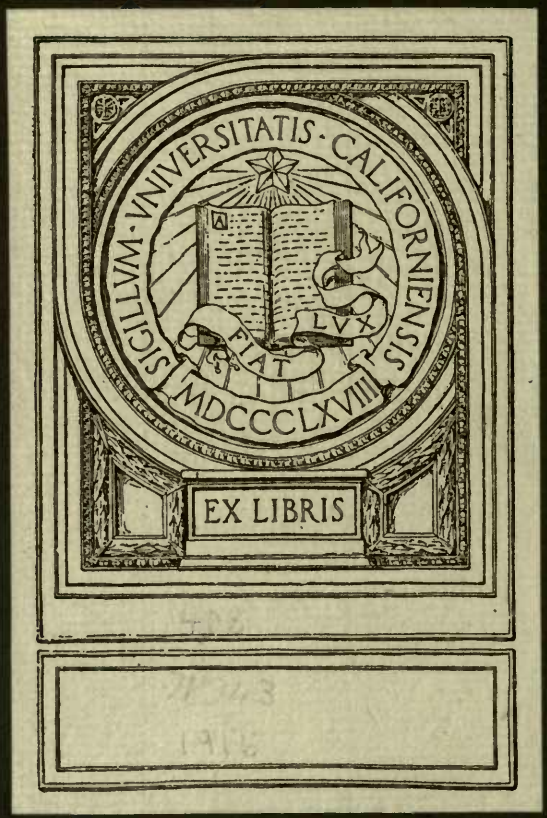
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GENERAL SPECIFICATIONS

FOR

CONCRETE BRIDGES

BY

WILBUR J. WATSON
Mem. Am. Soc. C. E.

THIRD EDITION

1916

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"Bridges ought to have the self-same qualifications we judge necessary in all other buildings, which are, that they should be commodious, beautiful and lasting."

—Andrea Palladio.

Preface

The first edition of these specifications was published in 1908 and the second in 1910. In order to bring this edition up to date, it has been found necessary to make some radical changes in the requirements, particularly in the section devoted to the Quality of Materials. The sections on Surface Finish and Waterproofing have been completely rewritten. It is in the branches of the Art, covered by these three sections, that the greatest advancement has been made in the past six years.

The two previous editions have been widely used by designing engineers for railroads, cities and counties, and as a standard basis for the preparation and comparison of competitive designs. It is hoped that the present edition will be found to be even more valuable for these purposes.

The value of concrete and reinforced concrete as a material of construction has been firmly established during the past decade, as has also the necessity for careful design, selection of materials and execution. Practically all of the troubles and failures which have occurred could have been avoided by the careful observance of specifications such as are given herein.

Cleveland, Ohio, January, 1916. WILBUR J. WATSON.

Index to Sections

Definitions, Classification and Loads

1. CONCRETE is defined as a structural material composed of a mixture of coarse and fine aggregates, with a cementing material, the latter being assumed to be Portland Cement, unless otherwise specified.

2. MASS CONCRETE is defined as concrete containing no steel reinforcement to assist in resistance to stress.

3. Mass concrete may contain dowels, anchors or ties.

4. RUBBLE CONCRETE is defined as concrete containing large embedded stone, and may be used where very large masses of concrete are required.

5. REINFORCED CONCRETE is defined as concrete containing reinforcing members of steel, so placed as to provide the necessary resistance to tensile stresses, and to assist in the resistance to shearing (web stresses) and compressive stresses when required.

6. Reinforced concrete is divided into two sub-classes:

(a) MONOLITHIC CONSTRUCTION or concrete moulded in place, and

(b) UNIT CONSTRUCTION or concrete not moulded in place but put together in units, such as structures consisting of slabs, beams, girders and columns manufactured in a factory or yard and erected in place.

7. CAST STONE work will include cast concrete facing blocks, railings and ornamental work constructed of separately moulded and cast blocks of concrete.

8. Concrete Bridges are divided according to use into the following classes:

Class A—Heavy Railroad Bridges.
" B—Light Railroad Bridges.
" C—Heavy Electric Railway Bridges.
" D—Light Electric Railway Bridges.
" E—City Highway Bridges carrying Electric Railway Tracks.
" F—City Bridges without Electric Railway Tracks.
" G—Suburban Bridges carrying Electric Railway Tracks.
" H—Suburban Bridges without Electric Railway Tracks.
" I—Light Country Bridges.
" J—Foot Bridges.

9. Concrete Bridges are divided according to design into the following types:

(1) Circular and Box Culverts.
(2) Slab Bridges.
(3) Deck Beam Bridges.
(4) Through Girder Bridges.
(5) Arch Bridges.
(6) Cantilever Bridges.
(7) Truss Bridges.
(8) Viaducts.

10. Bridges will be designated by reference to class and type; thus a city highway arch of 60 foot span and carrying electric railway tracks, should be designated as a Class E Arch Bridge.

11. Class A Bridges shall be designed, unless otherwise specified, for Coopers E60 loading and shall be used for all railroads carrying heavy traffic, hauled by locomotive power.

12. Class B Bridges shall be designed, unless otherwise specified, for Coopers E40 loading and shall be used for railroads carrying light traffic, hauled by locomotive power.

13. Class C Bridges shall be designed, unless otherwise specified, for two 100 ton (200,000 lb.) cars entrain, wheel base 6 feet, 22 feet center to center of trucks, and shall be used for electric railways carrying very heavy traffic.

14. Class D Bridges shall be designed, unless otherwise specified, for two 50 ton (100,000 lb.) cars entrain, wheel base 6 feet 22 feet center to center of trucks, and shall be used for electric railways carrying light traffic.

15. Class E Bridges shall be designed for

(a) A concentrated live load of 24 tons (48,000 lbs.) on two axles, 12 foot centers and 6 foot gauge, assumed to occupy a space 10 feet wide by 30 feet long; and

(b) A uniformly distributed load of 100 lbs. per square foot on all roadways and footwalks.

(c) The street railway tracks shall be assumed to carry the loads specified for Class D Bridges.

16. Class F Bridges shall be designed to carry the concentrated and uniformly distributed live loads as given for Class E.

17. Class G Bridges shall be designed to carry a concentrated live load of 18 tons (36,000 lbs.), and a uniformly distributed live load of 100 lbs. per square foot of roadways and footwalks arranged as for Class E Bridges. The street railway tracks shall be assumed to carry the loads specified for Class D Bridges.

18. Class H Bridges shall be designed to carry a concentrated live load of 15 tons (30,000 lbs.) and a uniformly distributed live load of 100 lbs. per square foot arranged as for Class E.

19. Class I Bridges shall be designed to carry a concentrated live load of 12 tons (24,000 lbs.) and a uniformly distributed live load of 75 lbs. per square foot arranged as for Class E.

20. Class J Bridges shall be designed for a uniformly distributed live load of 75 lbs. per square foot.

21. Bridges designed for other loads than given herein shall be classed special and that letter shall be used to designate them which is used herein to represent that class to which they most nearly conform; thus an electric railway bridge designed for 60 ton cars should be designated as Special Class D.

22. An addition shall be made to all stresses caused by concentrated live loads to cover the effects of impact, vibration, etc., which shall be determined in the following manner:

For Classes A and B, Impact $= S\frac{300}{L+300}$, and for Classes C and D, Impact $= S\frac{225}{L+300}$.

For all other Classes, Impact $= S\frac{150}{L+300}$.

where I = impact to be added to the live load stress,

S = calculated maximum live load static stress,

L = length of loaded distance in feet which produces the maximum stress in the member.

23. The above impact formulas are to be used without reduction when the concentrated loads are carried directly upon the structure and pass over same at full speed. When there is provided a cushion of sand, 6 inches or more in thickness, or an equivalent cushion between the pavement or ties, which carry concentrated loads, and the structure itself, the impact stresses may be reduced 20%, and 10% additional for each additional foot of such earth or sand cushion.

24. For Classes A, B, C and D, the amount of impact may be reduced for structures carrying sidetracks, or other locations that do not permit the passage of loads at high speed, the amount of reduction to be determined by the Engineer in charge for each case.

25. When the live load stress is of an opposite sign to the dead load stress, then the impact shall be assumed to be in all such cases equal to the live load stress, and in case of reversal of stress by live load the member shall be proportioned for a stress equal to the sum of the greater and one-half the lesser maximum stresses.

26. Wind pressure shall be assumed at 50 lbs. per square foot on the greatest vertical projection of the structure unloaded for all classes, and 30 lbs. per square foot on the same surface, plus 400 lbs. per lineal foot, applied 7 feet above the rail for Classes A, B, C and D, when loaded, the load being assumed to weigh 1,200 lbs. per lineal foot.

27. Classes A, B, C and D Bridges shall be computed for a lateral force of 200 lbs. per lineal foot plus 10% of the specified train load on one track, these forces being considered as moving. The lateral force shall be used for lateral systems only and shall be considered as replacing the wind load given above, when giving larger stresses.

28. When the structure is on a curve the Centrifugal Force shall be considered and calculated, for all classes carrying tracks, by the formula

$C = 0.03\ W\ D$ for curvature up to 5° $\quad D =$ degree of curvature

Where $C =$ Centrifugal force in pounds $\quad W =$ weight of train in pounds

The co-efficient for centrifugal force (0.03) shall be reduced 0.001 for every degree of curvature above 5°.

29. The effect of suddenly stopping the moving load shall be considered the co-efficient of friction of wheels sliding upon the rails being assumed at 0.2.

Rules for Computing and Designing

WEIGHTS.

1. The weight of Tracks (Rails and Ties) shall be taken at 250 lbs. per lineal foot for ballasted construction, and 400 lbs. per lineal foot for timber deck construction.

2. The weight of Ballast for Classes A, B, C and D shall be assumed at 1,200 lbs. per lineal foot of track with sub-grade 21 inches below top of rail and 14 feet wide for single track and 27 feet wide for double track.

LIVE LOAD DISTRIBUTION.

3. Concentrated axle loads from locomotive and motor wheels may be considered as distributed over a length of rail equal to 5 feet. The lateral distribution may be assumed to be equal to the gauge of track, plus 3 feet, plus twice the value of d_2, (See Section IV) but shall not exceed the spacing of the tracks.

4. When tracks are carried on a fill of 4 feet or more over concrete slabs or arches, the lateral distribution may be assumed as equal to the track spacing or as equal to 14 feet in the case of single track.

5. Concentrated loads on reinforced concrete slabs may be assumed to be distributed over a distance of 4 feet at right angles to the supports, and a distance equal to 2 feet plus 3/10 L, parallel to the supports where L = the clear span of the slab between main supports. For panels supported on four sides, when the long side does not exceed by more than 25% the short side, the load may be assumed to be distributed in both directions a distance equal to 2 feet plus 3/10 L.

6. In the case of stringers for highway bridges and similar construction, the maximum concentrated loads on any stringer shall be assumed to be the total concentrated load which can be placed directly over that stringer, multiplied by the distance between the stringers, and divided by the gauge or distance apart (measured at right angles to the line of the stringers) of the concentrated loads.

LENGTH OF SPAN.

7. The length of span for reinforced concrete slabs, beams, girders and trusses, when computed as simple beams, shall be considered to be the clear distance between supports. When computed as continuous or fixed beams, the length of span shall be considered to be the distance between centers of support.

8. All slabs, beams and girders of monolithic construction shall be considered, unless otherwise shown on the drawings, to be partially continuous and shall have reinforcement in the upper part of the beam at the supports. Provision for taking care of stress, due to negative moment over the supports, shall never be omitted, unless such slabs, beams and girders are so detailed that they cannot act as continuous beams.

9. The theoretical length of span for arches shall be considered to be equal to the span of the neutral axis of the arch ring.

10. The theoretical rise of arches shall be assumed to be the distance from the line connecting the ends of the neutral axis to the neutral axis at the crown.

11. The above definitions for span and rise of arches are for computing purposes only; the actual span and rise shown on construction drawings shall be the clear span between springing lines and the clear rise to the intrados of the arch.

MOMENTS.

12. For simple beams, the bending moments due to external forces shall be determined by the usual methods; and for partially continuous or restrained beams, the maximum positive bending moment shall be taken at 8/10 the corresponding moment as determined for simple beams, and the maximum negative moment at intermediate supports shall be taken at not less than ⅔ the maximum positive moment, and at end supports at not less than ⅓ the maximum positive moment. The above requirement is intended to apply to the usual "T" beam construction. Whenever it is practicable to determine more exactly the maximum positive and negative moment, such determination shall be made.

13. In proportioning columns, the effect of eccentric loading shall be taken fully into account, whether said eccentricity be caused by unbalanced or unequal loading or by details of construction.

THEORETICAL ASSUMPTIONS.

14. All tensile stresses shall be considered to be resisted by the steel reinforcement; no allowance shall be made for concrete in tension.

15. The stress-strain curve of concrete in compression shall be assumed to be a straight line.

16. The Modulus of Elasticity of concrete shall be taken as 2,000,000 lbs. per square inch (= 1/15 that of steel) for 1-2-4 (No. 6) concrete having an ultimate strength at 60 days of 2,000 lbs. per square inch, or less; 2,500,000 (= 1/12 that of steel) for 1-1½-3 (No. 4½) concrete having an ultimate strength between 2,200 and 2,400; and 3,000,000 (= 1/10 that of steel) for 1-1-2 (No. 3) concrete having an ultimate strength in excess of 2,400 lbs. per square inch. These modulii shall be assumed to be constant within the limits of the allowable range of stress.

17. A plane before bending shall be assumed to remain a plane after bending.

18. Initial stresses in concrete and steel due to shrinkage of concrete in setting shall be neglected.

"T" BEAMS.

19. In the computation of the resistance of "T" beams, the portion of the slab that may be assumed to assist in compression shall be limited so that in no case shall the projecting part of the slab portion exceed in width four times the thickness of the slab, and the total top width shall not exceed three times the thickness of the stem, or one-fourth the span of the slab or of the beam.

20. When the thickness of the slab portion is less than .35 the total depth of the beam, the increased compression in the slab shall be taken into account, and the ratio of steel area in tension to the area of the enclosing concrete rectangle shall be reduced. (See Table, page 21).

21. When the thickness of the slab portion of a "T" beam is less than one-fifth the depth of the stem, fillets shall be used at the juncture of slab and stem, the thickness of which at the stem shall be not less than one-fifth the depth of the stem, and such fillet shall extend, when possible, to the limits of the slab portion of the "T" beam. The slab part of the "T" beams shall be placed at the same time and be composed of the same materials and class of concrete as the stem.

22. In designing partially continuous "T" beams the compression in the lower portion of the stem at point of maximum negative moment shall be computed and if it exceeds the maximum allowable unit stress on concrete, sufficient compressive reinforcement shall be provided.

WEB REINFORCEMENT.

23. Whenever the unit web tensile stresses on concrete exceed the allowable unit stresses, as given in Section III, steel stirrups shall be used to provide for the excess tensile stresses or part of the rods shall be bent up in such a manner as to provide the necessary resistance, but in

the latter case, care shall be taken to leave enough rods in the lower portion of the beam at the ends to provide the adhesion required to develop the tensile stress at any point, and if necessary, the straight bars shall be anchored at the ends.

24. In no case shall flange reinforcement be assumed to assist in the resistance to web stresses.

25. In reinforcing to provide resistance to web tension, diagonal bars, rigidly attached to the main reinforcing bars in such a way as to transmit the full strength of the web bar into the main bar without distortion of the connection, shall be preferred. The web bars, designed in this way and having a length above the neutral axis sufficient to develop the full strength of the member by adhesion and having all bends of a radius not less than eight times the side or diameter of bar, may be stressed to 12,000 lbs. per square inch.

26. Vertical stirrups shall pass under the main bars or be rigidly attached thereto. Stresses in vertical stirrups shall not exceed 10,000 lbs. per square inch.

27. Web reinforcing bars shall be spaced a distance apart not exceeding the depth of the beam from the compressive surface to the reinforcement (d_2) for diagonal members or one-half this distance for vertical members when used alone. When vertical members are used in combination with diagonal members, each may be spaced a distance apart not exceeding d_2.

FOOTINGS.

28. In computing reinforced concrete footings, the combined compressive stress, due to bending in several directions, shall not exceed the allowable unit stress. In computing shearing stresses, the column load may be assumed to spread outward from the base of the column at an angle not greater than 35° with the vertical. The shear along this 35° surface shall not exceed the allowable unit for diagonal tension in concrete. The load carried by the footing area within the 35° planes may be deducted from the total column load in computing this shear.

29. All reinforcing bars in concrete footings shall be protected with not less than 2½ inches of concrete.

TEMPERATURE.

30. The coefficient of expansion of concrete due to temperature changes shall be assumed to be .0000055 per degree Fahrenheit.

31. A range of temperature from +20° to +90° Fahr. shall be assumed for latitude 40° and this shall be increased for higher latitudes and decreased for lower latitudes. Stresses due to temperature will be combined with dead and live load stresses to obtain maximum unit stresses.

32. In computing stresses in arches, the range of temperature shall be assumed at +35° Fahr. unless otherwise specified.

SHRINKAGE.

33. The coefficient of contraction or shrinkage of concrete set in air shall be assumed at .002 divided by the ratio of the amount of aggregates to the amount of cement (= .002 divided by number of mix).

34. The contraction or shrinkage of concrete set in air shall be provided for by proper details.

35. In computing stresses in arches, the effect of the rib shortening, due to loads, shall be taken fully into account, but the effect of contraction due to setting may be neglected.

LOADS ON CULVERTS.

36. The pressure of earth fill over the tops of culverts imbedded in earth embankments shall be assumed to be equal to the total weight of the material above the top of the culvert without any allowance for arching action.

