the bars for each ton stress or $16 \times \text{Stress} = 12 \times D$, from which $\text{Stress} = \frac{3}{4} D$.



SECTION THROUGH WALL FOOTING



PLAN OF WALL FOOTING

FIG. 1

This condition is necessary in order that the concrete shall not be strained beyond its safe compressive strength, and should be modified to suit this strength when the latter does not conform to the value of 35 tons. Substituting this value of Stress in the above formula and reducing, we have D equals the square root of $\frac{8\,LP}{21}$.

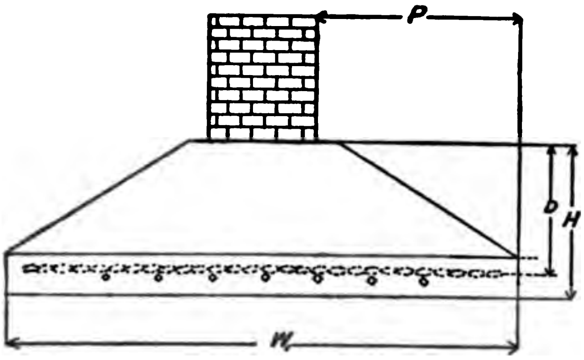
Having obtained D from this formula, the total stress in the bars in tons $= \frac{3}{4} D$. The bars may be placed as shown on plan. The size of the bars should be so taken that the bars will not be spaced more than 12 inches apart. The total height (H) of the footing should be at least 3 inches greater than the depth (D).

Example: Let $W = 2$ feet. Load $= 20$ tons per lin. ft. and Safe Bearing Power of Soil $= 2$ tons. Then $W_1 = 10$ feet and $P = 4$ feet. D equals the square root of $\frac{8 \times 20 \times 48 \text{ in.}}{21} = 19$ inches. And Stress $= \frac{3}{4} \times 19 = 14.25$ tons, requiring $\frac{3}{4}$-inch square bars $4\frac{3}{4}$ inches on centres. Their length would be $W_1 - \frac{P}{2} = 8$ feet.

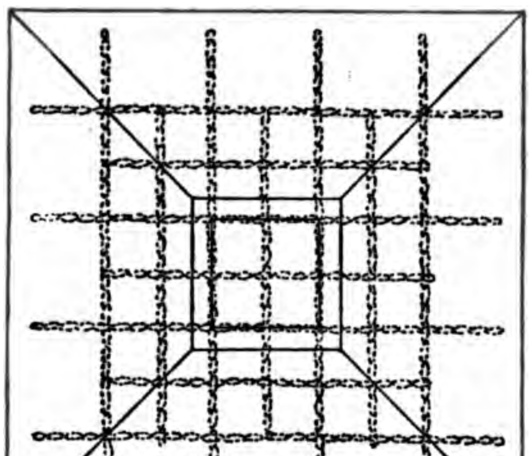
II. FORMULA FOR PIER FOOTINGS

As in the case for Wall footings, we have given the dimensions of the supported pier and footing (W and W_1) and the total load carried (L).

Our formula for obtaining the Stress in the tension bars running in each direction is $\frac{L \times P}{3 \times D}$ in which we have as before the two unknown quantities Stress and D. In order that the concrete may not be compressed beyond its safe working strength, we impose the condition $4 \times \text{Stress} = \frac{D}{2} \times (W + 6)$ from which Stress $= \frac{D \times (W + 6)}{8}$. Substituting this value of Stress in the above formula and reducing, we have D equals the square root of $\frac{8 \times L \times P}{3\,(W + 6)}$. Having obtained D by this formula, the total Stress in tons equals $\frac{W + 6}{8} \times D$, from which the size and number of bars running in each direction can be computed. These bars may be made in two lengths as shown on plan, Fig. 2, the shorter length being equal to $W + P$. The total height (H) should not be less than $D + 4$ inches.



ELEVATION OF PIER FOOTING



PLAN OF PIER FOOTING

FIG. 2

Example: Let $W = 16$ inches. Load $= 80$ tons. Safe bearing power of soil $= 2$ tons. The required area of base of footing is 40 square feet, and the width (W_1) equals the square root of $40 = 6$ feet 4 inches or 76 inches and $P = 30$ inches.

D equals the square root of $\frac{8 \times 80 \times 30}{3 \times 22} = 17$ inches. The total stress would therefore be $\frac{22}{8} \times 17 = 47$ tons requiring 9 $\frac{3}{4}$-inch bars or 19 $\frac{1}{2}$-inch bars in each direction.

