"The most perfect system of rules to insure success must be interpreted upon the broad grounds of professional intelligence and common sense."

GENERAL SPECIFICATIONS

FOR

Iron and Steel Railroad Bridges

AND VIADUCTS.

NEW AND REVISED EDITION,

1890.

By THEODORE COOPER,

Consulting Engineer.

ENGINEERING NEWS PUBLISHING COMPANY,

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AMERICAN RAILROAD BRIDGES.

By THEODORE COOPER, M. Am. Soc. C. E.,

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Specifications for Iron and Steel Railroad Bridges,	$0 25
" " " Highway " -	25

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General Specifications for Iron and Steel Railroad Bridges and Viaducts.

NEW AND REVISED EDITION.

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GENERAL DESCRIPTION.

1. All parts of the structures shall be of wrought-iron or steel, except ties and guard rails. Cast-iron or steel may be used in the machinery of movable bridges and in special cases for bed-plates.

2. The following kinds of girders shall preferably be employed:

Bridges.

Spans, up to 16 feet....Rolled beams.
" 16 to 70 " ....Riveted plate girders.
" 70 to 100 " ....Riveted plates or lattice girders.
" over 100 " ....Pin-connected trusses.

Generally "double tracks through" bridges will have but two trusses, to avoid spreading the tracks at bridges.

Length of Span.

In calculating strains the length of span shall be understood to be the distance between centres of end pins for trusses, and between centres of bearing plates for all beams and girders.

Spacing of Girders.

3. The girders shall be spaced, with reference to the axis of the bridge, as required by local circumstances, and directed by the Engineer of the Railroad Company. (§ 5.) Longitudinal floor girders shall in no case be less than three feet and three inches from centre line of tracks. (§ 6.)

Head-room.

4. For all through bridges and overhead structures there shall be a clear head-room of 20 feet above the base of the rails.

Clear width.

5. In all through bridges the clear width from the centre of the track to any part of the trusses shall not be less than

seven (7) feet at a height exceeding one foot above the rails where the tracks are straight, and an equivalent clearance shall be provided where the tracks are curved.

6. The standard distance, centre to centre of tracks on straight lines, will be thirteen (13) feet.

Trestle Towers. 7. Each trestle bent shall, as a general rule, be composed of two supporting columns, and the bents united in pairs to form towers; each tower thus formed of four columns shall be thoroughly braced in both directions. Transversely the column shall have a uniform batter sufficient to nearly or quite prevent tension at the base under the greatest wind force specified, either during erection or after completion.

8. Each tower shall have sufficient base, longitudinally, to be stable when standing alone, without other support than its anchorage. (§§ 25, 26.)

Trestle Spans. 9. Tower spans for high trestles shall not be less than 30 feet; intermediate spans about 60 feet.

Form of Trusses 10. Unless otherwise specified the form of bridge trusses may be selected by the bidder; but to secure uniformity in appearance it is desired that all "through" trusses shall be built with inclined end posts; for pin-connected trusses, preference shall be given to those of single intersections.

11. All "deck" trusses shall have top chord bearings at abutments, which are retaining walls, unless otherwise ordered for particular structures.

Wooden Floor. 12. The wooden floors shall consist of transverse ties or floor timbers; their scantling will vary in accordance with the design of the supporting iron floor. (§ 15.) They shall be spaced with openings not exceeding six inches, and shall be secured to the supporting girders by $\frac{3}{4}$-inch bolts at distances not over six feet apart. For deck bridges the ties will extend the full width of the bridge, and for through bridges at least every other tie shall extend the full width of bridge for a footwalk.

Guard Timbers. 13. There shall be a guard timber (scantling not less than 6 x 8″) on each side of each track, with its inner face parallel to and not less than 3 feet 3 inches from centre of track. Guard timbers must be notched one inch over every floor timber, and be spliced over a floor timber with a half-and-half joint of four inches lap. Each guard timber shall be fastened to every third floor timber and at each splice with a three-quarter ($\frac{3}{4}$) inch bolt.

14. The guard and floor timbers must be continued over all piers and abutments.

15. The maximum strain allowed upon the extreme fibre of the best yellow pine or white oak floor timbers will be 800 pounds per square inch. The weight of a single engine wheel being assumed as distributed over three ties spaced as per § 12. **Allowed Strain on Timber.**

16. The floor timbers from centre to each end of span must be notched down over longitudinal girders so as to reduce the camber in the track, as directed by the Engineer.

17. All the floor timbers shall have a full and even bearing upon the stringers; no open joints or shims will be allowed.

18. On curves the outer rail must be elevated, as may be directed by the Engineer.

19. In comparing different proposals, the relative cost to the Railroad Company of the required masonry or changes in existing work will be taken into consideration. **Proposals.**

20. Contractors in submitting proposals shall furnish complete strain sheets, general plans of the proposed structures, and such detail drawings as will clearly show the dimensions of all the parts, modes of construction, and the sectional areas.

21. Upon the acceptance of the proposal and the execution of contract, all working drawings required by the Engineer must be furnished free of cost.

22. No work shall be commenced or materials ordered until the working drawings are approved by the Engineer in writing; if such working drawings are detained more than one week for examination, the Contractor will be allowed an equivalent extension of time. **Approval of Plans.**

LOADS.

23. All the structures shall be proportioned to carry the following loads:

1st. The weight of iron in the structure. 2d. A floor weighing 400 pounds per linear foot of *track*, to consist of rails, ties, and guard timbers only.

ead Load.

These two items, taken together, shall constitute the "dead load."

ive Loads.

lass Lehigh eavy Grade ngine.

3d. For class Lehigh Heavy Grade Engine—A moving load for each *track*, supposed to be moving in either direction, and consisting of two "consolidation" engines coupled, followed by train weighing 4,000 pounds per running foot. This "live load" being concentrated upon points distributed as in Diagram No. 1. Or, 100,000 pounds equally distributed upon two pairs of drivers, seven feet centre to centre; or,

ass Extra eavy A.

3d. For class Extra Heavy A—A moving load for each *track*, supposed to be moving in either direction, and consisting of two "consolidation" engines coupled, followed by train weighing 3,000 pounds per running foot. This "live load" being concentrated upon points distributed as in Diagram No. 2. Or, 80,000 pounds equally distributed upon two pairs of drivers, seven feet centre to centre; or,

ass A.

3d. For class A—A moving load for each *track*, supposed to be moving in either direction, and consisting of two "consolidation" engines coupled, followed by train weighing 3,000 pounds per running foot. This "live load" being concentrated upon points distributed as in Diagram No. 3. Or, 80,000 pounds equally distributed upon two pairs of drivers, seven feet centre to centre; or,

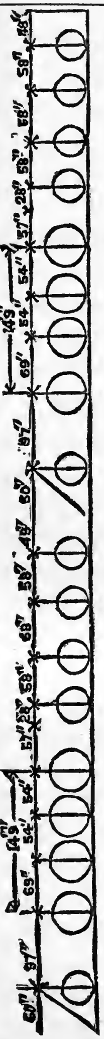
ass B.

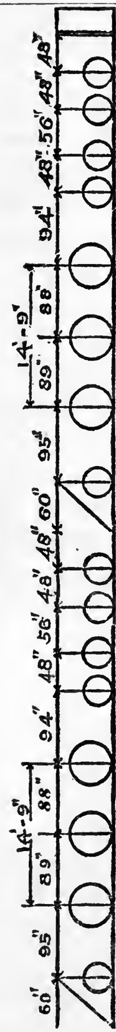
3d. For class B—A moving load for each *track*, supposed to be moving in either direction, and consisting of two "consolidation" engines coupled, followed by train weighing 2,240 pounds per running foot. This "live load" being concentrated upon points distributed as in Diagram No. 4. Or, 80,000 pounds equally distributed upon two pairs of drivers, seven feet six inches centre to centre; or,

lass C.

3d. For class C—A moving load for each *track*, supposed to be moving in either direction, and consisting of two "mogul" engines coupled, followed by train weighing 2,000 pounds per running foot. This "live load" being concentrated upon points distributed as in Diagram No. 5. Or, 80,000 pounds equally distributed upon two pairs of drivers, eight feet centre to centre.

Diagram No. 1.	Diagram No. 2.	Diagram No. 3.	Diagram No. 4.	Diagram No. 5.
4,000 lbs. per L. Ft.	3,000 lbs. per L. Ft.	3,000 lbs. per L. Ft.	2,240 lbs. per L. Ft.	2,000 lbs. per L. Ft.
Lehigh Heavy Grade Engine Class.	Class, Extra Heavy, A.	Class A.	Class B.	Class C.
20000	18000	15000	14500	13500
20000	18000	15000	14500	13500
18000	18000	15000	14500	13500
18000	18000	15000	14500	13500
40000	30000	24000	22000	25000
40000	30000	24000	22000	25000
40000	30000	24000	22000	25000
40000	30000	24000	22000	
16000	16000	15000	15000	15000
20000	18000	15000	14500	13500
20000	18000	15000	14500	13500
18000	18000	15000	14500	13500
18000	18000	15000	14500	13500
40000	30000	24000	22000	25000
40000	30000	24000	22000	25000
40000	30000	24000	22000	25000
40000	30000	24000	22000	
16000	16000	15000	15000	15000





The maximum strains due to all positions of either of the above "live loads," of the required class, and of the "dead load," shall be taken to proportion all the parts of the structure.

/ind Bracing. 24. To provide for wind strains and vibrations, the top lateral bracing in deck bridges, and the bottom lateral bracing in through bridges, shall be proportioned to resist a lateral force of 450 pounds for each foot of the span; 300 pounds of this to be treated as a moving load.

The bottom lateral bracing in deck bridges, and the top lateral bracing in through bridges, shall be proportioned to resist a lateral force of 150 pounds for each foot of the span.

Preference will be given to lateral bracing in the floor system, which is capable of resisting both compression and tension.

25. In trestle towers the bracing and columns shall be proportioned to resist the following lateral pressures, in addition to the strains from dead and live loads:

1st. The trusses fully loaded, a lateral pressure at the level of the tracks, of 650 pounds for each longitudinal lineal foot of the structure; and a lateral pressure of 125 pounds for each vertical lineal foot of the trestle bents; or,

2d. The trusses unloaded, a lateral pressure, at the level of the tracks, of 600 pounds for each longitudinal lineal foot of the structure; and a lateral pressure of 225 pounds for each vertical lineal foot of the trestle bents.

ongitudinal racing. 26. Longitudinally the bracing of the trestle towers and the attachments of the fixed ends of all trusses shall be capable of resisting the greatest tractive force of the engines, or any force induced by suddenly stopping upon any part of the work the assumed maximum trains; the coefficient of friction of the wheels upon the rails being assumed as 0.20.

emperature. 27. Variations in temperature, to the extent of 150 degrees, shall be provided for.

28. When the structures are on curves, the additional effects due to the centrifugal force of trains moving at high velocities shall be considered.

29. All parts shall be so designed that the strains coming upon them can be accurately calculated.

PROPORTION OF PARTS.

The following clauses are all intended to apply to wrought-iron construction.

30. All parts of the structure shall be proportioned in tension by the following allowed unit strains: **Tensile Strain.**

	Pounds per square inch.
Floor beam hangers, and other similar members liable to sudden loading (bar iron with forged ends)	6,000
Floor beam hangers, and other similar members liable to sudden loading (plates or shapes), net section	5,000
Lateral bracing	15,000
Solid rolled beams, used as cross floor beams and stringers	8,000
Bottom flanges of riveted cross girders, net section	8,000
Bottom flanges of riveted longitudinal plate girders, *over* 20 feet long, used as track stringers, net section	8,000
Bottom flanges of riveted longitudinal plate girders, *under* 20 feet long, net section	7,000

	For live loads.	For dead loads.
Bottom chords, main diagonals, counters and long verticals (forged eye-bars)	8,000	16,000
Bottom chords and flanges, main diagonals, counters and long verticals (plates or shapes), net section	7,500	15,000

For swing bridges and other movable structures, the dead load unit strains, during motion, must not exceed three-fourths of the above allowed unit strains for dead load on stationary structures.

The areas obtained by dividing the live load strains by the live load unit strains will be added to the areas obtained by dividing the dead load strains by the dead load unit strains to determine the required sectional area of any member. (§ 45.)

31. Angles subject to direct tension must be connected by both legs, or the section of one leg only will be considered as effective.

Net Section.

32. In members subject to tensile strains full allowance shall be made for reduction of section by rivet-holes, screw-threads, etc.

Compressive Strains.

33. Compression members shall be proportioned by the following allowed unit strains:

Chord segments $P=8{,}000-30\frac{l}{r}$ for live load strains.

$P=16{,}000-60\frac{l}{r}$ for dead load strains.

All posts $P=7{,}000-40\frac{l}{r}$ for live load strains.

$P=14{,}000-80\frac{l}{r}$ for dead load strains.

$P=10{,}500-60\frac{l}{r}$ for wind strains.

Lateral struts $P=9{,}000-50\frac{l}{r}$ for assumed initial strain. (§ 34.)

P=the allowed compression per square inch of cross-section.

L=the length of compression member, in inches.

R=the least radius of gyration of the section, in inches.

No compression member, however, shall have a length exceeding 45 times its least width.

For swing bridges and other movable structures, the dead load unit strains during motion must not exceed $\frac{3}{4}$ of the above allowed unit strains for dead load on stationary structures.

Struts.

34. The lateral struts shall be proportioned by the above formula (§ 33) to resist only the resultant due to an assumed initial strain of 10,000 pounds per square inch upon all the rods attaching to them, assumed to be produced by adjusting the bridge or towers. (§ 41.)

35. In beams and plate girders the compression flanges shall be made of same *gross* section as the tension flanges. **Compression Flanges.**

36. Riveted longitudinal girders shall have, preferably, a depth not less than $\frac{1}{10}$ of the span. **Depth of Girders.**

Rolled beams used as longitudinal girders shall have, preferably, a depth not less than $\frac{1}{12}$ of the span.

37. Members subject to alternate strains of tension and compression shall be proportioned to resist each kind of strain. Both of the strains shall, however, be considered as increased by an amount equal to $\frac{8}{10}$ of the least of the two strains, for determining the sectional areas by the above allowed unit strains. (§§ 30, 33.) **Alternate Strains.**

38. The strains in the chords and end posts from the assumed wind forces need not be considered, except as follows: **Effect of Wind on Chord Strains.**

1st. When the wind strains on any member exceed one-quarter of the maximum strains due to the dead and live loads upon the same member. The section shall then be increased until the total strain per square inch will not exceed by more than one-quarter the maximum fixed for dead and live loads only.

2d. When the wind strain alone or in combination with a possible temperature strain, can neutralize or reverse the tension in any part of the lower chord.

39. The rivets and bolts connecting the parts of any member must be so spaced that the shearing strain per square inch shall not exceed 7,500 pounds, or $\frac{3}{4}$ of the allowed strain per square inch upon that member; nor the pressure upon the bearing surface per square inch of the projected semi-intrados (diameter $\times$ thickness of piece) of the rivet or bolt hole exceed 12,000 pounds, or one and a half times the allowed strain per square inch upon that member. In the case of field riveting the above limits of shearing strain and pressure shall be reduced one-third part. Rivets must not be used in direct tension. **Rivets, Bolts and Pins.**

40. Pins shall be so proportioned that the shearing strain shall not exceed 7,500 pounds per square inch; nor the crushing strain upon the projected area of the semi-intrados of any member (other than forged eye-bars, see article 79) con-

nected to the pin be greater per square inch than 12,000 pounds, or one and a half times the allowed strain per square inch; nor the bending strain exceed 15,000 pounds per square inch when the centres of bearings of the strained members are taken as the points of application of the strains.

Combined Strains.

41. In case any member is subjected to a bending strain from local loadings, such as distributed floors on deck bridges, in addition to the strain produced by its position as a member of the structure, it must be proportioned to resist the combined strains.

If the fibre strain resulting from the weight only, of any member, exceeds ten per cent. of the allowed unit strain on such member, such excess must be considered in proportioning the areas.

Plate Girders, etc.

42. Plate girders shall be proportioned upon the supposition that the bending or chord strains are resisted entirely by the upper and lower flanges, and that the shearing or web strains are resisted entirely by the web-plate; no part of the web-plate shall be estimated as flange area.

The distance between centres of gravity of the flange areas will be considered as the effective depth of all girders.

Web Plates.

43. The webs of plate girders must be stiffened at intervals, about the depth of the girders, wherever the shearing strain per square inch exceeds the strain allowed by the following formula:

$$\text{Allowed shearing strain} = \frac{12{,}000}{1 + \dfrac{H^2}{3{,}000}}$$

where H = ratio of depth of web to its thickness; but no web-plates shall be less than three-eighths of inch in thickness.

Rolled Beams.

44. Rolled beams shall be proportioned (§§ 30, 35) by their moments of inertia.

45. The areas of counter rods shall be determined by taking the difference in areas due to the live and dead load strains considered separately (§ 30); the counter rods in any one panel must have a combined sectional area of at least three square inches, or else must be capable of carrying all the counter live load in that panel.

DETAILS OF CONSTRUCTION.

46. All the connections and details of the several parts of the structures shall be of such strength that, upon testing, ruptures shall occur in the body of the members rather than in any of their details or connections. Details.

47. Preference will be had for such details as shall be most accessible for inspection, cleaning and painting; no closed sections will be allowed.

48. The webs of plate girders must be spliced at all joints by a plate on each side of the web. Web Splices.

49. All web-plates must have stiffeners over bearing points and at points of local concentrated loadings. Stiffeners.

50. The pitch of rivets in all classes of work shall never exceed 6 inches, or sixteen times the thinnest outside plate, nor be less than three diameters of the rivet. Riveting.

51. The rivets used shall generally be $\frac{3}{4}$ and $\frac{7}{8}$ inch diameter.

52. The distance between the edge of any piece and the centre of a rivet-hole must never be less than $1\frac{1}{4}$ inches, except for bars less than $2\frac{1}{2}$ inches wide; when practicable it shall be at least two diameters of the rivet.

53. In punching plate or other iron, the diameter of the die shall in no case exceed the diameter of the punch by more than $\frac{1}{16}$ of an inch, and all holes must be clean cuts without torn or ragged edges.

54. All rivet-holes must be so accurately spaced and punched that when the several parts forming one member are assembled together, a rivet $\frac{1}{16}$ inch less in diameter than the hole can generally be entered, hot, into any hole, without reaming or straining the iron by "drifts;" occasional variations must be corrected by reaming.

55. The rivets when driven must completely fill the holes. The rivet-heads must be round and of a uniform size for the same sized rivets throughout the work. They must be full and neatly made, and be concentric to the rivet-hole, and thoroughly pinch the connected pieces together.

56. Wherever possible, all rivets must be machine driven. The machines must be capable of retaining the applied pres-

sure after the upsetting is completed. No hand-driven rivets exceeding $\frac{7}{8}$ inch diameter will be allowed.

57. Field riveting must be reduced to a minimum or entirely avoided, where possible.

58. The effective diameter of a driven rivet will be assumed the same as its diameter before driving. In deducting the rivet-holes to obtain net sections in tension members, the diameter of the rivet-hole will be assumed as $\frac{1}{8}$ inch larger than the undriven rivets.

Bolts.

59. When members are connected by bolts which transmit shearing strains, the holes must be reamed parallel and the bolts turned to a driving fit.

60. The several pieces forming one built member must fit closely together, and when riveted shall be free from twists, bends or open joints.

Splices.

61. All joints in riveted tension members must be fully and symmetrically spliced.

Abutting Joints.

62. In compression members, abutting joints with planed faces must be sufficiently spliced to maintain the parts accurately in contact against all tendencies to displacement.

63. In compression members, abutting joints with untooled faces must be fully spliced, as no reliance will be placed on such abutting joints. The abutting ends must, however, be dressed straight and true, so there will be no open joints.

64. All the angles, filling and splice plates on the webs of girders and riveted members must fit at their ends to the flange angles, sufficiently close to be sealed when painted, against admission of water; but need not be tool finished.

Web Plates.

65. Web-plates of all girders must be arranged so as not to project beyond the faces of the flange angles, nor on the top be more than $\frac{1}{16}$ inch below the face of these angles, at any point.

66. Wherever there is a tendency for water to collect, the spaces must be filled with a suitable waterproof material.

Flange Plates.

67. In girders with flange plates, at least one-half of the flange section shall be angles or else the largest sized angles must be used.

68. In lattice girders, the web members must be double and connect symmetrically to the web of the flanges.

69. The compression flanges of beams and girders shall be stayed against transverse crippling when their length is more than thirty times their width.

70. The unsupported width of plates subjected to compression shall not exceed thirty times their thickness; except cover plates of top chords and end posts, which will be limited to forty times their thickness.

71. The flange plates of all girders must be limited in width so as not to extend beyond the outer lines of rivets connecting them with the angles, more than five inches or more than eight times the thickness of the first plate. Where two or more plates are used on the flanges, they shall either be of equal thickness or shall decrease in thickness outward from the angles.

72. No iron shall be used less than $\frac{1}{4}$ inch thick, except for lining or filling vacant spaces.

73. The heads of eye-bars shall be so proportioned and made, that the bars will preferably break in the body of the original bar rather than at any part of the head or neck. The form of the head and the mode of manufacture shall be subject to the approval of the Engineer of the Railroad Company. The heads must be formed either by the process of upsetting and forging, or by the process of upsetting, piling and forging. No welding will be allowed in the body of the bars, nor in the process of piling, welding seams in any other direction than parallel to the sides of the original bars. Eye Bars.

74. The bars must be free from flaws and of full thickness in the necks. They shall be perfectly straight before boring. The holes shall be in the centre of the head, and on the centre line of the bar.

75. The bars must be bored to lengths not varying from the calculated lengths more than $\frac{1}{64}$ of an inch for each 25 feet of total length.

76. Bars which are to be placed side by side in the structure shall be bored at the same temperature and of such equal length that upon being piled on each other the

pins shall pass through the holes at both ends without driving.

77. The lower chord shall be packed as narrow as possible.

Pins.

78. The pins shall be turned straight and smooth, and shall fit the pin-holes within $\frac{1}{50}$ of an inch, for pins less than $4\frac{1}{2}$ inches diameter; for pins of a larger diameter the clearance may be $\frac{1}{32}$ inch.

79. The diameter of the pin shall not be less than two-thirds the largest dimension of any tension member attached to it. The several members attaching to the pin shall be so packed as to produce the least bending moment upon the pin, and all vacant spaces must be filled with wrought-iron filling rings.

Upset Ends.

80. All rods and hangers with screw ends shall be upset at the ends, so that the diameter at the bottom of the threads shall be $\frac{1}{16}$ inch larger than any part of the body of the bar.

81. All threads must be of the United States standard, except at the ends of the pins.

Hangers.

82. Floor beam hangers shall be so placed that they can be readily examined at all times. When fitted with screw ends they shall be provided with check nuts. Preference will be given to hangers without screw ends.

83. When bent loops are used, they must fit perfectly around the pin throughout its semi-circumference.

84. All nuts on floor beam hangers and counter rods must have the bearing faces faced square to the axes of the screw ends.

Compression Members.

85. Compression members shall be of wrought-iron, and of approved forms.

86. The pitch of rivets at the ends of compression members shall not exceed four diameters of the rivets for a length equal to twice the width of the member.

87. The open sides of all compression members shall be stayed by batten plates at the ends and diagonal lattice-work at intermediate points. The batten plates must be placed as near the ends as practicable, and shall have a length of $1\frac{1}{2}$ times the width of the member. The size and

spacing of the lattice bars shall be duly proportioned to the size of the member. They must not be less than $2 \times \frac{1}{4}$ inches for posts 6 inches wide, nor $4 \times \frac{3}{8}$ inches for posts 15 inches wide. They shall be inclined at an angle not less than 60° to the axis of the member. The pitch of the latticing must not exceed the width of the channel plus nine inches.

88. Where necessary, pin-holes shall be reinforced by plates, so the allowed pressure on the pins shall not be exceeded. These reinforcing plates must contain enough rivets to transfer their proportion of the bearing pressure, and at least one plate on each side shall extend not less than six inches beyond the edge of the batten plates. (§ 87.)

89. Where the ends of compression members are forked to connect to the pins, the aggregate compressive strength of these forked ends must equal the compressive strength of the body of the members; in order to insure this result the aggregate sectional area of the forked ends, at any point between the inside edge of the pin-hole and six inches beyond the edge of the batten plate, shall be about double that of the body of the member.

90. In compression chord sections, the material must mostly be concentrated at the sides, in the angles and vertical webs. Not more than one plate, and this not exceeding $\frac{1}{2}$ inch in thickness, shall be used as a cover plate, except when necessary to resist bending strains. (§ 41.)

Top Chord Splices.

91. The sections of compression chords shall be connected at the abutting ends by splices sufficient to hold them truly in position.

92. The ends of all square-ended members shall be planed smooth, and exactly square to the centre line of strain.

93. All members must be free from twists or bends. Portions exposed to view shall be neatly finished.

94. Pin-holes shall be bored exactly perpendicular to a vertical plane passing through the centre line of each member, when placed in a position similar to that it is to occupy in the finished structure.

Abutting Joints.

95. Abutting joints in truss bridges shall be in exact contact throughout.

Lateral Bracing. 96. In no case shall any lateral or diagonal rod have a less area than $\frac{3}{4}$ of a square inch.

97. The attachment of the lateral system to the chords shall be thoroughly efficient. If connected to suspended floor beams, the latter shall be stayed against all motion.

98. Preference will be given for a stiff angle iron lateral system between the chords on the level of the floor.

Transverse Diagonal Bracing. 99. All through bridges with top lateral bracing shall have wrought-iron latticed portals, of approved design, at each end of the span, connected rigidly to the end posts. They shall be as deep as the specified head-room will allow. (§ 38.)

100. When the height of the trusses exceed 25 feet, an approved system of overhead diagonal bracings shall be attached to each post and to the top lateral struts.

101. Pony trusses and through plate or lattice girders shall be stayed by knee braces or gusset plates attached to the top chords at the ends, and at intermediate points, not more than 10 feet or a panel length apart, and attached below to the cross floor beams or to the transverse struts.

102. All deck girders shall have transverse braces at the end. All deck bridges shall have transverse bracing at each panel point. This bracing shall be proportioned to resist the unequal loading of the trusses. The transverse bracing at the ends shall be of the same equivalent strength as the end top lateral bracing.

Bed Plates. 103. All bed-plates must be of such dimensions that the greatest pressure upon the masonry shall not exceed 250 pounds per square inch.

Friction Rollers 104. All bridges over 75 feet span shall have at one end nests of turned friction rollers, formed of wrought-iron or steel, running between planed surfaces. The rollers shall not be less than 2 inches diameter, and shall be so proportioned that the pressure per lineal inch of rollers shall not exceed the product of the square root of the diameter of the roller in inches multiplied by 500 pounds, ($500\sqrt{d}$.).

105. Bridges less than 75 feet span shall be secured at one end to the masonry, and the other end shall be free to move upon planed surfaces.

106. Where two spans rest upon the same masonry, a continuous wrought-iron plate, not less than $\frac{3}{8}$-inch thick, shall extend under the two adjacent bearings.

107. All the bed-plates and bearings under fixed and movable ends must be fox-bolted to the masonry; for trusses, these bolts must not be less than $1\frac{1}{4}$ inches diameter; for plate and other girders, not less than $\frac{7}{8}$-inch diameter. The contractor must furnish all bolts, drill all holes, and set bolts to place with sulphur.

108. While the roller ends of all trusses must be free to move longitudinally under changes of temperature, they shall be anchored against lifting or moving sideways.

109. All iron bridges with parallel chords shall be given a camber by making the panel lengths of the top chord longer than those of the bottom chord, in the proportion of $\frac{1}{8}$ of an inch to every ten feet. **Camber.**

110. All bolts must be of neat lengths, and shall have a washer under the heads and nuts where in contact with wood. **Bolts.**

111. The lower struts in trestle towers shall be securely anchored to intermediate masonry piers when the magnitude of the structure, in the opinion of the Engineer, requires it; these struts shall always have ample stiffness to move the tower columns under the effects of changes of temperature, and prevent the slacking of the diagonal brace rods.

112. Tower footings and bed-plates must be planed on all sliding surfaces; and the holes for anchor bolts slotted to allow for the proper amount of movement. (§ 27.) **Bed Plates.**

113. All joints in the tower columns shall be fully spliced for all possible tension strains, and to hold the parts firmly in position.

114. The connection of all the diagonal tension members with the columns shall, preferably, be made by means of pins passing through the column's axis.

115. The tension diagonals shall be adjustable, but must have check nuts at all adjustable points; and shall be supported and clamped at suitable intervals to prevent sagging and rattling.

Workmanship.

116. All workmanship shall be first-class in every particular.

117. Whenever necessary for the protection of the thread, provision shall be made for the use of pilot nuts in erection.

Use of Steel.