37. The lateral pressure on the side walls of culverts imbedded in earth embankments shall be assumed to be equal to 25% of the weight on the top.

GENERAL.

38. Rectangular slabs supported on four sides and reinforced in two directions shall be proportioned on the assumption that the loads carried by the two systems are in inverse proportion to the fourth powers of the sides.

39. All reinforcing bars shall be of sufficient length to develop the full stress in the bar at all points without exceeding the allowed unit stress of adhesion of concrete to steel, or proper anchorage must be provided.

40. Care shall be taken to insure that all reinforcing bars over supports have sufficient length to develop their computed stress by adhesion.

41. A bend of 90° or more at the end of a bar shall be considered capable of developing not more than one-half the tensile strength of the bar.

NOTE:—Usually, when bars are anchored at the ends, the stress at the point of anchorage is much less than the working strength of the bar, the greater part of the load having been already relieved by adhesion, and a radius of bend of 3 inches will be sufficient, provided that five-eighths of the load is taken care of by adhesion.

42. Members subject to combined stresses, such as a combination of direct compression and compression due to bending, shall be so proportioned that the combined stresses shall not exceed the allowed maximum stresses as given in Section III.

43. Floor systems composed of reinforced concrete beams, separated by tile or metal fillers, shall be so designed that no reliance is placed upon the tile or metal fillers for strength.

44. All calculations shall be made to working stresses and safe loads as given in Section III.

Working Unit Stresses

1. The unit stresses given in this section apply only to concrete of the mixtures proportioned as herein specified and possessing the strength specified therefor. For mixtures of other proportions, the unit stresses used shall be in direct ratio of the strength of such mixtures to the strength of the standard mixtures as given in Section VI, both strengths being taken at sixty days.

BEARING

2. The bearing of masonry plates on 1-3-6 (No. 9) concrete shall not exceed 400 lbs. per square inch; on 1-2-4 (No. 6) concrete 500 lbs.; on 1-1-2 (No. 3) concrete 600 lbs., and the area of the bearing plate shall not exceed one-half the area of the surface receiving said plate.

COMPRESSION

3. The direct compressive stress in massive concrete shall not exceed 400 lbs. for 1-3-6 (No. 9) concrete or 500 lbs. for 1-2-4 (No. 6) concrete.

4. The compressive stress in reinforced concrete due to bending shall not exceed 550 lbs. per square inch for 1-2½-5 (No. 7½) concrete nor 700 lbs. per square inch for 1-2-4 (No. 6) concrete, when determined by the straight line formula.

5. The maximum allowable stress on steel in compression, when not otherwise specified herein, shall not exceed the maximum co-existing stress in the contiguous concrete multiplied by the ratio of the modulus of elasticity of the steel to that of the concrete. See Paragraph 9.

COLUMNS

6. All concrete in columns, unless otherwise specified, shall be 1-2-4 (No. 6) mix.

7. The direct compression on plain concrete columns shall not exceed 300 lbs. per square inch and the length of such columns shall not exceed six times their least side.

8. For reinforced concrete columns, whose length exceeds twelve times the diameter or least side, the unit stresses in steel and concrete shall be reduced 10% for each additional foot, or fraction thereof, in length of column.

9. The direct compression on concrete columns, reinforced by vertical rods only, shall not exceed 400 lbs. per square inch on 1-2-4 (No. 6) concrete when the reinforcement is not less than ½% of the concrete section, which is the minimum amount of reinforcement which shall be considered in a reinforced concrete column. All columns having less than this amount shall be assumed to be plain concrete columns. The longitudinal reinforcing bars shall not exceed 4% of the total concrete section, and shall be assumed to assist in carrying the direct load at a unit stress of 10,000 lbs. per square inch. The unit compressive stress on concrete shall be applied to the total column section, no deduction being made for the area of the reinforcement.

10. When the reinforcement consists of vertical bars and spiral hooping, the concrete shall not be stressed more than 650 lbs. per square inch on the gross area within the hooping for 1-2-4 (No. 6) concrete, provided that the amount of vertical reinforcement be not less than the spiral reinforcement nor greater than 5% of the area within the hooping; that the percentage of spiral hooping be not less than ½% and not to exceed 1½% of gross area within the hooping; that the pitch of the spiral be uniform and not greater than 3 inches; that the spiral be properly secured

to the verticals; and that the verticals be not less than four in number for columns having cores 12 inches or less in diameter, nor less than eight for larger columns. In such columns the vertical steel may be assumed to assist in carrying the direct load at a unit stress of 10,000 lbs. per square inch, and the hooping may be considered as equivalent to 2.4 times its volume, taken as vertical reinforcement.

11. When a mixture of 1-1½-3 (No. 4½) is used for the concrete, the unit load on the concrete core may be taken at 750 lbs. per square inch on the gross area within the hooping, the steel stress remaining at 10,000 lbs. per square inch.

12. Longitudinal bars shall be securely tied together at intervals not exceeding one foot.

13. Hooping or ties for non-spiral columns shall be not less than ¼ inch in diameter for all main longitudinal bars of one inch or greater in diameter, or one-quarter the size of main bars for smaller sizes.

14. Longitudinal compression rods in columns shall be spliced by lapping above or below the floor level a sufficient amount to develop the stress in same by adhesion, or dowels or splice bars shall be provided sufficient to develop not less than three-quarters the calculated stress in the bars of the upper column.

PUNCHING SHEAR

15. The direct or punching shearing stress on concrete shall not exceed 150 lbs. for 1-2-4 (No. 6); 130 lbs. for 1-2½-5 (No. 7½) and 110 lbs. for 1-3-6 (No. 9) and shall be computed on the total depth.

NOTE: Direct or punching shear results from the action of a column on its footing, or similar construction, and is not to be used as a measure of diagonal tension.

VERTICAL SHEAR

16. The unit vertical shearing stress in beams shall be used as a measure of the diagonal web tension, and shall not exceed 150 lbs. per square inch on 1-2-4 (No. 6) concrete, or 120 lbs. on 1-2½-5 (No. 7½) concrete, disregarding the reinforcement. The concrete shall be assumed to take 50 lbs. per square inch for 1-2-4 (No. 6) concrete and 40 lbs. per square inch for 1-2½-5 (No. 7½) concrete. Reinforcing steel shall be provided for the balance. The unit vertical shearing stress shall be determined by dividing the total vertical shear by the effective shearing area [= beam width (b) into the depth between the lines of action of the compressive and tensile stresses (d_s)]. The unit stress in the concrete shall also be applied to the effective shearing area, in determining the total vertical shear taken by the concrete.

ADHESION

17. The adhesive stress of concrete to plain steel bars shall not exceed 60 lbs. per square inch for 1-2-4 (No. 6) concrete, nor 50 lbs. for 1-2½-5 (No. 7½) concrete. When deformed bars are used, these values may be doubled.

ANCHORAGE

18. The length of anchorage required to develop the full strength of plain and round bars shall be determined by the adhesion as given above. This anchorage may be reduced 50% for plain bars anchored at the ends by bending through 90° or more.

TENSION

19. The working unit stress of steel reinforcing bars in tension shall be taken at 16,000 lbs. per square inch for structural grade and 18,000 lbs. for hard grade, except as modified herein for steel reinforcement used as web members.

FOUNDATIONS

20. The maximum allowable loads on foundations shall, unless otherwise indicated, be taken as follows:

On dry coarse gravel, well cemented,	five tons (10,000 lbs.)	per sq. ft.
On dry, hard sand and clay,	four tons (8,000 lbs.)	" " "
On ordinary dry clay and sand,	three tons (6,000 lbs.)	" " "
On wet sand,	two tons (4,000 lbs.)	" " "
On wet clay,	one ton (2,000 lbs.)	" " "

The maximum allowable load on foundation material other than that given will be determined for each individual case by the Engineer in charge.

REINFORCED STEEL

21. In case of reinforced steel construction, in which a structural steel frame, before being encased in concrete, is designed to carry a definite portion of the loads, the unit stresses in the steel frame, when carrying its portion of the load alone, must not exceed those allowed by the specifications of The American Railway Engineering Association, and the unit stresses in the steel and concrete after completion shall not exceed those given herein for reinforced concrete construction.

Formulas

In computing unit stresses, moments of resistances, etc., the following formulas shall be used.

NOTATION

The units are always in pounds and inches unless otherwise stated.

d_1 = Total depth of beam
d_2 = Distance from compressive surface of concrete to center of steel reinforcement
$d_3 = jd_2$ = Distance from centroid of compressive forces to center of steel
d' = Depth from compressive surface of concrete to steel in compression
j = Ratio of distance between centroid of compressive forces and center of steel to distance of center of steel below compressive surface of concrete
k = Ratio of depth of neutral axis to depth of steel in tension
kd_2 = Distance from compressive surface to neutral axis of beam
h = Ratio of depth of steel in compression to depth of steel in tension
b_1 = Width of simple or width of stem of "T" beam
b_2 = Width of flange of "T" beam
t = Thickness of flange of "T" beam
O = Perimeter of a reinforcing bar at any section
ΣO = Sum of perimeters of all bars
a_1 = Area of steel tension bars at any cross-section
a_2 = Area of web reinforcing bars at any longitudinal section equal to d_3 in length
a_3 = Area of steel compression bars at any cross-section
p = Ratio of cross-section of steel in tension to cross-section of beam above the center of gravity of the steel in tension
p' = Ratio of cross-section of steel in compression to cross-section of beam above the center of gravity of the steel in tension
s = Spacing of stirrups at any section
M = Bending moment in inch pounds from exterior forces
m = Moment of resistance at any section in inch pounds
V = Vertical shear at any section
f_s = Unit stress in steel in tension
f'_s = Unit stress in steel in compression
f_c = Unit stress in concrete in compression
v = Unit stress in concrete in shear
u = Unit stress in adhesion of concrete to steel
E_s = Modulus of elasticity of steel
E_c = Modulus of elasticity of concrete in compression
E_t = Modulus of elasticity of concrete in tension
$\frac{E_s}{E_c} = n$
A = Area of concrete above steel in case of beams, also total area of columns
A_c = Area of concrete considered as taking direct compression in case of columns
C = Total compressive stress in concrete
S = Total tensile stress in steel
S' = Total compressive stress in steel
P = Total safe load on columns

1. RECTANGULAR BEAMS

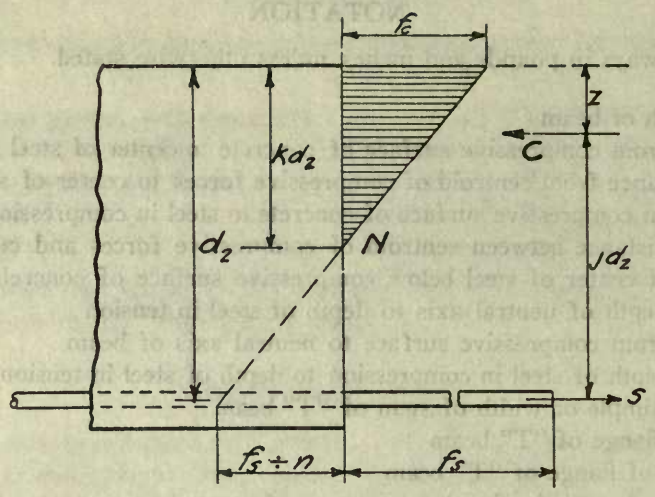

Fig. 1.

Position of neutral axis,

$$k = \sqrt{2pn + (pn)^2} - pn \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Arm of resisting couple,

$$j = 1 - \tfrac{1}{3}k \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

(For $f_s = 15{,}000$ to $16{,}000$, and $f_c = 600$ to 650, k may be taken at $\frac{3}{8}$.)

Fiber stresses,

$$f_s = \frac{M}{a_1\, jd_2} = \frac{M}{pjb_1\, d_2^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

$$f_c = \frac{2M}{jkbd_2^2} = \frac{2pfs}{k} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Steel ratio,

$$p = \frac{1}{2}\,\frac{1}{\frac{f_s}{f_c}\left(\frac{f_s}{nfc} + 1\right)} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

$$a_1 = \frac{M}{d_s\, f_s} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

2. "T" BEAMS

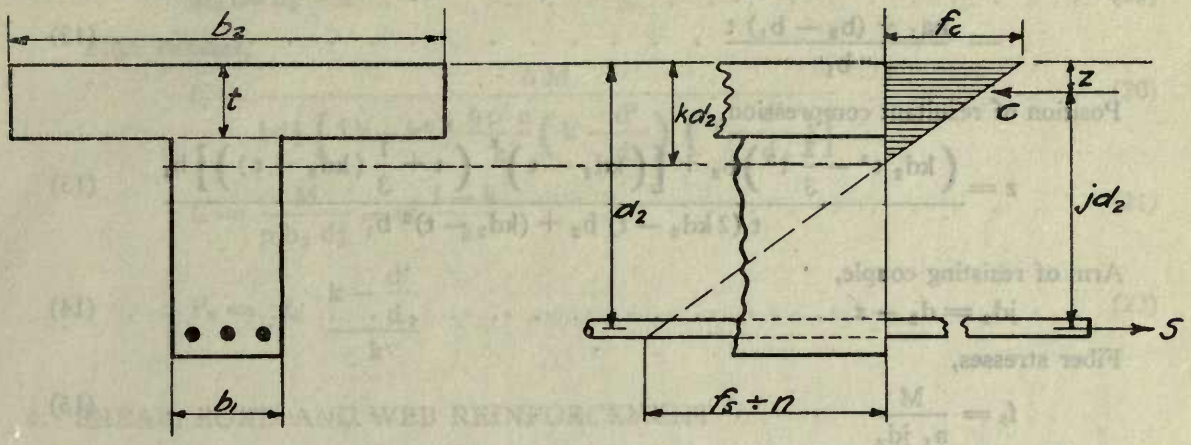

Fig. 2.

Case I. When the neutral axis lies in the flange (use the formulas for rectangular beams).

Case II. When the neutral axis lies in the stem.

The following formulas neglect the compression in the stem:

Position of neutral axis,

$$kd_2 = \frac{2nd_2 a + b_2 t^2}{2n a_1 + 2b_2 t} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

Position of resultant compression,

$$z = \frac{3kd_2 - 2t}{2kd_2 - t} \frac{t}{3} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

Arm of resisting couple,

$$jd_2 = d_2 - z \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

Fiber stresses,

$$f_s = \frac{M}{a_1 jd_2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

$$f_c = \frac{Mkd}{b_2 t (kd_2 - \frac{1}{2} t) jd_2} = \frac{f_s}{n} \frac{k}{1-k} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

(For approximate results, the formulas for rectangular beams may be used.)

The following formulas take into account the compression in the stem; they are recommended where the flange is small compared with the stem:

Position of neutral axis,

$$kd_2 = \sqrt{\frac{2nd_2 a_1 + (b_2 - b_1) t^2}{b_1} + \left(\frac{na_1 + (b_2 - b_1) t}{b_1}\right)^2} - \frac{na_1 + (b_2 - b_1) t}{b_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

Position of resultant compression,

$$z = \frac{\left(kd_2 t^2 - \frac{2}{3} t^3\right) b_2 + \left[\left(kd_2 - t\right)^2 \left(t + \frac{1}{3}(kd_2 - t)\right)\right] b_1}{t(2kd_2 - t) b_2 + (kd_2 - t)^2 b_1} \quad . \quad . \quad . \quad (13)$$

Arm of resisting couple,

$$jd_2 = d_2 - z \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

Fiber stresses,

$$f_s = \frac{M}{a_1 jd_2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

$$f_c = \frac{2Mkd_2}{\left((2kd_2 - t) b_2 t - (kd_2 - t)^2 b_1\right) jd_2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (16)$$

3. BEAMS REINFORCED FOR COMPRESSION

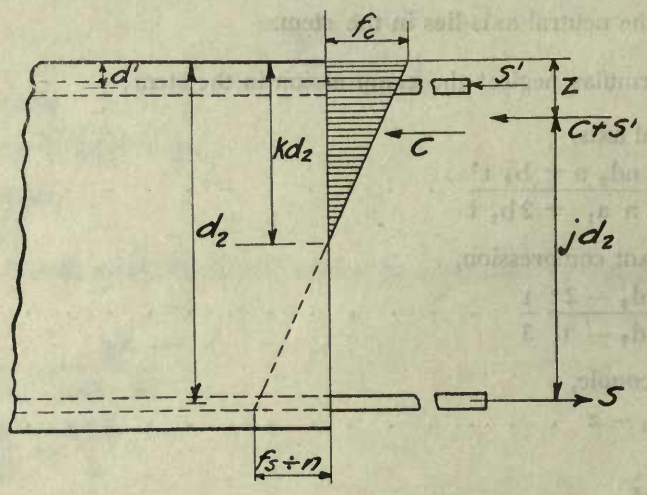

Fig. 3

Position of neutral axis,

$$k = \sqrt{2n\left(p + p'\frac{d'}{d_2}\right) + n^2 (p + p')^2 - n(p + p')} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (17)$$

Position of resultant compression,

$$z = \frac{\frac{1}{3} k^3 d_2 + 2p' nd'\left(k - \frac{d'}{d_2}\right)}{k^2 + 2p' n\left(k - \frac{d'}{d_2}\right)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (18)$$

Arm of resisting couple,

$$jd_2 = d_2 - z \quad (19)$$

Fiber stresses,

$$f_c = \frac{6M}{bd_2^2\left[3k - k^2 + \frac{6p'n}{k}\left(k - \frac{d'}{d_2}\right)\left(1 - \frac{d'}{d_2}\right)\right]} \quad (20)$$

$$f_s = \frac{M}{pjb_2\,d_2^2} = nf_c\frac{1-k}{k} \quad (21)$$

$$f'_s = nf_c\,\frac{k - \frac{d'}{d_2}}{k} \quad (22)$$

4. SHEAR, BOND AND WEB REINFORCEMENT

In the following formulas, Σo refers only to the bars constituting the tension reinforcement at the section in question, and jd_2 is the lever arm of the resisting couple at the section.