These bars should be spaced equally over $W\ D$. The total height (H) would be $D+4$ inches.

In the examples given by Mr. Ransome he has used the square twisted bar, for which he has assumed a working srength of 20,000 pounds per square inch.

FOUNDATIONS ON PILES

There are two classes of pile foundations: —

First: where the piles pass through a soft material to a hard underlying strata.

Second: Where the piles are sustained by friction or suction and do not reach a point where the penetration is suddenly arrested.

Wooden piles are more generally used, although there are several types of concrete piles. As a rule, however, concrete piles cannot be used to advantage for lengths of over 25 or 30 feet, and the economy in their use consists in the saving of the excavation for and the placing of heavy concrete foundations which would be necessary where wood piles must be cut off at a low grade.

A great many claims have been made as to the superior supporting value of concrete piles over wooden piles. The testimony supporting these claims has been mostly submitted by interested parties, and the author recommends that a thorough investigation of the character of the soil, the design and size of the pile, and the method of driving be made before the supporting value of the pile is fixed.

PENETRATION OF WOODEN PILES

In the first class of pile foundations the penetration due to a 2000-pound hammer falling ten feet should not be over one inch for the last blow, and if the penetration does not exceed this a safe load of 16 tons per pile may be assumed. In the second class an ordinary rule is that the penetration under the same hammer and drop shall not be over three inches for the last blow, and that a safe load of 10 tons per pile may be assumed.

There has been considerable dissension in regard to this rule, inasmuch that it makes no account of the frictional resistance of piles of different sizes.

W. M. Patton in his "Practical Treatise on Foundations" suggests a formula for frictional resistance of piles made up as follows: —

S equals $(W-P)\div F$ where

S = square feet of surface of pile in contact with soil.

W = load on pile.

P = bearing power of soil per square foot.

F = working value of friction of soil on superficial area of pile, per square foot.

P is the safe loads for various soils in the following table, and may be neglected in loose soils, as its proportional value is small.

Ledge Rock	36	tons per square foot.
Hard pan	8	" " " "
Gravel	5	" " " "
Clean sharp sand	4	" " " "
Dry clay	3	" " " "

Wet clay 2 tons per square foot.
Loam 1 " " " "

F will vary from 50 to 150 pounds per square foot for soft semi-fluid soils, varying with their consistency; from 150 to 250 pounds per square foot for mixed earths and gritty soils, and from 200 to 300 pounds per square foot for compact clays, sand, and gravel.

In the eastern section of the United States, spruce piles are the cheapest. They are cut in lengths of from 20 to 50 feet, and measure from 4 to 6 inches at the tip and from 10 to 14 inches at the head.

For the first class of foundations the diameter of tip only should be specified, and it should not be less than 6 inches under the bark.

For the second class, where friction is depended upon almost wholly, the size of the tip is of not so much importance, and the size of the head should be specified not less than 11 inches.

It is necessary sometimes to use a greater length of pile than can be obtained in spruce. Hard pine, Norway pine, or chestnut piles can be obtained in lengths up to 75 or 80 feet with a head diameter of approximately 16 inches.

CUTTING OFF PILES

Piles should be cut off at a grade where the soil is constantly wet, as an alternately wet and dry condition will inevitably cause decay.

Where piles are exposed to tide water by filtration through the soil, it is customary to specify cutting them off at half tide level.

In clay or muck which does not permit the water to escape readily on a receding tide, the piles may be cut off at a foot or two higher level without danger of decay. Many cities and towns have ordinances requiring piles to be cut off at certain fixed grades which must be complied with.