Medium Steel.

118. Medium steel (§ 139) may be used for tension members, plate girders, rolled beams and top chord sections with an allowance of 20 per cent. increase above allowed working strains on wrought-iron; and for all posts by use of the following formulæ, in place of those given for wrought-iron (§ 33):

$$P = 8{,}500 - 55\frac{l}{r} \text{ for live load strains.}$$

$$P = 17{,}000 - 110\frac{l}{r} \text{ " dead " "}$$

$$P = 13{,}000 - 85\frac{l}{r} \text{ " wind " "}$$

Provided that, in addition to the previous details of construction,

119. All sheared edges of plates and angles be planed off to a depth of one-quarter of an inch. All punched holes be reamed to a diameter of $\frac{1}{8}$-inch larger, so as to remove all the sheared surface of the metal.

120. No sharp or unfilleted re-entrant corners be allowed.

121. All rivets to be of steel.

122. Any piece which has been partially heated or bent cold, be afterwards wholly annealed.

Soft Steel.

123. Soft steel (§ 141) may be used under the same conditions as wrought-iron for all *riveted* work.

Provided, that

124. Any rivet hole punched, as in ordinary practice (§§ 52 and 53), will stand drifting to a diameter 25 per cent. greater than the original hole without cracking, either in the periphery of the hole or on the external edges of the piece, whether they be sheared or rolled.

QUALITY OF MATERIAL.

IRON.

125. All wrought-iron must be tough, fibrous and uniform in character. It shall have a limit of elasticity of not less than 26,000 pounds per square inch. Iron.

Finished bars must be thoroughly welded during the rolling, and be free from injurious seams, blisters, buckles, cinder spots, or imperfect edges: all iron for eye-bars or other forgings and for bent plates, must be capable of being worked at a proper heat without injury.

126. For all tension members high test bars must be used, capable of standing the following tests: Tension Tests.

127. Full sized pieces of flat, round or square iron, not over 4½ inches in sectional area, shall have an ultimate strength of 50,000 pounds per square inch, and stretch 12½ per cent. in the whole length of the body of the bars.

Bars of a larger sectional area than 4½ square inches will be allowed a reduction of 1,000 pounds per square inch for each additional square inch of section, down to a minimum of 46,000 pounds per square inch, and 10 per cent. stretch in the whole length of the body of the bars.

128. When tested in specimens of uniform sectional area of at least ½ square inch for a distance of 10 inches, taken from tension members which have been rolled to a section not more than 4½ square inches, the iron shall show an ultimate strength of 52,000 pounds per square inch, and stretch 18 per cent. in a distance of 8 inches.

Specimens taken from bars of a larger cross-section than 4½ inches will be allowed a reduction of 500 pounds for each additional square inch of section, down to a minimum of 48,000 pounds, and 15 per cent. stretch.

129. The same sized specimens taken from *angle* and other *shaped* iron shall have an ultimate strength of 48,000 pounds per square inch, and elongate 15 per cent. in 8 inches.

130. The same sized specimens taken from *plates* less than 24 inches in width, shall have an ultimate strength of 48,000 pounds, and elongate 15 per cent. in 8 inches.

131. The same sized specimens taken from *plates* exceeding 24 inches in width, shall have an ultimate strength of 46,000 pounds, and elongate 10 per cent.

Bending Tests.

132. All iron for tension members must bend cold for about 90 degrees, to a curve whose diameter is not over twice the thickness of the piece, without cracking. At least one sample in three must bend 180 degrees to this curve without cracking. When nicked on one side, and bent by a blow from a sledge, the fracture must be nearly all fibrous, showing but few crystalline specks.

133. Specimens from *angle*, *plate* less than 24 inches in width (130) and *shaped* iron must stand bending cold through 90 degrees, and to a curve whose diameter is not over three times its thickness, without cracking.

Specimens from *plates* wider than 24 inches must stand bending cold through 90 degrees; and to a curve whose diameter is not over six times its thickness, without cracking.

When nicked and bent the fracture must be mostly fibrous.

134. If any of the above material under the tests shows a decrease of stretch, accompanied by an increase of tensile strength, amounting to 500 pounds per square inch for each one per cent. change of stretch, this decrease of stretch will not be cause for rejection, if the material still satisfies the bending tests.

135. If the tests of the tension bars (127 and 128) show a decrease of the required tensile strength, accompanied with an increase of stretch, the decrease in the required tensile strength will not be cause for rejection if the tensile strength does not fall below the stated minimum requirements, and the increase of stretch amounts to an additional per cent. for each 500 pounds decrease in the tensile strength.

Rivet Iron.

136. Rivets shall be made from the best refined iron, and must be capable of being bent cold until the sides are in close contact without sign of fracture on the convex side.

Steel.

137. The steel must be uniform in character for each specified kind. The finished bars, plates and shapes must be free from cracks on the faces or corners, and have a clean, smooth finish. No work shall be put upon any steel at or near the blue temperature or between that of boiling water and of ignition of hard wood sawdust.

138. All tests shall be made by samples cut from the finished material after rolling. The samples to be at least 12 inches long, and to have a uniform sectional area not less than ½ square inch. All broken samples must show uniform fine grained fractures of a blue steel-gray color, entirely free from fiery lustre or a blackish cast.

139. **Medium Steel** shall have an ultimate strength, when tested in samples of the dimensions above stated, of 62,000 to 68,000 pounds per square inch, an elastic limit of not less than 33,000 pounds per square inch, and a minimum elongation of 20 per cent. in 8 inches. **Medium Steel.**

140. Before or after heating to a low cherry red and cooling in water at 82 degrees Fah., this steel must stand bending to a curve whose inner radius is one and a half times the thickness of the sample, without cracking.

141. **Soft Steel** shall have an ultimate strength, on same sized samples, of 54,000 to 62,000 pounds per square inch, an elastic limit not less than 30,000 pounds per square inch, and a minimum elongation of 25 per cent. in 8 inches. **Soft Steel.**

142. Before or after heating to a light yellow heat and quenching in cold water, this steel must stand bending 180 degrees, to a curve whose inner radius is equal to the thickness of the sample, without sign of fracture.

143. All rivets will be made of soft steel, and the steel for rivets must, under the above bending test, stand closing solidly together without sign of fracture.

Cast Iron.

144. Except where chilled iron is required, all castings must be of tough, gray iron, free from cold shuts or injurious blow holes, true to form and thickness, and of a work- **Cast Iron.**

manlike finish. Sample pieces, 1 inch square, cast from the same heat of metal in sand moulds, shall be capable of sustaining, on a clear span of 4 feet 6 inches, a central load of 500 pounds, when tested in the rough bar. A blow from a hammer shall produce an indentation on a rectangular edge of the casting without flaking the metal.

TIMBER.

Timber.

145. The timber shall be strictly first-class white pine, southern yellow pine or white oak bridge timber; sawed true, and out of wind, full size, free from wind shakes, large or loose knots, decayed or sap wood, worm holes, or other defects impairing its strength or durability. It will be subject to the inspection and acceptance of the Engineer.

INSPECTION.

Inspection.

146. All facilities for inspection of the materials and workmanship shall be furnished by the contractor. He shall furnish without charge such specimens (prepared) of the several kinds of iron or steel to be used, as may be required to determine their character.

147. The contractor must furnish the use of a testing machine capable of testing the above specimens at all mills where the iron or steel may be manufactured, free of cost.

148. Full sized parts of the structure may be tested at the option of the Engineer of the Railroad Company, but if tested to destruction, such material shall be paid for at cost, less its scrap value to the contractor, if it proves satisfactory. If it does not stand the specified tests, it will be considered rejected material, and be solely at the cost of the contractor.

PAINTING.

Painting.

149. All iron work before leaving the shop shall be thoroughly cleaned from all loose scale and rust, and be given one good coating of pure raw linseed oil, well worked into all joints and open spaces.

150. In riveted work the surfaces coming in contact shall each be painted before being riveted together. Bottoms of bed-plates, bearing-plates, and any parts which are not accessible for painting after erection, shall have two coats of paint; the paint shall be a good quality of iron ore paint, subject to approval of the Engineer.

151. After the structure is erected, the iron work shall be thoroughly and evenly painted with two additional coats of paint, mixed with pure linseed oil, of such color as may be directed. All recesses which will retain water, or through which water can enter, must be filled with thick paint or some water-proof cement before receiving the final painting.

152. Pins, bored pin-holes and turned friction rollers shall be coated with white lead and tallow before being shipped from the shop.

ERECTION.

153. The contractor shall furnish all staging and false **Erection.** work, shall erect and adjust all the iron work, and put in place all floor timbers, guards, etc., complete, ready for the rails.

154. The contractor shall so conduct all his operations as not to impede the operations of the road, interfere with the work of other contractors, or close any thoroughfare by land or water.

155. The contractor shall assume all risks of accidents to men or material prior to the acceptance of the finished structure by the Railroad Company.

The contractor must also remove all false work, piling and other obstructions, or unsightly material produced by his operations.

FINAL TEST.

156. Before the final acceptance the Engineer may make **Final Test.** a thorough test by passing over each structure the specified loads, or their equivalent, at a speed not exceeding 45 miles an hour, and bringing them to a stop at any point by means of the air or other brakes, or by resting the maximum load upon the structure for twelve hours.

After such tests the structures must return to their original positions without showing any permanent change in any of their parts.

SUPPLEMENTARY.

The following special clauses shall apply in addition to previous general clauses, to the special work included in the attached contract:

....

....

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Proposals for building and erecting complete, ready for the..., a bridge over...
...................................near...
on the...Division,...................................
....Railroad, in accordance with the attached specifications and accompanying profile, will be received up to.. The live load to be adopted for this bridge will be Class.......................... paragraph 23.

"The most perfect system of rules to insure success must be interpreted upon the broad grounds of professional intelligence and common sense."

GENERAL SPECIFICATIONS

FOR

STEEL HIGHWAY AND ELECTRIC RAILWAY BRIDGES AND VIADUCTS.

NEW AND REVISED EDITION,

1901.

By THEODORE COOPER,

Consulting Engineer.

General Specifications for Steel Highway and Electric Railway Bridges and Viaducts.

FIFTH EDITION.

1901.

GENERAL DESCRIPTION.

Bridges under these specifications are divided into six classes, for different localities and various loadings, as follows: (§ 38.) Classes.

Class A1. City bridges having buckle-plate floors and an accepted form of paving resting on a concrete base. (§ 29.)

Class A2. City bridges having plank flooring. (§ 29.)

Class B. Suburban bridges or Interurban bridges carrying heavy electric cars. (§ 29.)

Class C. Town or country bridges carrying light electric cars or bridges carrying heavy loads from quarries or manufactories.

Class D. Country bridges carrying only ordinary highway traffic.

Class E1. Bridges carrying heaviest motor cars, only.
Class E2. Bridges carrying light motor cars, only.

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1. All parts of the structures shall be of wrought steel, except the flooring, floor joists and wheel guards, when wooden floors are used. Cast-iron or cast-steel may be used in the machinery of movable bridges, for wheel guards, and in special cases for bed-plates.

Kind of Girders. 2. The following kinds of girders shall preferably be employed:

Spans,	up to 25	feet	....Rolled beams.
"	20 to 40	"	....Rolled beams or plate girders.
"	40 to 80	"	....Riveted plate or lattice girders.
"	80 to 120	"	....Lattice girders.
"	over 120	"	....Lattice or pin-connected trusses.

Length of Span. In calculating strains the length of span shall be understood to be the distance between centres of end pins for trusses, c. to c. of trusses for cross floor beams, and between centres of bearing plates for all longitudinal beams and girders.

Form of Trusses. 3. Unless otherwise specified, the form of bridge trusses may be selected by the bidder; for through bridges, the end vertical suspenders and two panels of the lower chord, at each end, will be made rigid members. In through bridges, the floor beams shall be riveted to the posts, above or below the pins.

Lateral Bracing. 4. All lateral, sway and portal bracing must be made of shapes capable of resisting compression as well as tension, and must have riveted connections. All bridges must have lateral struts at the ends, except where end floor beams act as such.

Trestle Towers. 5. Each trestle bent shall, as a general rule, be composed of two supporting columns, and the bents united in pairs to form towers; each tower thus formed of four columns shall be thoroughly braced in both directions, and have struts between the feet of the columns. The feet of the columns must be secured to an anchorage capable of resisting double the specified wind forces. (§ 40.)

6. Each tower shall have sufficient base, longitudinally, to be stable when standing alone, without other support than its anchorage. (§§ 40, 43.)

7. Tower spans for high trestles shall not be less than 30 feet.

8. Where footwalks are required, they will generally be placed outside of the trusses and supported on longitudinal beams resting on overhanging steel brackets. Foot-walks.

9. A strong and suitable handrailing will be placed at each side of the bridge and be rigidly attached to the superstructure. Railing.

10. For all through bridges there shall be a clear headroom of 15 feet above the floor, for Classes A, B, C and E; and a minimum head-room of 12½ feet for Class D. Head-room.

11. In comparing different proposals, the relative cost of the required masonry or changes in existing work will be taken into consideration. Proposals.

12. Contractors in submitting proposals shall furnish complete strain sheets, general plans of the proposed structures, and such detail drawings as will clearly show the dimensions of all the parts, modes of construction and the sectional areas.

13. Upon the acceptance of the proposal and the execution of contract, all working drawings required by the Engineer must be furnished free of cost.

14. No work shall be commenced or materials ordered until the working drawings are approved by the Engineer in writing; if such working drawings are detained more than one week for examination, the Contractor will be allowed an equivalent extension of time. Approval of Plans.

FLOOR SYSTEM.

15. All cross floor beams will be rolled or riveted steel girders, rigidly connected to the trusses at the panel points. Floor Girders.

16. All longitudinal girders of bridges of Classes A1 and

A2 will be of steel; all *track* stringers of bridges of Classes B, C and E will be of steel. Unless otherwise specified all other longitudinal girders of Classes B and C will be of steel. The longitudinal girders of bridges of Class D may be either of wood or steel. When the longitudinal beams are of steel, they must be securely fastened to the cross floor beams.

COUNTRY BRIDGES.

Wooden Floor. 17. Wooden floor joists will be spaced not over 2 feet centres, and will lap by each other, so as to have a full bearing on the floor beams, and will be separated ½ inch for free circulation of air. Their scantling will vary in accordance with the length of panels selected, but shall never be less than 3 inches, or one-fourth of depth in width. When spaced not over 2-foot centres, one joist shall be considered as carrying only two-thirds of the concentrated live load.

18. The floor plank shall be.................inches thick, laid with ¼-inch openings, and spiked to each supporting joist. When this is to be covered with an additional wearing floor (§ 19), it must be laid diagonally and with ½ inch openings; all plank shall be laid with the heart side down. The floor plank must have a thickness, *in inches*, at least equal to the distance apart of these beams, *in feet*, with a minimum thickness of 2½ inches. The floor plank must bear firmly upon the beams and be securely fastened to the same.

19. Where specified an additional wearing floor 1½ inches thick of white oak plank shall be placed over the above. (§ 18.)

20. The footwalk plank will be 2 inches thick and not over 6 inches wide, spaced with ½ inch openings.

21. There will be a wheel guard, of a scantling not less than 6 x 4, on each side of the roadway to prevent the hubs of wheels striking any part of the bridge. It should be blocked up from the floor to admit drainage and ventilation.

Allowed strain on Timber. 22. The maximum strain allowed upon the extreme fibre of the joist will be 1,200 pounds per square inch on yellow pine and white oak, and 1,000 pounds per square inch on white pine and spruce.

City Bridges.

23. Buckle-plates will be not less than $\frac{5}{16}$ inch thick and will crown 2 inches at the centre. Plates of this thickness and crown may be used to widths of 4 feet under the roadway and 5 feet under the footwalks. (§§ 93–96.) **Buckle Plates.**

24. Bridges with buckle plate floors will have a suitable metal curb on each side of the roadway to hold paving and act as a wheel guard. The wheel guard must be so arranged that it can be removed and replaced when worn or injured. There will also be a metal edging strip on each side of the footwalks to hold the paving in place. **Curbs and Guards.**

25. The concrete over buckle-plates shall be at least 3 inches thick on the roadway and 2 inches thick on the sidewalks, over the highest point to be covered, not counting rivet heads. **Concrete.**

26. The sidewalks shall slope 1 inch in 5 feet, preferably towards the roadway. The roadway shall crown from curb to centre 1 inch for each 10 feet of the roadway width. The depth of the curb will be 6 inches.

27. The subgrade, top of concrete, for the sidewalks will be------inches below final grade and slope.

The concrete over roadway will be laid to the correct crowning and elevation to allow------inches for the selected paving.

28. Scuppers must be provided at frequent intervals along the curbs or wheel guards for drainage and for passing the sweepings and snow, clear from contact with any parts of the tracks or floor system. **Scuppers.**

29. Classes A and B shall be designed to carry at any future time a double-track electric railway. **Double Track.**

Electric Railway Bridges.

30. The wooden floors will consist of transverse ties or floor timbers; their scantling will vary in accordance with **Wooden Floor.**

the design of the supporting steel floor. (§ 22.) They shall be spaced with openings not exceeding six inches, and shall be notched down ½ inch and be secured to the supporting girders by ¾-inch bolts at distances not over six feet apart. For deck bridges the ties will extend the full width of the bridge, and for through bridges at least every other tie shall extend the full width of bridge for a footwalk.

Guard Timbers. 31. There shall be a guard timber (scantling not less than 5 x 7″) on each side of each track, with its inner face parallel to and at-----feet-----inches from centre of track. Guard timbers must be notched one inch over every floor timber, and be spliced over a floor timber with a half-and-half joint of six inches lap. Each guard timber shall be fastened to every third floor timber and at each splice with a three-quarter (¾) inch bolt. All heads or nuts on upper faces of ties or guards must be countersunk below the surface of the wood. (§ 76.)

32. The guard and floor timbers must be continuous over all piers and abutments.

33. The floor timbers from centre to each end of span must be notched down over the longitudinal girders so as to reduce the camber in the track, as directed by the Engineer.

34. All the floor timbers shall have a full and even bearing upon the stringers; no open joints or shims will be allowed.

35. On curves the outer rail must be elevated, as may be directed by the Engineer.

Clear width. 36. In all through bridges the clear width from the centre of the track to any part of the trusses shall not be less than seven (7) feet at a height exceeding one foot above the rails where the tracks are straight, and an equivalent clearance, where the tracks are curved.

37. The standard distance, centre to centre of tracks on straight lines, will------------feet.

LOADS.

38. All the structures shall be proportioned to carry the following loads:

1st. The weight of metal in the structure and floor.

2d. The weight of the paving and concrete or the wooden floor, considering each foot of board measure to weigh 4½ pounds for oak and other hard woods, and 3½ pounds for spruce and white pine.

These two items, taken together, shall constitute "the dead load." Dead Load.

3d. A "live" or moving load, according to one of the following classes: Live Loads.

Class A1 and Class A2.—City Bridges:

For the floor and its supports, on any part of the roadway or on each of the street car tracks, a concentrated load of 24 tons on two axles 10 feet centres (assumed to occupy 12 feet in width for a single line and 22 feet for a double line), and upon the remaining portion of the floor, including footwalks, a load of 100 pounds per square foot.

For the trusses, loads as per Table A.

Class B.—Suburban or Interurban Bridges:

For the floor and its supports, on any part of the roadway, a concentrated load of 12 tons on two axles 10 feet centres or on each of the street car tracks a concentrated load of 24 tons on two axles 10 feet centres; and upon the remaining portion of the floor, including footwalks, a load of 100 pounds per square foot of floor.

For the trusses, loads as per Table A.

Class C.—(Class B2 of former editions):

For the floor and its supports, on any part of the roadway, a concentrated load of 12 tons on two axles 10 feet centres, or on street car track a concentrated load of 18 tons on two axles 10 feet centres; and upon the remaining portion of the floor, including footwalks, a load of 100 pounds per square foot of floor.

For the trusses, loads as per Table A.

Class D.—(Class C of former editions.) Country Highway Bridges:

For the floor and its supports, a load of 80 pounds per square foot of total floor surface, or 6 tons on two axles 10 feet centres.

For the trusses, loads as per Table A.

Class E1.—Electric Railway Bridges, with Heavy Equipment:

For the floor and its supports, a load of 24 tons on two axles 10 feet centres, on each track.

For the trusses, loads as per Table A.

Class E2.—Electric Railway Bridges, with Light Equipment:

For the floor and its supports, a load of 18 tons on two axles 10 feet centres, on each track.

For the trusses, loads as per Table A.

TABLE A.—Live Loads for the Trusses.

Class A.			Class B.		
Span in feet.	Pounds per lineal foot of each car track.	Pounds per square foot of remaining floor surface.	Span in feet.	Pounds per lineal foot of each car track.	Pounds per square foot of remaining floor surface.
Up to 100	1 800	100	Up to 100	1 800	80
105	1 770	99	105	1 770	79
110	1 740	98	110	1 740	78
115	1 710	97	115	1 710	77
120	1 680	96	120	1 680	76
125	1 650	95	125	1 650	75
130	1 620	94	130	1 620	74
135	1 590	93	135	1 590	73
140	1 560	92	140	1 560	72
145	1 530	91	145	1 530	71
150	1 500	90	150	1 500	70
155	1 470	89	155	1 470	69
160	1 440	88	160	1 440	68
165	1 410	87	165	1 410	67
170	1 380	86	170	1 380	66
175	1 350	85	175	1 350	65
180	1 320	84	180	1 320	64
185	1 290	83	185	1 290	63
190	1 260	82	190	1 260	62
195	1 230	81	195	1 230	61
200 and over	1 200	80	200 and over	1 200	60

Class C.

Up to 100	1 200	80	155	1 090	69
105	1 190	79	160	1 080	68
110	1 180	78	165	1 070	67
115	1 170	77	170	1 060	66
120	1 160	76	175	1 050	65
125	1 150	75	180	1 040	64
130	1 140	74	185	1 030	63
135	1 130	73	190	1 020	62
140	1 120	72	195	1 010	61
145	1 110	71	200 and over	1 000	60
150	1 100	70			

TABLE A (*Continued*)—LIVE LOADS FOR THE TRUSSES.

CLASS D.		CLASS E 1.		CLASS E 2.	
Span in feet.	Pounds per square foot of floor surface.	Span in feet.	Pounds per lineal foot of each car track.	Span in feet.	Pounds per lineal foot of each car track.
Up to 75	80	Up to 100	1 800	Up to 100	1 200
80	79	105	1 770	105	1 190
85	78	110	1 740	110	1 180
90	77	115	1 710	115	1 170
95	76	120	1 680	120	1 160
100	75	125	1 650	125	1 150
105	74	130	1 620	130	1 140
110	73	135	1 590	135	1 130
115	72	140	1 560	140	1 120
120	71	145	1 530	145	1 110
125	70	150	1 500	150	1 100
130	69	155	1 470	155	1 090
135	68	160	1 440	160	1 080
140	67	165	1 410	165	1 070
145	66	170	1 380	170	1 060
150	65	175	1 350	175	1 050
155	64	180	1 320	180	1 040
160	63	185	1 290	185	1 030
165	62	190	1 260	190	1 020
170	61	195	1 230	195	1 010
175	60	200 and over.	1 200	200 and over.	1 000
180	59				
185	58				
190	57				
195	56				
200 and over.	55				

The maximum strains due to all positions of either of the above "live loads," of the required class, and of the "dead loads," shall be taken to proportion all the parts of the structure.

39. To provide for wind strains and vibrations, the top Wind Bracing
lateral bracing in deck bridges, and the bottom lateral bracing in through bridges, shall be proportioned to resist a lateral force of 300 pounds for each foot of the span; 150 pounds of this to be treated as a moving load.

The bottom lateral bracing in deck bridges, and the top lateral bracing in through bridges, shall be proportioned to resist a lateral force of 150 pounds for each lineal foot. For spans exceeding 300 feet, add in each of the above cases 10 pounds additional for each additional 30 feet.

40. In trestle towers the bracing and columns shall be proportioned to resist the following lateral forces, in addition to the strains from dead and live loads:

The trusses loaded or unloaded, the lateral pressures specified above; and a lateral pressure of 100 pounds for each vertical lineal foot of the trestle bents.

Temperature. 41. Variation in temperature, to the extent of 150 degrees, shall be provided for.

Centrifugal Force. 42. For electric railways on curves, the additional effects due to the centrifugal force of cars single or coupled shall be considered as a live load. It will be assumed to act 5 feet above base of rail, and will be computed for a speed of 40 miles per hour.

Longitudinal Forces 43. The strains produced in the bracing of the trestle towers, in any members of the trusses, or in the attachments of the girders or trusses to their bearings, by suddenly stopping the maximum electric car trains on any part of the work must be provided for; the coefficient of friction of the wheels on the rails being assumed as 0.20.

44. All parts shall be so designed that the strains coming upon them can be accurately calculated.

PROPORTION OF PARTS.

Tensile Strain. 45. All parts of the structures shall be proportioned in tension by the following allowed unit strains:

Medium Steel.

For Medium Steel.		Pounds per square inch.
Floor beam hangers, and other similar members liable to sudden loading, net section		8,000
Longitudinal, lateral and sway bracing, for wind and live load strains (§§ 6, 39, 40)		18,000
Solid rolled beams, used as cross floor beams and stringers		13,000
Bottom flanges of riveted girders, net section		13,000
	For live loads.	For dead loads.
Bottom chords, main diagonals, counters and long verticals	12,500	25,000

For swing bridges and other movable structures, the dead load unit strains, during motion, must not exceed three-fourths of the above allowed unit strains for dead load on stationary structures.

Soft Steel. *Soft Steel* may be used in tension with unit strains ten per cent. less than those allowed for *Medium Steel.*

46. Angles subject to direct tension must be connected by both legs, or the section of one leg only will be considered as effective.

47. In members subject to tensile strains full allowance shall be made for reduction of section by rivet-holes, screw-threads, etc. (§§ 75, 79.) Net Section.

48. Compression members shall be proportioned by the following allowed unit strains: Compressive Strains.

For Medium Steel. Medium Steel.

Chord segments $P=12,000-55\frac{l}{r}$ for live load strains.

$P=24,000-110\frac{l}{r}$ for dead load strains.

All posts of through bridges. $P=10,000-45\frac{l}{r}$ for live load strains.

$P=20,000-90\frac{l}{r}$ for dead load strains.

All posts of deck bridges and trestles. $P=11,000-40\frac{l}{r}$ for live load strains.

$P=22,000-80\frac{l}{r}$ for dead load strains.

End posts are not to be considered chord segments.

Lateral struts and rigid bracing. $P=13,000-60\frac{l}{r}$ for wind strains;

for live load strains use two-thirds of the above. (§§ 42, 43, 124.)

P=the allowed strain in compression per square inch of cross-section, in pounds.

l=the length of compression member, in inches, c. to c., of connections.

r=the least radius of gyration of the section, in inches.

No compression member, however, shall have a length exceeding 100 times its least radius of gyration for main members, or 120 times for laterals.

For swing bridges and other movable structures, the dead load unit strains during motion must not exceed $\frac{3}{4}$ of the above allowed unit strains for dead load on stationary structures.

49. For long span bridges, when the ratio of the length and width of span is such that it makes the top chords acting as a whole, a longer column than the segments of the chord, the chord will be proportioned for this greater length.

Soft Steel. *Soft Steel* may be used in compression with unit strains fifteen per cent. less than those allowed for *Medium Steel.*

50. The areas obtained by dividing the live load strains by the live load unit strains will be added algebraically to the areas obtained by dividing the dead load strains by the dead load unit strains to determine the required sectional area of any member. (§ 62.)

Alternate Strains. 51. All members and their connections subject to alternate strains of tension and compression shall be proportioned to resist each kind of strain. Both of the strains shall, however, be considered as increased by an amount equal to $\frac{8}{10}$ of the least of the two strains, for determining the sectional areas by the above-allowed unit strains. (§§ 45, 48.)

Effect of Wind on Chord Strains. 52. The strains in the truss members or trestle posts from the assumed wind forces need not be considered except as follows:

1st. When the wind strains on any member exceed 25 per cent. of the maximum strains due to the dead and live loads upon the same member. The section shall then be increased until the total strain per square inch will not exceed by more than 25 per cent. the maximum fixed for dead and live loads only.

2d. When the wind strain alone or in combination with a possible temperature strain, can neutralize or reverse the strains in any member.

Rivets, Bolts and Pins. 53. The rivets in all members, other than those of the floor and lateral systems, must be so spaced that the shearing strain per square inch shall not exceed 10,000 pounds;

nor the pressure on the bearing surface (diameter × thickness of the piece) of the rivet-hole exceed 18,000 pounds per square inch.

The rivets in all members of the floor system, including all hanger connections, must be so spaced that the shearing strains and bearing pressures shall not exceed 80 per cent. of the above limits.