For rectangular beams.

$$v = \frac{V}{bjd_2} \quad (23)$$

$$u = \frac{V}{jd_2\,\Sigma o} \quad (24)$$

(For approximate results, j may be taken at $\frac{7}{8}$.)

The stresses in web reinforcement may be estimated by the following formulas:

Vertical web reinforcement,

$$S' = \frac{Vs}{jd_2} \quad (25)$$

Web reinforcement inclined at 45°.

$$S' = 0.7\,\frac{Vs}{jd_2} \quad (26)$$

in which S' = stress in single reinforcing member, V = amount of total shear assumed as carried by the reinforcement, and s = horizontal spacing of the reinforcing members.

The same formulas apply to beams reinforced for compression as regards shear and bond stress for tensile steel.

For "T" beams,

$$v = \frac{V}{b_1\,jd_2} \quad (27)$$

$$u = \frac{V}{jd_2\,\Sigma o} \quad (28)$$

(For approximate results, j may be taken as $\frac{7}{8}$.)

5. GENERAL

The length of reinforcing bars required in a simple beam uniformly loaded may be determined as follows:

$$x_n = L\sqrt{\frac{a_1 + a_2 + \ldots a_n}{A}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (29)$$

where x_n = length of nth rod in the order of length, counting the shortest as number one:

L = span length.

A = total area of steel at center; and a_1, a_2, etc., = area of each rod up to the nth rod.

For unsymmetrical loading the maximum moments and shears must be determined at various sections and the lengths of bars obtained therefrom preferably by plotting the moment and shear diagrams.

6. APPROXIMATE METHOD FOR DESIGNING "T" BEAMS

By the use of the "Table for Designing "T" Beams," "T" beams may be designed in exactly the same manner as simple rectangular beams, by considering the width b_2 of the "T" beam to correspond to the width b_1 of the rectangular beam, and the area of concrete above the steel to be equal to $d_2\ b_2$.

When the thickness t of the flange is less than the distance from the compressive surface of the slab to the neutral axis, the unit stresses on concrete in compression are increased, and therefore in designing such "T" beams as if they were simple rectangular beams, a corresponding reduction in the percentage of reinforcement must be made, in order to keep the ratio $f_s \div f_c$ constant.

The following table gives the allowable percentage of steel in terms of the ratio of the thickness of the flange to the depth d_2.

TABLE SHOWING THE ALLOWABLE PERCENTAGE OF STEEL FOR VARIOUS VALUES OF "f_s" & "f_c", IN TERMS OF THE RATIO OF THE THICKNESS OF THE FLANGE "t" TO THE DEPTH "d_2".

RATIO $t \div d_2$	f_s = 16000#/□"				f_s = 18000#/□"				RATIO $t \div d_2$
	f_c=600	f_c=650	f_c=700	f_c=750	f_c=600	f_c=650	f_c=700	f_c=750	
.10	.32	.35	.39	.42	.28	.31	.35	.38	.10
.15	.46	.50	.54	.58	.39	.43	.48	.52	.15
.20	.55	.60	.66	.72	.47	.52	.58	.63	.20
.25	.61	.68	.75	.83	.52	.58	.65	.72	.25
.30	.66	.74	.82	.90	.55	.62	.70	.78	.30
.35	.67	.76	.85	.94	.56	.63	.71	.80	.35
.40	.67	.77	.87	.97	.56	.63	.72	.81	40

THIS TABLE FOR USE IN THE DESIGN OF "T" BEAMS. COMPRESSION IN THE WEB IS NEGLECTED.

TABLE OF CONSTANTS & CONCRETE UNIT STRESSES FOR VARIOUS PERCENTAGES OF STEEL.

PERCENTAGE OF REINFORCEMENT	$n = \frac{E_s}{E_c}$	WORKING STRESS IN STEEL.	WORKING STRESS IN CONCRETE.	J.	K.
.20	15	18000	340	.928	.217
.30	15	18000	420	.914	.258
.40	15	18000	495	.903	.292
.45	15	18000	530	.898	.306
.50	15	18000	560	.893	.320
.55	15	18000	600	.889	.332
.60	15	18000	630	.885	.344
.65	15	18000	660	.882	.355
.70	15	18000	690	.878	.365
.75	15	18000	720	.875	.375
.80	15	18000	750	.872	.384
.40	15	16000	440	.903	.292
.50	15	16000	500	.893	.320
.60	15	16000	558	.885	.344
.65	15	16000	587	.882	.355
.70	15	16000	613	.878	.365
.75	15	16000	640	.875	.375
.80	15	16000	666	.872	.384
.87	15	16000	702	.868	.397
.90	15	16000	717	.866	.402
.95	15	16000	741	.863	.410
.97	15	16000	750	.862	.413

THIS TABLE APPLIES ONLY TO RECTANGULAR BEAMS & TO "T" BEAMS IN WHICH $\frac{t}{d_2} \leq K$.

Quality of Materials for Concrete Work

PORTLAND CEMENT

1. All cement shall be, unless otherwise specified, American Portland Cement of a well known and tried brand. Unless otherwise specified, all cement shall be purchased subject to the standard tests of the American Society for Testing Materials, and these tests shall be made in strict accordance with the methods prescribed by the Committee on Uniform Tests of the American Society of Civil Engineers. Tests shall be made from at least each carload of cement and no cement shall be used on the job until such tests shall have been made. Cement must be ordered sufficiently in advance of its use to allow at least 7 days for testing.

2. The requirements for Portland Cement are, briefly, as follows:

The specified gravity, thoroughly dried at 110° Centigrade, shall be not less than 3.10.

For fineness, it shall leave by weight a residue of not more than 8% on the No. 100 and not more than 25% on the No. 200 sieve.

For time of setting, it shall develop the initial set in not less than 30 minutes, but must develop the hard set in not less than 1 hour or more than 10 hours.

The minimum requirements for tensile strength of neat cement shall be as follows:

Age—24 hours in moist air.....175 lbs.
Age— 7 days (1 day in moist air, 6 days in water).....500 lbs.
Age—28 days (1 day in moist air, 27 days in water).....600 lbs.

For tensile strength of briquettes composed of one part cement to three parts sand, as herein specified, the minimum requirements shall be as follows:

Age— 7 days (1 day in moist air, 6 days in water).....175 lbs.
Age—28 days (1 day in moist air, 27 days in water).....200 lbs.

(Using Standard Ottawa sand, the above minimum requirements shall be 200 lbs. and 275 lbs. per square inch.)

For constancy of volume three pats of neat cement about 3 inches in diameter and about ½ inch at the center and tapering to a thin edge shall be made, one of which shall be kept in moist air for a period of 24 hours and then in air at normal temperature for 28 days. Another shall be kept in moist air for 24 hours and then kept in water maintained as near 70° Fahr. as practicable for 28 days. The third shall be kept 24 hours in moist air and then exposed in an atmosphere of steam above boiling water in a loosely closed vessel for 5 hours. These pats shall remain firm and hard under the above tests and shall show no signs of distortion, checking, cracking or disintegration.

Portland Cement shall contain not more than 1.75% of anhydrous sulphuric acid nor more than 4% of magnesia. (Mgo.)

3. True Portland Cement made from blast furnace slag will be classed with other Portland Cements.

POZZULAN CEMENT

4. Pozzulan Cement, if used, will be understood to mean cement made directly from blast furnace slag and lime without calcination subsequent to the mixing. It shall be used only under water or other places where thoroughly protected from the atmosphere. It shall weigh not less than 330 lbs. per barrel and it shall meet the fineness, soundness and setting tests as prescribed for true Portland Cement and shall have a specific gravity of not less than 2.7 and shall develop a tensile strength not less than 75% of that specified for Portland Cement.

CONCRETE AGGREGATE

5. Concrete will be composed of cement and aggregate, the latter being separated into fine aggregate, consisting of material less than ¼ inch in size, and coarse aggregate, consisting of material over ¼ inch in size. Unless otherwise specified, fine aggregate shall be composed of sand, and coarse aggregate of crushed stone, slag or screened gravel, as hereinafter described.

SAND

6. Sand shall consist of grains of hard, tough, durable rocks. For first grade sand, not more than 4% and for second grade sand, not more than 8%, by weight, of soft, decayed or friable material, shall be allowed. First grade sand shall contain not more than 2% and second grade sand not more than 4%, by weight, of finely divided clay, loam or other suspended materials, when tested by washing in such a manner as to remove all such material without removing any of the fine sand; provided that if the tensile strength of the mortar made from such sand, as hereinafter provided for, be greater than 110% of the strength of similar mortar made from standard Ottawa sand, the allowable amount of suspended material may be increased to 3% for first grade sand. This suspended matter must not form a coating around the grains that cannot be entirely removed by wetting and agitating, such as takes place in the ordinary process of mixing. Sand shall be free from oily or greasy matter in any form and shall not contain organic matter in excess of 10% of the amount of suspended matter when tested as above described.

7. The grains shall be well graded in size from the finest to the coarsest. Not more than 10% for first grade sand and 15% for second grade, by weight, including the suspended matter, shall pass the No. 100 sieve and not more than 75% for first grade sand and 85% for second grade, shall pass the No. 16 sieve.

8. The voids in the dry sand, when well shaken, shall not exceed 35% for first grade sand, nor 40% for second grade sand. The method of determining the voids shall be as follows:

A container holding not less than .12 cu. ft. (in shape either a cube or a cylinder, having a height approximately equal to its diameter) is filled in 1 inch layers, dropping twice a distance of 2 inches after placing each layer. Sand is then weighed carefully and the percentage of voids determined by computation, assuming the specific gravity of sand to be 2.60.

9. Mortar briquettes mixed in the proportion of 1 to 3 by weight and tested in accordance with the requirements of the standard specifications for testing cement, shall develop a tensile strength of at least 70% of the strength of similar briquettes made of the same cement and standard Ottawa sand.

10. Unless otherwise specified, first grade aggregate shall be used for all reinforced concrete work, for all mixtures of 1-2-4 (No. 6) or richer. Second grade aggregate may be used for large masses of concrete of 1-2½-5 (No. 7½) mix or poorer.

11. Stone screenings shall not be used for fine aggregate, except by express permission of the Engineer in charge, who will determine the amount of sand to be added to the screenings for each particular case, or, if found necessary to screen the material, he will decide what part of the material shall be screened out.

STONE

12. Stone for massive concrete work shall be crushed, hard limestone, granite, trap, or other suitable hard, clean stone in graded sizes of from ¼ inch to 3 inches where it is practical to use sizes as large as this. Stone for reinforced concrete work shall be of similar material, but of smaller size. For ordinary work, sizes shall be from ¼ to 1 inch. For small reinforced concrete sections the maximum size shall not exceed ¾ inch. All stone shall have a cubical fracture and shall be of material that is not subject to disintegration, due to atmospheric or other influences to which the concrete will be subject.

GRAVEL

13. Gravel for concrete work shall be clean graded gravel in sizes specified for stone. For first grade gravel, not more than 4% and for second grade gravel, not more than 8%, by weight, of soft, decayed or friable material will be allowed. When gravel is not well graded or not uniform, the Engineer may determine the proportions for each grade brought upon the work, so as to give results equivalent to those of the specified mix.

SLAG

14. Slag for concrete work shall be air cooled crushed slag in sizes similar to those specified for crushed stone. First grade slag shall contain not more than 1.75% of sulphur or 48% of lime and not less than 33% of silica and shall weigh not less than 75 lbs. per cubic foot. Second grade slag shall contain not more than 2% of sulphur or 50% of lime and not less than 30% of silica and shall weigh not less than 65 lbs. per cubic foot. In testing slag for weight, all materials over 1½ inch and under ¼ inch in size shall be screened out; the material thoroughly dried; placed in a container holding not less than 1 cubic foot, in shape either a cube or a cylinder (having a height approximately equal to its diameter); filled in four layers; and compacted by dropping twice a distance of 2 inches after placing each layer.

SCREENINGS AND SCREENS

15. All stone, gravel or slag shall be screened, unless otherwise distinctly arranged with the Engineer and shall be subject to the Engineer's acceptance. Crusher dust in excess of 5%, by weight, shall be cause for rejection. All material passing a No. 100 sieve shall be considered to be dust. In testing materials for size, sieves with round holes shall be standard.

CINDERS

16. First grade cinders, when used for concrete supporting work, shall be hard, well burned vitreous clinkers, free from soft powdered ash and containing not more than 10% of unburned coal. The crushing strength of standard cylinders of cinder concrete, mixed in the proportions of 1-2-4 (No. 6), shall be not less than 800 lbs. per square inch at 28 days. Material not meeting these requirements shall not be used for reinforced concrete. The sulphur contents shall not exceed 1%. Second grade cinders, which may be used for filling concrete subfloors or other non-supporting parts, may have 20% unburned coal and 2% sulphur, and will not be required to meet the compressive strength as given above.

WATER

17. Water used in concrete mixing shall be reasonably clear and free from oil, acids and injurious amounts of alkalies or vegetable matter. Roily or brackish water shall not be used. Sea water will not be allowed.

STEEL

18. Steel shall be manufactured in accordance with the Standard Specifications of the American Society for Testing Materials, as adopted June 1, 1912, and shall be purchased subject to the tests therein described. (Carnegie Hand-Book, 16th Edition, page 32).

19. The quality and shape of reinforcing steel to be used must be as shown on the drawings.

20. Chain or cable reinforcing shall not be used unless it is of a type that shall have been shown by tests, satisfactory to the Engineer, not to stretch more than plain bars of same net cross section under the same load.

21. Steel for reinforcing concrete shall not be painted and shall be free from grease, dirt and deep rust when placed in the work.

INSPECTION

22. When an inspector is furnished by the purchaser to inspect material at the mills, he shall have full access, at all times, to all parts of mills where material to be inspected by him is being manufactured.

Proportioning, Mixing and Placing Concrete

1. All concrete proportions specified herein will be based upon the assumption that one barrel of Portland Cement is equivalent to 3.8 cu. ft. and all proportioning must be done by means of a carefully gauged wheelbarrow or other apparatus which will be determined by the Engineer.

PROPORTIONS AND STRENGTH

2. The quantities of materials required for one cubic yard by specified proportions and the required minimum compressive strength at 60 days shall be as follows, all volumes being measured loose:

Mix No.	Proportion	Cement in barrels.	Sand cu. yds.	Stone, Slag or Gravel, cu. yds.	Compressive Strength at 60 days.
4½	1-1½-3	2.00	0.42	0.84	2400
5	1- 2 -3	1.81	0.51	0.76	2200
6	1- 2 -4	1.57	0.44	0.88	2000
7½	1-2½-5	1.30	0.46	0.92	1800
9	1- 3 -6	1.11	0.47	0.94	1600
11½	1- 3 -6 x ¼ rubble	0.83	0.35	0.71	1600
10½	1-3½-7	0.96	0.48	0.96	1400
13	1-3½-7 x ¼ rubble	0.72	0.36	0.72	1400

UNIT STRESSES

3. The unit stresses given in Section III and formulas given in Section IV apply to concrete which shall show strengths equal to those herein given for stone, slag or gravel concrete. For mixtures which show a less strength the unit stresses shall be correspondingly reduced. The values used for designing shall be the strength at 60 days, the samples being stored in water.

COMPRESSIVE STRENGTH

4. In determining the compressive strength of mortars, the latter may be assumed at nine times the tensile strength of standard briquettes having the same proportion of cement to sand as used in the concrete.

5. The compressive strength of concretes shall be determined from a standard test piece 8 inches in diameter and 16 inches in length (or 6 x 6 x 6 inch cubes, as directed), using same materials and same mixture as specified, storing in air for two days and in water for the balance. Such samples shall show a strength at least equal to that specified above at 60 days, or 75% of such strength at 30 days.

MIXING

6. All mixing shall be by machinery, except such hand mixing as may be allowed by special arrangement with the Engineer.

7. If concrete is mixed by hand, the sand and cement shall be spread upon the mixing board in thin layers and turned with spades until the mixture is of uniform color. Stone and water shall then be added and the mix turned at least three times, not counting the shoveling off the board.

8. Preference will be given to revolving batch machines which automatically measure the ingredients of the mix. Mixing must be very carefully and thoroughly done. Sufficient water shall be used to make the mass plastic enough to run freely. Excess of water over this shall not be used.

9. For massive concrete work, only enough water shall be used to make the concrete plastic, not so wet but that it may be churned with a light tamper to quake the mass.

10. The concrete shall be placed in position immediately after mixing and before the initial set shall have taken place.

TAMPING

11. All concrete work shall be tamped wherever, in the opinion of the Engineer in charge, tamping is required to properly compact the mass. In tamping concrete for reinforced work, special tools shall be provided for working around and under reinforcing bars, tamping against forms, etc.

RETEMPERING

12. No retempering of concrete which has been allowed to stand until the initial set has taken place will be allowed unless by special permission of the Engineer, who may, at his discretion, require additional cement to be used in retempering.

JOINTS

13. The mixing and placing of concrete shall be, as far as practicable, a continuous operation, and when it is necessary to make a joint in monolithic concrete, it shall preferably be made in the middle of a panel at right angles to the beams and by means of a stop board placed in a vertical position and containing a key on the side next the concrete first placed. When these stop boards are removed, the exposed surfaces of concrete shall be wet and carefully dusted with neat cement or painted with mortar before continuing the next block.