SPACING OF PILES

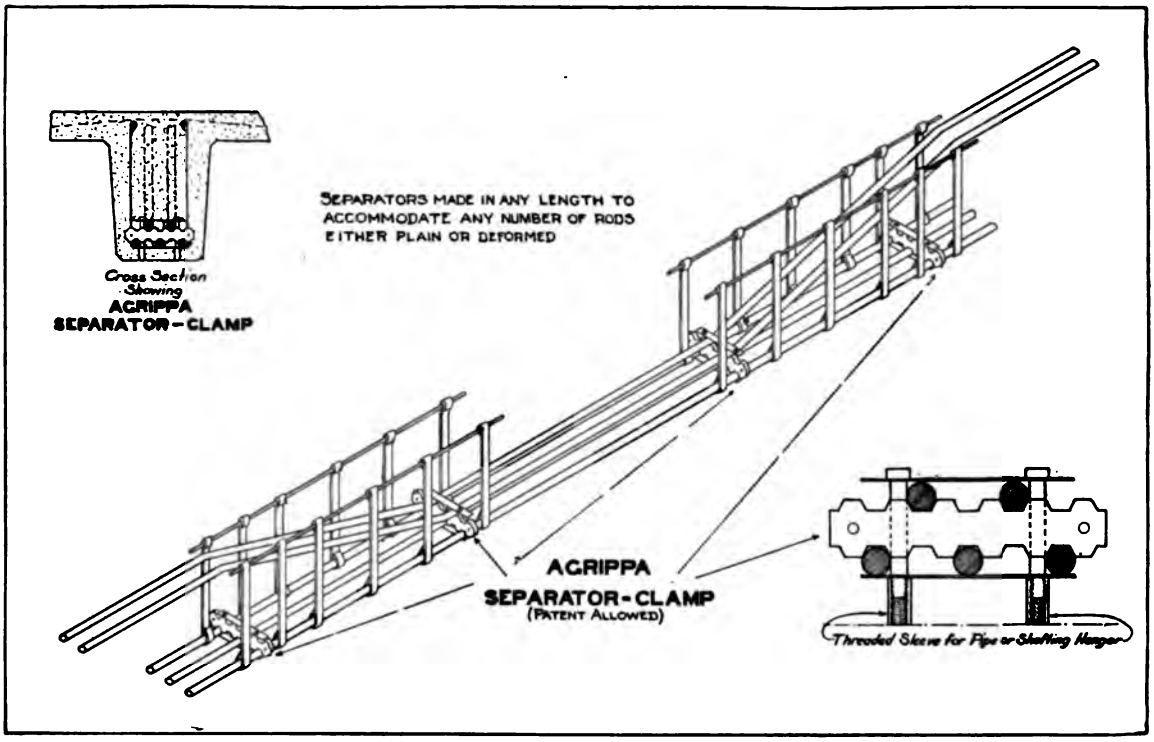
In hard soils piles may be spaced as closely together as 2 feet 6 inches on centres. In soft soils they should be spaced 3 feet or 3 feet 6 inches on centres. Heads of piles should be encased in concrete capping.

Saw all piles off in each footing either at the specified grade or lower if necessary, to cut off any broomed or damaged heads. Excavate around piles to a depth of 6 inches below top of pile and see that tops of piles are clean and that dirt is rammed solidly around them before concrete is deposited. The concrete should be of sufficiently rich mixture so that the load carried on the head of the pile does not exceed the safe compressive strength of the concrete.

For example. A pile with a 11-inch diameter head supports 16 tons or 32,000 pounds. The area of the head is approximately 85 square inches. 32,000 divided by 85 equals 376 pounds per square inch. The concrete capping in this case should not be leaner than 1–2½–5.

"AGRIPPA" SEPARATOR-CLAMP

FOR BEAM AND GIRDER REINFORCEMENT



The necessity of keeping steel reinforcement in the position designed is recognized by all engineers and architects. The cut above shows the simplest and most economical form that can be devised for this purpose.

Our " Agrippa " separator-clamp admits using any type of rod.

Steel may be bought in the open market, and assembled on the floor alongside of the beams.

When it is placed in the beams, after assembling, the concrete may be poured and tamped around it without danger of displacement.

It is not necessary to pay exorbitant prices for the patented "systems" of reinforcement to get this result.

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We have laid 9000 square feet of floor, including girders and beams in sixteen hours without a man on steel reinforcement after beginning concrete work.

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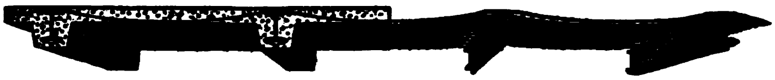

NOTE CONTINUOUS BOND

No Entire Collapse of any Arch Reinforced with CLINTON WELDED WIRE can occur

unless the weight imposed upon the arch is sufficient to strain and break all of the wires.

This is due to the fact that **Clinton Welded Wire,** made from 6 to 10 gauge drawn steel wire, galvanized or plain, can be laid in lengths up to 300 feet, thereby forming a continuous bond for that distance. In a building 200 feet long, for instance, our reinforcing is secured at the front or rear of the building, and carried through the entire distance without a break. Heavier gauge wire will be laid in lengths up to 150 feet and locked or hooked to the next sheet, where building requires more than one sheet in length.

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