The rivets in the lateral and sway bracing will be allowed 40 per cent. increase upon the above limits.

In the case of field riveting (and for bolts as per § 76) the above-allowed shearing strains and pressures shall be reduced one-third.

Rivets and bolts must not be used in direct tension.

54. Pins shall be proportioned so that the shearing strain shall not exceed 10,000 pounds per square inch; nor the pressure on the bearing surface of any member (other than forged eye-bars, see § 104) connected to the pin be greater per square inch than 18,000 pounds; nor the bending strain exceed 20,000 pounds, when the applied forces are considered as uniformly distributed over the middle half of the bearing of each member.

55. When any member is subjected to the action of both axial and bending strains, as in the case of end posts of through bridges (§ 52), or of chords carrying distributed floor loads, it must be proportioned so that the greatest fibre strain will not exceed the allowed limits of tension or compression on that member. Combined Strains.

If the fibre strain resulting from the weight only, of any member, exceeds ten per cent. of the allowed unit strain on such member, such excess must be considered in proportioning the areas.

56. In beams and plate girders the compression flanges shall be made of same *gross* section as the tension flanges. Compression Flanges.

57. Riveted longitudinal girders shall have, preferably, a depth not less than $\frac{1}{20}$ of the span. Depth of Girders.

Rolled beams used as longitudinal girders shall have, preferably, a depth not less than $\frac{1}{30}$ of the span.

58. Plate girders shall be proportioned upon the supposi- Plate Girders etc.

tion that the bending or chord strains are resisted entirely by the upper and lower flanges, and that the shearing or web strains are resisted entirely by the web-plate; no part of the web-plate shall be estimated as flange area.

The distance between centres of gravity of the flange areas will be considered as the effective depth of all girders.

Web Plates. 59. The webs of plate girders must be stiffened at intervals, not exceeding the depth of the girders or a maximum of 5 feet, wherever the shearing strain per square inch exceeds the strain allowed by the following formula:

$$\text{Allowed shearing strain} = 12{,}500 - 90H,$$

where $H =$ ratio of depth of web to its thickness; but no web-plates shall be less than $\frac{5}{16}$ of an inch in thickness.

Stiffeners. 60. All stiffeners must be capable of carrying the maximum vertical shear without exceeding the allowed unit strain.

$$P = 12{,}000 - 55\frac{l}{r}.$$

Each stiffener must connect to the webs by enough rivets to transfer the maximum shear to or from the webs (§ 83).

Rolled Beams. 61. Rolled beams shall be proportioned (§§ 45, 48) by their moments of inertia.

Counters. 62. The areas of counters shall be determined by taking the difference in areas due to the live and dead load strains considered separately (§ 45, 105).

63. For bridges carrying electric or motor cars counters shall be provided and proportioned, so that a future increase of 25 per cent. in the specified live load shall not in any case increase the allowed unit strain more than 25 per cent.

DETAILS OF CONSTRUCTION.

Details. 64. All the connections and details of the several parts of the structures shall be of such strength that, upon testing, rupture will occur in the body of the members rather than in any of their details or connections.

65. Preference will be had for such details as shall be most accessible for inspection, cleaning and painting; no closed sections will be allowed.

Riveting. 66. The pitch of rivets in all classes of work shall never exceed 6 inches, or sixteen times the thinnest outside plate, nor be less than three diameters of the rivet.

67. The rivets used shall generally be $\frac{3}{4}$ and $\frac{7}{8}$ inch diameter.

68. The distance between the edge of any piece and the centre of a rivet-hole must never be less than $1\frac{1}{4}$ inches, except for bars less than $2\frac{1}{2}$ inches wide; when practicable it shall be at least two diameters of the rivet.

69. For punching, the diameter of the die shall in no case exceed the diameter of the punch by more than $\frac{1}{16}$ of an inch, and all holes must be clean cuts without torn or ragged edges.

70. All rivet holes must be so accurately spaced and punched that when the several parts forming one member are assembled together, a rivet $\frac{1}{16}$ inch less in diameter than the hole can generally be entered, hot, into any hole, without reaming or straining the metal by "drifts"; occasional variations must be corrected by reaming.

71. The rivets when driven must completely fill the holes. The rivet-heads must be round and of a uniform size for the same sized rivets throughout the work. They must be full and neatly made, and be concentric to the rivet-hole, and thoroughly pinch the connected pieces together.

72. Wherever possible, all rivets must be machine driven. The machines must be capable of retaining the applied pressure after the upsetting is completed. No hand-driven rivets exceeding $\frac{7}{8}$ inch diameter will be allowed.

73. Field riveting must be reduced to a minimum or entirely avoided, where possible.

74. All holes for field rivets, except those in connections of the lateral and sway systems, shall be accurately drilled or reamed to an iron template or be reamed true while the parts are temporarily connected together.

75. The effective diameter of a driven rivet will be as- Net Sections.
sumed the same as its diameter before driving. In deducting the rivet-holes to obtain net sections in tension members, the diameter of the rivet-holes will be assumed as $\frac{1}{8}$ inch larger than the undriven rivets.

The rupture of a riveted tension member is to be considered as equally probable, either through a transverse line of rivet-holes or through a diagonal line of rivet-holes, where the net section does not exceed by 30 per cent. the net section along the transverse line.

The number of rivet-holes to be deducted for net section will be determined by this condition. (§§ 47-79.)

Bolts. 76. When members are connected by bolts the holes must be reamed parallel and the bolts turned to a driving fit. All bolts must be of neat lengths, and shall have a washer under the heads and nuts where in contact with wood. Bolts must not be used in place of rivets, except by special permission.

77. All nuts must be of hexagonal shape.

Splices. 78. All joints in riveted tension members must be fully and symmetrically spliced.

79. Riveted tension members shall have an effective section through the pin-holes 25 per cent. in excess of the net section of the member, and back of the pin at least 75 per cent. of the net section through the pin-hole.

80. In continuous compression members, as chords and trestle posts, the abutting joints with planed faces must be placed as close to the panel points as is practicable, and the joints must be spliced on all sides with at least two rows of closely pitched rivets on each side of the joint.

Joints in long posts must be fully spliced.

Abutting Joints. 81. In compression members, abutting joints with untooled faces must be fully spliced, as no reliance will be placed on such abutting joints. The abutting ends must, however, be dressed straight and true, so there will be no open joints.

Web Splices. 82. The webs of plate girders must be spliced at all joints by a plate on each side of the web.

Stiffeners. 83. All web-plates must have stiffeners over bearing points and at points of local concentrated loadings; such stiffeners must be fitted at their ends to the flange angles, at the bearing points. (§§ 59-60.)

84. All other angles, filling and splice plates on the webs of girders and riveted members must fit at their ends to

the flange angles, sufficiently close to be sealed, when painted, against admission of water.

85. Web-plates of all girders must be arranged so as not to project beyond the faces of the flange angles, nor on the top be more than $\frac{1}{16}$ inch below the face of these angles, at any point. Web Plates.

86. Wherever there is a tendency for water to collect, the spaces must be filled with a suitable waterproof material.

87. In girders with flange plates, at least one-half of the flange section shall be angles or else the largest sized angles must be used. Flange plates must extend beyond their theoretical length, two rows of rivets at each end. Flange Plates.

88. The flange plates of all girders must be limited in width so as not to extend beyond the outer lines of rivets connecting them with the angles, more than five inches or more than eight times the thickness of the first plate. Where two or more plates are used on the flanges, they shall either be of equal thickness or shall decrease in thickness outward from the angles.

89. The compression flanges of beams and girders shall be stayed against transverse crippling when their length is more than sixteen times their width. Compression Flanges.

90. The unsupported width (distance between rivets) of plates subject to compression shall not exceed thirty times their thickness; except cover plates of top chords and end posts, which will preferably be limited to forty times their thickness; where a greater relative width is used in chords and end posts, however, only forty times the thickness shall be considered as effective section. Width of Plates.

91. In lattice girders and trusses the web members must be double and connect symmetrically to the webs of the chords. The use of plates or flats, alone, for tension members must be avoided, where it is possible; in lattice trusses, the counters, suspenders and two panels of the lower chord, at each end, must be latticed; all other tension members must be connected by batten plates or latticed. (§ 111.)

92. Where the floor timbers are supported at their ends

on the flange of one angle, such angle must have two rows of rivets in its vertical leg, spaced not over 4 inches apart.

Buckle Plates. 93. Buckle plates must be firmly riveted to the supporting beams and be spliced at all free edges. Preferably they will be made in continuous sheets of panel lengths. They may be pressed or formed without heating. (§ 23.)

94. A buckle-plate floor, as specified, may be considered as the required lateral system of bracing at the floor level.

95. The buckle-plates of the sidewalks will be covered to the proper slope and level for the wearing pavement with bitumen concrete of an accepted and waterproof character.

96. The buckle-plates of the roadway will be covered with an acceptable and waterproof concrete (bitumen or cement) to the proper crown and grade for the wearing pavement, but at no place must the concrete be less than 3 inches thick.

Thickness of Metal. 97. For main members and their connections no material shall be used of a less thickness than $\frac{5}{16}$ of an inch; and for laterals and their connections, no material less than $\frac{1}{4}$ of an inch in thickness; except for lining or filling vacant spaces. No bars shall be used with a less net area than $\frac{3}{4}$ of one square inch.

Eye Bars. 98. The heads of eye-bars shall be so proportioned and made, that the bars will preferably break in the body of the original bar rather than at any part of the head or neck. The form of the head and the mode of manufacture shall be subject to the approval of the Engineer. (§§ 138, 139, 159, 160.)

99. The bars must be free from flaws and of full thickness in the necks. They shall be perfectly straight before boring. The holes shall be in the centre of the head, and on the centre line of the bar.

100. The bars must be bored to lengths not varying from the calculated lengths more than $\frac{1}{64}$ of an inch for each 25 feet of total length.

101. Bars which are to be placed side by side in the structure shall be bored at the same temperature and of such equal length that upon being piled on each other the

pins shall pass through the holes at both ends without driving.

102. The lower chord shall be packed as narrow as possible.

103. The pins shall be turned straight and smooth; chord pins shall fit the pin-holes within $\frac{1}{50}$ of an inch, for pins less than $4\frac{1}{2}$ inches diameter; for pins of a larger diameter the clearance may be $\frac{1}{32}$ inch. Pins.

104. The diameter of the pin shall not be less than three-quarters the largest dimension of any eye-bar attached to it. The several members attaching to the pin shall be so packed as to produce the least bending moment upon the pin, and all vacant spaces must be filled with wrought filling rings.

105. All bars with screw ends shall be upset at the ends, so that the diameter at the bottom of the threads shall be $\frac{1}{16}$ inch larger than any part of the body of the bar. Where closed sleeve nuts are used on adjustable members the effective length of thread shall be legibly stamped at the screw ends of each bar. Adjustable counters to be avoided where practicable. Upset Ends.

106. All threads must be of the United States standard, except at the ends of the pins.

107. Floor beam hangers when permitted shall be made without adjustment and so placed that they can be readily examined at all times. (§ 3.) Hangers.

108. All the floor beams must be effectually stayed against end motion or any tendency to rotate from the action of the lateral system.

109. Compression members shall be of steel, and of approved forms. Compression Members.

110. The pitch of rivets at the ends of compression members shall not exceed four diameters of the rivets for a length equal to twice the width of the member.

111. The open sides of all compression members shall be stayed by batten plates at the ends and diagonal latticework at intermediate points. The batten plates must be placed as near the ends as practicable, and shall have a

length not less than the greatest width of the member or $1\frac{1}{2}$ times its least width. The size and spacing of the lattice bars shall be duly proportioned to the size of the member. They must not be less in width than $1\frac{1}{2}$ inches for members 6 inches in width, $1\frac{3}{4}$ inches for members 9 inches in width, 2 inches for members 12 inches in width, nor $2\frac{1}{4}$ inches for members 15 inches in width, nor $2\frac{1}{2}$ inches for members 18 inches and over in width. Single lattice bars shall have a thickness not less than $\frac{1}{40}$ or double lattice bars connected by a rivet at the intersection, not less than $\frac{1}{60}$ of the distance between the rivets connecting them to the members. They shall be inclined at an angle not less than 60° to the axis of the member for single latticing, nor less than 45° for double latticing with riveted intersections. The pitch of the latticing must not exceed the width of the channel plus nine inches.

112. Where necessary, pin-holes shall be reinforced by plates, some of which must be of the full width of the member, so the allowed pressure on the pins shall not be exceeded, and so the strains shall be properly distributed over the full cross-section of the members. These reinforcing plates must contain enough rivets to transfer their proportion of the bearing pressure, and at least one plate on each side shall extend not less than six inches beyond the edge of the batten plates. (§ 111.)

113. Where the ends of compression members are forked to connect to the pins, the aggregate compressive strength of these forked ends must equal the compressive strength of the body of the members.

114. In compression chord sections and end posts, the material must mostly be concentrated at the sides, in the angles and vertical webs. Not more than one plate, and this not exceeding $\frac{3}{8}$ inch in thickness, shall be used as a cover plate, except when necessary to resist bending strains, or to comply with § 90. (§ 55.)

115. The ends of all square-ended members shall be planed smooth, and exactly square to the centre line of strain.

116. The ends of all floor beams and stringers shall be faced true and square, and to correct lengths. Allowance must be made in the thickness of the end angles to provide for such facing without reducing the required effective strength of such end angles. Floor Beams and Stringers.

117. All members must be free from twists or bends. Portions exposed to view shall be neatly finished.

118. Pin-holes shall be bored exactly perpendicular to a vertical plane passing through the centre line of each member, when placed in a position similar to that it is to occupy in the finished structure. Pin-Holes.

119. The several pieces forming one built member must fit closely together, and when riveted shall be free from twists, bends or open joints.

120. All through bridges shall have latticed portals, of approved design, at each end of the span, connected rigidly to the end posts and top chords. They shall be as deep as the specified head-room will allow, and provision shall be made in the end posts for the bending strains from wind pressure. (§§ 4, 10, 39, 52.) Transverse Diagonal Bracing

121. When the height of the trusses exceeds 20 feet, an approved system of overhead diagonal bracings shall be attached to each post and to the top lateral struts.

122. Knee braces shall be placed at each intermediate panel point, and connected to the vertical posts and top lateral struts, for trusses 20 feet and less in depth.

123. Pony trusses and through plate or lattice girders shall be stayed by knee braces or gusset plates attached to the top chords at the ends and at intermediate points, and attached below to the cross floor beams or to the transverse struts.

124. All deck girders shall have transverse braces at the ends. All deck bridges shall have transverse bracing at each panel point. This bracing shall be proportioned to resist the unequal loading of the trusses.

125. All members of the web, lateral, longitudinal or sway systems must be securely riveted at their intersections to prevent sagging and rattling.

Bed Plates. 126. All bed-plates must be of such dimensions that the greatest pressure upon the pedestal stone shall not exceed 250 pounds per square inch.

Friction Rollers. 127. All bridges over 80 feet span shall have hinged bolsters on both ends, and at one end nests of turned friction rollers running between planed surfaces. These rollers shall not be less than $2\frac{7}{8}$ inches diameter for spans 100 feet or less, and for greater spans this diameter shall be increased in proportion of 1 inch for 100 feet additional.

The rollers shall be so proportioned that the pressure per lineal inch of roller shall not exceed the product of the diameter in inches by 300 pounds (300d.).

The rollers must be of machinery steel and the bearing plates of medium steel.

The rollers and bearings must be so arranged that they can be readily cleaned and so that they will not hold water.

128. Bridges less than 80 feet span shall be secured at one end to the masonry, and the other end shall be free to move longitudinally upon smooth surfaces.

129. Where two spans rest upon the same masonry, a continuous plate, not less than $\frac{3}{8}$ inch thick, shall extend under the two adjacent bearings, or the two bearings must be rigidly tied together.

Pedestals and Bed-Plates. 130. Pedestals shall be made of riveted plates and angles. All bearing surfaces of the base plates and vertical webs must be planed. The vertical webs must be secured to the base by angles having two rows of rivets in the vertical legs. No base plate or web connecting angle shall be less in thickness than $\frac{1}{2}$ inch. The vertical webs shall be of sufficient height and must contain material and rivets enough to practically distribute the loads over the bearings or rollers.

Where the size of the pedestal permits, the vertical webs must be rigidly connected transversely.

131. All the bed-plates and bearings under fixed and movable ends must be fox-bolted to the masonry; for trusses, these bolts must not be less than $1\frac{1}{4}$ inches diameter; for plate and other girders, not less than $\frac{7}{8}$ inch diameter.

The contractor must furnish all bolts, drill all holes and set bolts to place with sulphur or Portland cement.

132. While the expansion ends of all trusses must be free to move longitudinally under changes of temperature, they shall be anchored against lifting or moving sideways.

133. All bridges shall be cambered by giving the panels of the top chord an excess of length in the proportion of $\frac{3}{16}$ of an inch to every ten feet. **Camber.**

134. The lower struts in trestle towers must be capable of resisting the strains due to changes of temperature or of moving the tower pedestals under the effects of expansion or contraction. **Trestle Towers.**

For high or massive towers, these lower struts will be securely anchored to intermediate masonry piers, or the tower pedestals will have suitably placed friction rollers, as may be directed by the Engineer.

135. All joints in the tower columns shall be fully spliced for all possible tension strains, and to hold the parts firmly in position. (§ 80.)

136. Tower footings and bed-plates must be planed on all bearing surfaces; and the holes for anchor bolts slotted to allow for the proper amount of movement. (§ 41.)

137. All workmanship shall be first-class in every particular. **Workmanship.**

138. All eye-bars must be made of medium steel. **Eye-Bars.**

139. Eye-bars, all forgings and any pieces which have been partially heated or bent cold must be wholly annealed. Crimped stiffeners need not be annealed.

140. No reliance will be placed upon the welding of steel.

141. No sharp or unfilleted angles or corners will be allowed in any piece of metal.

142. Medium steel may be used in compression in chords, posts and pedestals without reaming of punched holes, for all thicknesses of metal, which will stand the drifting test § 154); provided all sheared edges are planed off to a depth of $\frac{1}{8}$ inch. **Medium Steel.**

In all other cases medium steel over $\frac{5}{8}$ inch thick must have all sheared edges planed off to a depth of $\frac{1}{8}$ inch and all holes drilled or reamed to a diameter $\frac{1}{8}$ inch larger than the punched holes, so as to remove all the sheared surface of the metal.

Soft Steel. 143. Soft steel need not be reamed if it satisfies the drifting test (§§ 154, 155).

144. All parts of any tension or compression flange or member, must be of the same kind of steel, but webs of plate girders and the tension members of all girders, plate or lattice, may be made of soft steel in connection with compression members of medium steel.

145. All splices must be of the same kind of steel as the parts to be joined.

Pilot Nuts. 146. Pilot nuts must be used during the erection to protect the threads of the pins.

QUALITY OF MATERIAL.

Steel.

147. All steel must be made by the Open Hearth process. The phosphorus must not exceed 0.06 of one per cent. for steel made by the acid method, or 0.04 for steel by the basic method.

148. The steel must be uniform in character for each specified kind. The finished bars, plates and shapes must be free from cracks on the faces or corners, and have a clean, smooth finish. No work shall be put upon any steel at or near the blue temperature or between that of boiling water and of ignition of hard wood sawdust.

149. The tensile strength, elastic limit* and ductility shall be determined by samples cut from the finished material after rolling. The samples to be at least 12 inches long, and to have a uniform sectional area not less than $\frac{1}{2}$ square inch.

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* For the purpose of these specifications, the Elastic Limit will be considered the least strain producing a visible permanent elongation in a length of 8 inches, as shown by scribe marks of a pair of finely pointed dividers.

If the yield point or drop of the beam can be calibrated for any machine and its speed to represent the elastic limit within 5 per cent., it may be used for general cases. Test reports must state by which method the elastic limit was determined.

150. Material which is to be used without annealing or further treatment is to be tested in the condition in which it comes from the rolls. When material is to be annealed or otherwise treated before use, the specimen representing such material is to be similarly treated before testing, for tensile strength.

The elongation shall be measured on an original length of 8 inches. Two test pieces shall be taken from each melt or blow of finished material, one for tension and one for bending. (Art. 166.)

151. All samples or full-sized pieces must show uniform fine grained fractures of a blue steel-gray color, entirely free from fiery lustre or a blackish cast.

152. **Medium Steel** shall have an ultimate strength, when tested in samples of the dimensions above stated, of 60,000 to 68,000 pounds per square inch, an elastic limit of not less than one-half of the ultimate strength, and a minimum elongation of 22 per cent. in 8 inches. Steel for pins may have a minimum elongation of 15 per cent. Medium Steel.

153. Before or after heating to a low cherry red and cooling in water at 82 degrees Fahr., this steel must stand bending to a curve whose inner radius is one and a half times the thickness of the sample, without cracking.

154. For all medium steel, $\frac{5}{8}$ inch or less in thickness, rivet holes punched as in ordinary practice (§§ 68, 69, 70), must stand drifting to a diameter one-third greater than the original holes, without cracking either in the periphery of the holes or on the external edges of the piece, whether they be sheared or rolled.

155. **Soft Steel** shall have an ultimate strength, on same sized samples, of 54,000 to 62,000 pounds per square inch, an elastic limit not less than one-half the ultimate strength, and a minimum elongation of 25 per cent. in 8 inches. Soft Steel.

For soft steel the above drifting test (§ 154) shall apply to all material to be riveted.

156. Before or after heating to a light yellow heat and quenching in cold water, this steel must stand bending 180

degrees, to a curve whose inner radius is equal to the thickness of the sample, without sign of fracture.

Rivet Steel. 157. **Rivet Steel** shall have an ultimate strength of 50,000 to 58,000 pounds per square inch, an elastic limit not less than one-half the ultimate strength and an elongation of 26 per cent.

158. The steel for rivets must, under the above bending test (156), stand closing solidly together without sign of fracture.

Eye Bars. 159. Eye-bar material, $1\frac{1}{2}$ inches and less in thickness, shall, on test pieces cut from finished material, fill the above requirements. For thicknesses greater than $1\frac{1}{2}$ inches, there will be allowed a reduction in the percentage of elongation of 1 per cent. for each $\frac{1}{8}$ of an inch increase of thickness, to a minimum of 20 per cent. (Art. 138.)

160. Full sized eye-bars shall show not less than 10 per cent. elongation in the body of the bar, and an ultimate strength not less than 56,000 pounds per square inch. Should a bar break in the head, but develop 10 per cent. elongation and the ultimate strength specified, it shall not be cause for rejection, provided not more than one-third of the total number of bars tested break in the head.

Pins. 161. Pins over 7 inches in diameter shall be forged. Blooms for pins shall have at least three times the sectional area of the finished pins.

162. A variation of cross-section or weight in the finished members of $2\frac{1}{2}$ per cent. from the specified size may be cause for rejection.

Steel Castings.

Steel Castings. 163. Steel castings will be used for drawbridge wheels, track segments and gearing. (Art. 1.)

They must be true to form and dimensions, of a workmanlike finish and free from injurious blowholes and defects. All castings must be annealed.

When tested in specimens of uniform sectional area of at least $\frac{1}{2}$ square inch for a distance of 2 inches, they must show an ultimate strength of not less than 67,000 pounds per square inch, an elastic limit of one-half the ultimate, and an elongation in 2 inches of not less than 10 per cent.

The metal must be uniform in character, free from hard or soft spots, and be capable of being properly tool finished.

Cast Iron.

164. Except where cast steel or chilled iron is required, all castings must be of tough, gray iron, free from cold shuts or injurious blowholes, true to form and thickness, and of a workmanlike finish. Sample pieces, 1 inch square, cast from the same heat of metal in sand moulds, shall be capable of sustaining, on a clear span of 12 inches, a central load of 2,400 pounds, when tested in the rough bar. A blow from a hammer shall produce an indentation on a rectangular edge of the casting without flaking the metal. Cast Iron.

Timber.

165. The timber, unless otherwise specified, shall be strictly first-class spruce, white pine, southern yellow pine or white oak bridge timber, sawed true, and out of wind, full size, free from wind shakes, large or loose knots, decayed or sap wood, worm holes, or other defects impairing its strength or durability. It will be subject to the inspection and acceptance of the Engineer. Timber.

INSPECTION.

166. All facilities for inspection of the materials and workmanship shall be furnished by the contractor. He shall furnish without charge such specimens (prepared) of the several kinds of steel to be used, as may be required to determine their character. Inspection.

167. The contractor must furnish the use of a testing machine capable of testing the above specimens at all mills where the steel may be manufactured, free of cost.

168. Full sized parts of the structure may be tested at the option of the Engineer, but if tested to destruction, such material shall be paid for at cost, less its scrap value

to the contractor, if it proves satisfactory. If it does not stand the specified tests, it will be considered rejected material, and be solely at the cost of the contractor.

PAINTING.

Painting. 169. All metal work before leaving the shop shall be thoroughly cleaned from all loose scale and rust, and be given one good coating of pure raw linseed oil, well worked into all joints and open spaces.

Buckle-plates shall be given a thick and thorough coating of red lead and linseed oil before shipment. All rivet heads in the buckle-plate floor shall also be coated with this read lead paint as soon as practicable after they are driven.

170. In riveted work the surfaces coming in contact shall each be painted before being riveted together. Bottoms of bed-plates, bearing-plates, and any parts which are not accessible for painting after erection, shall have two coats of paint; the paint shall be a good quality of iron ore paint, mixed with pure linseed oil.

171. After the structure is erected, the metal work shall be thoroughly and evenly painted with two additional coats of paint, mixed with pure linseed oil. All recesses which will retain water, or through which water can enter, must be filled with thick paint or some waterproof cement before receiving the final painting.

172. Pins, bored pin-holes, screw threads and turned friction rollers shall be coated with white lead and tallow before being shipped from the shop.

ERECTION.

Erection. 173. The contractor, unless it be otherwise specified, shall furnish all staging and false work, shall erect and adjust all the metal work, and put in place all floor timbers, guards, etc., complete.

174. The contractor shall so conduct all his operations as not to interfere with the work of other contractors, or close any thoroughfare by land or water, except by written consent of....................................

175. The contractor shall assume all risks of accidents to men or material prior to the acceptance of the finished structure.

The contractor must also remove all false work, piling and other obstructions, or unsightly material produced by his operations.

FINAL TEST.

176. Before the final acceptance the Engineer may make a thorough test by passing over each structure the specified loads, or their equivalent, or by resting the maximum load upon the structure for twelve hours. **Final Test.**

After such tests the structures must return to their original positions without showing any permanent change in any of their parts.

EXPORT WORK.

All plans, including working drawings, must be submitted for the examination and approval of the Consulting Engineer before the material is ordered or any work done. **Export Work.**

Any proposed modification of accepted plans, to adapt them to the plant and methods of the manufacturer or to facilitate the prompt delivery of the work, must also be submitted to and approved by the Consulting Engineer, before such changes can be allowed.

In all designs, the length and size of parts must be so arranged that they can be readily handled and stored during transportation to the site.

Length of bars, posts, chords and pieces of small section must not exceed..feet.

Length of girders or girder sections over........................feet in width must not exceed..feet.

Weight of any single piece must not exceed................................ pounds.

Pins, roller-nests, bolts, rivets and all small pieces must be packed in strong, iron-bound boxes, with the detailed contents of each box legibily marked on the outside. Boxes to be consecutively lettered or numbered.

The screw-ends of all bars to be securely protected by canvass wrapped and wired about the same.

Every piece must not only be legibily marked by paint, but also by letters stamped on the metal, showing its location in the structure.

All necessary rivets for the field connections, with an extra allowance of 25 per cent. for each kind, shall be sent with each shipment.

The customary pilot-nuts (§ 146) for all pins shall be sent with the pins.

SUPPLEMENTARY.

The following special clauses shall apply in addition to previous general clauses, to the special work included in the attached contract:

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GENERAL DATA.

For a bridge crossing........................in the town of.................County of................State of ....to be built according to the general requirements of the accompanying specifications:

Width of roadway.....................................
Number of footwalks.................................
Width of footwalks....................................
Kind of floor or paving...............................
Number of car tracks.................................
Spacing " " ....
Height of floor above flood line.........................
Height of floor above ordinary stage of water............
Depth of river at ordinary stage of water................
Character of river bed...............................
Usual seasons for floods.............................
Length of haul from nearest freight station..............
Specified live load, Class A1, A2, B, C, D, E1 or E2, paragraph 38, to be adopted for this bridge..............
Sizes of piers (if built or contracted for)...............
Skew of piers, or angle of current with line of the bridge.
Total length of bridge................................
Length of spans centre to centre of piers.................

APPENDIX.

TABLE I.

Maximum End Shears S, Moments M, and Reactions R for Live Loads (only), on Stringers and Floor-Beams of Class E_1.