BONDING

14. When it is necessary to bond new concrete to concrete partially or wholly set, the Engineer may require that the surfaces of the old concrete be roughened either by picking or by washing with acid, thoroughly rinsing same off and applying a thin coat of rich cement mortar, 1 to 1, or a bonding preparation may be used by permission of the Engineer. It will always be required in joining new concrete to old that has partially set, that part of the old concrete next to the forms on exposed surfaces shall be removed for a depth of at least one inch and a distance back from the face of the concrete of at least two inches, in order to avoid the appearance of a joint. It will also be necessary to remove all laitance from the surface of concrete which has partially set before attempting to bond new concrete thereto. When practicable, large angular stones shall be embedded in horizontal joints of massive concrete work, to assist in bonding the old concrete to the new.

WETTING

15. Concrete shall be kept wet for one week after depositing and in dry hot weather shall, in addition, be kept covered from exposure to the sun during this time, or shall be constantly sprinkled during the day by a workman especially detailed for this work.

PLACING UNDER WATER

16. When it is necessary to place concrete under water, the site shall be inclosed with a cofferdam or other means taken to procure quiet water and then the material shall preferably be deposited from a bucket provided with a bottom dump, or a tremie may be used. Care must be taken to keep the surface of the concrete as nearly horizontal as possible when depositing under water. When concrete is deposited under water, the deposition shall be continuous, or else means shall be provided to remove the laitance from the top of concrete previously deposited before resuming the pouring.

17. When concrete must be deposited in running water, it shall be done by placing the concrete in bags and depositing the bags in place, or by other means equally satisfactory to the Engineer.

18. Unit stresses on concrete deposited as per paragraph No. 16 must be decreased 33⅓%, and when deposited as per paragraph No. 17, 50%.

RUBBLE CONCRETE

19. In heavy foundation work or other work requiring large masses of concrete, the Contractor may use not to exceed 50% of stones to embed in the concrete when so indicated on the drawings. Such stones must be sound, clean and wet before placing, and shall not be placed nearer than six inches from the surface of the concrete and not less than six inches apart. They must be laid with their largest face at right angles to the line of principal stress.

DROPPING

20. In placing concrete it shall not be dropped from a greater height than 10 feet. When it is required to place concrete from a greater height than 10 feet, it shall be placed by means of chutes or other devices satisfactory to the Engineer in charge.

CHUTES

21. When concrete is deposited by inclined chutes, the slope shall be adjusted so that there will be no separation of ingredients in transit. The Engineer in charge may require remixing, whenever, in his judgment, there is such separation of ingredients.

APPROVAL OF METHOD OF MIXING AND PLACING

22. The method of mixing and placing shall be submitted to the Engineer in charge before beginning work and shall be subject to his approval.

SAMPLE BLOCKS

23. Whenever requested, by the Engineer, the Contractor shall pour sample blocks, eight inches in diameter and 16 inches high, or six inch cubes, as directed, which shall be properly marked for identification and stored as directed by the Engineer.

GENERAL

24. If materials other than screened broken stone, slag or gravel and sand, as herein described, be used, the proportions shall be subject to such changes as shall be found to give equivalent results in strength and density to the results obtained by use of the specified proportions and materials.

25. It is understood that these proportions and all other proportions given in these specifications are subject to such changes as may be found necessary in order to obtain properly proportioned mixtures after the Engineer shall have had made careful analyses of the materials proposed to be used.

26. In case such adjustment of the proportions entails a larger proportion of cement to aggregates than that specified, the Contractor will be allowed the actual cost, delivered at the mixer, of such additional cement, the amount to be determined by using the amount as given in the preceding table as a basis. In case a less amount of cement be required, a corresponding amount shall be deducted from the contract price.

27. In any mixture, the matrix (cement and sand mortar) shall exceed the voids in the aggregate (broken stone, gravel, etc.).

28. Reinforced concrete footings shall be poured in one continuous operation, unless otherwise indicated on the plans.

29. "T" beams must have the stem and slab poured in one continuous operation, except in the case of constructions especially designed to secure a positive bond between the several parts.

30. Spandrel beams projecting above the slab shall be poured at the same time as the slab unless otherwise specified or shown on the drawings.

31. Sufficient time shall be allowed after pouring columns and walls and before pouring the beams and slabs at top of same, to allow for shrinkage of columns or walls.

Requirements for Placing Reinforcing Steel, Inserts, Etc.

1. Steel reinforcement shall be secured against displacement during the pouring of the concrete, by mechanical spacers and chairs, or other positive means, and shall be subject to a rigid inspection by and approval of the Engineer in charge immediately prior to placing concrete.

CLEARANCE

2. The clear distance from the surfaces of the concrete to the steel shall be, unless otherwise shown, 2½ inches for footings, arches, retaining walls, etc., 2 inches for columns, 1½ inches for girders and beams, 1 inch for slabs 8 inches and more in thickness, and ¾ inch for slabs under 8 inches thick.

3. Main bars in slabs shall be spaced a distance apart not to exceed one and one-half times the thickness of the slab, and cross bars shall always be used at right angles to the main carrying bars. Cross bars shall not be less than ¼ inch diameter and spaced a distance apart not to exceed twice the specified maximum distance for main carrying bars. These limits do not apply to wire mesh or other fabricated reinforcement.

4. The clear distance between reinforcing bars shall never be less than twice the maximum diameter of stone or bar used.

COLUMN BARS

5. In the case of columns containing longitudinal reinforcing bars, positive means shall be provided for splicing such bars. At the base of the column, proper provision must be made for transmitting the load carried by the reinforcing bars to footings. Unless otherwise shown on the drawings, this shall be done by means of anchor dowels. Column bar splices shall be made at the floor level by means of dowels, unless otherwise shown on the drawings.

6. Column bars 1 inch in diameter and over shall be tied together by horizontal hoops not less than ¼ inch diameter and not farther apart than 12 inches. The distance between spirals shall not exceed 3 inches. For column bars less than 1 inch diameter, the size of the tie bars may be one-fourth of the diameter of the column bars.

7. Spirals, hoops and tie bars shall be secured to vertical bars at intervals of not over 12 inches and all spirals shall be provided with satisfactory spacers.

ANCHOR BOLTS, ETC.

8. Wherever bolts are to be embedded in the concrete, these bolts shall be placed in position by the Contractor for concrete work, unless otherwise specified.

9. The Contractor for concrete work shall place all anchor bolts for columns, beams, etc., and shall place all anchors and ties for all attachments to the concrete work, such as terra cotta or cast concrete trimmings and facings, brick facings, etc.

10. Wherever pipes, wires, conduits, or other fixtures not otherwise provided for herein, are to be encased in the concrete work, they shall be furnished and placed under separate contract, unless otherwise provided for on the plans or in the contract. This Contractor shall not pour the concrete without notifying the other trades sufficiently in advance to allow them to place their work.

GENERAL

11. All steel for reinforcing shall be placed with great care; all abrupt bends must be avoided, except where one steel member is bent around another.

12. Bending shall be done cold unless otherwise ordered. If bars are heated and blacksmith work done, care must be exercised that the steel is not burned in the operation and it shall be heated to a low cherry red only.

13. Vertical stirrups shall always pass under the main tension bars, or be rigidly attached thereto.

14. For all floor steel, column spirals and wherever else it is practicable, mechanical means shall be provided for holding the reinforcing bars in place.

15. Reinforcing steel shall be clean, free from scale, grease, paint, oil and rust (except a thin film of red rust, easily rubbed off with the fingers). The Engineer may require rods to be cleaned, wherever, in his opinion, it is necessary.

16. Unless otherwise shown on plans, all splices in steel shall be made by lapping a sufficient amount to develop the stress in the bar without exceeding the allowable adhesive stress as given in Section III.

17. Reinforcing bars shall be wired together at splices and as far as practicable shall be so arranged as to provide continuous contact between the bars, the purpose being to minimize the danger from electrolysis.

18. As far as practicable, electrical conduits, outlet boxes or other apparatus, shall not come into contact with the reinforcing bars.

19. Whenever practicable, concrete inserts shall not be placed in contact with reinforcing bars.

20. When long anchor bolts for setting machinery, etc., are required to be set in concrete before pouring, there shall be provided metal sleeves equal in length to one-half the length of bolt and 1½ inch greater in diameter, set flush with the surface of the concrete to allow some adjustment of the bolts. All such anchor bolts and sleeves are to be set by means of templates.

21. The Contractor shall furnish the Engineer with duplicate copies of all orders for reinforcing steel and duplicate copies of bending and marking diagrams, which shall be approved in writing by the Engineer before work is begun.

Placing Concrete in Cold Weather

1. Concrete shall not be placed in freezing weather except by special arrangement with and under the supervision of the Engineer in charge.

2. Mixing water having a temperature of less than 60° Fahr. shall not be used.

3. When the temperature is below 40° Fahr., the mixing water shall be heated to at least 100° Fahr.

4. When the temperature is below 30° Fahr., the mixing water shall be heated as before, and, in addition, the aggregates shall be heated before using, and the work properly protected by covering.

5. No supports shall be removed from concrete poured at a temperature below 40°, and no load allowed to be carried by same, until it shall have been thoroughly cured and dried by artificial heat.

6. No concrete shall be poured at a temperature below 20° Fahr., without such additional precautions as may be required by the Engineer in charge.

7. In general, the use of salt or calcium chloride will be allowed only for massive concrete work, and then only by written permission of the Engineer in charge. If used, salt shall be No. 2 grade common, and shall equal in amount .002% by weight of water for each degree of temperature (Fahr.) under 32°. The salt shall be thoroughly dissolved in the mixing water, the amount specified being equivalent to ½ lb. of salt for each barrel of 4 cu. ft. capacity and for each degree of temperature below 32° Fahr.

8. In addition to the above requirements, the Engineer may, at his discretion, require the use of 10% excess of cement.

9. For concrete work in cold weather, the use of quick setting cements is preferable, and the amount of mixing water should not be greater than actually required for proper placing and setting.

10. All precautions specified shall be at the Contractor's expense unless otherwise stated in the contract.

11. Concrete shall not be poured against steel forms exposed to the weather when the temperature is below 30° Fahr.

Forms and Centers

STRENGTH

1. All forms for molded concrete work shall be constructed of sufficient strength to obtain the necessary rigidity to prevent motion of the forms while concrete is being placed and shall be strong enough to carry any load which may come upon the concrete within thirty days from the date of pouring.

MATERIAL, ETC.

2. Forms shall, in general, be composed of tongue and grooved or square edge sheeting, properly held by joists, studding, posts and bracing against the concrete surfaces. Sheeting shall be as nearly as possible watertight and shall be surfaced on the side next the concrete for all surfaces which will be exposed in the finished work, unless otherwise specified.

3. Forms shall be constructed by experienced and capable workmen only, and shall be true to line and grade and of first-class workmanship throughout.

4. When concrete is to be plastered, rough sheeting shall preferably be used.

5. Sheeting lumber which is used more than once shall be carefully cleaned after each usage.

6. Great care must be taken to clean all saw dust, dirt or debris from forms just before placing concrete, and whenever necessary, forms shall be cleaned out by steam jet or equally effective means. All forms shall be so constructed as to be readily cleaned.

7. Lubricated or oiled forms shall not be used for surfaces that are to be plastered, painted or colored, or against surfaces to which other concrete is to be bonded.

REMOVAL OF FORMS

8. Centers shall not be struck from under arches in less than 28 days, except in the case of arch culverts of less than 30 foot span.

9. In general forms shall not be removed from concrete in less than 14 days of good setting weather at a temperature over 50° Fahr., except in the case of vertical surfaces, etc., which do not carry loads, the forms for which may be removed in from 3 to 6 days.

10. Forms shall not be removed from under concrete which has been poured at a temperature under 50° Fahr., without first determining if the concrete has properly set, without regard to the time element.

11. Forms shall always be removed from columns before removing shores from beneath beams and girders, in order to determine the condition of the column concrete.

12. No forms whatever shall be removed at any time without first notifying the Engineer in charge, who shall ascertain if the concrete be set sufficiently hard and so notify the Contractor. Such notification shall not be considered to relieve the Contractor of responsibility for the construction and for the removal of such forms.

13. All forms shall be designed so that they may be removed with as little damage as possible to the concrete or to the forms.

STEEL FORMS

14. When steel forms are used, all bolt and rivet heads shall be countersunk on the side against the concrete, unless otherwise specifically arranged with the Engineer, and the several pieces must join together neatly. All surfaces must be true, free from bends or other irregularities and free from open holes.

15. When steel forms are used in freezing weather, they shall be covered with canvas or otherwise protected from the weather. Pouring of concrete against unprotected steel forms in freezing weather will not be allowed.

TIMBER FORMS.

16. In constructing timber centers for arches of more than 30 foot span, all main members shall be bolted together at joints.

17. In constructing timber centers for arches, an allowance for settlement shall be made equal to ¾ inch for each 30 feet vertical height.

GENERAL

18. The Contractor shall furnish the Engineer with duplicate copies of plans for forms and centers, which must be approved in writing by the Engineer before work is begun.

19. Wherever practicable, edges of beams, girders and columns shall be chamfered and sides of beams and girders shall be splayed slightly in order that forms may be more readily removed.

20. All projecting wires and bolts or other devices that are used for holding forms and that pass through the concrete shall be cut off at the surface and the ends depressed with a nail set.

21. In proportioning forms and centering, concrete shall be treated as a liquid of its full weight for vertical loads and one-half its weight for horizontal pressures.

22. Wedges shall have a slope of 1 to 10.

23. Forms for beams and girders shall be cambered ¼ inch for each 20 foot span.

24. Forms for flat slab system of construction shall be cambered ¼ inch for each 10 foot span; camber to start at the edge of the column head.

25. The use of shims shall be avoided as much as possible and when shores carry heavy loads, hardwood shims and wedges may be required at the discretion of the Engineer.

26. In the removal of forms from buildings, the Engineer in charge may require reshoring, wherever, in his opinion, it is necessary, and all such shores shall be wedged to a tight bearing and be thoroughly braced.

27. Forms for columns shall be built up of 1½ inch plank and stayed at intervals of not more than 18 inches vertically, by bands or straps; or steel forms may be used.

Surface Finish

1. The surface finish for all exposed parts of the structure will be called for on the plans, and the character of finish desired will be indicated by initialing as follows:

"W" indicates a cement wash
"S" " " scrubbed finish
"R" " " rubbed finish
"T" " " tooled finish
"M" " " mortar facing
"P" " " plastered surface
"SB" " " sand blasted surface
"C" " " colored surface

2. If no surface finish be called for, a special flat tool shall be worked between the concrete and the sheeting to force back the coarse aggregates and produce a mortar face, then, after removal of the forms, the entire surface shall be gone over and all cavities, etc., filled with mortar of the same proportions as used in the original work, the mortar being forced into the cavities by pressure. All fins and projections exceeding ½ inch shall be removed by tooling. All surfaces that have been disturbed either by closing cavities or tooling to remove projections, shall be rubbed down to obtain a uniform color.

3. For all kinds of finish, the surface shall be gone over immediately after the removal of the forms and all loose stone and defective places cleaned out, wires and rods cut off at surface and depressed with nail set, and then all holes and cavities shall be filled with mortar of the same mix as used in the body of the work. Projecting fins and inequalities due to bulging of forms, etc., shall be removed by tooling, as directed by the Engineer in charge.

4. CEMENT WASH FINISH shall consist in the application to the surface of a thin cement grout, composed of one part cement to one part fine sand, applied with a brush and immediately rubbed in with a wooden float.

5. SCRUBBED FINISH shall be obtained by removing the forms as soon as practicable and washing away the cement film on the surface by means of a scrubbing brush and water, exposing the aggregates. If the cement has set so that it cannot be washed out with water, then a weak solution of hydrochloric or muriatic acid shall be used, the surface being thoroughly rinsed off afterwards.

6. RUBBED FINISH shall be obtained by rubbing down the surface with a piece of carborundum brick, or other abrasive, sufficiently to remove all marks of timber forms and other irregularities. The surface to be rubbed shall be wet, and a thin grout, composed of one part cement to one part fine sand, brushed in during the rubbing. The rubbing shall always be the final operation. A finish application of the cement grout will not be allowed. The cement grout may be omitted entirely by direction of the Engineer in charge.

7. TOOLED FINISH shall be obtained by removing the surface mortar a sufficient amount to expose the aggregates, by means of stone dressing tools, as called for on plans. Unless otherwise specified, the surface shall be dressed to a smooth finish equal to fine pointed or crandalled work in stone masonry. Cast stone surfaces, when tooled, shall be ground out in parallel lines by revolving carborundum wheels or equally effective means, using eight cuts to the inch, unless otherwise specified.

8. MORTAR FACE FINISH, if called for, shall consist of a facing, not less than 1 inch thick, composed of specially selected materials, which shall be as uniform as possible for the entire job, and proportioned so as to be, as nearly as practicable, of the same strength and consistency as the backing. The surface finish of the mortar face shall be as indicated on the drawings.

9. PLASTERED SURFACES shall be obtained by plastering a coat of mortar on a backing of concrete. The surface of the backing shall be rough, in order to give sufficient bond and the mortar shall be thoroughly trowelled on. Plastering shall only be done by skilled labor.

10. SAND BLAST FINISH shall be obtained by means of the sand blast on thoroughly hardened surfaces only, using crushed quartz or other hard material. All cavities shall be filled and pronounced projections removed before using the sand blast. Mouldings, sharp edges, etc., must be properly protected from the blast.

11. COLORED SURFACES will be used only when specifically called for on the drawings and described in detail. Only mineral colors shall be used.

Waterproofing

1. Concrete, which is desired to have water-resisting qualities, shall, unless otherwise specified, be No. 6 mix, of carefully graded materials so that the percentage of voids shall be as low as practicable, and shall be laid as nearly monolithic as possible.