Span.	Each stringer.			Floor-Beams. Single track.		Floor-Beams. Double track.	
L. Ft.	S. Lbs.	$\frac{M}{1\,000}$ inch-lbs.	Least size.	R. Lbs.	M. Lbs.-ft.	R. Lbs.	M. Lbs.-ft.
10	12 000	360		12 000	....	24 000	....
11	13 100	396	12-in. I.				
12	14 000	432					
13	14 800	468					
14	15 400	504	....				
15	16 000	540					
16	16 500	576					
17	16 900	612					
18	17 300	676	15-in. I.				
19	17 700	743					
20	18 000	810					
21	18 300	878	....	$R = S$.	$M = \frac{S}{2}(d-f)$.	$R = 2S$.	$M = S(d-e)$.
22	18 500	946					
23	18 800	1 014	18-in. I.				
24	19 000	1 083	....				
25	19 200	1 152					
26	19 400	1 221					
27	19 600	1 291	20-in. I.				
28	19 700	1 360					
29	19 900	1 430					
30	20 000	1 500	....	20 000	....	40 000	....

$$S = P\left(1 + \frac{l-10}{l}\right)$$

Moment for stringers equals

$$M = \frac{Pl}{4} \text{ up to 17 feet.}$$

$$M = P\,\frac{(l-5)^2}{2l} \text{ over 17 feet, in foot-pounds.}$$

S = end shear of one stringer.
M = maximum moment.
P = concentrated load on one wheel.
l = span in feet.
d = distance in feet, center to center of trusses.
e = distance in feet, center to center of tracks.
f = " " " " stringers.

TABLE II.

Same for Class E_2.

Span.	Each stringer.			Floor-Beams.			
				Single track.		Double track.	
L. Ft.	*S.* Lbs.	*M.* 1 000 inch-lbs.	Least size.	*R.* Lbs.	*M.* Lbs. ft.	*R.* Lbs.	*M.* Lbs. ft.
10	9 000	270	10-in. *I.*	$R = S.$	$M = \frac{S}{2}(d - f).$	$R = 2S.$	$M = S(d - e).$
11	9 800	297	....				
12	10 500	324					
13	11 100	351					
14	11 600	378	12-in. *I.*				
15	12 000	405					
16	12 400	432					
17	12 700	459					
18	13 000	507	....				
19	13 300	557					
20	13 500	607					
21	13 700	658	15-in. *I.*				
22	13 900	709					
23	14 100	761					
24	14 200	812	....				
25	14 400	864					
26	14 500	916	18-in. *I.*				
27	14 700	968	....				
28	14 800	1 020					
29	14 900	1 073					
30	15 000	1 125	20-in. *I.*				

TABLE III.

Maximum End Shears S, Moments M and Reactions R for Live Loads (only) on Stringers and Floor-Beams of Classes A and B, with Double-Track Railway.

Span.	Each Stringer.					Floor-Beams (A and B).					
	A.	*B.*				Width of roadway.					
	All.	Under tracks.	Under roadway.			20 ft.	24 ft.	28 ft.	32 ft.	36 ft.	40 ft.
L. Ft.	*S.* and *M.*	*S* and *M.*	*S.* Lbs.	*M.* 1 000 inch-lbs.	Least size.	*R.* Lbs.	*R.* Lbs.	*R.* Lbs.	*R.* Lbs.	*R.* Lbs.	*R.* Lbs.
10	Same as for E_1, double track.	Same as for E_1, double track.	6 000	180		24 000	25 000	27 000	29 000	31 000	33 000
11			6 500	198	9-in. *I.*	26 200	27 300	29 500	31 700	33 900	36 100
12			7 000	216		28 000	29 200	31 600	34 000	36 400	38 800
13			7 400	234		29 600	30 800	33 400	36 100	38 600	41 200
14			7 700	252		30 800	32 300	35 000	37 800	40 700	43 500
15			8 000	270		32 000	33 500	36 500	39 500	42 500	45 500
16			8 300	288	10-in. *I.*	33 000	34 600	37 800	41 000	44 200	47 400
17			8 500	306		33 900	35 600	39 000	42 400	45 000	49 200
18			8 700	338		34 700	36 600	40 600	43 700	47 300	50 900
19			8 800	371		35 400	37 300	41 100	44 900	48 700	52 500
20			9 000	405		36 000	38 000	42 000	46 000	50 000	54 000
21			9 100	439		36 600	38 700	42 900	47 100	51 300	55 500
22			9 300	473	12-in. *I.*	37 200	39 300	43 700	48 100	52 500	56 900
23			9 400	507		37 600	39 900	44 500	49 100	53 700	58 300
24			9 500	541		38 000	40 400	45 200	50 000	54 800	59 600
25			9 600	576		38 400	40 900	45 900	50 900	55 900	60 900
26			9 700	611		38 800	41 400	46 600	51 800	57 000	62 200
27			9 800	646		39 100	41 800	47 200	52 600	58 000	63 400
28			9 900	680	15-in. *I*	39 400	42 200	47 800	53 400	59 000	64 600
29			9 900	715		39 700	42 600	48 400	54 200	60 000	65 800
30			10 000	750		40 000	43 000	49 000	55 000	61 000	67 000

$R = 2S + \frac{w-22}{2} 100\, l$ for widths over 22 feet.

$M = \frac{R}{2}(d-e) - \frac{w-22}{8}(w + 22 - 2e)\, 100\, l$ in foot-pounds.

e = distance c. to c., of tracks.
d = " " " trusses.
w = width of roadway in the clear
= span of stringers in feet.

TABLE IV.

MAXIMUM END SHEAR S, MOMENTS M AND REACTIONS R, FOR LIVE LOAD (ONLY) ON STRINGERS AND FLOOR-BEAMS OF CLASS C, WITH SINGLE-TRACK RAILWAY.

Span.	Each Stringer.				Floor-Beams.				
	Under tracks.	Under roadway.			Width of roadway.				
					12-ft. track, central.		18-ft. track one side; center of track 5 ft. clear of truss.		
L. Ft.	S. and M.	S. lbs.	M. 1 000-inch lbs.	Least size.	R. lbs.	M.† 1 000-inch lbs.	R_1. lbs.	R_2. lbs.	M.† 1 000-inch lbs.
10	Same as for E_2 single track.	6 000	180		9 000	459	13 800	10 200	830
11		6 500	198	9-in. I.	9 800	500	15 100	11 100	908
12		7 000	216		10 500	536	16 200	12 000	973
13		7 400	234	....	11 100	565	17 100	12 900	1 031
14		7 700	252		11 600	590	17 900	13 600	1 081
15		8 000	270	10-in. I.	12 000	612	18 600	14 400	1 126
16		8 300	288		12 400	631	19 300	15 000	1 168
17		8 500	306	....	12 700	648	19 900	15 700	1 205
18		8 700	338		13 000	663	20 400	16 400	1 241
19		8 800	371		13 300	676	20 900	17 000	1 273
20		9 000	405		13 500	688	21 300	*18 000	1 304
21		9 100	439		13 700	699	21 800	*18 900	1 331
22		9 300	473	12-in. I.	13 900	709	22 200	*19 800	1 359
23		9 400	507		14 100	719	22 500	*20 700	1 385
24		9 500	541		*14 400	727	22 900	*21 600	1 409
25		9 600	576	....	*15 000	734	23 200	*22 500	1 432
26		9 700	611		*15 600	742	23 500	*23 400	*1 474
27		9 800	646		*16 200	748	*24 300	*24 300	*1 531
28		9 900	680	15-in. I.	*16 800	*756	*25 200	*25 200	*1 588
29		9 900	715		*17 400	*783	*26 100	*26 100	*1 644
30		10 000	750		*18 000	*810	*27 000	*27 000	*1 701

For bridges with one track on one side of roadway only.

$$R_1 = S + \frac{(w-12)\,l\,p}{2} + \frac{2\,a\,S - (w-12)\,6\,l\,p}{D}$$
$$R_2 = \text{do.} \quad \text{do.} \quad - \quad \text{do.}$$
$$M \text{ under inner rail} = \frac{R_1}{2}\,(D + 5 - 2\,a) - 5\,S.$$
For concentrated load.

$$R_1 = R_2 = \frac{w}{2}\,p\,l.$$
$$M = \frac{w}{2}\,p\,l\,\frac{2\,D - w}{4}$$
For uniform load.

w = width of roadway.
l = length of panel.
p = uniform load per square foot.
D = width of bridge, center to center of trusses.
a = distance between center of track and center of roadway.

* Maximum from load per square foot.
† Moments calculated for chords 18 ins. wide.

TABLE V.

Maximum End Shears S, Moments M and Reactions R for Live Load (only) on Stringers and Floor-Beams, Class D.

Span.	Stringers (each).			Floor-Beams. Width of roadway.									
				12 ft.		14 ft.		16 ft.		18 ft.		20 ft.	
L. Ft.	*S.* lbs.	*M* 1 000 inch-lbs.	Least size. § 17.	*R.* lbs.	*M.* 1 000 inch-lbs.	*R.* lbs.	*M.* 1 000 inch-lbs.	*R.* lbs.	*M.* 1 000 inch-lbs.	*R.* lbs.	*M.* 1 000 inch-lbs.	*R.* lbs.	*M.* 1 000 inch-lbs.
10.......	3 000	90	Yellow Pine, 3 x 12..	4 800	216	5 600	286	6 400	365	7 200	454	8 000	552
11.......	3 300	99	or	5 300	238	6 200	314	7 000	401	7 900	499	8 800	607
12.......	3 500	108	Spruce. 4 x 12.......	5 800	259	6 700	343	7 700	438	8 600	544	9 600	662
13.......	3 700	117		6 200	281	7 300	371	8 300	474	9 400	590	10 400	718
14.......	3 900	126	....	6 700	302	7 800	400	9 000	511	10 100	635	11 200	773
15.......	4 000	135	4 x 12, Y. P. or......	7 200	324	8 400	428	9 600	547	10 800	680	12 000	828
16.......	4 100	144	4 x 14, S.............	7 700	346	9 000	457	10 200	584	11 500	726	12 800	883
17.......	4 200	153	....	8 200	367	9 500	486	10 900	621	12 200	771	13 600	938
18.......	4 300	169	4 x 14, Y. P. or......	8 600	388	10 100	515	11 500	657	13 000	816	14 400	994
19.......	4 400	186	4 x 15, S.............	9 100	410	10 600	544	12 200	693	13 700	862	15 200	1 049
20.......	4 500	203	....	9 600	432	11 200	572	12 800	730	14 400	907	16 000	1 104
21.......	4 600	220		10 100	454	11 800	601	13 400	766	15 100	953	16 800	1 159
22.......	4 700	237		10 600	475	12 300	629	14 100	803	15 800	998	17 600	1 214
23.......	4 700	254	10-in. *I.* beam.	11 000	497	12 900	657	14 700	839	16 600	1 043	18 400	1 270
24.......	4 800	271		11 500	518	13 400	686	15 400	876	17 300	1 089	19 200	1 325
25.......	4 800	288	....	12 000	540	14 000	714	16 000	912	18 000	1 134	20 000	1 380
26.......	4 900	305		12 500	562	14 600	743	16 600	948	18 700	1 179	20 800	1 435
27.......	4 900	323		13 000	583	15 100	771	17 300	985	19 400	1 225	21 600	1 490
28.......	4 900	340		13 500	605	15 700	800	17 900	1 021	20 200	1 270	22 400	1 546
29.......	5 000	357		13 900	626	16 200	828	18 600	1 058	20 900	1 316	23 200	1 601
30.......	5 000	375	12-in. *I.* beam.	14 400	648	16 800	857	19 200	1 094	21 600	1 361	24 000	1 656
31.......	5 000	392											
32.......	5 100	410											
33.......	5 100	428											
34.......	5 100	445	....										
35.......	5 100	463											
36.......	5 200	480											
37.......	5 200	498											
38.......	5 200	516	15-in. *I.* beam.										
39.......	5 300	534											
40.......	5 300	551											

The floor-beam moments in above table are calculated for a width of truss of 18 inches. For other widths take the following percentages of the above moments from the table.

For floor-beams:

$$M = R\frac{2D - w}{4} : R = 40\,w\,l.$$

Width of roadway.	Width of Truss. 12 ins.	15 ins.	18 ins.	21 ins.	24 ins.
12 ft.........	96%	98%	100%	102%	104%
14 ".........	97 "	98 "	100 "	102 "	104 "
16 ".........	97 "	99 "	100 "	101 "	103 "
18 ".........	98 "	99 "	100 "	101 "	103 "
20 ".........	98 "	99 "	100 "	101 "	102 "

"The most perfect system of rules to insure success must be interpreted upon the broad grounds of professional intelligence and common sense."

GENERAL SPECIFICATIONS

FOR

STEEL RAILROAD BRIDGES

AND VIADUCTS.

NEW AND REVISED EDITION,

1901.

By THEODORE COOPER,

Consulting Engineer.

By THEODORE COOPER, M. Am. Soc. C. E.

Specifications for Steel Railroad Bridges, 1901, . . .	$0 50
" " " " previous editions	25
" " Highway Bridges, 1901, . .	50
" " " " previous editions	25
American Railroad Bridges (reprint from Transactions of American Society of Civil Engineers, July, 1889), 60 pages, 8vo, cloth, ...	2 00

General Specifications for Steel Railroad Bridges and Viaducts.

SIXTH EDITION.

1901.

GENERAL DESCRIPTION.

1. All the structures shall be of wrought steel, as specified. (§§ 128–141.) Cast-iron or cast-steel may be used in the machinery of movable bridges and in special cases for bed-plates.

2. The following kinds of girders shall preferably be employed: Kind of Girders.

Spans, up to	20	feet	----	Rolled beams, or longitudinal trough floors.
" 20 to	75	"	----	Riveted plate girders.
" 75 to	120	"	----	Riveted plate or lattice girders.
" 120 to	150	"	----	Lattice or pin-connected trusses.
" over	150	"	----	Pin-connected trusses.

Generally "double track through" bridges will have but two trusses, to avoid spreading the tracks at bridges.

In calculating strains the length of span shall be understood to be the distance between centres of end pins for trusses, and between centres of bearing plates for all beams and girders. Length of Span.

3. The girders shall be spaced, with reference to the axis of the bridge, as required by local circumstances, and directed by the Engineer of the Railroad Company. (§ 5.) Spacing of Girders.

Longitudinal floor girders shall in no case be less than three feet and three inches from centre line of tracks for single track bridges, or one-half standard distance centre to centre of tracks for double track bridges. (§ 6.)

Head-room. 4. For all through bridges and overhead structures there shall be a clear head-room of 21 feet above the base of the rails, for a width of six feet over each track.

Clear width. 5. In all through bridges the clear width from the centre of the track to any part of the trusses shall not be less than seven (7) feet at a height exceeding one foot above the rails where the tracks are straight, and an equivalent clearance, where the tracks are curved.

[The additional clearance required on curves for passenger cars, 54 feet c. to c. of trucks and 75 feet over all, will be as follows:

For curvature, 0.8 D inches on each side;
1.6 D inches between tracks,

where D equals degree of curve.

For elevation, the clearance at top of the car on inside of curve must be increased $2\frac{1}{2}$ inches for each inch of track elevation]

6. The standard distance, centre to centre of tracks on straight lines, will be............feet for............R. R.

Trestle Towers. 7. Each trestle bent shall, as a general rule, be composed of two supporting columns, and the bents united in pairs to form towers; each tower thus formed of four columns shall be thoroughly braced in both directions, and have struts between the feet of the columns. Transversely the columns shall have a batter of not less than one horizontal to six vertical for single track, and one horizontal to eight vertical for double track. The feet of the columns must be secured to an anchorage capable of resisting double the specified wind forces. (§§ 25, 27.)

8. Each tower shall have sufficient base, longitudinally, to be stable when standing alone, without other support than its anchorage. (§§ 25, 27.)

Trestle Spans. 9. Tower spans for high trestles shall not be less than 30 feet.

10. Unless otherwise specified, the form of bridge trusses may be selected by the bidder; for through bridges, the end vertical suspenders and two panels of the lower chord, at each end, will be made rigid members. In general, all spans shall have end floor beams for supporting the stringers; such end floor beams may have one intermediate bearing on the masonry. In through bridges, the floor beams shall be riveted to the posts, above or below the pins. Form of Trusses.

11. All lateral, sway and portal bracing must be made of shapes capable of resisting compression as well as tension, and must have riveted connections. Lateral Bracing.

12. The wooden floors will consist of transverse ties or floor timbers; their scantling will vary in accordance with the design of the supporting steel floor. (§ 15.) They shall be spaced with openings not exceeding six inches, and shall be notched down ½ inch and be secured to the supporting girders by ¾-inch bolts at distances not over six feet apart. For deck bridges the ties will extend the full width of the bridge, and for through bridges at least every other tie shall extend the full width of bridge for a footwalk. Wooden Floor.

13. There shall be a guard timber (scantling not less than 6 x 8″) on each side of each track, with its inner face parallel to and at.....feet.....inches from centre of track. Guard timbers must be notched one inch over every floor timber, and be spliced over a floor timber with a half-and-half joint of six inches lap. Each guard timber shall be fastened to every third floor timber and at each splice with a three-quarter (¾) inch bolt. All heads or nuts on upper faces of ties or guards must be countersunk below the surface of the wood. (§ 61.) Guard Timbers.

14. The guard and floor timbers must be continuous over all piers and abutments.

15. The maximum strain allowed upon the extreme fibre of the best yellow pine or white oak floor timbers will be 1,000 pounds per square inch. The weight of a single engine wheel may be assumed as distributed over three ties, spaced as per § 12. Allowed Strain on Timber.

16. The floor timbers from centre to each end of span must be notched down over the longitudinal girders so as to reduce the camber in the track, as directed by the Engineer.

17. All the floor timbers shall have a full and even bearing upon the stringers; no open joints or shims will be allowed.

18. On curves the outer rail must be elevated, as may be directed by the Engineer.

Proposals. 19. In comparing different proposals, the relative cost to the Railroad Company of the required masonry or changes in existing work will be taken into consideration.

20. Contractors in submitting proposals shall furnish complete strain sheets, general plans of the proposed structures, and such detail drawings as will clearly show the dimensions of all the parts, modes of construction and the sectional areas.

21. Upon the acceptance of the proposal and the execution of contract, all working drawings required by the Engineer must be furnished free of cost.

Approval of Plans. 22. No work shall be commenced or materials ordered until the working drawings are approved by the Engineer in writing; if such working drawings are detained more than one week for examination, the Contractor will be allowed an equivalent extension of time.

LOADS.

23. All the structures shall be proportioned to carry the following loads:

1st. The weight of metal in the structure and floor.

Dead Load. 2d. The weight of rails, fastenings, ties, guards, footwalk and ballast when used. The rails and fastenings being assumed at 100 pounds per foot of track; timber at 4½ pounds per foot B. M.; and ballast at 110 pounds per cubic foot. Minimum will be assumed at 400 pounds per foot of track.

These two items, taken together, shall constitute the "dead load."

STANDARD TRAIN LOADINGS.

Distances in feet.

Class.	8	5	5	5	9	5	6	5	8	8	5	5	5	9	5	6	5	5	Uniform Load.
E 27	13500	27000	27000	27000	27000	17550	17550	17550	17550	13500	27000	27000	27000	27000	17550	17550	17550	17550	2700 lbs. per lin. ft.
E 30	15000	30000	30000	30000	30000	19500	19500	19500	19500	15000	30000	30000	30000	30000	19500	19500	19500	19500	3000 lbs. per lin. ft.
E 35	17500	35000	35000	35000	35000	22750	22750	22750	22750	17500	35000	35000	35000	35000	22750	22750	22750	22750	3500 lbs. per lin. ft.
E 40	20000	40000	40000	40000	40000	26000	26000	26000	26000	20000	40000	40000	40000	40000	26000	26000	26000	26000	4000 lbs. per lin. ft.
E 50	25000	50000	50000	50000	50000	32500	32500	32500	32500	25000	50000	50000	50000	50000	32500	32500	32500	32500	5000 lbs. per lin. ft.

Live Loads. 3d. A " live load " on each track, supposed to be moving in either direction, consisting of two " consolidation " engines, coupled and followed by a train load, distributed as shown on diagram E------ ; or a special load equally distributed on two pairs of driving wheels, spaced six feet, centre to centre, of 100,000 pounds up to class E40; and of 120,000 pounds for all classes above E40.

NOTE.—As all the wheel loads in each diagram are made of the same percentages of the driving wheel loads, the strains due to the different engine diagrams will be proportionate to the numerical classes of the engines.

Any intermediate numbers may be selected, with the understanding that this rule of proportion applies.

The maximum strains due to all positions of either of the above "live loads," of the required class, and of the "dead loads," shall be taken to proportion all the parts of the structure.

Wind Bracing. 24. To provide for wind strains and vibrations from high-speed trains, the top lateral bracing in deck bridges, and the bottom lateral bracing in through bridges, shall be proportioned to resist a lateral force of 600 pounds for each foot of the span; 450 pounds of this to be treated as a moving load, and as acting on a train of cars, at a line 6 feet above base of rail.

The bottom lateral bracing in deck bridges, and the top lateral bracing in through bridges, shall be proportioned to resist a lateral force of 150 pounds for each lineal foot for spans up to 300 feet, and 10 pounds additional for each additional 30 feet.

25. In trestle towers the bracing and columns shall be proportioned to resist the following lateral forces, in addition to the strains from dead and live loads:

1st. With either one track loaded with cars only, or with both tracks loaded with maximum train load, the lateral forces specified in § 24; and a lateral force of 100 pounds for each vertical lineal foot of the trestle bents; or

2d. With both tracks unloaded, a lateral force of 500 pounds for each longitudinal lineal foot of the structure, acting at the centre line of the girders; and a lateral force of 200 pounds for each vertical lineal foot of the trestle bents.

26. For determining the requisite anchorage for a loaded structure, the train shall be assumed to weigh 800 pounds per lineal foot.

27. The strains produced in the bracing of the trestle towers, in any members of the trusses or in the attachments of the girders or trusses to their bearings, by the greatest tractive force of the engines or by suddenly stopping the maximum trains on any part of the work must be provided for; the coefficient of friction of the wheels on the rails being assumed as 0.20. Longitudinal Forces.

28. Variation in temperature, to the extent of 150 degrees, shall be provided for. Temperature.

29. When the structures are on curves, the additional effects due to the centrifugal force of trains shall be considered as a live load. It will be assumed to act 5 feet above base of rail, and will be computed for a speed of 60-3D miles per hour; D being the degree of curve. Centrifugal Force.

30. All parts shall be so designed that the strains coming upon them can be accurately calculated.

PROPORTION OF PARTS.

31. All parts of the structures shall be proportioned in tension by the following allowed unit strains: Tensile Strain.

For Medium Steel.		Pounds per square inch.
Floor beam hangers, and other similar members liable to sudden loading, net section		6,000
Longitudinal, lateral and sway bracing, for wind strains (§§ 8, 24, 25)		18,000
Longitudinal, lateral and sway bracings, for live load strains (§§ 27, 29, 105)		12,000
Solid rolled beams, used as cross floor beams and stringers		10,000
Bottom flanges of riveted cross girders, net section.		10,000
Bottom flanges of riveted longitudinal plate girders, used as track stringers, net section		10,000
	For live loads.	For dead loads.
Bottom chords, main diagonals, counters and long verticals	10,000	20,000

Medium Steel.

For swing bridges and other movable structures, the dead load unit strains, during motion, must not exceed three-fourths of the above allowed unit strains for dead load on stationary structures.

The areas obtained by dividing the live load strains by the live load unit strains will be added algebraically to the areas obtained by dividing the dead load strains by the dead load unit strains to determine the required sectional area of any member. (§ 47.)

Soft Steel. *Soft Steel* may be used in tension with unit strains ten per cent. less than those allowed for *Medium Steel.*

32. Angles subject to direct tension must be connected by both legs, or the section of one leg only will be considered as effective.

Net Section. 33. In members subject to tensile strains full allowance shall be made for reduction of section by rivet-holes, screw-threads, etc. (§ 60.)

Compressive Strains. 34. Compression members shall be proportioned by the following allowed unit strains:

Medium Steel. *For Medium Steel.*

Chord segments $P = 10{,}000 - 45\frac{l}{r}$ for live load strains.

$P = 20{,}000 - 90\frac{l}{r}$ for dead load strains.

All posts of through bridges. $P = 8{,}500 - 45\frac{l}{r}$ for live load strains.

$P = 17{,}000 - 90\frac{l}{r}$ for dead load strains.

All posts of deck bridges and trestles. $P = 9{,}000 - 40\frac{l}{r}$ for live load strains.

$P = 18{,}000 - 80\frac{l}{r}$ for dead load strains.

End posts are not to be considered chord segments.

Lateral struts and rigid bracing. $P=13{,}000-60\frac{l}{r}$ for wind strains;

for live load strains use two-thirds of the above. (§§ 27, 29, 105.)

P=the allowed strain in compression per square inch of cross-section, in pounds.

l=the length of compression member, in inches, c. to c., of connections.

r=the least radius of gyration of the section, in inches.

No compression member, however, shall have a length exceeding 100 times its least radius of gyration for main members, or 120 times for laterals.

Soft Steel may be used in compression with unit strains fifteen per cent. less than those allowed for *Medium Steel.* Soft Steel.

For swing bridges and other movable structures, the dead load unit strains during motion must not exceed $\frac{3}{4}$ of the above allowed unit strains for dead load on stationary structures.

35. For long span bridges, when the ratio of the length and width of span is such that it makes the top chords acting as a whole, a longer column than the segments of the chord, the chord will be proportioned for this greater length.

36. All members and their connections subject to alternate strains of tension and compression shall be proportioned to resist each kind of strain. Both of the strains shall, however, be considered as increased by an amount equal to $\frac{8}{10}$ of the least of the two strains, for determining the sectional areas by the above-allowed unit strains. (§§ 31, 34.) Alternate Strains.

37. The strains in the truss members or trestle posts from the assumed wind forces need not be considered except as follows: Effect of Wind on Chord Strains.

1st. When the wind strains on any member exceed 30 per cent. of the maximum strains due to the dead and live loads upon the same member. The section shall then be increased until the total strain per square inch will not exceed by more than 30 per cent. the maximum fixed for dead and live loads only.

2d. When the wind strain alone or in combination with a possible temperature strain, can neutralize or reverse the strains in any member.

Rivets, Bolts and Pins.

38. The rivets in all members, other than those of the floor and lateral systems, must be so spaced that the shearing strain per square inch shall not exceed 9,000 pounds; nor the pressure on the bearing surface (diameter × thickness of the piece) of the rivet-hole exceed 15,000 pounds per square inch.

The rivets in all members of the floor system, including all hanger connections, must be so spaced that the shearing strains and bearing pressures shall not exceed 80 per cent. of the above limits.

The rivets in the lateral and sway bracing will be allowed 50 per cent. increase upon the above limits for lateral forces as per §§ 24, 25, but not per §§ 27, 29.

In the case of field riveting (and for bolts as per § 61) the above-allowed shearing strains and pressures shall be reduced one-third.

Rivets and bolts must not be used in direct tension.

39. Pins shall be proportioned so that the shearing strain shall not exceed 9,000 pounds per square inch; nor the pressure on the bearing surface of any member (other than forged eye-bars, see § 85) connected to the pin be greater per square inch than 15,000 pounds; nor the bending strain exceed 18,000 pounds, when the applied forces are considered as uniformly distributed over the middle half of the bearing of each member.

Combined Strains.

40. When any member is subjected to the action of both axial and bending strains, as in the case of end posts of through bridges (§ 37), or of chords carrying distributed floor loads, it must be proportioned so that the greatest fibre strain will not exceed the allowed limits of tension or compression on that member.

If the fibre strain resulting from the weight only, of any member, exceeds ten per cent. of the allowed unit strain on such member, such excess must be considered in proportioning the areas.

41. In beams and plate girders the compression flanges shall be made of same *gross* section as the tension flanges. Compression Flanges.

42. Riveted longitudinal girders shall have, preferably, a depth not less than $\frac{1}{10}$ of the span. Depth of Girders.

Rolled beams used as longitudinal girders shall have, preferably, a depth not less than $\frac{1}{12}$ of the span.

43. Plate girders shall be proportioned upon the supposition that the bending or chord strains are resisted entirely by the upper and lower flanges, and that the shearing or web strains are resisted entirely by the web-plate; no part of the web-plate shall be estimated as flange area. Plate Girders, etc.

The distance between centres of gravity of the flange areas will be considered as the effective depth of all girders.

44. The webs of plate girders must be stiffened at intervals, not exceeding the depth of the girders or a maximum of 5 feet, wherever the shearing strain per square inch exceeds the strain allowed by the following formula: Web Plates.

$$\text{Allowed shearing strain} = 10{,}000 - 75H,$$

where H = ratio of depth of web to its thickness; but no web-plates shall be less than three-eighths of an inch in thickness.

45. All stiffeners must be capable of carrying the maximum vertical shear without exceeding the allowed unit strain. Stiffeners.

$$P = 10{,}000 - 45\frac{l}{r}.$$

Each stiffener must connect to the webs by enough rivets to transfer the maximum shear to or from the webs.

46. Rolled beams shall be proportioned (§§ 31, 41) by their moments of inertia. Rolled Beams.

47. The areas of counters shall be determined by taking the difference in areas due to the live and dead load strains considered separately (§ 31); the counters in any one panel must have a combined sectional area of at least three square Counters.

inches, or else must be capable of carrying all the counter live load in that panel. (§ 86.)

48. Counters shall be provided and proportioned, so that a future increase of 25 per cent. in the specified live load shall not in any case increase the allowed unit strain more than 25 per cent.

DETAILS OF CONSTRUCTION.

Details. 49. All the connections and details of the several parts of the structures shall be of such strength that, upon testing, rupture will occur in the body of the members rather than in any of their details or connections.

50. Preference will be had for such details as shall be most accessible for inspection, cleaning and painting; no closed sections will be allowed.

Riveting. 51. The pitch of rivets in all classes of work shall never exceed 6 inches, or sixteen times the thinnest outside plate, nor be less than three diameters of the rivet.

52. The rivets used shall generally be $\frac{3}{4}$ and $\frac{7}{8}$ inch diameter.

53. The distance between the edge of any piece and the centre of a rivet-hole must never be less than $1\frac{1}{4}$ inches, except for bars less than $2\frac{1}{2}$ inches wide; when practicable it shall be at least two diameters of the rivet.

54. For punching, the diameter of the die shall in no case exceed the diameter of the punch by more than $\frac{1}{16}$ of an inch, and all holes must be clean cuts without torn or ragged edges.

55. All rivet holes must be so accurately spaced and punched that when the several parts forming one member are assembled together, a rivet $\frac{1}{16}$ inch less in diameter than the hole can generally be entered, hot, into any hole, without reaming or straining the metal by " drifts "; occasional variations must be corrected by reaming.

56. The rivets when driven must completely fill the holes. The rivet-heads must be round and of a uniform size for the same sized rivets throughout the work. They must be full and neatly made, and be concentric to the

rivet-hole, and thoroughly pinch the connected pieces together.

57. Wherever possible, all rivets must be machine driven. The machines must be capable of retaining the applied pressure after the upsetting is completed. No hand-driven rivets exceeding $\frac{7}{8}$ inch diameter will be allowed.

58. Field riveting must be reduced to a minimum or entirely avoided, where possible.

59. All holes for field rivets, except those in connections of the lateral and sway systems, shall be accurately drilled or reamed to an iron template or be reamed true while the parts are temporarily connected together.

60. The effective diameter of a driven rivet will be assumed the same as its diameter before driving. In deducting the rivet-holes to obtain net sections in tension members, the diameter of the rivet-holes will be assumed as $\frac{1}{8}$ inch larger than the undriven rivets. **Net Sections.**

The rupture of a riveted tension member is to be considered as equally probable, either through a transverse line of rivet-holes or through a diagonal line of rivet-holes, where the net section does not exceed by 30 per cent. the net section along the transverse line.

The number of rivet-holes to be deducted for net section will be determined by this condition.

61. When members are connected by bolts the holes must be reamed parallel and the bolts turned to a driving fit. All bolts must be of neat lengths, and shall have a washer under the heads and nuts where in contact with wood. Bolts must not be used in place of rivets, except by special permission. **Bolts.**

62. All nuts must be of hexagonal shape.

63. All joints in riveted tension members must be fully and symmetrically spliced. **Splices.**

64. Riveted tension members shall have an effective section through the pin-holes 25 per cent. in excess of the net section of the member, and back of the pin at least 75 per cent. of the net section through the pin-hole.

65. In continuous compression members, as chords and

trestle posts, the abutting joints with planed faces must be placed as close to the panel points as is practicable, and the joints must be spliced on all sides with at least two rows of closely pitched rivets on each side of the joint.

Joints in long posts must be fully spliced.

Abutting Joints. 66. In compression members, abutting joints with untooled faces must be fully spliced, as no reliance will be placed on such abutting joints. The abutting ends must, however, be dressed straight and true, so there will be no open joints.

Web Splices. 67. The webs of plate girders must be spliced at all joints by a plate on each side of the web.

Stiffeners. 68. All web-plates must have stiffeners over bearing points and at points of local concentrated loadings; such stiffeners must be fitted at their ends to the flange angles, at the bearing points.

69. All other angles, filling and splice plates on the webs of girders and riveted members must fit at their ends to the flange angles, sufficiently close to be sealed, when painted, against admission of water.

Web Plates. 70. Web-plates of all girders must be arranged so as not to project beyond the faces of the flange angles, nor on the top be more than $\frac{1}{16}$ inch below the face of these angles, at any point.

71. Wherever there is a tendency for water to collect, the spaces must be filled with a suitable waterproof material.

Flange Plates. 72. In girders with flange plates, at least one-half of the flange section shall be angles or else the largest sized angles must be used. Flange plates must extend beyond their theoretical length, two rows of rivets at each end.

73. In lattice girders and trusses the web members must be double and connect symmetrically to the webs of the chords. The use of plates or flats, alone, for tension members must be avoided, where it is possible; in lattice trusses, the counters, suspenders and two panels of the lower chord, at each end, must be latticed; all other tension members must be connected by batten plates or latticed. (See Arts. 90, 91 and 92.)

74. The compression flanges of beams and girders shall be stayed against transverse crippling when their length is more than sixteen times their width. Compression Flanges.

75. The unsupported width (distance between rivets) of plates subject to compression shall not exceed thirty times their thickness; except cover plates of top chords and end posts, which will preferably be limited to forty times their thickness; where a greater relative width is used in chords and end posts, however, only forty times the thickness shall be considered as effective section. Width of Plates.

76. The flange plates of all girders must be limited in width so as not to extend beyond the outer lines of rivets connecting them with the angles, more than five inches or more than eight times the thickness of the first plate. Where two or more plates are used on the flanges, they shall either be of equal thickness or shall decrease in thickness outward from the angles.

77. Where the floor timbers are supported at their ends on the flange of one angle, such angle must have two rows of rivets in its vertical leg, spaced not over 4 inches apart.

78. For main members and their connections no material shall be used of a less thickness than $\frac{3}{8}$ of an inch; and for laterals and their connections, no material less than $\frac{5}{16}$ of an inch in thickness; except for lining or filling vacant spaces. Thickness of Metal.

79. The heads of eye-bars shall be so proportioned and made, that the bars will preferably break in the body of the original bar rather than at any part of the head or neck. The form of the head and the mode of manufacture shall be subject to the approval of the Engineer of the Railroad Company. (Art. 141.) Eye Bars.

80. The bars must be free from flaws and of full thickness in the necks. They shall be perfectly straight before boring. The holes shall be in the centre of the head, and on the centre line of the bar.

81. The bars must be bored to lengths not varying from the calculated lengths more than $\frac{1}{64}$ of an inch for each 25 feet of total length.

82. Bars which are to be placed side by side in the structure shall be bored at the same temperature and of such equal length that upon being piled on each other the pins shall pass through the holes at both ends without driving.

83. The lower chord shall be packed as narrow as possible.

Pins. 84. The pins shall be turned straight and smooth; chord pins shall fit the pin-holes within $\frac{1}{50}$ of an inch, for pins less than $4\frac{1}{2}$ inches diameter; for pins of a larger diameter the clearance may be $\frac{1}{32}$ inch.

85. The diameter of the pin shall not be less than three-quarters the largest dimension of any eye-bar attached to it. The several members attaching to the pin shall be so packed as to produce the least bending moment upon the pin, and all vacant spaces must be filled with wrought filling rings.

Upset Ends. 86. All bars with screw ends shall be upset at the ends, so that the diameter at the bottom of the threads shall be $\frac{1}{16}$ inch larger than any part of the body of the bar. Where closed sleeve nuts are used on adjustable members the effective length of thread shall be legibly stamped at the screw ends of each bar. Adjustable counters to be avoided where practicable.

87. All threads must be of the United States standard, except at the ends of the pins.

Hangers. 88. Floor beam hangers when permitted shall be made without adjustment and so placed that they can be readily examined at all times. (§ 10.)

89. All the floor beams must be effectually stayed against end motion or any tendency to rotate from the action of the lateral system.

Compression Members. 90. Compression members shall be of steel, and of approved forms.

91. The pitch of rivets at the ends of compression members shall not exceed four diameters of the rivets for a length equal to twice the width of the member.

92. The open sides of all compression members shall be

stayed by batten plates at the ends and diagonal lattice-work at intermediate points. The batten plates must be placed as near the ends as practicable, and shall have a length not less than the greatest width of the member or $1\frac{1}{2}$ times its least width. The size and spacing of the lattice bars shall be duly proportioned to the size of the member. They must not be less in width than 2 inches for members 9 inches or less in width, nor $2\frac{1}{4}$ inches for members 12 to 9 inches in width, nor $2\frac{1}{2}$ inches for members 15 to 12 inches in width. Single lattice bars shall have a thickness not less than $\frac{1}{40}$ or double lattice bars connected by a rivet at the intersection, not less than $\frac{1}{60}$ of the distance between the rivets connecting them to the members. They shall be inclined at an angle not less than 60° to the axis of the member for single latticing, nor less than 45° for double latticing with riveted intersections. The pitch of the latticing must not exceed the width of the channel plus nine inches.

93. Where necessary, pin-holes shall be reinforced by plates, some of which must be of the full width of the member, so the allowed pressure on the pins shall not be exceeded, and so the strains shall be properly distributed over the full cross-section of the members. These reinforcing plates must contain enough rivets to transfer their proportion of the bearing pressure, and at least one plate on each side shall extend not less than six inches beyond the edge of the batten plates. (§ 92.)

94. Where the ends of compression members are forked to connect to the pins, the aggregate compressive strength of these forked ends must equal the compressive strength of the body of the members.

95. In compression chord sections and end posts, the material must mostly be concentrated at the sides, in the angles and vertical webs. Not more than one plate, and this not exceeding $\frac{1}{2}$ inch in thickness, shall be used as a cover plate, except when necessary to resist bending strains, or to comply with § 75. (§ 40.)

96. The ends of all square-ended members shall be planed smooth, and exactly square to the centre line of strain.

Floor Beams and Stringers.

97. The ends of all floor beams and stringers shall be faced true and square, and to correct lengths. Allowance must be made in the thickness of the end angles to provide for such facing without reducing the required effective strength of such end angles.

98. All members must be free from twists or bends. Portions exposed to view shall be neatly finished.

Pin-Holes.

99. Pin-holes shall be bored exactly perpendicular to a vertical plane passing through the centre line of each member, when placed in a position similar to that it is to occupy in the finished structure.

100. The several pieces forming one built member must fit closely together, and when riveted shall be free from twists, bends or open joints.

Transverse Diagonal Bracing

101. All through bridges shall have latticed portals, of approved design, at each end of the span, connected rigidly to the end posts and top chords. They shall be as deep as the specified head-room will allow, and provision shall be made in the end posts for the bending strains from wind pressure. (§ 24.) (§ 4.) (§ 11.)

102. When the height of the trusses exceeds 25 feet, an approved system of overhead diagonal bracings shall be attached to each post and to the top lateral struts.

103. All members of the web, lateral, longitudinal or sway systems must be securely riveted at their intersections to prevent sagging and rattling.

104. Pony trusses and through plate or lattice girders shall be stayed by knee braces or gusset plates attached to the top chords at the ends and at intermediate points, and attached below to the cross floor beams or to the transverse struts.

Deck Bridges.

105. All deck girders shall have transverse braces at the ends. All deck bridges shall have transverse bracing at each panel point. This bracing shall be proportioned to resist the unequal loading of the trusses.

106. In double-track deck bridges, where three trusses are used, all three trusses will be made of equal strength ; the unequal loading being distributed through the trans-

verse diagonal bracing as a live load. (For the purpose of reducing the unequal deflection under single-track loadings.)

107. All bed-plates must be of such dimensions that the greatest pressure upon the pedestal stone shall not exceed 250 pounds per square inch. **Bed Plates.**

108. All bridges over 80 feet span shall have hinged bolsters on both ends, and at one end nests of turned friction rollers running between planed surfaces. These rollers shall not be less than $2\frac{7}{8}$ inches diameter for spans 100 feet or less, and for greater spans this diameter shall be increased in proportion of 1 inch for 100 feet additional. **Friction Rollers.**

The rollers shall be so proportioned that the pressure per lineal inch of roller shall not exceed the product of the diameter in inches by 300 pounds (300d.).

The rollers must be of machinery steel and the bearing plates of medium steel.

The rollers and bearings must be so arranged that they can be readily cleaned and so that they will not hold water.

109. Bridges less than 80 feet span shall be secured at one end to the masonry, and the other end shall be free to move longitudinally upon smooth surfaces.

110. Where two spans rest upon the same masonry, a continuous plate, not less than $\frac{3}{8}$ inch thick, shall extend under the two adjacent bearings, or the two bearings must be rigidly tied together.

111. Pedestals shall be made of riveted plates and angles. All bearing surfaces of the base plates and vertical webs must be planed. The vertical webs must be secured to the base by angles having two rows of rivets in the vertical legs. No base plate or web connecting angle shall be less in thickness than $\frac{3}{4}$ inch. The vertical webs shall be of sufficient height and must contain material and rivets enough to practically distribute the loads over the bearings or rollers. **Pedestals and Bed-Plates.**

Where the size of the pedestal permits, the vertical webs must be rigidly connected transversely.

112. All the bed-plates and bearings under fixed and

movable ends must be fox-bolted to the masonry; for trusses, these bolts must not be less than $1\frac{1}{4}$ inches diameter; for plate and other girders, not less than $\frac{7}{8}$ inch diameter. The contractor must furnish all bolts, drill all holes and set bolts to place with sulphur or Portland cement.

113. While the expansion ends of all trusses must be free to move longitudinally under changes of temperature, they shall be anchored against lifting or moving sideways.

Camber. 114. All bridges shall be cambered by giving the panels of the top chord an excess of length in the proportion of $\frac{1}{8}$ of an inch to every ten feet.

Trestle Towers. 115. The lower struts in trestle towers must be capable of resisting the strains due to changes of temperature or of moving the tower pedestals under the effects of expansion or contraction.

For high or massive towers, these lower struts will be securely anchored to intermediate masonry piers, or the tower pedestals will have suitably placed friction rollers, as may be directed by the Engineer.

116. All joints in the tower columns shall be fully spliced for all possible tension strains, and to hold the parts firmly in position. (§ 65.)

117. Tower footings and bed-plates must be planed on all bearing surfaces; and the holes for anchor bolts slotted to allow for the proper amount of movement. (§ 28.)

Workmanship. 118. All workmanship shall be first-class in every particular.

119. All eye-bars must be made of medium steel.

Eye-Bars. 120. Eye-bars, all forgings and any pieces which have been partially heated or bent cold must be wholly annealed. Crimped stiffeners need not be annealed.

121. No reliance will be placed upon the welding of steel.

122. No sharp or unfilleted angles or corners will be allowed in any piece of metal.

Medium Steel. 123. Medium steel may be used in compression in chords, posts and pedestals without reaming of punched holes, for all thicknesses of metal, which will stand the drifting test

(§ 135); provided all sheared edges are planed off to a depth of ⅛ inch.

In all other cases medium steel over ⅝ inch thick must have all sheared edges planed off to a depth of ⅛ inch and all holes drilled or reamed to a diameter ⅛ inch larger than the punched holes, so as to remove all the sheared surface of the metal.

124. Soft steel need not be reamed if it satisfies the drifting test (§§ 135, 136).

125. All parts of any tension or compression flange or member, must be of the same kind of steel, but webs of plate girders and the tension members of all girders, plate or lattice, may be made of soft steel in connection with compression members of medium steel.

126. All splices must be of the same kind of steel as the parts to be joined.

127. Pilot nuts must be used during the erection to protect the threads of the pins. Pilot Nuts

QUALITY OF MATERIAL.

Steel.

128. All steel must be made by the Open Hearth process. The phosphorus must not exceed 0.06 of one per cent. for steel made by the acid method, or 0.04 for steel by the basic method.

129. The steel must be uniform in character for each specified kind. The finished bars, plates and shapes must be free from cracks on the faces or corners, and have a clean, smooth finish. No work shall be put upon any steel at or near the blue temperature or between that of boiling water and of ignition of hard wood sawdust.

130. The tensile strength, elastic limit* and ductility shall be determined by samples cut from the finished material after rolling. The samples to be at least 12 inches long,

* For the purpose of these specifications, the Elastic Limit will be considered the least strain producing a visible permanent elongation in a length of 8 inches, as shown by scribe marks of a pair of finely pointed dividers.

Ifthe yield point or drop of the beam can be calibrated for any machine and its speed to represent the elastic limit within 5 per cent., it may be used for general cases. Test reports must state by which method the elastic limit was determined.

and to have a uniform sectional area not less than ½ square inch.

131. Material which is to be used without annealing or further treatment is to be tested in the condition in which it comes from the rolls. When material is to be annealed or otherwise treated before use, the specimen representing such material is to be similarly treated before testing, for tensile strength.

The elongation shall be measured on an original length of 8 inches. Two test pieces shall be taken from each melt or blow of finished material, one for tension and one for bending. (Art. 147.)

132. All samples or full-sized pieces must show uniform fine grained fractures of a blue steel-gray color, entirely free from fiery lustre or a blackish cast.

Medium Steel. 133. **Medium Steel** shall have an ultimate strength, when tested in samples of the dimensions above stated, of 60,000 to 68,000 pounds per square inch, an elastic limit of not less than one-half of the ultimate strength, and a minimum elongation of 22 per cent. in 8 inches. Steel for pins may have a minimum elongation of 15 per cent.

134. Before or after heating to a low cherry red and cooling in water at 82 degrees Fah., this steel must stand bending to a curve whose inner radius is one and a half times the thickness of the sample, without cracking.

135. For all medium steel, ⅝ inch or less in thickness, rivet holes punched as in ordinary practice (§§ 52, 53, 54), must stand drifting to a diameter one-third greater than the original holes, without cracking either in the periphery of the holes or on the external edges of the piece, whether they be sheared or rolled.

Soft Steel. 136. **Soft Steel** shall have an ultimate strength, on same sized samples, of 54,000 to 62,000 pounds per square inch, an elastic limit not less than one-half the ultimate strength, and a minimum elongation of 25 per cent. in 8 inches.

For soft steel the above drifting test (§ 135) shall apply to all material to be riveted.

137. Before or after heating to a light yellow heat and

quenching in cold water, this steel must stand bending 180 degrees, to a curve whose inner radius is equal to the thickness of the sample, without sign of fracture.

138. **Rivet Steel** shall have an ultimate strength of 50,000 to 58,000 pounds per square inch, an elastic limit not less than one-half the ultimate strength and an elongation of 26 per cent. Rivet Steel.

139. The steel for rivets must, under the above bending test (137), stand closing solidly together without sign of fracture.

140. Eye-bar material, 1½ inches and less in thickness, shall, on test pieces cut from finished material, fill the above requirements. For thicknesses greater than 1½ inches, there will be allowed a reduction in the percentage of elongation of 1 per cent. for each ⅛ of an inch increase of thickness, to a minimum of 20 per cent. (Art. 119.) Eye Bars.

141. Full sized eye-bars shall show not less than 10 per cent. elongation in the body of the bar, and an ultimate strength not less than 56,000 pounds per square inch. Should a bar break in the head, but develop 10 per cent. elongation and the ultimate strength specified, it shall not be cause for rejection, provided not more than one-third of the total number of bars tested break in the head.

142. Pins over 7 inches in diameter shall be forged. Blooms for pins shall have at least three times the sectional area of the finished pins.

143. A variation of cross-section or weight in the finished members of 2½ per cent. from the specified size may be cause for rejection.

Steel Castings.

144. Steel castings will be used for drawbridge wheels, track segments and gearing. (Art. 1.) Steel Castings.

They must be true to form and dimensions, of a workmanlike finish and free from injurious blowholes and defects. All castings must be annealed.

When tested in specimens of uniform sectional area of at least ½ square inch for a distance of 2 inches, they must show an ultimate strength of not less than 67,000 pounds per square inch, an elastic limit of one-half the ultimate, and an elongation in 2 inches of not less than 10 per cent.

The metal must be uniform in character, free from hard or soft spots, and be capable of being properly tool finished.

CAST IRON.

Cast Iron. 145. Except where cast steel or chilled iron is required, all castings must be of tough, gray iron, free from cold shuts or injurious blowholes, true to form and thickness, and of a workmanlike finish. Sample pieces, 1 inch square, cast from the same heat of metal in sand moulds, shall be capable of sustaining, on a clear span of 12 inches, a central load of 2,400 pounds, when tested in the rough bar. A blow from a hammer shall produce an indentation on a rectangular edge of the casting without flaking the metal.

TIMBER.

Timber. 146. The timber, unless otherwise specified, shall be strictly first-class southern yellow pine or white oak bridge timber, sawed true, and out of wind, full size, free from wind shakes, large or loose knots, decayed or sap wood, worm holes, or other defects impairing its strength or durability. It will be subject to the inspection and acceptance of the Engineer.

INSPECTION.

Inspection. 147. All facilities for inspection of the materials and workmanship shall be furnished by the contractor. He shall furnish without charge such specimens (prepared) of the several kinds of steel to be used, as may be required to determine their character.

148. The contractor must furnish the use of a testing machine capable of testing the above specimens at all mills where the steel may be manufactured, free of cost.

149. Full sized parts of the structure may be tested at the option of the Engineer of the Railroad Company, but if tested to destruction, such material shall be paid for at

cost, less its scrap value to the contractor, if it proves satisfactory. If it does not stand the specified tests, it will be considered rejected material, and be solely at the cost of the contractor.

PAINTING.

150. All metal work before leaving the shop shall be thoroughly cleaned from all loose scale and rust, and be given one good coating of pure raw linseed oil, well worked into all joints and open spaces. Painting.

151. In riveted work the surfaces coming in contact shall each be painted before being riveted together. Bottoms of bed-plates, bearing-plates, and any parts which are not accessible for painting after erection, shall have two coats of paint; the paint shall be a good quality of iron ore paint, mixed with pure linseed oil, unless otherwise directed. It will be subject to approval of the Engineer.

152. After the structure is erected, the metal work shall be thoroughly and evenly painted with two additional coats of paint, mixed with pure linseed oil. All recesses which will retain water, or through which water can enter, must be filled with thick paint or some waterproof cement before receiving the final painting.

153. Pins, bored pin-holes, screw threads and turned friction rollers shall be coated with white lead and tallow before being shipped from the shop.

ERECTION.

154. The contractor, unless it be otherwise specified, shall furnish all staging and false work, shall erect and adjust all the metal work, and put in place all floor timbers, guards, etc., complete, ready for the rails. Erection.

155. The contractor shall so conduct all his operations as not to impede the operations of the road, interfere with the work of other contractors, or close any thoroughfare by land or water.

156. The contractor shall assume all risks of accidents to men or material prior to the acceptance of the finished structure by the Railroad Company.

The contractor must also remove all false work, piling and other obstructions, or unsightly material produced by his operations.

FINAL TEST.

Final Test. 157. Before the final acceptance the Engineer may make a thorough test by passing over each structure the specified loads, or their equivalent, at a speed not exceeding 60 miles an hour, and bringing them to a stop at any point by means of the air or other brakes, or by resting the maximum load upon the structure for twelve hours.

After such tests the structures must return to their original positions without showing any permanent change in any of their parts.

EXPORT WORK.

Export Work. All plans, including working drawings, must be submitted for the examination and approval of the Consulting Engineer before the material is ordered or any work done.

Any proposed modification of accepted plans, to adapt them to the plant and methods of the manufacturer or to facilitate the prompt delivery of the work, must also be submitted to and approved by the Consulting Engineer, before such changes can be allowed.

In all designs, the length and size of parts must be so arranged that they can be readily handled and stored during transportation to the site.

Length of bars, posts, chords and pieces of small section must not exceed..feet.

Length of girders or girder sections over........................feet in width must not exceed..feet.

Weight of any single piece must not exceed.............................. pounds.

Pins, roller-nests, bolts, rivets and all small pieces must be packed in strong, iron-bound boxes, with the detailed contents of each box legibily marked on the outside. Boxes to be consecutively lettered or numbered.

The screw-ends of all bars to be securely protected by canvass wrapped and wired about the same.

Every piece must not only be legibily marked by paint, but also by letters stamped on the metal, showing its location in the structure.

All necessary rivets for the field connections, with an extra allowance of 25 per cent. for each kind, shall be sent with each shipment.

The customary pilot-nuts (§ 127) for all pins shall be sent with the pins.

....

....

....

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....

Proposals for building and erecting complete, ready for the..., a bridge over...
....near...
on the..Division,..............................
....Railroad, in accordance with the attached specifications and accompanying profile, will be received up to... The live load to be adopted for this bridge will be Class E....., paragraph 23.

APPENDIX.

TABLE I.

Maximum Moments *M*, End Shears *S*, and Floor-Beam Reactions *R*, per Track, for Loading E 40, for Girder Bridges.

Span *L*. Ft.	Max. mom. *M*. Ft.-lbs.	Max. end shear *S*. Ft.-lbs.	Max. floor reac. *R*. Ft.-lbs.	Equivalent Uniform Load. *M*. Lbs.	*S*. Lbs.	*R*. Lbs.
10.........	112 500	60 000	80 000	9 000	12 000	8 000
11.........	131 400	65 500	87 300	8 690	11 910	7 940
12.........	160 000	70 000	93 300	8 890	11 670	7 770
13.........	190 000	73 800	98 500	9 000	11 350	7 580
14.........	220 000	77 200	104 300	8 980	11 030	7 450
15.........	250 000	80 000	109 300	8 890	10 670	7 290
16.........	280 000	85 000	113 700	8 750	10 620	7 110
17.........	310 000	89 500	117 600	8 580	10 530	6 920
18.........	340 000	93 400	121 300	8 400	10 380	6 740
19.........	373 200	96 800	125 800	8 270	10 190	6 620
20.........	412 500	100 000	131 100	8 250	10 000	6 560
21.........	452 000	102 800	136 000	8 200	9 790	6 480
22.........	491 400	105 500	140 300	8 120	9 590	6 380
23.........	530 800	107 900	144 300	8 030	9 380	6 270
24.........	570 400	110 800	148 000	7 920	9 230	6 170
25.........	610 000	113 600	151 300	7 810	9 090	6 050
26.........	649 600	116 100	155 400	7 690	8 930	5 970
27.........	689 200	118 500	160 100	7 560	8 780	5 930
28.........	731 000	120 800	164 600	7 460	8 630	5 875
29.........	775 800	123 100	168 700	7 370	8 490	5 820
30.........	821 000	126 100	172 500	7 300	8 410	5 750
31.........	865 700	128 800	176 900	7 210	8 310	5 710
32.........	910 800	131 500	182 000	7 120	8 220	5 690
33.........	955 600	133 900	186 700	7 020	8 110	5 660
34.........	1 000 700	136 100	191 100	6 920	8 010	5 620
35.........	1 046 000	138 400	195 200	6 840	7 910	5 570
36.........	1 097 000	141 100	....	6 770	7 840	....
37.........	1 148 500	143 800	....	6 710	7 770	....
38.........	1 200 000	146 200	....	6 650	7 700	....
39.........	1 253 500	148 600	....	6 590	7 620	....
40.........	1 311 000	150 800	....	6 560	7 540	....
42.........	1 427 000	156 200	....	6 480	7 460	....
44.........	1 543 000	161 100	....	6 370	7 320	....
46.........	1 659 000	165 600	Trestles	6 280	7 200	....
48.........	1 776 000	169 600	30 and 60 feet	6 170	7 070	....
50.........	1 902 000	174 200	spans,	6 090	6 970	....
52.........	2 030 000	178 500	238,900.	6 010	6 870	....
54.........	2 162 000	182 400	....	5 930	6 760	....
56.........	2 304 000	186 000	....	5 880	6 640	....
58.........	2 446 000	190 800	40 and 60 feet	5 820	6 580	....
60.........	2 599 000	195 200	spans,	5 780	6 510	....
62.........	2 753 000	200 200	262,900	5 730	6 460	....
64.........	2 911 000	205 200	....	5 690	6 410	....
66.........	3 079 000	210 000	....	5 660	6 360	....
68.........	3 247 000	215 600	....	5 610	6 340	....
70.........	3 415 000	221 000	....	5 580	6 310	....
72.........	3 584 000	226 700	....	5 540	6 300	....
74.........	3 758 000	232 600	....	5 490	6 290	....
76.........	3 942 000	238 100	....	5 460	6 270	....
78.........	4 129 000	243 400	....	5 430	6 240	....
80.........	4 321 000	248 400	....	5 400	6 210	....
82.........	4 513 000	253 800	....	5 370	6 190	....
84.........	4 713 000	259 000	....	5 340	6 190	....
86.........	4 919 000	264 200	....	5 320	6 150	....
88.........	5 128 000	269 400	....	5 300	6 120	....
90.........	5 341 000	274 500	....	5 280	6 100	....
92.........	5 552 000	279 600	....	5 250	6 080	....
94.........	5 771 000	284 700	....	5 230	6 060	....
96.........	5 988 000	289 600	....	5 200	6 030	....
98.........	6 213 000	295 000	....	5 180	6 020	....
100.........	6 440 000	300 000	....	5 150	6 000	....
105.........	7 075 000	312 200	....	5 150	5 950	....
110.........	7 774 000	324 000	....	5 140	5 890	....
115.........	8 490 000	335 800	....	5 140	5 840	....
120.........	9 228 000	347 400	....	5 130	5 790	....
125.........	9 993 000	358 800	....	5 120	5 740	....