2. Waterproofing will be divided into four classes, as follows:

1. Integral Method (I. W. P.) —Mixing foreign substances with the concrete.
2. Membrane Method (M. W. P.) —Protecting the concrete surface by means of an independent waterproof layer, usually of fabric impregnated with bitumen.
3. Bituminous Mastic Method (A. W. P.)—Applying a coating of bituminous mastic to the surface to be waterproofed.
4. Coating Method (D. P.) —Applying bitumen or other waterproofing material directly to the concrete surface.

3. The method to be used shall be shown on the drawings, by marking as above indicated.

INTEGRAL METHODS

4. When waterproofing by the integral method is called for, it shall be done by mixing with the cement or water used the material specified, consisting of alum and soap solution, hydrated lime, or one of the various compounds sold for this purpose, such as Toxment, Ceresit, Trus-con waterproofing paste, Medusa waterproofing compound, etc.

5. If alum and soap be specified, a 5% solution of ground alum and water shall be prepared, and a 7% solution of soap and water. The alum solution shall be mixed with the mortar to the amount of one-half the ordinary gaging water. The soap solution shall then be applied in amount required to obtain the desired plasticity. (From Prof. Hatt.)

6. If hydrated lime be called for, 5% by weight (of the weight of the cement) of thoroughly hydrated lime shall be added to the mixing water or an equivalent amount may be mixed dry with the cement. Care shall be taken to insure that the lime be completely hydrated. Hydrated lime shall pass the Standard Specifications for hydrated lime of the American Society for Testing Materials, and shall be of the class known commercially as Calcium, unless otherwise specified.

7. If the use of any of the patented compounds be called for, the work shall be done in strict accordance with the instructions issued by the manufacturers thereof.

8. The integral method shall not be used with a leaner mixture than 1-2-4 (No. 6).

9. If so indicated on the plans, the integral waterproofing method may be used for a mortar coat applied to the body of the concrete, which shall be 1 inch thick unless otherwise specified, and mixed 1 to 2.

10. When the character of the integral method is not shown on the drawings, either Toxment, Ceresit, Trus-con or Medusa compound shall be used, or other material may be substituted with the permission of the Engineer.

MEMBRANE METHODS

11. The membrane method shall consist of alternate layers of cementing material or binder and fabric, the first and final layer being, in all cases, composed of the binder. The number of layers, or ply, shall refer to the number of layers of fabric used and shall be as indicated on the drawings. The binder shall be either asphalt or coal tar pitch, as specified.

12. Unless otherwise shown on the drawings, the number of plies will be as follows:

	Class A	Class B & C
For head of 0 feet	1	2
" " " 1 foot	2	3
" " " 2 feet	3	4
" " " 6 feet	4	5
" " " 8 feet	5	6
" " " 10 feet	6	7
" " " 15 feet	7	8
" " " 20 feet	8	9

13. The entire waterproofing course shall be flexible, pliable and elastic between 150° F. and 0° F. All expansion joints and cracks in the concrete surface shall be covered by specially designed joints. At such joints and cracks the membrane shall not be cemented to the concrete for a distance of at least 12 inches on each side of such joint or crack.

14. Each strip of fabric shall lap 2 inches over the preceding strip, and the strips of alternate plies shall lap one-half the width of the strip. Each layer or ply shall alternate with the preceding layer in the direction of laying. Each layer shall be applied to the binder while the latter is still hot and pressed against it so as to insure its being completely stuck to the binder over the entire surface. All end laps shall be at least 10 inches. The binder shall completely cover the surface on which it is laid without cracks or blowholes. The first coat (except the cementing coat, if used) shall be a binder coat, and the final coat shall always be a binder coat.

15. The surfaces to be waterproofed shall be dry and free from sharp projections. All corners and angles shall be waterproofed without cutting or slitting the fabric. Flashing shall be carefully done around all openings and obstructions.

ASPHALT AND CLOTH FABRIC WATERPROOFING—CLASS "A"

16. The cloth fabric shall be thoroughly saturated with the bituminous material with which it is applied or cemented together, so that when an individual strand is split, the center of the strand shall be black with the saturant. It must be flexible and elastic at all temperatures between 0° and 250° Fahr., and have a stretch in two directions of at least 5% without fracture.

17. A 1 inch strip shall have a tensile strength of at least 100 lbs. It must stand a puncture-proof test of 100 lbs. to the square inch. It must not crack or flake when folded back on itself and creased at the fold, irrespective of temperature. It must be unaffected by all acids and alkalies; that is be chemically inert.

18. The material with which the cloth is to be applied (sometimes called the binder) shall be a naturally occurring asphaltic bitumen, at least 96% of which shall be pure hydro-carbon. It shall have a melting point of approximately 200° Fahr. and shall be flexible at 0° Fahr. It shall volatilize not more than 1% upon heating for 5 hours at 325° Fahr. in an open Cleveland cup. It shall be unaffected by 25% solutions of hydrochloric or sulphuric acid or saturated solutions of alkalies and brine. It shall have strong adhesive qualities and bond firmly to the concrete to which it is applied. It shall be refined by direct heat and not by the "blown" process.

19. The surface to be waterproofed shall be carefully cleaned and dry and shall have a coat of liquid asphalt paint to serve as a bonding coat, applied with a brush before the first mop coat, unless the plans call for the omission of the priming coat.

PITCH AND FABRIC WATERPROOFING—CLASS "B"

20. The fabric shall be the same as specified in Paragraphs 16 and 17, saturated with coal tar pitch.

21. The binding material and saturant shall be straight run coal tar pitch distilled direct from American coal tar. The pitch shall have a melting point of from 130° to 140° Fahr., and be applied at a temperature of not less than 250° Fahr.

PITCH AND FELT WATERPROOFING—CLASS "C"

22. The felt shall weigh not less than 14 lbs. per 100 sq. ft., single thickness, and shall be thoroughly saturated with the pitch.

23. The saturant and binder shall be the same as specified in Paragraphs 18 or 21.

BITUMINOUS MEMBRANE WATERPROOFING—CLASS "D"

24. Waterproofing of this class shall be similar to that specified for Class "C," except that there shall be not less than three plies, the center ply being a cloth fabric equal to that specified in Paragraph 16, the remaining plies being felt.

BITUMINOUS MASTIC WATERPROOFING

25. After the cement concrete in the structure has thoroughly dried, the entire top surface to be waterproofed shall be painted with the asphalt hereinafter specified, melted and diluted with 62° Beaume's naphtha to the proper consistency.

26. The surface so prepared shall then be waterproofed with asphalt mastic equal in quality to the following specification:

Neufchatel Seyssel or Sicilian Rock Asphalt Mastic .....60 parts
Clean, sharp graded grit and sand to pass sieve of 8 meshes per inch....30 parts
Refined Bermudez or Trinidad Asphalt.....10 parts

These proportions shall be varied where required by special conditions of the work.

27. The mixture shall be made at the site of the work, and heated to a temperature of from 250 to 300° F. and stirred until all the ingredients are thoroughly incorporated. It shall be spread and thoroughly worked to free it from voids and ironed to a smooth, dense surface with hot smoothing irons, if so directed.

28. The waterproofing shall be applied in two coats; each finished coat shall be ¾ of an inch in thickness. The different coats shall break joints and the mastic be distributed evenly.

COATING OR DAMPPROOFING

29. When one or more coats of dampproofing are called for on the plans, there shall be applied to the surface natural asphalt or coal tar pitch of sufficient body to completely fill all pores in the concrete. Such pitch shall be applied hot, if necessary, and the surface to be waterproofed shall be clean and dry.

30. If proprietary compounds are called for, they shall be applied in accordance with directions from the manufacturers.

31. In dampproofing basement walls, etc., the Engineer may require the walls to be first plastered if the surface is not smooth enough to receive the dampproofing properly.

32. If it be necessary to dampproof wet concrete, a special binder shall be used to bond the pitch to the concrete.

GENERAL

33. All surfaces waterproofed by the membrane method, and which are to be covered with an earth fill, such as basement walls, etc., shall have the waterproofing protected by a course of brick or a 1 inch plaster coat of 1 to 3 mortar, before applying the back fill or covering.

34. Especial care shall be taken to provide proper laps at the juncture of floors and walls, when using the membrane method. These laps shall be at least 1 foot wide and thoroughly protected from damage.

35. All concrete surfaces to be waterproofed shall be trowelled to a smooth finish. This work shall be done by the Contractor for the concrete work.

36. All waterproofing shall be carefully protected from injury. Where brick or concrete protection is shown on the plans, it shall be laid by the Contractor for waterproofing, and the materials shall be furnished by the mason or concrete Contractor, unless otherwise arranged.

Reinforced Steel Construction

1. When the steel reinforcement is so designed that it will carry in itself, without support from the encasing concrete, a definite proportion of the loads, all parts of the steel construction shall be designed to carry such proportion of the loads, using the specifications of The American Railway Engineering Association.

2. In addition to its portion of the specified loads, the steel frame shall also be proportioned to provide for all bending stresses due to the negative bending moment, in the case of partially continuous construction, or the bending moments due to eccentric loads, etc.

3. The steel shall be proportioned to resist all tensile stresses due to the full load.

4. The concrete shall be so proportioned as to provide the additional compressive resistance required for the balance of the load, in conformity with the requirements of the other sections of these specifications.

5. Unless special provision is made to develop continuity, all beams and girders of reinforced steel construction shall be computed as simple beams.

6. Forms for reinforced steel beams, girders and columns may be removed in one-half the time specified for monolithic reinforced concrete construction when the steel frame is proportioned to carry the full dead load then in place without assistance from the concrete.

7. In reinforced steel construction the occurrence of large flat surfaces of steel shall be avoided as far as practicable, and in no case shall a single surface exceed 6 inches for horizontal surfaces covered with concrete, or else soffit clips or other satisfactory devices for securing adhesion of the concrete to the steel shall be provided.

8. All horizontal surfaces of steel shall be covered with concrete not less in thickness than one-half the width of the surface so covered, and shall be wrapped with expanded metal or wire cloth, when exceeding 4 inches in width.

9. Angles placed back to back shall be separated a distance at least twice the maximum diameter of stone used in the concrete.

10. Compression members encased in concrete shall be stressed not more than fifteen times the stress in the concrete, except where part of the stress is developed in the steel prior to the placing of the concrete, in which case the increment of stress after placing the concrete shall not exceed fifteen times the stress in the concrete, nor shall the total unit stress exceed the allowed tensile unit stress.

11. Unit stresses shall be as follows:

Tension, net section, rolled steel	16000
Direct compression, rolled steel and steel castings (not columns)	16000
Bending, on extreme fibers of rolled shapes, built sections, girders and steel castings	16000
Bending on extreme fibers of pins	24000
Shear on shop rivets and pins	12000
Shear on bolts and field rivets	10000
Shear—average—on webs of plate girders and rolled beams, gross section	10000
Bearing pressure on shop rivets and pins	24000
Bearing on bolts and field rivets	20000

The pressure per linear inch on expansion rollers shall not exceed 600 times the diameter of rollers in inches.

Axial compression on gross sections of columns for

ratio of $\frac{1}{r}$ up to 120 $\quad 16000 - 70 \frac{1}{r}$ with a maximum of 14000

where 1 = effective length of members in inches, using full length for abutting ends and one-half full length for fixed ends.

r = corresponding radius of gyration of section in inches.

12. Steel to be encased in concrete shall not be painted, unless otherwise provided for, but shall be free from rust, scale, grease or dirt.

13. Unless otherwise specified, all connections shall be riveted.

14. Satisfactory provision shall be made for wind bracing during erection of steel work.

15. All structural material shall be subject to inspection and tests at mill and shop, and no material shall be shipped until so inspected and accepted.

16. Reinforced steel columns shall preferably be of the "Gray" or other type of open section.

17. In proportioning reinforced steel columns, no direct allowance shall be made for the concrete in compression, unless it be secured by hooping, but in such columns the unit stress on the steel, assuming the steel to carry the entire load, may be taken at 16000 lbs. per square inch when the ratio of $\frac{1}{d} < 15$.

18. When the concrete encasing structural steel columns is provided with hooping as provided for in Section III, Paragraphs 10 and 11, the column may be proportioned as therein provided for, using 650 lbs. per square inch working stress on the concrete (No. 6) and 10000 lbs. per square inch on the steel, assuming the spiral steel as equivalent to 2.4 times its volume, taken as vertical steel.

Cast Stone and Blocks

1. Cast Stone work includes facing blocks, parapets, railings and ornamental work constructed of separately molded or cast blocks of concrete.

2. Cast Stone shall preferably be cast in a sand mold in an established factory, and all exposed surfaces shall be dressed by hand, by means of revolving carborundum wheels, or similar devices used in such factories to produce tooled or other good stone finish. At least 1/12 inch of such surfaces shall be removed.

3. When any Cast Stone exceeds in any dimension six times its least dimension it shall be properly reinforced to insure safety in handling, such reinforcement to be not less than .5% of the cross section at right angles to the line of reinforcement, unless the reinforcement be shown on the drawings.

4. The proportion of cement to aggregate in Cast Stone and Blocks must not be less than 1 to 6 nor greater than 1 to 4 and the aggregate must not be too fine but shall be of graded sizes from ⅜ inch diameter down when screened aggregate is used.

5. Aggregates for Cast Stone shall preferably be made by crushing whole pieces of such material as granite and marble and not over 40% should pass a 1/16 inch mesh screen. Aggregates should be mixed with the cement in a mixer, preferably of the rotary type, with not less than 15% of water by weight. If it is to be cast in sand molds it shall be constantly agitated from the time it is removed from the mixer until it is distributed in the mold.

6. Building Blocks shall be used wherever shown on the drawings and shall be well cured and dense, with good edges, shall show a strength of at least 1,000 lbs. per square inch at 28 days and an absorption of not over 5% by weight when thoroughly dried and immersed in water for 48 hours.

7. The Contractor shall furnish samples of the concrete Blocks and Cast Stone proposed to be used, which shall be satisfactory to the Engineer, and the Blocks and Stone used must conform in every way to such samples.

8. No broken, chipped, or checked blocks or castings will be allowed to be used in the work and all blocks or castings shall be carefully protected from injury. By checked blocks are meant blocks showing fine hair checks on the surface.

9. All cast stone must be provided with suitable dowels and anchors for securing same to the work and with hooks for handling, and all cast stone and blocks must be laid up in white or non-staining Portland cement mortar, when mortar is used.

10. The material to be used for aggregates and the finish shall be as indicated on the drawings.

11. All cast stone shall be carefully bedded in full mortar joints, and shall be cleaned and wet before placing. Joints shall be 3/16 inch thick and allowance made for same. Joints shall be pointed flush at the time blocks are laid and before the mortar has set.

12. Unless otherwise shown on the drawings, railings, parapets and other ornamental work shall be composed of 1 part cement, 2 parts selected white sand, and 2 parts crushed silica gravel. The forms shall be removed as soon as can be done without injury to the concrete, and the surface scrubbed with a brush and clear water, until the aggregates are exposed, using acid in the water if necessary.

13. All thin sections of cast stone work shall be reinforced sufficiently to prevent shrinkage cracks.

14. Cast stone railings and parapets shall have expansion joints at frequent intervals, and all such joints shall be lined with asbestos board, or other material which will not adhere to concrete nor discolor same.

Concrete Piling

1. Concrete piles will be divided into two classes: first, concrete piles precast and driven to place, and second, concrete piles cast in place. The former shall be sufficiently reinforced to withstand handling and shall be provided with proper cushions for driving and will be entirely at Contractor's risk. They shall be driven to elevations as given by the Engineer or else they shall be cut off to such elevations. Piles of the second class will preferably be of the "Simplex," "Raymond," "Pedestal" or similar patented types, as indicated on the drawings.

FORMULAS

2. The safe bearing power of concrete piles shall be determined by means of the following formula, for straight or tapered piles, either precast or cast-in-place, when not driven to refusal.

(a) Using drop hammer weighing not less than the weight of the pile $P = \frac{1.5\ W\ H}{S + 1}$

(b) Using steam hammer, the striking parts of which weigh not less than the weight of the pile $P = \frac{1.5\ W\ H}{S + 0.1}$

Where P = working load in tons
W = weight of hammer in pounds
H = fall in feet
S = average penetration for last foot in inches

(c) When the weight of the striking parts of the hammer is less than the weight of the pile, the working loads, as given by the above formula, shall be increased by multiplying same by the ratio of the weight of the pile to the weight of the striking part of the hammer. The weight of striking part of hammer shall equal at least one-half the weight of the pile.

TESTING

3. If tests are called for in the contract, the Contractor shall, at his own expense, and under the direction of the Engineer, test the number of test piles called for by the plans, which will be, in general, one pile for each different condition of foundation encountered, by loading to one and one-half times the specified loads without exceeding a settlement of ¼ inch, unless otherwise specified on the drawings or herein.

CAST IN PLACE PILES

4. If piles of the "Raymond" type be used, the shell shall be inspected for each pile before concrete is poured and, whenever practicable, no pile shall be filled with concrete until all shells within 6 feet of same shall have been driven.

5. Piles cast in place shall not be reinforced unless so indicated on plans, but all such piles shall be provided with at least four ¾ inch dowel bars when capped with concrete.

PRECAST PILES

6. Precast piles shall always be reinforced with sufficient steel so that when supported at the third points in the length, the stresses in the reinforcement, computed in accordance with the methods prescribed herein, shall not exceed the allowed unit stresses given.

7. In addition to the reinforcement specified above, all precast piles shall be provided with dowels, similar to those molded in place, unless otherwise specified or indicated on plans.

8. All precast piles shall be provided with special reinforcement, or other means, at the top to give greater resistance to the impact of the hammer.

9. The reinforcement shall be carefully centered in the form, and provided with mechanical devices for holding all parts rigidly in place while concrete is being poured.

10. Care shall be taken to thoroughly ram the concrete around the reinforcement.

11. Precast piles shall be provided with shoes and cushion for driving, whenever necessary, at the Contractor's expense.

12. All precast piles shall be seasoned at least 30 days at a temperature over 60° Fahr. before driving.

GENERAL

13. The number of piles required may be changed by the Engineer, at his discretion, and such change shall not affect the price per lineal foot bid, provided that the change does not exceed 25% of the total length of piles, and in the case of lump sum bids, the amount to be paid shall be to the amount bid in the proportion of the total length of piling used, to that shown on the plans, provided that such change does not exceed 25% of the quantities shown on the contract drawings.

14. All piles shall be straight and a variation from a straight line exceeding 1 inch in 24 feet shall be cause for rejection of the piles. No allowance will be made for the side pressure of earth in holding piles in line, when they are computed and loaded as concrete columns.

15. The maximum allowable load on concrete piles, not reinforced as columns, shall not exceed 300 lbs. per square inch. When the principal resistance to settlement is from the side or skin friction of the piles, this allowable load may be computed upon the average diameter of the imbedded pile. When concrete piles act as columns, the allowable load shall be computed upon the minimum cross-section of the pile and the design of such piles shall be in accordance with the rules for designing concrete columns given herein.

16. Unless otherwise called for, all concrete used in piles shall be No. 5½ (1-2-3½), the coarse aggregates being 1 inch maximum size.

17. No allowance shall be made for direct bearing on rock or hard pan when tapered or pointed piles are used.

18. No piles shall be loaded eccentrically nor shall any concrete pile be used when driven out of plumb more than ⅛ inch per foot of length.

19. The minimum distance, center to center, of piles shall be not less than 3 feet.

20. Payment shall be made per lineal foot, at the contract prices for piles furnished and for piles driven.

Inspection and Tests

1. The Engineer will have an Inspector on the work, whose duties will be to see that these specifications, the plans and contract are correctly interpreted and carried out.

2. All materials shall be purchased subject to thorough inspection and tests by the Engineer or a Laboratory appointed by him.

3. Cement shall be tested in accordance with the methods adopted by the Committee on Uniform Tests of Cement of the American Society of Civil Engineers, and no cement shall be used until the seven day test shall have been made. Unless otherwise specified, the cost of testing cement shall be paid by the Owner.

4. Reinforcing steel shall be purchased subject to tests provided for in the Standard Specifications for Steel Reinforcing Bars of the American Society for Testing Materials. Ladle analyses shall be furnished by the mill. Tension and bending tests shall be made from each melt.

5. Structural steel shall be purchased subject to tests provided for in the Standard Specifications for Structural Steel for Bridges, adopted by the American Society for Testing Materials. Ladle analyses shall be furnished by the mill. Tension and bending tests shall be made from each melt by or in the presence of an Inspector representing the Owner.

6. When the Owner, or the Engineer so notifies the Manufacturer, tension and bending tests shall be made by the Manufacturer and copies of results of such tests furnished the Engineer.

7. Aggregates shall be tested by the Engineer, or by a Laboratory designated by him, and the Contractor shall furnish, free of charge, sufficient material for such testing.

8. The Contractor shall, at the request of the Engineer in charge, cast standard cubes or cylinders for testing, which shall be tested by an approved Laboratory, in order to determine the strength of the concrete.

9. Unless otherwise specifically agreed, no concrete shall be poured in the absence of the Inspector representing the Engineer.

10. On the completion of the work and before it has been accepted, the Engineer may cause final tests to be made at the expense of the Contractor, provided that such tests are called for in the contract, by loading a typical unit of the structure with twice the specified live load applied statically. These tests will not be made on concrete which has had less than sixty days of good setting weather at a temperature of over 60° Fahr. The static load shall be held in place not less than 24 hours. Under such loads there shall be no deflection of slabs or beams exceeding 1/800 of the span, nor any other indication of weakness in any part of the structure.

11. When necessary to make tests on concrete less than sixty days old, the test load shall be reduced to an amount proportionate to the strength at the age tested, the proper reduction to be determined by the Engineer in charge.

12. In event of failure of any part of the structure under test, the Engineer may require tests to be made of all such other parts as he may deem advisable, the expense of such tests to be borne by the Contractor.

13. The Engineer may, at his discretion, apply a test load equivalent to the specified live load, at full speed, instead of the static test load described herein.

14. In case the structure, or any part thereof, does not meet satisfactorily the tests specified herein, the Contractor shall remove and replace all such defective work at his own expense.

Retaining Walls, Abutments, Piers, Etc.

1. In the design of reinforced concrete retaining walls, the lateral pressure, due to the back filling, shall be ascertained by means of Rankine's method of analysis, assuming the weight of ordinary earth fill as equal to 100 lbs. per cubic foot. The resultant of the lateral pressure shall be assumed to act at a point one-third the height of the wall from the base.

2. In the case of massive concrete vertical retaining walls, the width of the footing should not be less than 30% of the height for walls not surcharged to 40% for walls which are surcharged, for hard foundations. For walls which carry heavy electric railway or steam railroad traffic, the ratio of width of footing to height of walls shall never be less than four-tenths.

3. For reinforced concrete retaining walls, the same relation of width of footing to height of wall, as given above, may be used, provided that approximately one-third of the width of the footing lies in front of the abutment and two-thirds to the rear. When a greater proportion than this is in the rear of the abutment, the ratio of depth to height must be increased.

4. Whenever the material back of a retaining wall is subject to saturation with water, the wall must be designed to resist the full theoretical hydraulic pressure.

5. Instead of Rankine's theory, retaining walls may be computed by means of the use of an equivalent fluid pressure which may be taken at from 13 to 33 lbs. per cubic foot, according to the nature of the material and the nature of the surcharge load.

6. In using Rankine's theory for retaining walls which are used to support a non-surcharged fill, but which are subject to use as abutments for railroad bridges or other structures carrying heavy loads upon the top of the back fill, such walls shall always be computed as though supporting a surcharged fill, equivalent in weight to the live load.

7. In the design of mass concrete retaining walls and similar structures, expansion joints shall be provided at intervals not exceeding 50 feet. This distance may be increased if longitudinal reinforcement be used and walls may be built without expansion joints if the ratio of the longitudinal reinforcing steel to the area of the concrete equals or exceeds ½ of 1%.

8. Sea walls or other retaining walls which may be subjected to saturation of the back fill shall be proportioned to resist the fluid pressure due to the action of a fluid equal in weight to the weight of the filling material.

9. Sea walls subject to wave action shall be proportioned to resist the pressure of a head of water equal to twice the greatest wave height.

10. Sea walls and all other concrete construction in salt water shall be composed of a dense waterproof, rich mixture, and the cement shall be one which shall have shown its fitness for use in salt water. Whenever practicable, all concrete exposed to the action of the sea water shall be cast and set in air before placing.

11. All abutments shall be designed to resist the thrust of the backing in combination with the direct vertical loads and horizontal forces (due to tractive forces, etc.), without exceeding the specified unit stresses.

12. In assuming the angle of repose of the back filling, a slope of one vertical to one and one-half horizontal shall be assumed for loose dry earth or sand and a slope of one to one for carefully laid and compacted dry earth filling.

13. All abutments shall be carefully drained by means of tile carried through the wall, with the openings at the back carefully protected by broken stone.

14. The faces of abutments and piers shall be given a batter, unless otherwise shown on the plans, of ½ inch to the foot, and there shall be provided a coping course under the bridge seat in the case of abutments for steel bridges, which shall, unless otherwise shown on the plans, be 16 inches deep and project 4 inches.

15. Back walls for abutments of steel bridges shall have a thickness at the base of at least 60% of their height for Classes A, B, C and D, and 50% for all other classes, or else be reinforced.

16. Unless otherwise specified, concrete for abutments shall be mixed in the proportion of 1 part Portland Cement, 2½ parts sand and 5 parts broken stone (No. 7½) for massive concrete, and imbedded stone (rubble concrete) may be used if so indicated on the drawing or permitted (in writing) by the Engineer in charge.

17. Concrete for bridge seats shall be No. 5 mix, composed of 1 part Portland cement, 2 parts hard sand and 3 parts hard stone.

18. All anchor bolts for steel superstructure, when used, shall be furnished by the Owner and set by the Contractor.

19. All abutments and retaining walls shall have all surfaces in contact with earth fill waterproofed, using coal tar pitch as specified for dampproofing in Section XI, unless otherwise called for on the drawings.

20. The mixtures to be used in concrete piers shall be the same as those used in abutments.

21. The pressure of ice against concrete piers shall be considered and shall be taken as equal to the water line on the exposed side multiplied by the maximum depth of ice for that latitude and multiplied by 1,000 lbs. per square foot.

22. Piers shall also be proportioned to withstand impact from floating logs or other forces to which they may probably be subjected.

Concrete Arches

1. All arches shall be computed and proportioned in accordance with the regulations given under Sections II and III, and complete stress diagrams, using an approved method of elastic analysis, must accompany all plans.

2. All arches shall be assumed to be subject to a range of temperature of ±35° Fahr. for latitude 40. The limit shall be increased for higher and decreased for lower latitudes and provision shall be made for expansion and contraction due to this change at the crown and at the piers. The effect of the shortening of the arch ring, due to axial compression, shall be taken fully into account.

3. Unless otherwise indicated, the following proportions shall be used in arch construction:

(a) For the arch ring, light spandrel walls, light spandrel arches, etc., one part Portland cement, two parts sand and four parts stone (Mix No. 6).

(b) For heavy spandrel walls, light piers and wing walls, one part Portland cement, two and one-half parts sand and five parts stone (Mix No. 7½).

(c) For heavy piers, wing walls, etc., of massive concrete, one part Portland cement, two and one-half parts sand and five parts stone (Mix No. 7½), in which may be imbedded 25% of large stones.

(d) For heavy footings of massive concrete, one part Portland cement, three parts sand and six parts stone (Mix No. 9), in which may be imbedded 25% of large stones, or Mix No. 6 may be used with Puzzulan cement.

4. In general the arch rings of concrete arches shall be laid in transverse sections, laying the crown section first, then the sections at the quarter points and filling in between. The voussoirs thus formed shall be provided with keys equal in depth to one-fourth the depth of the arch ring.

5. The crown thickness of reinforced arches shall be not less than one-sixtieth of the span, nor the thickness at the springing point less than one and one-half times the crown thickness.

6. The reinforcing steel for reinforced concrete arches shall not be less than ½ of 1% of the section at the crown.

7. The spandrel walls shall be securely anchored to the arch rings by means of proper dowels, and the arch ring reinforced transversely sufficiently to provide for the maximum lateral thrust on the spandrel walls.

8. All earth covered arches shall be waterproofed on all surfaces in contact with the filling material.

9. In case hinged arches are used, the hinges shall preferably be of annealed cast steel, imbedded as much as practicable in the concrete and effectively anchored thereto.

10. In case ribbed arches are used each rib shall be considered as a beam to resist the bending stresses and the thrust, and in case full spandrel braced concrete arches are used, the spandrels shall be considered only as assisting in the resistance to bending and the rib shall be sufficiently strong to resist the direct thrust. In the case of full spandrel braced arches the span and rise may be taken as the span and rise of the intrados, and the non-elastic theory be used in computing.

11. Arches shall be fully analyzed by methods of analysis based upon the elastic theory of the arch and at least two conditions of live load shall be assumed.

First: The live load covering the entire arch.

Second: Live load covering one-half the arch. For arches over 100 feet in span, positions of the live load giving maximum stresses at critical sections shall be determined.

The method developed by Prof. Cain (Van Nostrand Science Series) is recommended or Principles of Reinforced Concrete Construction by Turneaure & Maurer.

12. All arch rings shall be of sufficient thickness so that the resultant line of pressure as found by the methods prescribed in the preceding article will not pass outside of the middle third of the arch ring or else they shall be reinforced.

13. The fill over arches shall be thoroughly compacted, and shall not be placed in less than two weeks after the completion of the arch ring.

Reinforced Concrete Slabs, Beams, Girders, Columns and Trusses

1. Reinforced concrete for slab, beam, girder and column construction and for all other types of reinforced concrete construction shall, unless otherwise specified, be proportioned as follows:

For carefully screened stone or gravel concrete, 1 part Portland cement, 2 parts sand and 4 parts broken stone (Mix No. 6).

For slag concrete, 1 part Portland cement, 2 parts sand and 4 parts No. 1 slag (Mix No. 6).

All materials are to be of the quality and sizes as herein described.

2. The sizes of broken stone or slag for use in reinforced concrete slab, beam, girder and column work shall not exceed 1 inch for large work nor ¾ inch for small work.

3. When reinforced concrete columns are exposed to probable injury by vehicles, etc., they shall be protected for a height of 4 feet from the ground, preferably by metal forms of structural steel or cast iron.

4. When through girders or beams carry slabs or beams attached near the lower edge, they shall be provided with stirrups at such points sufficient to carry the applied load to the upper part of the girder, such stirrups to be suitably anchored to the slab or beam or other satisfactory provision shall be made.

5. Provision shall be made for expansion at distances not greater than 100 feet apart in all slab, beam and girder construction when the reinforcement in such direction is not less than ½ of 1% of the concrete section, and at less distance when the reinforcement is less. For concrete not reinforced continuously in two directions, expansion joints shall be provided at distances not exceeding 50 feet apart in the direction in which the concrete is not reinforced.

6. Reinforced concrete trusses shall be designed in such a manner that the tensile stresses will be entirely resisted by the steel and the compressive stresses, as far as practicable, by the concrete.

7. As far as possible, they shall have no eccentric connections, and the tension bars must be anchored at the connections in such a way as to develop their full stress without producing bending moment about the joints, unless such moments be carefully determined and provided for.

8. In general, reinforced steel construction for trusses will be preferrd to reinforced concrete.

9. Concrete used for trusses of reinforced concrete or reinforced steel shall not be leaner than 1-2-4 and preferably should be 1-1½-3 with maximum size of stone not greater than ¾ inch. Unless otherwise specified, these latter proportions will be required.

Foundations and Footings

1. The hydraulic uplift of water penetrating underneath the footings of piers and abutments shall be considered.

2. All footings shall, wherever practicable, be laid free from water and no concrete footings shall be laid in water except by special arrangement with the Engineer.

3. Footings having heads of piles imbedded therein shall have the contents of the imbedded piles deducted in computing contents of masonry.

4. Reinforced concrete footings shall be designed in accordance with the provisions of preceding sections, but no reinforcement shall be placed at a less distance than 2½ inches from any concrete surface. When the footing is submerged, or in wet ground, the reinforcement shall be protected by not less than 4 inches of concrete.

5. The reinforcement shall be so arranged as to distribute the loads equally on the foundation.

6. Reinforced concrete footings shall always be 1-2-4 (No. 6) mix Portland cement concrete, and Mass concrete footings shall be 1-2½-5 (No. 7½) mix concrete, unless otherwise shown on the drawings. (See Paragraph 3, Section I).

NOTE.—A mat of reinforcing bars in the bottom of a mass concrete footing, used as ties and not to resist bending stresses, shall not be considered as changing the classification of the concrete to reinforced concrete.

7. In estimating the excavation for footings, the size of excavations shall be taken as equal to the neat size of the footings, plus one foot all around, with sides vertical, and no allowance shall be made for additional excavation, unless so stated in the contract.

8. Unless otherwise agreed upon, the price bid by the Contractor for the footings shall include all sheeting, pumping, cofferdams, bracing, etc., required to keep the pits open and free from water while depositing concrete, the removal of same, and backfilling to the original level of the ground.

9. When permanent timber sheet piling is called for on the plans, it shall be built as shown thereon, and paid for per foot board measure of timber in place. In general, timber sheet piling shall be left in place around piers in streams or other places subject to scour.

10. When Wakefield sheet piling is called for, it shall be triple lap, of thickness as indicated on plans, bolted at intervals of not over six feet with two bolts, and spiked at intermediate points not over 18 inches apart. Bolts shall be ⅜ inch for three inch piling, ½ inch for six inch and ⅝ inch for 9 and 12 inch thicknesses. The thickness called for shall be assumed to be based upon the theoretical thickness of plank before planing. The middle plank shall be surfaced two sides. The tongue shall be not less in width than the thickness of the plank.

11. When permanent steel sheet piling is called for on the plans, it shall be of the size and type shown thereon, and paid for per pound in place.

12. When temporary steel sheet piling is shown on the plans, and the cost is not included in the excavation, it shall be paid for per square foot of piling driven, and shall be removed without extra charge.

13. When permanent concrete sheet piling is called for, it shall be constructed and driven as indicated on the plans, and paid for per square foot in place.

14. When cofferdams are required, they shall, unless otherwise specified, be paid for on a lump sum basis, to include construction, maintenance and removal, including pumping when required.

15. All foundations shall be carried to a depth well below the frost line, or possible scour.

16. No concrete shall be laid on any foundation until such foundation shall have been inspected and accepted by the Engineer in charge.

Timber Piling

1. No. 1 grade timber piles shall be of white, burr and post oak; Southern yellow pine; Douglas fir; tamarack; Eastern white and red cedar; chestnut; Western cedar; redwood or cypress.

2. No. 2 grade piles shall include red and all other oaks not included in the No. 1 grade; sycamore; sweet, black and tupelo gum; maple; elm; hickory; Norway pine, or any sound timber that will stand driving.

3. Piles shall be cut from sound trees; shall be close grained and solid, free from defects, such as injurious ring shakes, large and unsound or loose knots, decay or other defects, which may materially impair their strength or durability. In Eastern red or white cedar a small amount of heart rot at the butt, which does not materially injure the strength of the pile, will be allowed.