Note—For all other classes, the above values to be proportional to the classes.

TABLE II.

Maximum Moments *M.* and End Shears *S.* per Track, produced by Special Loads on Two Axles. § 23.

Span in feet.	100,000 Lbs. for All Classes up to E 40.				Class.	120,000 Lbs. for All Classes over E 40.				Class.
	Max. mom., *M.* Ft.-lbs.	Max. shears, *S.* Lbs.	Equiv. unif. load. *M.* Lbs.	Equiv. unif. load. *S.* Lbs.		Max. mom., *M.* Lbs.	Max. shear, *S.* Lbs.	Equiv. unif. load. *M.* Lbs.	Equiv. unif. load. *S.* Lbs.	
10....	125 000	70 000	10 000	14 000		150 000	84 000	12 000	16 800	
11....	145 500	72 700	9 620	13 220		174 600	87 250	11 550	15 850	
12....	168 750	75 000	9 370	12 500		202 500	90 000	11 250	15 000	
13....	192 300	76 900	9 100	11 830		230 760	92 300	11 000	14 200	
14....	216 100	78 600	8 820	11 220		259 300	94 300	10 600	13 500	E 50
15....	240 000	80 000	8 540	10 670	E 40	288 000	96 000	10 250	12 800	
16....	264 000	81 250	8 250	10 160		316 800	97 500	9 900	12 200	
17....	288 250	82 300	7 990	9 680		345 900	98 800	9 580	11 600	E 45
18....	312 500	83 300	7 700	9 260		375 000	100 000	9 260	11 100	
19....	336 850	84 200	7 460	8 860		404 200	101 100	8 960	10 600	
20....	361 200	85 000	7 220	8 500	E 35	433 500	102 000	8 660	10 300	E 41
21....	385 700	85 700	7 000	8 160		462 900	102 900	8 400	9 800	
22....	410 200	86 350	6 780	7 850		492 300	103 600	8 140	9 400	
23....	434 800	86 950	6 570	7 560						
24....	459 400	87 500	6 380	7 300						
25....	484 000	88 000	6 200	7 040						
26....	508 650	88 600	6 020	6 810						
27....	533 300	88 900	5 850	6 585						
28....	558 000	89 300	5 700	6 380	E 30					
29....	582 900	....	5 540	....						

TABLE No. III.

Recent Heavy Passenger and Freight Engines.

Engine.	Total weight.	Weight of engine.	Weight of tender.	Max. load on one driver.	Total load on drivers.	Load per foot for 2 drivers.	Load per foot for all drivers.	Load per foot for whole engine.	Load per foot for tender.	Load per foot for engine & tender.	Equivalent typical engine.
	Tons.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	
Passenger Engines:											
C. R. R. N. J., 582	136.7	163 510	109 900	44 230	122 215	12 120	8 428	6 150	6 868	5 126	E. 35
Ill. Cen. R. R., 1-16	129.6	157 200	102 000	40 767	122 300	12 006	9 060	6 460	6 310	5 057	" "
A. T. & S. F. R. R., B. 15	131.1	162 200	100 000	42 430	125 930	11 700	8 830	6 444	5 600	4 947	" "
L. V. R. R., 673	129	161 480	96 500	44 280	125 180	12 517	9 216	6 500	6 127	4 983	" "
D. L. & W. R. R., Brooks	138	170 000	106 000	44 000	132 000	12 570	9 429	6 800	6 456	5 412	" 37
L. S. & M. S., Class J	146	174 500	118 000	44 000	130 000	12 370	9 285	5 482	6 500 ?	5 100	" 35
L. V. R. R., 1899	146.4	180 000	112 800	45 000	135 000	13 846	10 385	7 080	6 267	5 280	" 38
N. C. & H. R. R. R., Class Q.	134.8	172 000	97 600	45 000	135 000	13 846	9 310	6 490	5 515	5 087	" 35
P. R. R., Class E. 1	131.7	173 450	90 000	51 200	135 325	13 692	9 122	6 535	7 200	5 215	" 35
D. L. & W. R. R., 1900	149.5	179 000	120 000	45 667	137 000	13 045	9 786	7 089	7 309	5 877	" 40
P. R. R., G. 4	144.7	185 300	104 100	48 175	138 300	13 102	9 880	7 290	5 948	5 398	" 38
Cooper's E. 35	124.3	157 500	91 000	50 000	140 000	14 000	9 333	6 848	5 688	5 177	
" E. 40	142	180 000	104 000	......	160 000	16 000	10 666	7 826	6 500	5 916	
Freight Engines:											
L. S. & M. S. R. R.	143	168 000	118 000	38 000 ?	149 000	15 000 ?	8 637	6 588	6 500 ?	5 167	E. 36
C. R. N. J. R. R.	170.8	201 000	140 600	41 000	159 000	16 758	10 600	6 505	6 727	5 354	" 40
B. & O. R. R.	141.2	182 330	100 000	42 000 ?	163 300	16 500 ?	10 652	7 700	6 000 ?	......	" "
N. C. & H. R. R. R., G. 1	150.4	190 000	110 800	43 000 ?	164 000	16 000 ?	9 647	7 379	6 700	5 596	" "
L. V. R. R., 1100 class	156	195 000	117 000	42 750	171 000	15 785	10 523	7 671	6 500	5 707	" "
P. R. R., H. 5	151.3	198 000	104 600	45 600	177 000	13 665	10 114	7 627	6 000	5 527	" "
D. L. & W. R. R., Brooks	155.5	205 000	106 000	46 000	184 000	18 100	12 000	8 367	6 460	6 130	" 45
M. St. P. & S. S. M. R. R., Decapod	167	214 000	120 000	42 000 ?	190 000	17 000 ?	9 828	7 643	6 600	6 990	" 47
Ill. Cen. R. R.	182.5	232 200	132 700	50 000 ?	193 200	18 500	12 267	8 762	7 582	6 605	" 46
L. V. R. R., Class 681	175.5	227 000	124 000	52 186	204 200	20 780	13 350	9 525	7 889	6 745	" 50
Union R. R., 1895	167	230 000	104 000	57 700	208 000	23 131	13 350	9 583	5 943	6 095	" 50
Cooper's E. 50	177.5	225 000	130 000	60 000	200 000	20 000	13 333	9 782	8 125	7 395	
P. B. & L. E. R. R., 150	197.2	250 300	141 100	57 500	225 200	23 000 ?	14 444	10 274	6 000	6 750	E. 50 *

* As the actual engines in use become heavier and heavier and approach, as is probable, the maximum possible single motor for railroad service, the necessity of considering in our unit strains the heretofore constantly increasing train-loads, becomes less and less. The small increase of strains of this engine over the typical one, for certain spans, may be considered perfectly justifiable.

RELATIVE COST OF BRIDGES

Built Under These Specifications

FOR THE

DIFFERENT CLASSES OF LOADINGS.

The increased cost and weight of metal of bridges of all kinds, built under the requirements of these specifications, will be approximately as follows:

For bridges of	Class	E 35 over those of	Class	E 30	will be	10 per cent.
"	"	E 40 "	"	E 35	"	
"	"	E 45 "	"	E 40	"	
"	"	E 50 "	"	E 45	"	

Recommendation.

Table III gives a selection of heavy passenger and freight engines in use on the principal railroads of the United States at the end of the Nineteenth century.

As far as the effects upon the bridges are concerned, these engines are represented by the typical train loadings of these specifications, E 35 to E 50.

That the heavier of these engines is close to the possible maximum, considering the limitations of the permissible cross section of existing railroads and the mechanical details of design and proportions, is not improbable.

That the economical tendency towards heavier and heavier engines will in the near future reach the heavier class E 50 upon the most important roads, is to be expected.

The cars will also follow the same tendency for many kinds of traffic, as experience justifies the advance.

There are now in use self-dumping coal cars of a *nominal* capacity of 100,000 pounds, which have on four axles a total load of 146,000 pounds (10 per cent. increase over nominal capacity) on a wheel base, for two adjacent cars, of 17 ft. 2 ins. These cars on all ordinary bridges produce strains equivalent to those of E 33.

In view of these facts and tendencies, it is recommended that train loading E 35 be the *minimum* adopted for any railroad in the United States having a future.

Taking into consideration the relative costs of the several classes, as shown above, many railroads will find it best to adopt classes as high as E 40 or E 50.

One important system has already adopted Class E 50 for all renewals on its main line.

THEODORE COOPER.

SPECIFICATIONS

...FOR...

Electric Railway Bridges.

1902.

By C. S. Davis.

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SHOP WORK.

QUALITY OF MATERIAL

SPECIFICATIONS
FOR
Electric Railway Bridges.

By C. S. DAVIS.

1902.

GENERAL DESCRIPTION.

Classes — (1) Electric railway bridges shall be classified in accordance with their capacity or loading they will be called upon to carry. In these specifications there will be three general classes—L 20, L 30 and L 40. Intermediate or heavier classes may be used if so desired.

L. 20. (2) Bridges of this class shall be designed to carry a train of electric railway passenger cars, and also a light freight or express service. The weight of the loaded cars should not exceed 80,000 pounds each, and the length of each car should not be less than 40 feet.

(3) NOTE—An 84-ton locomotive (engine and tender) may be used during construction to haul supply trains at slow speeds, or a 56-ton locomotive may be used in regular service.

L. 30. (4) Bridges of this class shall be designed to carry a train of 80,000 pounds capacity freight cars hauled by an electric motor. It is not intended to include pressed steel cars or cars less than 40 feet in length in this class.

(5) NOTE—A 127-ton locomotive (engine and tender) may be used during construction to haul supply trains at slow speeds, or an 85-ton locomotive may be used in regular service.

L. 40

(6) Bridges of this class shall be designed to carry a train of 100,000 pounds capacity freight cars hauled by an electric motor. It is intended to include pressed steel cars and other cars with a short wheel base in this class.

(7) NOTE—A 170-ton locomotive (enigne and tender) may be used during construction to haul supply trains at slow speeds, or a 113-ton locomotive may be used in regular service.

Recommendations.

(8) Although loading L 20 is sufficient for the traffic of electric railway lines at the present time, the Author, in view of the rapid development of the service, recommends a loading of not less than L 30. See tables of equivalent loads in the appendix.

Type

(9) The type of bridge used will depend upon local conditions, but the following will be preferred:

Spans of 20 feet or less—Rolled beams.

Spans 20 to 100 feet— Plate girders.

Spans 100 to 120 feet— Riveted trusses.

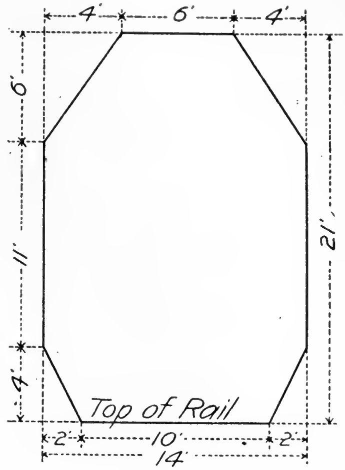
Spans over 120 feet— Pin-connected trusses.

Material

(10) All timber for ties and guard-rails shall be white oak. All metal shall generally be medium steel, but soft steel, wrought iron, cast steel and cast iron may be used as noted hereafter.

Clearance

Single Track



(11) All single track through bridges on straight track shall have a clear opening of not less than that shown by the accompanying diagram.

Double Track

(12) For double track bridges, the clear width shall be increased by an amount equal to the distance between centers of tracks.

Curves

(13) When a bridge is on a curve additional clearance must be provided so that the net clearance shall not be less than given above. Curvature of track and tip of car due to super-elevation of outer rail must both be considered.

Curvature

(14) When a bridge is located on a curve the center line of the bridge must be parallel to the chord of the curve connecting the centers of the track at the ends of the span, and must bisect the middle ordinate of the curve. In double track bridges the center between tracks shall be used instead of center line of track as above.

End Beams

(15) All through bridges shall have end beams to carry the ends of stringers over piers and abutments.

Stringer spacing

(16) When two lines of stringers are used for each

track they shall be spaced 6 feet 6 inches apart center to center. When four lines of stringers are used for each track the distance from the center of the track to point midway between each pair of stringers shall be 2 feet 6 inches, and they shall be so spaced that the bolt fastening the guard-rail to the stringer shall pass just outside the flange of the outer stringers.

Girder Spacing

(17) Deck girders, less than 80 feet in length shall be spaced 6 feet 6 inches apart center to center.

Deck girders 80 feet or more in length shall be spaced 8 feet apart center to center.

Floor-deck

(18) The floor-deck, consisting of rails, guard-rails, cross-ties and the fastenings for the same, shall be constructed as follows:

Rails

(19) The rails shall be what are known as T rails and shall weigh not less than 70 pounds per yard; they shall be spiked to each cross-tie with two spikes to each rail.

Cross-ties

(20) The cross-ties, of white oak, shall be spaced at intervals of not more than 16 inches center to center, and they shall not be less than 7 inches by 8 inches by 9 feet for stringers, or girders spaced 6 feet 6 inches apart and 8 inches by 9 inches by 11 feet for girders spaced 8 feet apart. They shall be dapped at least 1-2 of an inch over the stringers, but must not be dapped to a thickness less than 6 1-2 inches.

Guard rails

(21) A guard-rail, of white oak, shall be used along the outside of each rail, and it shall be notched 1 inch over the cross-ties and bolted to the stringers through every third tie with a 3-4 inch round bolt. A cast iron washer or clip shall be used under each head,

and a cast iron washer and nut lock under each nut. The distance between inner faces of the guard rails shall be 7 feet.

Plans.

(22) The Contractor shall prepare stress-sheets and working drawings upon tracing linen which, upon completion of the work are to become the property of the Railway Company.

Stress-sheets

(23) Before beginning work, the Contractor shall submit for formal approval stress sheets of a uniform size, 18 by 24 inches, showing:

(a) Length of span center to center of end bearings.

(b) Height of truss between centers of chords or distance back to back of flange angles for stringers, beams and girders.

(c) Live and dead loads assumed in making calculations.

(d) Stresses in all members.

(e) Sections and cross-sectional areas of all members.

(f) Size of rivets in principal members and required rivet spacing in the flanges of all stringers, floor beams and girders.

Working drawings

(24) Before beginning actual construction at the bridge shops the Contractor shall submit for formal approval a complete set of working drawings of a uniform size, 24 by 36 inches.

Changes

(25) After the approval of the plans, no changes shall be made without the written consent of the Railway Company.

Extras

(26) No extra charges, due to changes made, shall

be allowed except as agreed upon in writing at the time the changes are accepted.

Patents (27) If any patented devices or parts are used, the Contractor shall protect the Railway Company against all claims on account of such patents.

Proposal (28) All proposals must be accompanied by stress-sheets and an estimate of the weight of each span.

Price (29) The price named in the proposal shall be in cents per pound of the finished weight of the metal, and shall be for the bridge erected, ready for the rails. The timber guard-rails and cross-ties will be furnished delivered at the bridge site by the Railway Company but shall be framed and put in place by the Contractor.

Time (30) Each Bidder shall state in his proposal a time in which he can complete the bridge after the acceptance of his proposal, and the Contractor shall agree to complete the bridge in the time mentioned in his proposal.

Delays (31) When delays occur, due to causes beyond the control of the Contractor, an extension of time will be granted. However, notice of such delay must be given by the Contractor at the time of its occurrence.

Damage (32) If any damage is caused by the failure of the Contractor to complete the bridge in the time agreed upon he shall be liable for all such damage.

LOADS (33) All bridges shall be proportioned to carry the following loads:

Dead Load (34) A dead load consisting of the entire weight of the structure. The weight of the rails, cross-ties, guard-rails and the fastenings for the same shall not be assumed at less than 300 pounds per foot of track.

(35) The weight of the floor system shall be considered

as applied at the loaded chord and the remainder of the dead load as applied equally between the loaded and unloaded chords of the main trusses.

Live Load (36) The live load used in the calculations shall be one of the following loadings:

L 20 (37) A continuous, uniformly distributed moving load of 2000 pounds per foot of track, and a concentrated load of 20,000 pounds so placed as to produce the maximum effect in every case.

L 30 (38) A continuous, uniformly distributed moving load of 3,000 pounds per foot of track, and a concentrated load of 30.000 pounds so placed as to produce the maximum eflect in every case.

L 40 (39) A continuous, uniformly distributed moving load of 4,000 pounds per foot of track and a concentrated load of 40,000 pounds so placed as to produce the maximum effect in every case.

Wind Loads (40) All bridges shall be braced to resist the followling wind loads:

Fixed Load (41) The lateral system for the unloaded chords of a bridge shall be designed for a fixed wind load of 150 pounds, and the lateral system for the loaded chords shall be designed for a fixed wind load of 200 pounds per foot of bridge.

Moving Load (42) The lateral system for the loaded chords of a bridge shall be designed for a moving wind load of 300 pounds per foot of bridge in addition to the fixed wind load.

Additional Section (43) When the stresses from wind loads in the floor beams and chords of the main trusses exceed one-third of the stresses from live and dead loads, additional section must be provided for such excess

(44) When the top flange of a floor beam acts as a strut for the lateral system, additional section must be provided for such excess.

Initial Stress

(45) All adjustable lateral rods shall be proportioned for an initial stress of 10,000 pounds in addition to the stresses as determined above.

Lateral Struts

(46) Lateral struts, in addition to the wind load stresses, shall be considered as taking the resultant from an initial stress of 10,000 pounds on each of the adjustable rods attached to them.

Centrifugal Force

(47) When a bridge is on a curve, the lateral bracing shall be designed to resist the stresses due to centrifugal force in addition to the stresses due to wind.

Additional Section

(48) To resist the stresses from centrifugal force, additional section must be provided in the floor beams and in the chords of the main trusses to resist the chord stresses of the lateral truss due to the centrifugal force.

Speed

(49) Speed for the moving load shall be assumed at 40-2d miles per hour where d is the degree of curvature.

Longitudinal Stresses

(50) Due allowance shall be made for the stresses due to stopping the load upon the bridge. The coefficient of friction between the wheels and the rails shall be assumed at 0.20.

UNIT STRESSES

(51) All members shall be so proportioned that the stresses in pounds per square inch will not exceed those given by the following formula:

	Wrought Iron.	Soft Steel.	Medium Steel.
TENSION			
Main members	$8000\left\{\frac{2}{2-\theta}\right\}$	$9000\left\{\frac{2}{2-\theta}\right\}$	$10000\left\{\frac{2}{2-\theta}\right\}$
Counters and long hangers	$7000\left\{\frac{2}{2-\theta}\right\}$	$8000\left\{\frac{2}{2-\theta}\right\}$	$9000\left\{\frac{2}{2-\theta}\right\}$
Rolled beam flanges	$8000\left\{\frac{2}{2-\theta}\right\}$	$9000\left\{\frac{2}{2-\theta}\right\}$	$10000\left\{\frac{2}{2-\theta}\right\}$
Built beam flanges	$8000\left\{\frac{2}{2-\theta}\right\}$	$9000\left\{\frac{2}{2-\theta}\right\}$	$10000\left\{\frac{2}{2-\theta}\right\}$
Beam Hangers	$6000\left\{\frac{2}{2-\theta}\right\}$	$7000\left\{\frac{2}{2-\theta}\right\}$	$8000\left\{\frac{2}{2-\theta}\right\}$
Bracing	$9000\left\{\frac{2}{2-\theta}\right\}$	$11000\left\{\frac{2}{2-\theta}\right\}$	$12000\left\{\frac{2}{2-\theta}\right\}$
COMPRESSION			
Chords	$\left\{8000-35\frac{1}{r}\right\}\left\{\frac{2}{2-\theta}\right\}$	$\left\{9000-40\frac{1}{r}\right\}\left\{\frac{2}{2-\theta}\right\}$	$\left\{10000-45\frac{1}{r}\right\}\left\{\frac{2}{2-\theta}\right\}$
Posts	$\left\{7000-30\frac{1}{r}\right\}\left\{\frac{2}{2-\theta}\right\}$	$\left\{8000-35\frac{1}{r}\right\}\left\{\frac{2}{2-\theta}\right\}$	$\left\{9000-40\frac{1}{r}\right\}\left\{\frac{2}{2-\theta}\right\}$
Lateral struts	$\left\{9000-40\frac{1}{r}\right\}\left\{\frac{2}{2-\theta}\right\}$	$\left\{11000-50\frac{1}{r}\right\}\left\{\frac{2}{2-\theta}\right\}$	$\left\{12000-55\frac{1}{r}\right\}\left\{\frac{2}{2-\theta}\right\}$
SHEARING			
Web plates	$4000\left\{\frac{2}{2-\theta}\right\}$	$5000\left\{\frac{2}{2-\theta}\right\}$	$5500\left\{\frac{2}{2-\theta}\right\}$
Shop rivets	$5000\left\{\frac{2}{2-\theta}\right\}$	$6000\left\{\frac{2}{2-\theta}\right\}$	
Field rivets	$4000\left\{\frac{2}{2-\theta}\right\}$	$5000\left\{\frac{2}{2-\theta}\right\}$	
Pins			$6000\left\{\frac{2}{2-\theta}\right\}$
BEARING			
Shop rivets	$10000\left\{\frac{2}{2-\theta}\right\}$	$12000\left\{\frac{2}{2-\theta}\right\}$	
Field rivets	$8000\left\{\frac{2}{2-\theta}\right\}$	$10000\left\{\frac{2}{2-\theta}\right\}$	
Pins			$12000\left\{\frac{2}{2-\theta}\right\}$
Rollers			$350D\left\{\frac{2}{2-\theta}\right\}$
Masonry	$200\left\{\frac{2}{2-\theta}\right\}$	$200\left\{\frac{2}{2-\theta}\right\}$	$200\left\{\frac{2}{2-\theta}\right\}$
BENDING			
Pins			$15000\left\{\frac{2}{2-\theta}\right\}$

ALTERNATE STRESSES

Tension and compression

Use $\left\{\frac{2}{2+\Phi}\right\}$ in place of $\left\{\frac{2}{2-\Theta}\right\}$ in the above formulae and proportion for both compression and tension and use the larger area obtained.

COMBINED STRESSES

Compression and bending

$$A = \left\{ C + \frac{M\,y}{r^2} \right\} \div f$$

Tension and bending

$$A = \left\{ T + \frac{M\,y}{r^2} \right\} \div f$$

TURNTABLE DETAILS

Bearing:	Cast iron wheels on a cast iron track	$250\ D\left\{\frac{2}{2-\Theta}\right\}$
Bearing:	Cast steel wheels on a cast steel track	$400\ D\left\{\frac{2}{2-\Theta}\right\}$
Bearing:	Hard steel rollers on a hard steel track	$400\ D\left\{\frac{2}{2-\Theta}\right\}$
Bearing:	Phosphor-bronze discs on steel	$2500\ D\left\{\frac{2}{2-\Theta}\right\}$

NOTE

Θ = Dead load stress $\div$ Total stress.

Φ = Maximum Stress of the lesses kind $\div$ Maximum stress of the greater kind.

y = Distance from centre of inertia to outer edge of the section in inches.

r = Radius of gyration in inches.

l = Length of member in inches.

f = Unit stress from above formulae

A = Required cross sectional area.

C = Total direct compression in pounds.

T = Total direct tension in pounds.

M = Bending moment in inch pounds.

D = Diameter in inches.

The same required areas will be obtained by dividing the live load stress by the first factor of the above formulae and the dead load stress by two times the same factor and adding the two quotients as by the use of the above formulae.

(52) Values of Θ and $\frac{2}{2-\Theta}$

Θ	$\frac{2}{2-\Theta}$	Θ	$\frac{2}{2-\Theta}$	Θ	$\frac{2}{2-\Theta}$	Θ	$\frac{2}{2-\Theta}$	Θ	$\frac{2}{2-\Theta}$
.000	1.0000	.200	1.1111	.400	1.2500	600	1.4286	.800	1.6667
.005	1.0025	.205	1.1142	.405	1.2539	.605	1.4337	.805	1.6736
.010	1.0050	.210	1.1173	.410	1.2579	.610	1.4388	.810	1.6807
.015	1.0076	.215	1.1205	.415	1.2618	.615	1.4440	.815	1.6878
.020	1.0101	.220	1.1236	.420	1.2658	.620	1.4493	.820	1.6949
.025	1.0127	.225	1.1267	.425	1.2698	.625	1.4545	.825	1.7021
.030	1.0152	.230	1.1299	.430	1.2739	.630	1.4598	.830	1.7094
.035	1.0178	.235	1.1332	.435	1.2780	.635	1.4652	.835	1.7167
.040	1.0204	.240	1.1364	.440	1.2820	.640	1.4706	.840	1.7241
.045	1.0230	.245	1.1396	.445	1.2862	.645	1.4760	.845	1.7316
.050	1.0256	.250	1.1429	.450	1.2903	.650	1.4815	.850	1.7391
.055	1.0283	.255	1.1461	.455	1.2945	.655	1.4870	.855	1.7467
.060	1.0309	.260	1.1494	.460	1.2987	.660	1.4925	.860	1.7544
.065	1.0336	.265	1.1527	.465	1.3029	.665	1.4981	.865	1.7621
.070	1.0363	.270	1.1561	.470	1.3072	.670	1.5038	.870	1.7699
075	1.0390	.275	1.1594	.475	1.3115	.675	1.5094	.875	1.7778
.080	1.0417	.280	1.1628	.480	1.3158	.680	1.5151	.880	1.7857
.085	1.0444	.285	1.1662	.485	1.3201	.685	1.5209	.885	1.7937
.090	1.0471	.290	1.1696	.490	1.3245	.690	1.5267	.890	1.8018
.095	1.0499	.295	1.1730	.495	1.3289	.695	1.5326	.895	1.8100
.100	1.0526	.300	1.1765	.500	1.3333	.700	1.5385	.900	1.8182
.105	1.0554	.305	1.1799	.505	1.3378	.705	1.5444	.905	1.8265
.110	1.0582	.310	1.1834	.510	1.3423	.710	1.5504	.910	1.8349
.115	1.0610	.315	1.1869	.515	1.3468	.715	1.5564	.915	1.8433
.120	1.0638	.320	1.1905	.520	1.3514	.720	1.5625	.920	1.8519
.125	1.0667	.325	1.1940	.525	1.3559	.725	1.5686	.925	1.8605
.130	1.0695	.330	1.1976	.530	1.3605	.730	1.5748	.930	1.8692
.135	1.0724	.335	1.2012	.535	1.3652	.735	1.5810	.935	1.8779
.140	1.0753	.340	1.2048	.540	1.3699	.740	1.5873	.940	1.8868
.145	1.0782	.345	1.2085	.545	1.3746	.745	1.5936	.945	1.8957
.150	1.0811	.350	1.2121	.550	1.3793	.750	1.6000	.950	1.9048
.155	1.0840	.355	1.2158	.555	1.3841	.755	1.6064	.955	1.9139
.160	1.0870	.360	1.2195	.560	1.3889	.760	1.6129	.960	1.9231
.165	1.0899	.365	1.2232	.565	1.3937	.765	1.6194	.965	1.9324
.170	1.0929	.370	1.2270	.570	1.3986	.770	1.6260	.970	1.9417
.175	1.0959	.375	1.2308	.575	1.4035	.775	1.6327	.975	1.9512
.180	1.0989	.380	1.2346	.580	1.4085	780	1.6393	.980	1.9608
.185	1.1019	.385	1.2384	.585	1.4134	.785	1.6461	.985	1.9704
.190	1.1050	.390	1.2422	.590	1.4184	.790	1.6529	.990	1.9802
.195	1.1080	.395	1.2461	.595	1.4235	.795	1.6597	.995	1.9901
....	......	....	......	....	......	....	......	1.00	2.0000

(53) Values of Φ and $\frac{2}{2+\Phi}$

Φ	$\frac{2}{2+\Phi}$	Φ	$\frac{2}{2+\Phi}$	Φ	$\frac{2}{2+\Phi}$	Φ	$\frac{2}{2+\Phi}$	Φ	$\frac{2}{2+\Phi}$
.000	1.0000	.200	0.9091	.400	0.8333	.600	0.7693	.800	0.7143
.005	0.9975	.205	0.9070	.405	0.8316	.605	0.7678	.805	0.7131
.010	0.9950	.210	0.0950	.410	0.8299	.610	0.7663	.810	0.7118
.015	0.9926	.215	0.9030	.415	0.8282	.615	0.7648	.815	0.7105
.020	0.9901	.220	0.9009	.420	0.8265	.620	0.7634	.820	0.7092
.025	0.9877	.225	0.8989	.425	0.8248	.625	0.7620	.825	0.7080
.030	0.9852	.230	0.8969	.430	0.8231	.630	0.7605	.830	0.7067
.035	0.9828	.235	0.8949	.435	0.8214	.635	0.7591	.835	0.7055
.040	0.9804	.240	0.8929	.440	0.8197	.640	0.7576	.840	0.7042
.045	0.9780	.245	0.8909	.445	0.8180	.645	0.7562	.845	0.7030
.050	0.9756	.250	0.8889	.450	0.8164	.650	0.7548	.850	0.7018
.055	0.9733	.255	0.8869	.455	0.8147	.655	0.7533	.855	0.7006
.060	0.9709	.260	0.8850	.460	0.8130	.660	0.7519	.860	0.6993
.065	0.9686	.265	0.8830	.465	0.8114	.665	0.7505	.865	0.6981
.070	0.9662	.270	0.8810	.470	0.8098	.670	0.7491	.870	0.6969
.075	0.9639	.275	0.8791	.475	0.8081	.675	0.7477	.875	0.6957
.080	0.9616	.280	0.8772	.480	0.8065	.680	0.7463	.880	0.6945
.085	0.9593	.285	0.8753	.485	0.8049	.685	0.7449	.885	0.6933
.090	0.9570	.290	0.8734	.490	0.8033	.690	0.7435	.890	0.6921
.095	0.9547	.295	0.8715	.495	0.8016	.695	0.7422	.895	0.6909
.100	0.9524	.300	0.8696	.500	0.8000	.700	0.7408	.900	.06897
.105	0.9502	.305	0.8677	.505	0.7984	.705	0.7394	.905	0.6885
.110	0.9480	.310	0.8658	.510	0.7968	.710	0.7380	.910	0.6873
.115	0.9457	.315	0.8639	.515	0.7952	.715	0.7367	.915	0.6862
.120	0.9434	.320	0.8621	.520	0.7937	.720	0.7353	.920	0.6850
.125	0.9412	.325	0.8602	.525	0.7921	.725	0.7340	.925	0.6838
.130	0.9390	.330	0.8584	.530	0.7905	.730	0.7327	.930	0.6826
.135	0.9368	.235	0.8566	.535	0.7890	.735	0.7313	.935	0.6814
.140	0.9346	.340	0.8548	.540	0.7874	.740	0.7300	.940	0.6803
.145	0.9324	.345	0.8529	.545	0.7859	.745	0.7286	.945	0.6792
.150	0.9303	.350	0.8511	.550	0.7843	.750	0.7273	.950	0.6780
.155	0.9281	.355	0.8493	.555	0.7828	.755	0.7260	.955	0.6769
.160	0.9259	.360	0.8475	.560	0.7813	.760	0.2747	.960	0.6757
.165	0.9238	.365	0.8457	.565	0.7798	.765	0.7234	.965	0.6746
.170	0.9217	.370	0.8439	.570	0.7782	.770	0.7221	.970	0.6734
.175	0.9196	.375	0.8421	.575	0.7767	.775	0.7208	.975	0.6723
.180	0.9175	.380	0.8403	.580	0.7752	.780	0.7195	.980	0.6712
.185	0.9154	.385	0.8386	.585	0.7737	.785	0.7182	.985	0.6701
.190	0.9133	.390	0.8368	.590	0.7722	.790	0.7169	.990	0.6690
.195	0.9112	.395	0.8351	.595	0.7708	.795	0.7156	.795	0.6678
								1.00	0.6667

(54) Shearing and Bearing value of Rivets in pounds with $\Theta = O$.

Diameter		Iron Rivets		Steel Rivets	
		Shop	Field	Shop	Field
$\frac{5}{8}$ in. Rivet.	Single Shear.....	1534	1227	1841	1534
$\frac{5}{8}$ in. Rivet.	$\frac{1}{4}$ in. Bearing.....	1562	1250	1875	1562
$\frac{5}{8}$ in. Rivet.	5-16 in. Bearing..	1953	1562	2344	1953
$\frac{5}{8}$ in. Rivet.	$\frac{3}{8}$ in. Bearing.....	2344	1875	2812	2344
$\frac{5}{8}$ in. Rivet.	7-16 in. Bearing..	2734	2187	3281	2734
$\frac{5}{8}$ in. Rivet.	Double Shear....	3068	2454	3682	3068
$\frac{3}{4}$ in. Rivet.	Single Shear.....	2209	1767	2651	2209
$\frac{3}{4}$ in. Rivet.	$\frac{1}{4}$ in. Bearing.....	1875	1500	2250	1875
$\frac{3}{4}$ in. Rivet.	5-16 in. Bearing.	2344	1875	2812	2344
$\frac{3}{4}$ in. Rivet.	$\frac{3}{8}$ in Bearing.....	2812	2250	3375	2812
$\frac{3}{4}$ in. Rivet.	7-16 in. Bearing..	3281	2625	3937	3281
$\frac{3}{4}$ in. Rivet.	$\frac{1}{2}$ in. Bearing.....	3750	3000	4500	3750
$\frac{3}{4}$ in. Rivet.	9-16 in. Bearing..	4219	3375	5062	4219
$\frac{3}{4}$ in. Rivet.	Double Shear....	4418	3534	5302	4418
$\frac{7}{8}$ in. Rivet.	Single Shear.....	3006	2405	3608	3006
$\frac{7}{8}$ in. Rivet.	$\frac{1}{4}$ in. Bearing.....	2187	1750	2625	2187
$\frac{7}{8}$ in. Rivet.	5-16 in. Bearing..	2734	2187	3281	2734
$\frac{7}{8}$ in. Rivet.	$\frac{3}{8}$ in. Bearing.....	3281	2625	3937	3281
$\frac{7}{8}$ in. Rivet.	7-16 in. Bearing..	3828	3062	4593	3828
$\frac{7}{8}$ in. Rivet.	$\frac{1}{2}$ in. Bearing.....	4375	3500	5250	4375
$\frac{7}{8}$ in. Rivet.	9-16 in. Bearing..	4922	3937	5906	4922
$\frac{7}{8}$ in. Rivet.	$\frac{5}{8}$ in. Bearing.....	5469	4375	6562	5469
$\frac{7}{8}$ in. Rivet.	11-16 in. Bearing.	6015	4812	7218	6015
$\frac{7}{8}$ in. Rivet.	Double Shear....	6012	4810	7216	6012

DETAILS OF DESIGN

Limiting Sizes

Thickness

(55) No metal less than 5-16 of an inch thick shall be used except for fillers. Web plates in stringers beams and girders shall not be less than 3-8 of an inch thick.

Angles

(56) No angle weighing less than 5 pounds per lineal foot shall be used.

Bars

(57) No bar having an area of less than 1 square inch shall be used.

Columns

(58) The ratio of the length of any column to its least radius of gyration shall not exceed 125 for main members and 150 for lateral struts.

(59) The thickness of plates in columns shall not be less than 1-40 of the distance between supports in a direction at right angles to the line of stress and not less than 1-16 of the distance between supports or rivets in the line of stress.

Flanges

(60) Beams and girders having a length greater than 16 times the width of the flange shall be braced horizontally.

Pins

(61) The diameter of no pin shall be less than 3-4 of the width of the widest bar attached to the same.

End Bearings

Lead

(62) Sheet lead not less than 1-8 of an inch in thickness, shall be interposed between all bearing plates and masonry.

Anchors

(63) All bearings shall be thoroughly and efficiently anchored to the masonry by means of bolts, not less than 1 1-4 inches in diameter, set at least 12 inches into the masonry with neat Portland cement mortar.

Pin Bearings

(64) To insure a more even bearing on the masonry, spans of 80 feet or more in length shall have pin end bearings. Cast steel pedestals will be preferred for plate girder spans.

Sliding Ends

(65) Spans less than 75 feet in length may have sliding plates at one end of the span to allow for expansion and contraction due to a change in temperature of 150 degrees Fahrenheit. Each bearing shall consist of two plates, an upper or shoe plate and a lower or ma sonry plate. Both shoe and masonry plates shall be planed, and the joint between the two plates shall be planed with tongue and groove for both fixed and sliding ends of the span. The finished thickness of the plates shall not be less than 3-4 of an inch. The anchor bolt holes in the shoe plates on the sliding end must be slotted to allow for expansion and contraction.

Roller Ends

(66) One end of all spans of 75 feet or more in length shall have roller end bearings to permit free expansion and contraction, due to a change in temperature of 150 degrees Fahrenheit.

(67) The rollers shall not be less than 3 inches in diameter, shall be turned with a groove at the center, and shall travel between shoe and masonry plates, each of which shall be planed with a tongue.

(68) All rollers of a single bearing shall be joined by spacing bars at their ends. All roller bearings shall have guards to protect them from dirt and shall be made accessible for cleaning.

(69) For heavy or long spans, segmental rollers and a masonry plate, built up of railroad rails, and a plate will be preferred.

Pin Plate

(70) On piers, the masonry plate shall be continuous, extending under both bearings of contiguous spans.

Camber

Trusses

(71) All trusses shall have just sufficient camber so that under a full load the truss will come to a level

line. This will be accomplished by shortening each tension member and lengthening each compression member by an amount equal to the change in length of that member under full load.

Plate Girders

(72) Plate girders shall be given a camber equal to one one-thousandth of the span.

Framing Out

(73) One-half of the camber shall be framed out in the beams and stringers, and the other half in the ties.

Rivets

(74) Rivets shall generally be 3-4 and 7-8 of an inch in diameter, they shall be spaced at least 3 diameters apart and except in lacing bars their centers shall not be nearer the edge of any member through which they pass than 1 1-4 inches. No rivet shall have a grip exceeding five times its diameter.

Net Section

(75) The net section of any tension member or flange shall be determined by a plane cutting the member square across at any point. The greatest number of rivet holes which can be cut by the plane or whose centers come within one inch of the plane, is the number to be deducted from the gross section.

Rolled Beams

(76) Rolled Beams shall be proportioned for bending stresses in accordance with their moments of inertia.

Built Beams

(77) Built beams, used for stringers, floor beams or girders, shall be proportioned in accordance with the following assumptions:

Flanges

(78) It shall be assumed that the bending stresses are resisted entirely by the flange section. No part of the web plate shall be assumed as effective for flange section.

(79) Flanges shall be proportioned from the

tension stresses, and the compression flange shall have the same gross section as the tension flange.

Web Plate

(80) It shall be assumed that all the shear is carried by the web plate.

Effective Depth

(81) The effective depth shall be the distance between centers of gravity of the flanges except when this exceeds the distance out to out of flange angles. In no case shall the effective depth be taken at more than the distance out to out of flange angles.

Flange Splices

(82) So far as possible, splices in the flanges shall be avoided. When splices become necessary, all joints must be fully spliced, all abutting surfaces must be machine finished and must be brought into perfect contact in assembling. In the tension flanges, sufficient section must be provided in the splices to make up for all lost section in the member spliced.

Web Splices

(83) Splices in web plates shall be made at points where stiffeners occur, and shall be made with a plate on each side of the web, wide enough to take two rows of rivets on each side of the splice. The splice plates shall not be thinner than the web itself.

Stiffeners

(84) When the unit shear on the web plate exceeds that allowed by the formula

$$S = 11000 - \frac{110h}{t}$$

stiffeners shall be used.

NOTE:—S = Allowed shear in pounds per square inch.

h = Unsupported height of web in inches.

t = Thickness of web in inches.

See curves in appendix.

(85) Stiffeners shall consist of a pair of angles, one on each side of the web and they shall be spaced at intervals, about equal to the depth of the girder.

(86) The size of the stiffener angles shall be as follows, depending upon the width of the horizontal leg of flange angles:

For an 8 inch leg use 6 x 3 1-2 x 3-8 angles.
For an 7 inch leg use 6 x 3 1-2 x 3-8 angless.
For a 6 inch leg use 5 x 3 1-2 x 3-8 angles.
For a 5 inch leg use 4 x 3 x 3-8 angles.
For a 4 inch leg use 3 x 3 x 3-8 angle.

(87) A pair of stiffeners shall be used over each end of each end bearing, and when pin bearings are used, there shall be an additional pair over the center of each bearing.

Fillers

(88) Fillers, equal in thickness to the flange angles, shall be used under all stiffeners, except at splice points where the splice plates serve for fillers.

(89) When side plates are used under the flange angles, the fillers shall be of the same thickness as the side plates, and the stiffeners may be crimped over the flange angles.

Rivet Spacing

(90) The pitch of rivets uniting the flange angles to the web plate shall not exceed that given by the formula:

$$p = r\,d \div s$$

where p = Pitch of rivets
r = Value of one rivet
d = Distance between rivet lines
s = Shear at the point under consideration.

(91) The pitch of rivets between stiffeners shall be uniform, and shall be determined from the shear at the siffener nearer the end of the girder, but in no case shall the pitch of rivets in each gauge line exceed 9 inches.

Bracing

(92) Deck girders less than 30 feet in length, shall be braced in the plane of the top flanges, and shall have cross frames at ends and at intermediate points. Deck girders 30 feet or more in length shall have top and bottom bracing, and cross frames at the ends and at intermediate points. The bracing shall generally take the form of a Warren truss, the diagonal members in the top system being made of two angles back to back, and in the bottom system, of a single angle. This diagonals in the cross frames shall consist of two angles in each direction, the top and bottom horizontals of two angles for the end frames, and of one or two angles for the intermediate frames as may be required. All angles shall be connected at their ends so as to develope their full strength.

(93) Through girders shall have one set of adjustable, horizontal, lateral bracing, generally using the floor beams for struts. The floor beams shall be attached to the main girders through gusset plates extending the full depth of the girders. When the gusset plate extends more than 96 times its thickness above or below the beam, there shall be two 3x2 1-2 inch angles riveted to its edge.

End Finish

(94) All through girders shall have their upper corners rounded and the first flange plate shall extend down to the bottom of the girder.

(95) The ends of all deck girders shall be covered

with a plate riveted to the end stiffener angles, and in addition, there shall be corner cover plate riveted over each upper corner of the girder.

Ends Faced

(96) When the detail will permit, the ends of all stringers and floor beams shall be faced and extra material must be provided in the end angles to allow for planing.

Pin-connected Bridges

Compression Members

(97) End post and top chord sections shall generally consist of two rolled or built channels, joined on their upper flanges by a cover plate, and on their lower flanges by batten plates near the ends and diagonal lattice bars between the battens.

(98) Intermediate posts shall generally consist of two rolled or built channels joined on both flanges by battens near the ends, and diagonal lattice bars between the battens.

Battens

(99) The length of the batten plate shall not be less than the greatest width of the member and its thickness shall not be less than 1-40 of its unsupported width. No batten shall have less than three rivets along each edge.

Lattice

(100) Lattice bars shall have a width of at least three diameters of the rivet and a thickness of at least 1-50 of the unsupported length. The spacing of the bars shall be such that the angle between the bar and the center line of the section shall not be less than 60 degrees, for single lattice and 45 degrees for double lattice and the distance between rivets in either channel flange shall not exceed 60 times the thickness of the flange. Double lattice bars shall have a rivet at each intersection. On large or wide sections, 3x2 inch angles shall be used instead of bars for lattice.

Riveting

(101) At each end of any compression member for a distance equal to twice its width the pitch of the rivets shall not exceed four diameters of the rivet and throughout the remaining portion of the member the pitch shall not exceed 6 inches or 16 times the thickness of the thinnest plate or angle.

Pin-plates

(102) Where necessary pin holes shall be reinforced by pin plates. At points where the stress is transmitted entirely to the pin, the first pin plate shall extend back from the pin far enough to overlap the batten plate by at least 6 inches.

(103) When computing the necessary number of rivets for the pin plate, the bearing per square inch between the pin and pin plate shall be assumed the same as between the pin and main member.

Pin-holes

(104) Pin holes shall be placed with reference to the center of moments of the section and they shall be placed enough below that center to balance the bending moment due to the weight of the member.

Splices

(105) Splices in the top chord shall generally be made a short distance from the pin point and all splices shall be equiped with splice plates and cover plates to hold the members truly in position.

Eyebars

(106) The main diagonal and bottom chord members shall be made of die forged eyebars, constructed in such a way that when tested to destruction they will break in the main body of the bar rather than in the head.

Stiffened Sections

(107) The first two panels of bottom chord at each end of the span and the hip verticals or long suspenders shall be stiffened. These members may be laced eyebars.

Adjustable Members

(108) All counters and lateral rods shall be adjustable by means of open turnbuckles or clevices. The threaded ends of all rods must be upset. The ends of all rods attached to pins shall have loop eyes with the distance from the back of the pin to the apex of the loop not less than three diameters of the pin.

Only iron bars may have loop eyes.

Stringers

(109) The stringers shall preferably be framed in between the floor beams; if placed on top they shall have a cross frame at each end.

Beams

(110) The floor beams shall be built in between the posts of the main trusses and shall be connected to the same through gussets extending at least 3 feet above the top of the beam.

Bracing

(111) All pin connected bridges shall have adjustable bracing in the planes of the top and bottom chords and as near as practicable to the pin center lines.

Top Struts

(112) The top struts shall generally be made of four angles laced the full depth of the chord.

Knees

(113) When the distance from rail to top strut does not exceed 25 feet, knee braces shall be used connecting the top struts to the vertical posts of the main trusses.

Cross Bracing

(114) When the distance from rail to top strut exceeds 25 feet, sub-struts and cross-bracing shall be used instead of knee braces.

Portals

(115) The end posts shall be connected by portal struts, so designed as to effectively transmit

the wind stresses from the top lateral system to the bridge seat. Portals shall be as deep as the specified clearance will permit and brackets usually curved, shall be used connecting the bottom flange of the portal strut to the end posts.

Viaducts or Trestles

Type

(116) Viaducts shall generally consist of plate or open web riveted girders, supported by bents and towers.

Bents

(117) A bent consists of a pair of columns braced transversely.

Towers

(118) A tower consists of two bents braced longitudinally.

Rocker

(119) When a bent is used separately it shall be designed as a rocker and shall have pin ends at top and bottom.

Batter

(120) Each column in a bent shall have a batter of not less than one horizontally to six vertically.

Bearings

(121) Provision shall be made at the foot of each bent for expansion and contraction due to changes in temperature of 150 degrees Fahrenheit. All sliding surfaces shall be planed and anchor bolt holes slotted

Anchorage

(122) All bents and towers shall be anchored to the foundations in such a way as to be safe against overturning whether loaded, unloaded or loaded with empty cars.

(123) When a viaduct is located on a curve, the effects of centrifugal force must be considered in addition to the wind loads.

Bracing

(124) Transversely all bents shall be braced with angles against all effects of wind and centrifugal force. Longitudinally all towers shall be braced with

angles or channels against the effects of stopping a train on the viaduct. Transverse struts shall be used at the bottom of all bents and longitudinal struts at the bottom of all towers strong enough to slide the columns when changes in temperature occur.

Swing Bridges

Floor System

(125) The floor system of swing bridges shall be designed the same as for fixed spans.

Trusses

(126) With the bridge closed, the trusses shall be designed under the same unit stresses as for fixed spans, but with the bridge open the dead load unit stresses shall not exceed three-quarters of the dead load unit stresses for fixed spans.

Turntable

(127) The turntable may be center bearing, rim bearing or a combination of the two. If the combination table is used the supporting girders shall be so arranged that some definite and known portion of the load will be carried to the center.

Disc Center

(128) When a disc center is used there shall be three discs, the upper and lower of hard steel and the center of phosphor bronze, and so arranged that all sliding will occur between the steel and phosphor bronze discs. The discs shall have oil grooves and the center shall be so arranged that the discs may be kept flooded with oil.

Roller Center

(129) When a roller center is used the rollers shall be turned truly conical and shall be provided with a band to hold them in position. All rollers shall be of hard steel and will travel between tracks of hard steel, planed to a true bevel to fit the rollers. The center shall be so arranged that the rollers may be kept flooded with oil.

Rim Bearing

(130) When a rim bearing table is used, the load shall be conveyed by means of a circular drum to a set of cast steel wheels turned truly conical which travel between two steel tracks, one above attached to the drum and one below attached to the foundation. The tracks shall be planed circular and to a true bevel to fit the wheels.

(131) The bottom track, wheels and drum shall be connected to an iron casting at the center of the table in order to keep all properly centered. The drum shall be connected by means of radial struts to a hub which is free to rotate about the center casting. The wheels shall be connected by means of spider rods to another similar hub.

(132) There shall be two circular bands to keep the wheels properly spaced one inside and the other outside the wheels. The outer band shall be made in short sections so arranged that any wheel may be easily removed and replaced without disturbing the others. Each spider rod shall extend through a wheel and both bands and shall be provided with nuts and washers making it possible to adjust the conical wheels to a shorter or longer radius.

Latches

(133) Both ends of the bridge shall be provided with strong latches arranged to close automatically and to be opened from the tender's house.

End Lifts

(134) End lifts shall be provided for raising both ends of the bridge by an amount sufficient to prevent the lifting of either end clear from its seat under any position of the load. They shall be so arranged that they may be operated from the tender's house.

Rail Lifts

(135) Both ends of the bridge shall be equipped with suitable rail lifts arranged to be operated from the tender's house.

End Signals

(136) At each shore end of the bridge there shall be an automatic signal so arranged that the bridge cannot be opened without setting the signal to the position of danger.

Machinery

(137) Under this head shall be included all motors, cables, wires, switches, controllers, lightening arresters, electric heaters, gears, shafting, rack and such other equipment as is necessary to make a complete and perfect plant for the operation of the bridge by both hand and electric power.

Cables

(138) The necessary sub-marine cables shall be furnished by the Contractor for the superstructure, but shall be put in place by the Contractor for the substructure.

Motors

(139) The motor for turning the bridge shall be of sufficient capacity to turn the bridge through a quadrant in one minute, starting from rest and ending at rest.

(140) The motors for operating the end lifts, rail lifts and end signals may be placed at the ends of the bridge.

Material

(141) All shafting shall be medium steel, all pinions, gears, rack and shaft bearings shall be cast iron or cast steel. All shaft bearings shall be babbitted.

Tender's House

(142) A tender's house of neat design shall be provided at the center of the bridge, preferably over the track, in which all controllers, switches, lightening arresters, heaters and other electric equipment shall be

placed. When necessary a stairway shall be provided for the tender's house.

SHOP WORK

First Class

(143) All shop work shall be first class in every particular.

Straightening

(144) When necessary all material shall be straightened before being laid off. After punching and before assembling all material shall be carefully straightened and freed from all twists and buckles. All web plates must be free from buckles.

(145) All straightening shall be done in presses or between rolls. Hammering will not be allowed.

Punching

(146) All punched holes shall be made with a punch one-eighth of an inch smaller in diameter than the rivet. The die shall not be more than one-sixteenth of an inch greater in diameter than the punch.

Reaming

(147) After punching and assembling all punched holes shall be reamed to a diameter not more than one-sixteenth of an inch greater than the diameter of the cold rivet. After reaming all holes shall be smooth, showing that metal has everywhere been removed around the hole.

Drilling

(147) When any metal is too thick for successful punching, all holes shall be drilled. All rivet holes in eyebars shall be drilled and all pin holes shall be drilled or bored.

Riveting

(149) All shop rivets so far as possible shall be driven with a machine capable of holding the pressure after the rivet is driven. All rivets shall be driven tight and upset so as to completely fill the hole. No calking or cupping will be allowed. Rivets of the same size shall have the same size heads and the heads must be concentric with the rivet. All loose or poor rivets must be cut out and replaced.

Facing

(150) The ends of all beams and stringers, when built in, shall be faced square and true to length.

(151) Abutting ends of all compression members shall be faced in a machine so that their ends will be in perfect contact when in place in the bridge.

Fitting

(152) The ends of all stiffeners shall be trimmed to fit tight against the flange angles and all fillers under the stiffeners shall be made to fit tight against the edges of the flange angles.

Planing

(153) All abutting ends of web plates for plate girders shall be planed.

(154) The edges of all sheared plates shall be planed.

(155) All shoe and masonry plates shall be planed so that the two faces of each plate are truly parallel.

Pin Holes

(156) Pin holes in riveted members shall be bored truly parallel to each other and at right angles to the axis of the member.

(157) Pin holes in eyebars must be in the axis of the bar, in the center of the heads and at right angles to the planes of the flat surfaces. When all the bars of the same member are piled together, the pins shall pass through both ends of all bars without driving.

(158) The diameter of the pin hole shall not exceed that of the pin by more than 1-50 of an inch except for pins over 4 inches in diameter when this excess shall not exceed 1-32 of an inch.

Lathe Work

(159) All pins and rollers shall be turned smooth and true to size.

Eye-bars

Material

(160) All eyebars shall be made from bars of full section and free from folds, cracks, or other defects.

Heads

(161) The heads shall be made by upsetting and forging the bars. No head shall be more than one-six-

teenth of an inch thicker than the body of the bar. All heads shall be so proportioned and made that the bars will break in the body of the original bar and not in the head or neck.

Annealing

(162) After the heads are completed the bars shall be annealed by being heated to a bright red heat throughout their entire length and then allowed to cool slowly.

Adjustable Rods

Loop Eyes

(163) The ends of all rods attached to pins shall have loop eyes formed by bending the bar around a pin and welding the end to the main body of the bar. All loop eyes shall have holes bored to fit the pin. Only iron bars may have loop eyes.

Upsetting

(164) The ends of all rods that take nuts, turnbuckles or clevices shall have their ends enlarged by upsetting the bar. The cross-sectional area of the upset end at the root of the thread shall be at least 10 per cent. greater than the original area of the bar and under test to destruction the bar must break in the main body and not in the upset end.

Annealing

(165) Steel bars with upset ends shall be annealed the same as eyebars. See paragraph 162.

Painting

Cleaning

(166) All material shall be thoroughly cleaned from dirt rust and scale before any oil or paint is applied. Wire brushes and steel scrapers shall be used when necessary.

Before Assembling

(167) All surfaces coming in contact shall have one coat of red lead paint before assembling.

Inaccessible Parts

(168) All parts not accessible after erection shall have two coats of red lead paint.

Machined Surfaces

(169) All machine finished surfaces shall have a coat of white lead and tallow before shipment.

Other Parts (170) All other parts shall have one coat of boiled linseed oil before shipment.

Application (171) No oil or paint shall be applied in wet or freezing weather, or when the metal is not dry, and no coat shall be applied until the one before is thoroughly dried. No material shall be painted until after it has been examined and accepted by the inspector.

(172) All oil and paint shall be applied with good thick brushes (round preferred) with elastic bristles, by skilled painters and shall be thoroughly brushed out and worked into all open spaces and so applied as to completely cover the surface.

(173) All oil, when applied, shall be heated to a temperature of from 150 to 200 degrees Fahrenheit.

(174) All red lead paint shall be kept well stirred while it is being used.

FIELD WORK

Ready for Rails (175) Unless otherwise specified all bridges shall be erected by the Contractor ready for the rails.

Floor Deck (176) All rails, splices and fastenings for the same shall be furnished and put in place by the Railway Company; all ties and guard-rails shall be furnished, delivered at the bridge site, by the Railway Company, but will be put in place by the Contractor, all floor deck bolts, washers, nut locks, etc., being furnished by the Contractor. See paragraphs 18 to 21 inclusive.

Falsework (177) All falsework timber, bolts, etc., shall be furnished and put in place by the Contractor and shall be removed by him after completion of the work.

Interrupting Traffic (178) When a bridge is being erected on a line already in operation, the work shall be done without interrupting traffic, except as arrangements are made for such interruption.

Renewal

(179) In case of a renewal the Contractor shall take down the old bridge and pile the same on the bank or load it on cars as may be directed.

Anchorage

(180) The Contractor shall drill all the necessary anchor bolt holes in the masonry, and shall set the bolts in place, fastening the same with neat Portland cement mortar.

Watchmen

(181) When necessary the Contractor shall provide watchmen and other safeguards during erection.

Laws

(182) The Contractor shall comply with all laws and ordinances whenever there are any applicable to the work in execution.

Risks

(183) The Contractor shall assume all risks of accidents or from floods or other causes until the final completion of the work.