4. Piles must be cut above the ground swell and have a uniform taper from butt to tip. Short bends will not be allowed. A line drawn from the center of the butt to the center of the tip shall lie within the body of the pile.

5. Unless otherwise specified, piles must be cut when the sap is down. No. 1 grade piles shall be peeled soon after cutting. All knots shall be trimmed close to the body of the pile.

6. For round piles the minimum diameter at the tip shall be nine inches for lengths not exceeding 30 feet; eight inches for lengths over 30 feet, but not exceeding 50 feet and seven inches for lengths over 50 feet. The minimum diameter at one-quarter of the length from the butt shall be 12 inches and the maximum diameter at the butt 20 inches.

7. For square piles the minimum width of any side of the tip shall be nine inches for lengths not exceeding 30 feet; eight inches for lengths over 30 feet, but not exceeding 50 feet, and seven inches for lengths over 50 feet. The minimum width of any side at one-quarter of the length from the butt shall be 12 inches.

8. No. 1 grade square piles shall show at least 80% heart on each side at any cross section of the stick, and round piles shall show at least 10½ inches diameter of heart at the butt.

9. The bearing capacity of timber piles shall be based, unless otherwise specified, upon the following formula:

$P = \frac{1.5\ Wh}{S+1}$ where P = total safe load on pile in pounds, W = weight of hammer in pounds, h = fall of hammer in feet and S = average penetration for last foot in inches.

When a steam hammer is used $P = \frac{1.5\ Wh}{S+0.1}$ where W = weight of striking parts of hammer in pounds and the other symbols are the same as given above for drop hammers.

10. When driving is done, or assisted, by water jet, the hammer shall be used to test the bearing of the pile after the jetting is completed.

11. The Engineer may require the use of the steam hammer instead of the drop hammer, whenever, in his opinion, there is a possibility of damage to adjoining work by the impact of driving.

12. Piles shall not be pointed when driven into soft material, and may be pointed to a six-inch square for driving in ordinary material.

13. Steel or cast iron shoes shall be provided for piles when driving in very hard material, as shall be required by the Engineer in charge.

14. Steel bands shall be provided whenever necessary to prevent brooming the head of the pile.

15. Driving caps shall be provided when, in the opinion of the Engineer, they are necessary.

16. Timber piles shall be paid for at the contract prices for piling furnished and for piling driven.

17. Tops of piles shall be sawed off true and level at elevations shown.

18. In general, timber piles for foundations shall be spaced not to exceed two feet six inches apart, shall be not less than 12 feet in length in firm ground and 30 feet in soft ground, shall be embedded in the concrete footings at least six inches, and the load carried shall not exceed 20 tons per pile.

19. No reliance shall be placed upon vertical timber piles to resist horizontal thrust.

General

1. Specifications given on drawings shall supersede requirements given herein for the particular structure for which such drawings are made.

2. In estimating quantities of reinforced concrete, no deduction shall be made for the volume occupied by the reinforcing rods.

3. Concrete structures built on the Unit system, in which the several parts are molded separately and erected into place, shall be subject to all the restrictions given herein, the same as for monolithic construction. When proper provision is made for bonding unit slabs into unit beams and girders, the usual assumption for the "T" beams may be used. When members are made on a jarring machine, or similar device, to increase the strength of the concrete, the unit stresses used may be increased proportionately to the increased strength, the percentage of increase to be determined by the Engineer in charge.

4. Expansion joints in concrete work shall be provided at all points where cracks would naturally occur and in mass concrete, walls, etc., shall, in general, be spaced not to exceed 50 feet apart. In reinforcing to provide against cracking, due to contraction of concrete, the amount of reinforcement provided shall be not less than ¼ of 1% of the concrete area. Expansion joints shall be provided with concrete keys. Between the surfaces there shall be placed at least two thicknesses of asbestos board, ⅛ inch thick, or other satisfactory separators.

5. The royalty for all patented constructions shown on the plans, or called for in the specifications, shall be paid by the Owner, except when such plans and specifications are prepared, or submitted, by the Contractor, in which case all royalties are to be paid by the Contractor.

6. The royalty for all patented devices used by the Contractor in the execution of the work or for patented details used by the Contractor, but not shown or called for on the drawings, shall be paid by the Contractor.

7. The party responsible for the payment of royalties for the use of patents shall also defend any and all suits that may be brought for infringement of such patents and shall pay all damages arising from such suits to either the Owner or the Contractor.

8. Patented construction shown on plans shall be so designated thereon, giving the number of the patent and indicating the part of the design which is covered thereby, and the Contractor shall not knowingly use a patented device in construction without notifying the Owner.

9. When anchor bolts or other devices are to be placed in concrete, they shall, unless otherwise specified, be placed by the Contractor for the concrete work, who shall notify the Owner at least one week in advance of such placing. All anchor bolts or other devices to be imbedded in the concrete, which are not part of the concrete work, shall, unless otherwise arranged, be furnished by the Owner.

Cement Walks, Concrete Curbs and Roadways

1. Portland cement walks on bridges shall, in general, consist of a reinforced concrete slab base with a wearing course, one inch thick, of rich mortar. The slab base shall be computed to sustain the actual dead and the required live loads, in accordance with preceding sections of these specifications. Expanded metal, woven or welded wire mesh will be preferred for the reinforcement of sidewalk slabs. The wearing course shall be one inch thick, and shall be placed as soon as possible after the base, but not more than 45 minutes thereafter. The wearing course shall consist of one part cement to two parts crushed stone, carefully selected for greatest resistance to abrasion, well graded in size, passing a ½ inch screen, and held on a No. 30 sieve. The Engineer in charge may, at his discretion, allow a selected sand, conforming in size to the crushed stone specified, to be used.. The sidewalk surface shall, unless otherwise noted, have a slope of ⅜ inch to the foot. Sidewalk surfaces shall have all corners rounded to ½ inch radius. The wearing course shall be of the proper consistency to work well with a wood float.

2. When the sidewalk finish cannot be laid at the same time as the slab, the finish coat shall be two inches thick and the base shall be carefully cleaned, scored, soaked with water and painted with a cement grout immediately before placing the finish.

3. When one course walks are specified, the entire slab shall be composed of one part cement, two parts selected sand and three parts crushed stone, and immediately finished as specified above for two course work.

4. All sidewalks of Portland cement shall be finished by workmen especially skilled in the art.

5. Portland cement sidewalks on approaches to bridges will not usually be considered part of the bridge contract, but when they are so specified, they shall be built with a surface finish similar to that described for sidewalks on the bridge, laid on a base prepared as follows:

The sub-grade surface shall be 12 inches below finished grade, thoroughly compacted by rolling or tamping and well drained. On this shall be laid a course of broken stone, gravel or cinders six inches in thickness, after rolling with a roller weighing not less than five tons or compacting with a rammer weighing not less than 50 lbs. on a surface of 100 square inches. No material over four inches in size shall be used in the foundation thus prepared. Upon this foundation shall be laid the concrete walk with a thickness of six inches.

6. If a two course walk be specified, the first course shall be five inches thick, of 1-2½-5 (No. 7½) concrete, using 1¼ inch to ¼ inch coarse aggregate. The wearing course shall be placed and proportioned as above specified for concrete slabs on bridges. If one course work be specified, the entire thickness of six inches shall be composed of 1-2-3 (No. 5) concrete as before specified.

7. Expansion joints in cement walks shall be placed at intervals of not over 30 feet, unless the walks be reinforced.

8. Cement walks shall be divided into blocks containing not more than 36 square feet, and not more than six feet in any dimension, or else reinforcement shall be provided of a cross-section of not less than 0.041 square inch per square foot.

9. Concrete curbs on bridges shall be laid at the same time as the sidewalk slabs, and when combined curbs and gutters are specified, the gutters shall be poured integral with the curbs. All proportions, materials, finish, etc., of concrete curbs shall be same as specified for walks.

10. The thickness of curbs shall be not less than six inches and all curbs shall be battered one inch in eight inches. The edge of curb next to roadway shall be rounded to 1½ inch radius, unless metal protection strip be specified. The corner between curb and gutter shall be rounded to 1½ inch radius and all other corners to ½ inch radius.

11. Expansion joints shall coincide with expansion joints in sidewalks and roadway.

12. Concrete curbs on fills over arches and on approaches shall be not less than six inches thick at top and 12 inches thick at base, and 24 inches deep, laid on a foundation course of compacted gravel, broken stone, cinders, or slag, not less than six inches thick.

13. Combined curbs and gutters on fill over arches or on approaches shall be not less than six inches thick at top and 12 inches thick at base, and the width of gutter shall be not less than 16 inches nor more than 24 inches. Such curbs and gutters shall be laid in sections, from five to eight feet in length, on a compacted base of cinders, gravel or broken stone or slag, and all proportions, method of laying, etc., shall be the same as specified for cement walks. The backfill for curbs shall be composed of the same material as the base.

14. The radius of curb at all street intersections shall be six feet unless otherwise specified.

15. Walks and curbs shall be kept wet by sprinkling and covered with canvas or other suitable material for a period of at least four days.

16. When concrete sidewalks or curbs are laid on a newly placed fill, which exceeds two feet in depth, there shall be provided metal reinforcement placed ¾ inch in from the under side of the slab and two inches from the under side of the curb, the area of such reinforcement to be not less than 1/200 of the cross sectional area of the concrete.

17. Two course concrete pavement shall be constructed in the following manner:

If on filled material, the fill shall be deposited in layers of one foot thickness, compacted by rolling with a roller weighing not less than five tons, or by ramming with a hand tamper weighing not less than 50 lbs. on 100 square inch area.

If pavement is to be built in cut, the sub-grade shall be thoroughly rolled or compacted as above described.

18. On the sub-grade thus prepared, lay the first course, six inches thick, of 1-2½-4 concrete, using ½ inch stone, first wetting the surface of the sub-grade.

19. The second or wearing course shall be two inches thick and shall be laid on the first course within 45 minutes after the first course is poured, and shall consist of one part cement to one part selected sand and 1½ parts crushed stone, especially selected for resistance to abrasion, and composed of ½ to ¼ inch material, not more than 10% being allowed to pass a ¼ inch screen. This stone shall contain no soft, flat or elongated particles.

20. All concrete pavements shall be crowned not more than 1/100 of the width, with transverse joints not more than 36 feet apart, shall be screeded to grade, floated with wood float and kept wet and protected from the weather by canvas or other suitable material for at least ten days, and shall be closed to traffic for at least fourteen days in favorable weather.

21. Joints shall be ¼ inch wide, filled with prepared bitumen saturated expansion strips and protected by soft steel plates not less than 2½ inches wide and ¼ inch thick, curved to crown and thoroughly anchored into the concrete.

22. All pavements over 20 feet wide shall be reinforced with metal placed two inches below the top surface, and having not less than 0.05 square inches of metal per foot of section each way.

23. Drains and catchbasins shall be located as indicated on plans.

24. If the curb be integral with the pavement, use the same proportion as specified for the pavement for the curb base, and use the wearing course mixture for that part of the curb above the base.

25. If one course pavement be specified, the mixture shall be 1-2-3, using specially selected sand and 1½ inch stone, containing no soft, flat or elongated particles. The thickness shall be not less than six inches and all preceding requirements for two course pavement in regard to preparation of sub-grade, finish, joints, etc., shall be observed.

26. Scuppers, catchbasins, downspouts and drains shall be furnished and placed as shown on drawings. Scuppers and catchbasins shall be of cast iron, not less than ¾ inch thick, free from defects, and subject to hammer testing for soundness and toughness. Downspouts and drains shall be of cast or wrought iron. All shall be heavily coated with asphaltum fluxed with residuum oil, or such other protective coating as may be specified.

27. Curbs on bridges and approaches thereto shall be eight inches high, unless otherwise specified.

Brick Pavement

1. When so shown on the plans, the roadways of bridges or bridge approaches shall be paved with brick.

2. All materials shall be carefully excavated to a sub-grade uniformly below the required surface of the finished pavement, allowing for the depth of the brick, one inch sand cushion, and six inches of concrete. All soft, or unsuitable material below the sub-grade shall be removed. Excavation or shrinkage below the sub-grade shall be filled with 1-3-6 (No. 9) concrete, which shall form a part of the concrete foundation specified below. When the pavement is to be laid on embankments, the filling shall be made in layers of about six inch thickness, compacted by ramming or rolling, or other means satisfactory to the Engineer.

3. Upon the subgrade shall be laid and thoroughly rammed for the full width between curbs a layer of 1-3-6 (No. 9) concrete not less than six inches in depth at any point, unless otherwise indicated on the plans.

4. Upon the concrete foundation, prepared as specified, shall be placed a cushion of sand of such thickness that, after the brick are firmly bedded by rolling, the upper surface thereof shall be exactly at the required grade and the sand cushion shall be about 1½ inches thick. The cushion shall consist of sand, stone dust or granulated slag, passing a ¼ inch screen. The sand cushion shall be compressed by rolling with a hand roller of about 300 lbs. weight. The cushion is to be rolled, depressions filled, and rerolled not less than three times. The sand shall be slightly wet at the time the brick are laid.

5. Upon the sand cushion shall be laid vitrified paving bricks of best quality, sound, hard burned, of uniform size, well formed, all from one manufactory, all of one color, made and burned especially for street pavements. They shall be homogeneous in character and compact in structure, free from lumps of uncrushed clay or injurious lamination, fire cracks or checks of more than a superficial extent and when immersed in water for four days they shall not develop cracks nor spall.

6. When dried for 24 hours at a temperature of not less than 212° Fahr. and then immediately immersed in water for 24 hours, no brick shall absorb more than 3% of its weight.

7. No paving brick shall crush under a load of 10,000 lbs. per square inch when tested on edge.

8. The bricks shall be laid on edge at right angles to the street or as directed by the Engineer. Each alternate course shall commence with a half brick, but half bricks or bats shall not be used except at the ends of courses.

9. All longitudinal joints shall be broken with a lap of not less than three inches. The joints shall be laid tight and all bricks shall be laid by skilled workmen who shall stand on the brick already laid. In no case shall the sand bed be disturbed after being brought to the exact sub-grade and crown of the street.

10. After the bricks are laid, they shall be rolled to the proper surface with a roller weighing not less than five tons.

11. The entire surface shall be closely inspected, brick by brick, by a skilled workman, who shall remove any brick which may be found chipped or broken, irregular in shape, not a perfect fit, or not to exact surface, and who shall remedy such defective spots if found.

12. The joint next to the curb shall be one inch wide and filled before the balance of the roadway is grouted with bituminous cement which must not run at a temperature of 100° Fahr., nor become brittle at 0° Fahr. A similar transverse joint shall be made at all expansion joints in bridges and over the crown of all arches.

13. The entire surface shall finally be flushed and the joints filled with Portland cement grout in the following manner: First, a pure thin grout shall be formed of one part cement to one of clean, fine, sharp sand, passing a No. 10 sieve, and the whole surface shall be flushed with this from a portable grout box, care being taken to fill all the joints. Afterwards a thicker grout, formed of the same proportions of cement and sand with just enough water to enable it to run, shall be forced into the joints and the pavement shall then be completely covered with sand and left undisturbed for not less than eight days before being thrown open to traffic. Before the final acceptance of the work, the Contractor shall sweep the street clean and remove the sweepings.

14. The top surface of the finished pavement shall conform accurately to the grades and pitch to be given by the Engineer.

15. When brick pavement is laid on bridges, the floor of which forms a base for same, the sand cushion shall be laid directly on such base.

16. The contract price of brick pavement shall include the cost of all labor and materials required to prepare the subgrade, lay the concrete foundation, sand cushion and the brick surface as specified in the preceding paragraphs. Payment will be made for the actual number of square yards of brick pavement measured in place.

17. When "T" rails are laid in brick pavement, special shaped brick shall be used on gage side of rails, and care shall be taken to insure that all spaces between rails and bricks be filled with cement mortar.

18. The Contractor must file sample brick with his bid or else must name some well known brand which he will use.

19. For operations not covered by these specifications, the Standard Specifications of the National Paving Brick Manufacturers Association shall be followed.

Asphalt Block Pavement

1. The blocks shall be standard size (usually five inches in width by twelve inches in length). Unless otherwise specified, blocks shall be two inches in depth. A variation ¼ of an inch from these dimensions will be sufficient ground for rejecting any block.

2. The blocks shall be composed of the following materials:

Asphaltic Cement	9 to 13%
Conglomerate copper sand (see note)	76 to 62%
Limestone Dust	15 to 25%

3. The copper sands in the blocks must be brushed so that every particle will pass a screen of ⅜ inch mesh. The blocks must receive a compression in the molds of not less than 220 tons, and must weigh not less than 10 lbs. per block. The blocks shall yield, when extracted with bisulphide of carbon and after the evaporation of the solvent, not less than 6%, or more than 8% of bituminous matter.

NOTE.—Other sands may be used subject to the approval of the Engineer.

4. The asphaltic cement shall be composed of steam refined Trinidad Lake asphalt and heavy petroleum oil, or other equally good flux. The refined asphalt and the flux shall be mixed in such proportions as will produce an asphaltic cement of a proper consistency and quality. The heavy petroleum oil shall be free from impurities and brought to a specific gravity of from 10° to 14° Beaume and shall have a fire test of not less than 350° Fahr.; it shall contain an appreciable amount of light oils or matter volatile under 250° Fahr., and the distillate at 400° Fahr. for 30 hours shall be less than 10%. Any other flux, if used, as a substitute for the heavy petroleum oil, shall also fulfill the above tests except that for specific gravity.

5. Upon the surface of the cement foundation shall be spread a bed of cement mortar ½ inch in thickness. This mortar bed shall be composed of Portland cement and sand, as specified, and mixed in the proportion of one part cement to four parts sand. This mortar bed shall be "struck," by an approved method, to a true surface exactly parallel to the top of the finished pavement and the depth of the block below it.

6. Upon this mortar bed the blocks shall be immediately laid with close joints and uniform top surface.

7. The blocks shall be laid by the pavers standing upon the blocks already laid, and not upon the bed of mortar.

8. The blocks shall be laid at right angles with the line of the street with such crown as the Engineer may direct; and in such manner that all longitudinal joints shall be broken by a lap of at least four inches. The blocks shall be so laid as to make the lateral joints as tight as possible, consistent with keeping a good alignment of the courses across the street and the longitudinal joints shall be immediately closed by pressing each course in the direction of its length by lever. When thus laid the blocks shall be immediately covered with clean, fine dry sand, entirely free from any loam or earthy matter. This sand shall be swept over the surface until the joints are all filled and shall be allowed to remain on the pavement not less than thirty days or for such length of time as will allow the street traffic to thoroughly grind the sand into all the joints.

9. The price bid per square yard of asphalt block surface must include the laying, and furnishing of all materials, labor and implements necessary to complete the wearing surface, including the mortar bed, as specified above.

10. When asphalt block pavements are laid on filled or natural foundations requiring a sub-base, the base shall be prepared as follows:

All materials shall be carefully excavated to a sub-grade uniformly below the required surface of the finished pavement, allowing for the depth of the block, one inch sand cushion and six inches of concrete. All soft or unsuitable material below the sub-grade shall be removed. Excavation or shrinkage below the sub-grade shall be filled with 1-3-6 (No. 9) concrete, which shall form a part of the concrete foundation specified below.

Upon the sub-grade shall be laid and thoroughly rammed for the full width between curbs a layer of 1-3-6 (No. 9) concrete, not less than six inches in depth at any point. To mark the top grade of the concrete, sound stones of suitable size and depth shall be set upon the sub-grade about 12 feet apart along the center and each side of the roadway as the Engineer may direct. Such marking stones shall remain and form a part of the concrete foundation.

11. When the plans call for the asphalt block to be laid on a cushion, sand, stone dust or granulated slag, passing a ¼ inch screen, shall be used, slightly wet, and carefully screeded to grade. All other work shall conform to that specified for block laid directly on the concrete.

Sheet Asphalt Pavement

1. Sheet asphalt pavements on bridges shall generally be laid upon a concrete or asphalt binder base, which in the case of buckle plate floor construction shall never be less than 1½ inches thick over the heads of projecting rivet heads and buckles.

2. When asphalt pavements are laid upon concrete sub-base the surface shall be carefully cleaned and roughened and a neat cement or other binding material be placed thereon and the asphalt binder and wearing surface to the depth of 2½ inches shall be immediately placed thereon.

3. The pavement shall be equal in all respects to the best grade of standard asphalt pavement which is being built by any established paving company at the time the pavement herein described is built.

4. When asphalt pavement is called for on filled approaches or other filled constructions, the said fill shall be carefully excavated or graded to a subgrade 8½ inches below the required surface of the finished pavement. All soft or unsuitable material below the subgrade shall also be removed and any excavation below the subgrade shall be filled with concrete or carefully tamped sand, gravel or broken stone.

5. Upon the subgrade shall be laid a thoroughly rammed layer of concrete (1-3-6), not less than six inches in depth. Upon this concrete base shall be laid the asphalt binder and wearing surface, 2½ inches thick.

6. The 2½ inch asphalt pavement shall be composed of two courses, the binder course and the pavement mixture or wearing surface.

7. The binder course shall be composed of clean, broken stone, gravel or slag of such size as will pass through a one-inch ring.

8. The asphalt cement shall be composed of 100 lbs. of asphalt and about 18 lbs. of heavy oil; the quantity of oil will vary as may be necessary to produce the best results.

9. The broken stone, gravel or slag shall be heated and thoroughly mixed with asphaltic cement in such proportions as shall thoroughly coat the particles of stone, gravel or slag.

10. The mixture shall be spread on the foundations to such a thickness that, after being compacted by a roller weighing not less than five tons, it shall have a thickness of one inch.

11. The pavement mixture shall be laid immediately upon the binder course. It shall be brought to the work at a temperature of 250° Fahr. It shall then be carefully spread by means of iron rakes in such manner as to give a uniform and regular grade and to such depth that after having received its ultimate compression, it shall have a thickness of two inches. The surface shall then be compressed by a hand roller, after which a small amount of cement shall be swept over it and it shall then be thoroughly compressed by a heavy steam roller, the rolling being continued as long as it makes an impression on the surface.

12. Asphalt shall not be laid directly against Street Railway Tracks, but special shaped paving block, in full lengths and half lengths alternating, shall be laid alongside the rails, and filled with asphaltic cement, unless other details are shown on the drawings.

13. This paving block shall be equal to that specified for brick paving and will be paid for at the same rate as asphalt paving.

14. Next to the curb the pavement shall be coated over with pure hot asphalt for a width of 15 inches after the paving is completed.

15. The composition of the pavement mixture shall be from 12 to 16 parts of asphaltic cement mixed with 67 to 73 parts of clean, sharp sand and from 15 to 17 parts of pulverized carbonate of lime.

16. The sand and asphaltic cement shall be heated separately to about 300° Fahr.

17. The pulverized carbonate of lime while cold shall be mixed with the hot sand in the required proportions and shall then be mixed with the asphaltic cement at the required temperature and in the required condition with an apparatus suited to affect a perfect mixture.

18. The asphaltic cement shall be composed of 100 parts, by weight, of refined asphalt mixed with 12 to 15 parts of heavy petroleum oil.

19. Asphalt pavement shall be laid only by workmen experienced in that class of work. If a guarantee is required, the Owner will deduct and retain from the final estimate or other estimates, an amount equal to .....% of the amount due for paving, which money will be retained for a period of ..... years, and if at the end of ..... years the Contractor shall have made good all defects which may have developed in the paving, the Owner will return to the Contractor the amount so retained.

20. Expansion joints must be provided in the base wherever shown on the plans.

21. When the asphalt pavement is laid directly upon concrete floor plates of bridges, the base, as specified above, shall be omitted and only the 2½ inch thick pavement be required.

22. The price bid per square yard of sheet asphalt surface shall include the laying, furnishing of all materials, labor and implements necessary to complete both base and finished surface.

Wood Block Pavement

1. On the concrete floor slab shall be laid a dry sand and cement cushion, composed of one part of a slow setting Portland cement and four parts clean, dry sand, thoroughly mixed before spreading, and after spreading shall be surfaced and then rolled to the correct crown and grade. The cushion, after compacting, shall not be less than ½ inch.

2. As the block is laid, the layer of sand and cement shall be moistened by sprinkling and the block laid immediately after sprinkling, in order that the cement will not have an opportunity to set before the blocks are placed. The blocks shall then be laid at right angles to the length of the bridge, in parallel lines, grain vertical, and adjoining courses breaking joints not less than three inches. Two lines of block, next to each curb and next to each rail, shall be laid with long dimension of block parallel to curb; the balance of the blocks to be at right angles to these. Blocks shall not be laid in contact. Transverse joints shall, unless otherwise specified, be ⅛ inch open joints, and longitudinal joints shall be ¼ inch. Satisfactory mechanical spacing devices shall be provided to secure uniform width of joints.

3. Along the curb lines, on both sides of the roadway, for the entire length of the bridge, shall be provided an expansion joint, one inch thick, of the depth of the paving block, and transverse joints ½ inch thick shall be provided across the roadway at the ends and approximately 50 feet apart for the entire length of the bridge, or as shown on plans. These joints shall be made by placing boards of the proper thickness in position to hold the block in place until ready for filler. The boards shall then be removed carefully and the joints filled with a bituminous filler, as specified. At expansion joints in the bridge structure, the transverse joints shall be sufficient to provide for the maximum possible movement of the joint.

4. The fitting and piecing of blocks along the sides and ends shall be neatly and carefully done and as the Engineer directs. No piecing will be allowed except along sides and ends and all irregular, uneven or unsatisfactory block shall be removed.

5. After the block have been laid, they shall be properly rolled or tamped to a firm bearing and uniform surface. All blocks which are defective, broken, split or otherwise damaged or displaced, shall be removed immediately after rolling or tamping and replaced with sound blocks. Blocks should be inspected as carefully as possible before laying and rolling, in order that the blocks may not be disturbed after rolling unless necessary.

6. After the block have passed the inspection of the Engineer, the joints between blocks and the expansion joints shall be filled to two-thirds the depth of block with a bituminous filler, acceptable to the Engineer. The filler shall not become brittle at 0° Fahr. nor flow at 120° Fahr.

7. The paving filler shall be heated and flushed into the joints to two-thirds the depth of the block, and poured at a temperature at which it is so liquid that it will run freely into the joints and in no case at a temperature of less than 300° Fahr.

8. After the first has set, a second coat shall be applied to complete all unfilled joints to the proper height. The filling of the joints shall be done only in clear dry weather when the temperature of the air is not less than 50° Fahr. While the last application is still hot, a ¼ inch layer of clean, coarse, dry sand shall be spread over and rolled into the entire surface, filling the balance of the joints.

9. The wood block shall be purchased from a reputable firm engaged in creosoting timber; said firm to be satisfactory to the Engineer.

10. If, for any reason, the blocks cannot be laid within a reasonable time after treatment, they shall be piled closely and covered to protect them from the weather.

11. The wood from which the blocks are made must be of Southern Yellow pine of the grade known as Prime Timber. All timber must be sound, well manufactured, all square edge, and free from the following defects: unsound, loose and hollow knots, worm and knot holes or other defects which will be detrimental to the life of the block or interfere with its laying. No second growth timber will be allowed. The annual rings shall average not less than eight and there shall not be less than six to any one inch, measured radially from the heart.

12. The blocks shall average 80% and no blocks shall contain less than 50% of heart wood. The blocks shall be from six to ten inches long (except the necessary number of shorter blocks to break joints), but shall average eight; their depth (parallel to fibre) shall be of the depth specified, but not less than three inches, and their width shall be from three to four inches, but all blocks used in any one contract shall be of the same width. The blocks shall be truly rectangular, smoothly and evenly sawn and of uniform dimensions. The depth may not vary more than 1/8 inch from that specified.

13. The blocks shall be treated, preserved or creosoted as hereinafter specified and each block shall contain at least 16 lbs. of creosote oil per cubic foot of wood or when a block contains much natural pitch, it shall receive as much creosote as can be forced into it by the same process and pressure as is used in the treatment of the blocks of the same kind of wood which will receive 16 lbs. of creosote oil per cubic foot.

14. The creosote oil shall be a dead oil or coal tar product. It shall not contain more than 3% of water and if it does contain this amount of water, a corresponding correction must be made so that an equivalent additional amount of creosote is forced into the blocks. It shall contain only traces of acetic acid and acetates. Its specific gravity at 100° Fahr. (38° C.) shall be at least 1.03 and not more than 1.07 so as to assure its thoroughly penetrating the wood blocks. The residue insoluble by filtration with benzol and chloroform must not exceed 3% of the weight of the creosote oil. Fractional distillation of 100 grams of the creosote oil shall produce percentages of dry oil by weight within the following limits:

Up to	150° C. (302° F.)	Not to exceed	2%
Between	150° C. (302° F) and 170° C. (338° F.)	"	1.5%
"	170° C. (338° F.) and 235° C. (455° F.)	"	35%
"	235° C. (455° F.) and 300° C. (572° F.)	"	35%

15. The residue remaining shall be soft and adhesive. The creosote oil shall contain about 25% of crystalizable napthalene and at least 15% anthracene oils. At least 95% of the creosote oil shall be soluble in carbon-bisulphide and equally in absolute alcohol.

16. The wood blocks, after being cut and ready for treatment, shall be placed in a suitable iron receptacle or cylinder and there sterilized with dry steam under a pressure of at least 30 lbs. and not to exceed 50 lbs. per square inch during at least three hours and as much longer, not to exceed seven hours, as the condition of the wood and the season of the year requires. The temperature within the cylinder during the process of steaming shall be between 200° and 240° Fahr. At intervals during this process, the condensed steam, sap and other liquid matter shall be drawn from the receptacle by means of valves. At the completion of the steaming process, all condensed steam and other fluid matter shall be blown from the cylinder through an opening in its bottom, and the steam shall be caused to pass out through an opening in its top.

17. The draining and exhaust valves of the cylinder shall then be closed and a vacuum pump shall immediately produce, as quickly as possible, a vacuum of at least 24 inches and as much

more as may be necessary, and maintained in the cylinder until moisture and gases cease to come from the cylinder. During this process the wood blocks within the cylinder shall be kept hot by means of steam coils within it.

18. Immediately thereafter and while the vacuum exists, the creosote oil at a temperature between 180° Fahr. and 200° Fahr. shall be run into the cylinder and forced and maintained under such pressure that the wood blocks shall absorb and be impregnated with creosote oil to the amount specified above. The excess of creosote oil in the cylinder shall then be withdrawn; the blocks drained and prepared for shipment.

19. The blocks ready for use must meet the following indentation pressure test, which may be made, at the discretion of the Engineer, to replace the requirements of Paragraphs 11 and 12.

The blocks to be tested are first dried at 100° Fahr. during 12 hours. Then a polished steel die of one square inch on its lower face, square edges, corners, and perpendicular sides, is placed on a dried block, firmly supported in a compression machine. A pressure of 8,000 lbs. is applied quickly and maintained exactly one minute. The die must not descend and indent the block more than ⅛ inch. The measurements are to be taken from when the die is lightly pressed against the block to the instant the 8,000 lbs. pressure has been applied one minute. The die is placed anywhere within ½ inch of the edges of the block and so as to compress lengthwise the wood fibres.

20. The wood blocks shall be inspected by the Engineer at the place of manufacture or on arrival at the point where they are to be used or when piled adjacent to the street to be paved. All blocks not in conformity with the requirements of these specifications will be rejected and shall be removed from the locality of the pavement to be laid.

21. Alternate proposals will also be received on Lug or special shaped blocks, which shall, so far as possible, comply with the above specifications. Such alternate proposals shall be on the regular form of proposal.

22. When wood block pavements are laid on approaches or fill, a concrete base shall be provided as specified for brick pavements.

23. The price bid for wood block pavements shall include all labor and materials required to complete the work, including the concrete base, when required.

Bituminous Pavement

1. The concrete base shall be dry, thoroughly cleaned of all laitance, dirt, grease and loose materials. It shall preferably be given a rough finish, either by leaving coarse aggregate at the surface or by brooming, or otherwise mechanically roughening the surface of the green concrete. On this base shall be laid the bituminous wearing surface, two inches in thickness, as follows:

2. The aggregate shall be composed of gravel or hard crushed stone, passing a one inch screen with the dust screened out. To this shall be added sufficient sand, from one-quarter to one-half the volume of the stone, according to the character of the stone. This sand shall be clean, hard, preferably silicious, and at least 25% shall be retained on a screen having 20 meshes per inch and 5% shall pass a screen having 80 meshes per inch.

3. The aggregate shall be heated to a temperature of 325° Fahr. for Binder "a," 120° to 200° for Binder "b" and Binder "c," when the bituminous cement at the proper temperature and in the proper proportion shall be added.

4. The bituminous cement shall be composed of one of the following materials, or a similar product approved by the Engineer in charge.

(a) Standard Paving Asphalt (manufactured by the Standard Oil Company of New Jersey) not less than 22 gallons to the cubic yard of aggregate, applied at a temperature of not less than 350° Fahr.

(b) Bermudez Road Asphalt (The Barber Asphalt Paving Co.) not less than 17 nor more than 20 gallons to the cubic yard of aggregate, applied at a temperature of not less than 300° or more than 375° Fahr.

(c) Tarvia X (The Barrett Company) not less than 15 gallons to the cubic yard of aggregate, heated to a temperature of from 200 to 300° Fahr.

5. The aggregate and binder shall be thoroughly mixed by hand with warm shovels, or in a suitable machine. Hand mixing will be allowed only when the quantity is less than 200 square yards.

6. The mixture shall be applied hot to the concrete surface and spread by means of hot hoes or rakes, screeded to the proper thickness and thoroughly rolled with a roller weighing not less than five tons.

7. A finish coat shall then be applied to the surface of the pavement, consisting of a seal coat of the hot bituminous material, followed by an application of stone screenings, or fine sand where screenings are not obtainable, passing a ¼ inch screen and free from fine dust.

8. The bituminous finish shall stop at the gutter line, and the gutter be finished with a two inch cement finish, mixed in the proportion of one part Portland cement to two parts hard, clean sand, or screenings, and carefully trowelled to surface and grade.

9. The bituminous finish shall not be laid next to steel rails, but a course of creosoted wood, stone or brick paving shall always be used adjacent to such rails.

10. Bituminous pavement shall be estimated by the square yard.

11. The Engineer in charge may require any one of the above specified materials to be used on any particular job and the Contractor shall not place order for same until such order is approved by the Engineer. The Engineer may modify the quantities given in these specifications

to meet the requirements of the particular aggregate to be used. The Engineer may also, at his discretion, require the surface of the concrete base to be swabbed with hot bituminous cement before placing the two inch finish.

12. The Engineer in charge may, at his discretion, require the use of the "Penetration Method" for small areas when a mixing machine is not available, instead of the mixing method herein described. Hand sprinkling pots of approved design shall be used to distribute the bitumen.

13. When bituminous pavements are specified for approaches or on fills, a concrete base shall be provided, the same as specified for brick pavements.

14. The price bid for bituminous pavements shall include all labor and materials required to complete the work, including the concrete base, when required, except that an extra price shall be bid for swabbing the base with bituminous cement, if required as specified in Paragraph 11.