Reaming

(184) When assembling the work in the field, any inaccuracies in the rivet holes must be corrected by reaming, drifting will not be allowed. Drift pins may only be used to bring the pieces together.

Riveting

(185) All rivets must have full heads, concentric with the rivet, of a uniform size for the same size of rivet and must be driven so as to completely fill the holes. Loose or poor rivets must be cut out and replaced.

Turned Bolts

(186) Where it is impossible to drive rivets in the field, turned bolts may be used provided they are turned to a driving fit.

Pilot Nuts

(187) Pilot nuts shall be used on pins to protect the threads when the pins are being driven.

Painting

Cleaning

(188) Before applying the field coats of paint, all members shall be cleaned from all blisters, loose paint and dirt.

Rivet Heads

(189) After erection and before applying the

finishing coats all heads of field rivets shall be painted with the same material as used for the first field coat.

First Coat

(190) After erection all accessible parts shall receive one coat of "Red Lead Metal Preservative."

Second Coat

(191) After the "Red Lead Metal Preservative" is thoroughly dry all accessible parts shall receive a second field coat which shall be a high grade graphite or carbon paint.

Application

(192) No paint shall be applied in wet or freezing weather, or when the metal is not dry. All paint shall be applied with good thick brushes (round preferred) having elastic bristles and by skilled painters. All paint must be well rubbed onto the surface and worked into all open spaces and so applied as to completely cover the surface.

QUALITY OF MATERIAL

Wrought steel

Process

(193) All wrought steel shall be made by the open hearth process.

Finish

(194) The finished product shall be true to size and shape and free from imperfections such as cracks or roughness. When two or more universal mill plates of the same width come together in the finished work they must be of uniform width and their edges must not be beveled.

Variation

(195) No greater variation than 2½ per cent. shall be allowed between the estimated and actual weight of any piece of material except for wide plates where the actual weight may exceed the estimated weights by the amounts given in the following table:

Thickness in Inches.	Width of Plate in Inches.		
	48 to 75	75 to 100.	Over 100.
1-4	10 per cent.	14 per cent.	18 per cent.
5-16	8 per cent.	12 per cent.	16 per cent.
3-8	7 per cent.	10 per cent.	13 per cent.
7-16	6 per cent.	9 per cent.	10 per cent.
1-2	5 per cent.	7 per cent.	9 per cent.
9-16	4½ per cent.	6½ per cent.	8½ per cent.
5-8	4 per cent.	6 per cent.	8 per cent.
Over 5-8	3½ per cent.	5 per cent.	6½ per cent.

Phosphorus

(196) The amount of phosphorus shall not exceed .08 per cent. in steel made in an acid furnace and .04 per cent. in steel made in a basic furnace.

Test Pieces

(197) The properties of steel shall be determined from test prices cut from the finished product, representing each melt.

(198) The test pieces, about 12 inches long, shall be planed or turned to a uniform area of not less than ½ of a square inch for a length of 10 inches.

(199) Pieces representing annealed bars may be annealed before testing.

(200) When a melt is rolled into several varieties of material a test piece shall be taken from each variety.

Ultimate Strength

(201) The ultimate strength of the several grades of steel, as determined from the test pieces, shall be within the following limits:

Hard steel, 70,000 to 78.000 lbs. per square inch.

Medium steel 62,000 to 70,000 lbs per square inch.

Soft steel, 54.000 to 62,000 lbs. per square inch.

Rivet steel, 50,000 to 58,000 lbs. per square inch.

Elastic Limit

(202) The elastic limit shall not be less than 55 per cent. of the ultimate strength.

Elongation

(203) The elongation in 8 inches shall not be less than—

18 per cent. for hard steel.

22 per cent. for medium steel.

24 per cent. for soft steel.

26 per cent. for rivet steel.

Reduction of area

(204) The reduction of area at the point of fracture shall not be less than—

35 per cent. for hard steel.

40 per cent. for medium steel.

45 per cent. for soft steel.

48 per cent. for rivet steel.

Fracture

(205) The entire fracture must be silky.

Bending

(206) A piece of each test piece shall be bent cold 180 degrees.

Hard Steel

(207) No specimen from hard steel shall show any signs of cracks until the diameter of the circle around which the bar is bent becomes less than 3 times the thickness of the specimen.

Medium Steel

(208) No specimen from medium steel shall show any signs of cracks until the diameter of the circle around which the bar is bent becomes less than the thickness of the specimen.

Soft and Rivet Steel

(209) Each specimen from soft or rivet steel shall bend 180 degrees and close upon itself without sign of crack or flow on the convex surface.

Drifting

(210) The ductility of medium and soft steel shall be such that a punched hole, the center of which is not more than 1½ inches from the sheared or rolled edge of any piece may be enlarged by drifting to a diam-

eter 50 per cent. greater than the original hole without cracking the specimen at any point.

Duplicate Tests

(211) Duplicate tests may be made when the sample fulfills all but one of the requirements. If the second test and the average of the two tests meet all the requirements, the melt may be accepted.

Marking

(212) All material shall be plainly stamped with a number identifying the melt.

Eyebar Tests

(213) The eyebars required for tests and those for the structure shall be made at one time. The test bars to be selected by the Inspector, must be fair average specimens of those which would be classed as good bars acceptable for the work. No bar which is known to be defective shall be selected for testing.

(214) These bars will be required to develope a minimum stretch of 14 per cent. before breaking if of soft steel and 12 per cent. if of medium steel. The elongation to be measured on a gauged length of 10 feet including the fracture.

(215) If medium steel is used the bars shall show an ultimate strength of not less than 62,000—9.000 (area --:-- perimeter) and if soft steel not less than 54,000—8,000 (area --:-- perimeter). The elastic limit in all cases shall not be less than 55 per cent. of the ultimate strength.

(216) In general bars will be required to break in the body. When a bar breaks in the head but developes 14 per cent. elongation before breaking. a second bar shall be selected from the same lot. If this bar breaks in the body and the average elongation of the two bars is not less than 16 per cent., the bars of this lot may be accepted.

(217) If more than one-third of all the bars tested break in the head, this shall be deemed sufficient cause for the rejection of the entire bill of eybars.

(218) Tests of full sized sections that meet the requirements shall be paid for at cost less the scrap value of the material. Tests that fail to meet the requirements will be at the expense of the Contractor.

Wrought Iron

Grade

(219) All wrought iron shall be be the best double rolled and double refined iron It must be tough fibrous, uniform in quality, thoroughly welded in rolling and finished straight and smooth. It must be free from flaws blisters, cinder spots, cracks and imperfect edges. It must be worked from the muck bar and no steel scrap will be allowed in its manufacture.

Test Pieces

(220) Test pieces shall be prepared the same as for wrought steel. See paragraphs 197 to 200 inclusive.

Ultimate Strength

(221) The ultimate strength as determined from the test pieces shall not be less than 50,000 pounds per square inch.

(222) Tension tests of full sized bars must show an ultimate strength of at least 52,000—7,000 (area --:-- perimeter) in pounds per square inch.

Elastic Limit

(223) The elastic limit in no case shall be less than 26,000 pounds per square inch.

Elongation

(224) The elongation in 8 inches shall be at least 18 per cent.

Bending

(225) All iron must bend cold 180 degrees to a curve, the diameter of which is not more than twice the thickness of the piece without cracking. When nicked and bent the piece must show no signs of being brittle, but shall bend and break gradually, showing a uniform fibrous fracture.

(226) Rivet iron must be capable of being bent double and closed upon itself, hot or cold, without sign of fracture on the convex surface. When nicked and broken the fracture must be fibrous.

Cast Steel

Process

(227) All steel castings shall be made by the open hearth process and shall be true to pattern and of workmanlike finish.

Phosphorus

(228) The amount of phosphorus shall not exceed .08 per cent.

Coupon

(229) All castings shall be made with a coupon for testing which shall not be cut off until after the castings have been annealed.

Annealing

(230) All castings shall be thoroughly annealed.

Blow holes

(231) When the bearing surface of any casting is finished, there shall be no blow hole visible exceeding one inch in length or exceeding one-half square inch in area. The length of blow holes cut by any straight line shall never exceed one inch in any one foot.

Ultimate Strength

(232) The ultimate strength as determined from a $\frac{3}{4}$ of an inch round turned from the coupon shall be from 65000 to 70000 pounds per square inch.

Elastic limit

(233) The elastic limit shall not be less than 40000 pounds per square inch.

Elongation

(234) The elongation shall not be less than 15 per cent. in 2 inches.

Reduction of area

(235) The reduction of area at the point of fracture shall not be less than 20 per cent.

Cast iron

Grade

(236) All iron castingss shall be made of tough, gray iron and shall be smooth, sound, true to pattern, of workmanlike finish and must be free from blow holes.

Coupon

(237) One casting from each melt shall be made with a coupon about one inch square and 15 inches long, for testing.

Tests

(238) Tests shall be made on the coupons by applying a load midway between supports 12 inches apart. The test bars shall show a deflection of at least .15 inches and develope a fiber stress of at least 43000 pounds per square inch.

Phosphor bronze

Composition.

(239) Castings of phosphor bronze shall contain 88 per cent. copper and 12 per cent. phosphorized tin. The phosphorized tin shall contain 5 per cent. phosphorus.

Coupon

(240) Each casting shall be made with a coupon from which a one inch cube can be cut for testing.

Tests

(241) A compression test on this cube shall show an elastic limit of not less than 20000 pounds. The permanent set on the test cube under a load of 100000 pounds shall not exceed one-sixteenth of an inch.

Babbitt Metal

(242) All babbitt metal shall be composed of 50 parts tin, 1 part copper and 5 parts antimony.

Timber

(243) All timber shall generally be white oak or long leaf yellow pine. It shall be first-class in all respects, sawed true and of full size and must be free from sap wood and large or loose knots.

Paint

Oil

(244) All oil shall be boiled; linseed oil and shall be of a pale yellow color, brilliant, limpid, drying well, with a rich luster, and having a pleasant nutty taste. Oil of a greenish or dark color, cloudy or with an uncertain taste will not be accepted.

Red Lead

(245) All red lead paint shall be high grade. When properly mixed for use and applied to a smooth, vertical surface, it should neither run, separate nor sag.

1st Field coat

(246) The first field coat of paint shall be the "A" brand of "Red Lead Metal Preservative," made by the Lowe Brothers Co., of Dayton, Ohio.

2nd Field coat

(247) The second field coat of paint shall be one of the following: First, Graphite paint made by the Joseph Dixon Crucible Co., of Jersey City, N. J. Second, "Black Metal Coating No. 1407," made by the Lowe Brothers Co., of Dayton, Ohio.

INSPECTION

Inspectors

(248) The Railway Company will employ an Inspector who will examine and test all material before any work is done upon it. He shall have free access to the mills and shops at all times during the construction of the work and shall have power to reject material when the material or workmanship does not comply with the requirements of these specifications.

Notice of rolling

(249) No material shall be rolled until arrangements have been made for the proper testing and inspection of the same.

Surface Inspection

(250) Each and every piece of material shall be submitted to examination on all sides and for that purpose turned over when required. All plates shall be suspended for examination and each piece shall be weighed separately when required by the Inspector.

Subsequent discovery of defects

(251) Acceptance of any material by the Inspector shall not prevent its subsequent rejection if found defective after delivery, and such material shall be replaced by and at the expense of the Contractor.

Marks

(252) Material, when examined at the rolling mills by the Inspector, shall when found acceptable, be stamped with his private mark. No work shall be done upon any material that does not bear this mark. Small bars, rods,

etc., may be put up in bundles with the Inspector's mark on a metal tag wired to the same.

Facilities

(253) All facilities, labor, tools and instruments necessary for the inspection and testing of all material in accordance with the letter and intent of these specifications shall be furnished free of expense to the Railway Company.

Full size tests

(254) Upon request, the contractor shall be advised as to the number of pieces required for full size tests.

MAINTENANCE

(255) The life of a steel bridge depends quite largely upon the care it receives and in view of this fact the Author recommends.

First Painting

(256) That the bridge be repainted whenever the final coat becomes deteriorated and exposes the first field coat of paint. An effort should be made to at all times keep the first field coat protected. Before repainting all surfaces should be thoroughly cleaned, using wire brushes and steel scrapers where necessary. The paint used should be the same as that used for the second field coat. A marked difference in the colors of the first and second field coats has been selected in order to more clearly show when the bridge needs painting.

Second Inspection

(257) That the bridge should be inspected at frequent intervals by some competent person and any necessary repairs be made. Especially should the rivets in the floor system be tested and if any are found loose cut and replace.

APPENDIX.

Table giving maximum moments (M) and end reactions (R) for a train of 80000 pounds street cars each 40 feet long cen er to center of couplings and upon a wheel base of 5 plus 20 plus 5 equals 30 feet and the values of w based upon M and also upon R where the equivalent load is "w pounds per lineal foot uniformly distributed plus 10 w pounds concentrated, so placed as to give the maximum effect in every case."

Span in feet	M in foot pounds.	R in pounds	W based on M	W based on R
10	56250	30000	1500	2000
12	75210	31670	1567	1979
16	113910	35000	1582	1945
20	153120	40000	1531	2000
24	211670	46670	1604	2121
28	277820	51430	1654	2143
32	355600	55000	1701	2115
36	433800	57780	1721	2063
40	512550	60000	1708	2000
44	591300	63640	1680	1989
48	670400	67920	1643	1998
52	749600	71930	1602	1998
56	850000	75720	1598	1993
60	950000	80000	1583	2000
64	1070000	83750	1592	1994
68	1190000	89410	1591	2032
72	1320000	93330	1594	2029
76	1460000	96850	1601	2018
80	1600000	100000	1600	2000
84	1780000	103800	1630	1997
88	1960000	107950	1650	1999
92	2150000	111950	1661	1999
96	2350000	117700	1688	2030
100	2550000	120000	1700	2000
105	2800000	125720	1707	2010
110	3050000	130900	1706	2014
115	3400000	135900	1752	2013
120	3900000	140000	1857	2000
125	3925000	144800	1732	1997
150	5650000	170700	1773	2008
200	9950000	220000	1809	2000

While the above table is not necessarily exact, it is close enough to illustrate the value of the loadings selected in these specifications.

Table giving maximum moments (M) and end reactions (R) for a train of pressed steel cars weighing as follows:

Rated capacity ....100000 pounds
Excess load 10 per cent.......... 10000 pounds
Weight of car.................... 40000 pounds

Total load for each car..........150000 pounds

each car having a length of 32½ feet center to center of couplings and a wheel base of 5 plus 15 plus 5 equals 25 feet, and the values of w based upon M and also upon R where the equivalent load is "w pounds per lineal foot uniformly distributed plus 10 w pounds concentrated so placed as to give the maximum effect in every case."

Span in feet	M in foot pounds.	R in pounds	W based on M	W based on R
10	105460	56250	2812	3750
12	141000	59375	2938	3711
16	254300	71480	3532	3971
20	328120	84375	3281	4218
24	453100	95312	3432	4332
28	600000	103130	3572	4297
32	747700	108980	3595	4191
36	895800	117190	3555	4185
40	1044200	126560	3481	4219
44	1162500	135510	3303	4235
48	1387500	145310	3401	4274
52	1612500	155770	3446	4327
56	1846900	166070	3472	4370
60	2132500	175000	3554	4375
64	2428000	182810	3613	4353
68	2690600	191360	3597	4349
72	3028100	200520	3657	4360
76	3375000	209700	3701	4369
80	3750000	219140	3759	4383
84	4162500	229020	3811	4405
88	4575000	239060	3851	4427
92	5006200	248230	3887	4433
96	5456200	256640	3920	4425
100	5906200	265310	3938	4422
105	6468800	276790	3943	4429
110	7078100	288070	3960	4432
115	7687500	300000	3961	4445
120	8343800	312500	3972	4465
125	9421900	324000	4159	4469
150	13078000	381250	4104	4486
200	23109000	495940	4202	4508

While the above table is not necessarily exact, it is close enough to illustrate the value of the loadings selected in these specifications.

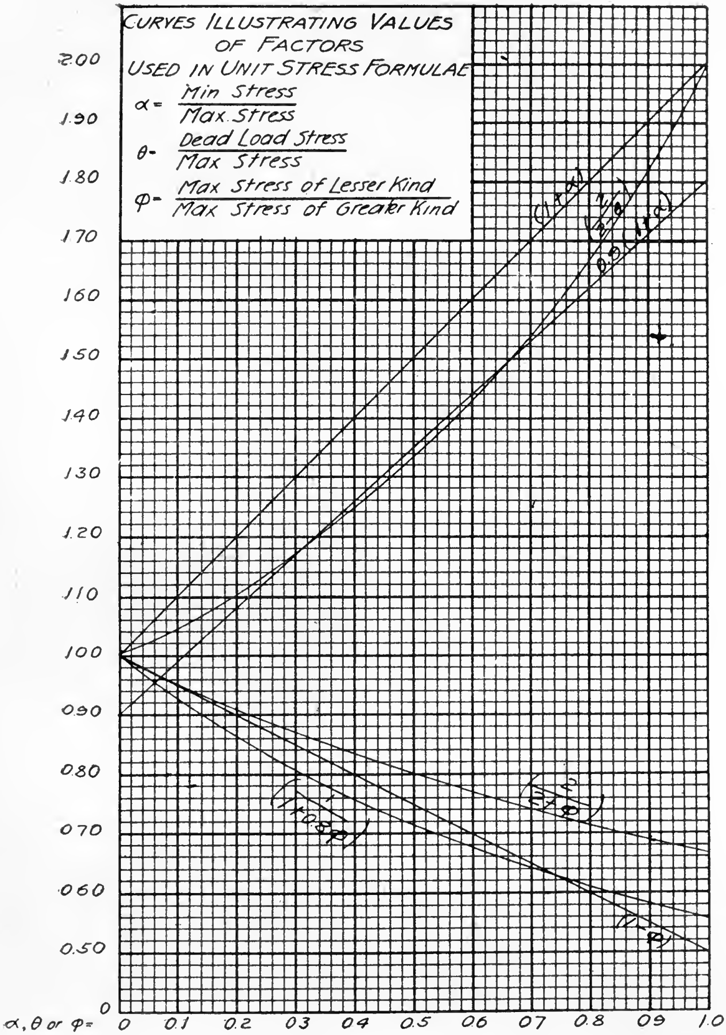
Table giving maximum moments (M) and end reactions (R) for various spans for E 40 loading of Theodore Cooper's Specifications and the values of "w" based on M and also on R where the equivalent load is "w pounds per lineal foot uniformly distributed plus 10 w pounds concentrated, so placed as to give the maximum effect in every case."

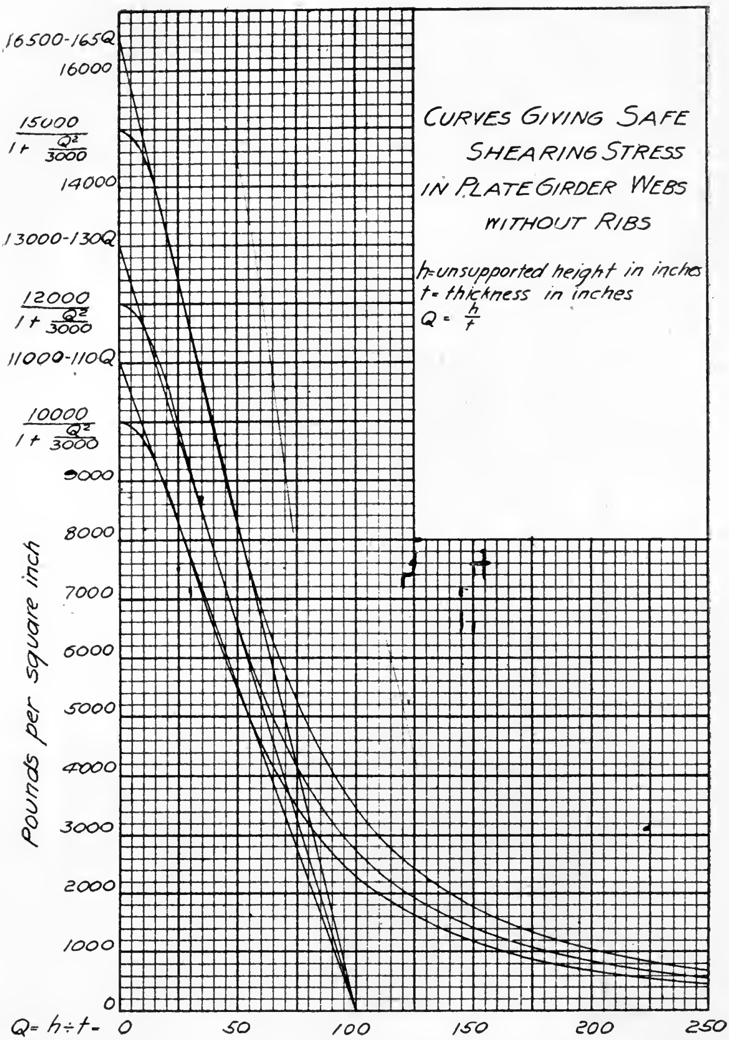
Span in feet	M in foot pounds.	S in pounds	W based on	
			M	S
10	112500	60000	3000	4000
12	160000	70000	3333	4375
16	280000	85000	3889	4722
20	412500	100000	4125	5000
24	570400	110800	4321	5036
28	731000	120800	4351	5033
32	910800	131500	4379	5058
36	1097000	141100	4354	5040
40	1311000	150800	4370	5027
44	1543000	161100	4384	5034
48	1776000	169600	4353	4989
52	2030000	178500	4338	4959
56	2304000	186000	4331	4895
60	2599000	195200	4332	4880
64	2911000	205200	4332	4886
68	3247000	215600	4341	4900
72	3584000	226700	4339	4929
76	3942000	238100	4323	4961
80	4321000	248400	4321	4968
84	4713000	259000	4316	4981
88	5128000	269400	4317	4989
92	5552000	279600	4311	4993
96	5988000	289600	4302	4994
100	6440000	300000	4293	5000
105	7075000	312200	4312	4994
110	7774000	324000	4349	4985
115	8490000	335800	4375	4975
120	9228000	347400	4394	4963
125	9993000	358800	4411	4950
150	14112000	414670	4428	4879
200	23712000	522000	4312	4745

Load equivalent to E 40 equals, say 5000 pounds uniform plus 50000 pounds concentrated, based on R and 4500 pounds uniform plus 45000 pounds concentrated, based on M.

Table giving a comparison between the loads used in these specifications and the tpyical loads shown in Theodore Cooper's Specifications:

L 20	equals	E 16	(2- 56.8 ton engines followed by 1600 pounds per lineal foot.)
L 30	equals	E 24	(2- 85.2 ton engines followed by 2400 pounds per lineal foot.)
L 37.5	equals	E 30	(2-106.5 ton engines followed by 3000 pounds per lineal foot.)
L 40	equals	E 32	(2-113.5 ton engines followed by 3200 pounds per lineal foot.)
L 43.75	equals	E 35	(2-124.2 ton engines followed by 3500 pounds per lineal foot.)
L 50	equals	E 40	(2-142.0 ton engines followed by 4000 pounds per lineal foot.)
L 60	equals	E 48	(2-170.4 ton engines followed by 4800 pounds per lineal foot.)
L 62.5	equals	E 50	(2-177.5 ton engines followed by 5000 pounds per lineal foot.)


CURVES ILLUSTRATING VALUES OF FACTORS USED IN UNIT STRESS FORMULAE
α = Min Stress / Max. Stress
θ = Dead Load Stress / Max Stress
φ = Max Stress of Lesser Kind / Max Stress of Greater Kind
2.00
1.90
1.80
1.70
1.60
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0
α, θ or φ =
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
(1+α)
0.9(1+α)
(1-φ)


CURVES GIVING SAFE SHEARING STRESS IN PLATE GIRDER WEBS WITHOUT RIBS
h=unsupported height in inches
t= thickness in inches
Q = h/t
16500-165Q
16000
15000 / 1+ Q²/3000
14000
13000-130Q
12000 / 1+ Q²/3000
11000-110Q
10000 / 1+ Q²/3000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Pounds per square inch
Q= h÷t- 0
50
100
150
200
250

SPECIFICATIONS

FOR..BRIDGE..

AT__________________________________

FOR__________________________________

GENERAL SPECIFICATIONS

FOR

RAILWAY BRIDGE SUPERSTRUCTURE

THE OSBORN ENGINEERING CO
OSBORN BUILDING.
CLEVELAND, - OHIO.

1903.

TABLE OF CONTENTS.

SPECIFICATIONS.

FOR ....BRIDGE OVER.....................................

at..

The engineer's general drawings consist of:—

....

....

....

....

....

....

....

....

....

....

The Superstructure will consist of ....spans..................long.

....

Live load to be................................ ....

....

....

Paint "first coat" to be ....

"finish coats" to be... ....

Contractor to erect... ......

....

....

The entire work to be completed on or before..........................19......

Traffic to be maintained...

....

Old Structure to be removed...

....

Contractor to furnish falsework timber...

" " " and place wooden floor..................................

GENERAL SPECIFICATIONS

FOR

Railway Bridge Superstructures

THE OSBORN ENGINEERING COMPANY
Osborn Building. Cleveland, O.

1903.

I. CLEARANCE.

1. On a straight track a section, as per diagram given in appendix, must be kept clear in single track through bridges. On a curved track and in double track structures the clear width must be proportionately increased. The distance center to center of the double track is 13 feet. Assuming length of cars 75 feet and spacing of trucks 54 feet, center to center, 2½ inches additional clear width must be provided on the inside of curves for every inch of elevation of outer rail, on account of tipping of cars. The width from center to center of trusses shall not be less than 1-20th of the span.

See Appendix A.

II. DRAWINGS.

Engineer's General Drawings.

2. Accompanying these specifications, and forming a part hereof, are general drawings, as enumerated on the second page of these specifications, embodying the information and data furnished the contractor for his guidance.

Contractor's General Drawings.

3. If general drawings are submitted by the contractor with his proposal, they shall include all stress sheets giving the lengths of spans from center to center of chords; the width of the bridge in the clear and from center to center

of trusses; the dead, live and other loads on which calculations are based; the dead, live and other load stresses as well as the minimum stresses, and sections for all members; the sections and areas of lateral and portal struts, lateral and sway rods or angles; stringers, floor-beams and their connections; sizes of rivets; size, arrangement and character of floor system; and the class or classes of material proposed for use in the various parts of the structure.

The dead loads assumed for calculating the stresses shall not be less than the actual weight of the structure.

The plus (+) sign shall be used to indicate compression stresses and the minus (—) sign to indicate tension stresses.

Stresses shall be given in pounds, and weights of shape metal in pounds per foot of one piece.

The plans shall also include such detail drawings as are necessary to express the general intent of the whole work.

Shop Drawings.

4. The contractor shall not, except at his own risk, order any material until after the shop drawings have been approved by the engineer. After approval, the contractor shall furnish the engineer, without charge, as many sets of the shop drawings as he may require.

Drawings.

5. After the award of the contract, two complete sets of drawings and details, including stress sheet described above shall be furnished for approval, one set of approved drawings will be returned to the contractor and one will be retained by the Railway Company. One or more sets of drawings may also be required for the use of the inspector. These drawings shall in general be drawn to a scale of one inch to the foot.

Shop and Order Bills.

6. The contractor shall also furnish the engineer with duplicate copies of all shop and order bills of material and shipping lists of all finished parts, with exact itemized weights of same.

Size of Drawings.

7. All drawings shall be of uniform size twenty-four by thirty-six inches (24″ x 36″). They shall be numbered, arranged in systematic order and indexed.

8. On all drawings, dimensions shown in figure shall govern in cases of discrepancy between scale and figures. **Dimensions.**

9. The contractor shall check all leading dimensions and clearances as a whole and in detail, the fitting of all details, and becomes responsible for the exact position and elevation of all parts of the work; and the approval of the working drawings by the engineer shall not relieve the contractor of this responsibility. **Contractor Responsible for Accuracy.**

10. In constructing the work, no variations at any time from the approved drawings, nor from these specifications, shall be made by the contractor, without a written order from the engineer in each case, describing and directing such change. **Variations.**

11. Notes or specifications appearing on the engineer's general drawings are to be construed as superseding and voiding any clauses, or parts of clauses, in these specifications, with which they may conflict. **Notes.**

12. Rivets shall be indicated in accordance with the code shown in the appendix. **Rivets.**

See Appendix B.

III. FLOOR.

13. Cross-ties shall be of the best quality of long leaf southern yellow pine, white or burr oak. They shall have a width of 8″ and a depth depending upon the distance between centers of supports, as follows: **Cross-ties.**

Spans.

Up to	7′-0″	c. to c.	Dimensions.	8″x 8″x10′-0″
	7′-0″	"	"	8″x 9″x10′-0″
	8′-0″	"	"	8″x10″x10′-0″
	9′-0″	"	"	8″x11″x12′-0″
	10′-0″	"	"	8″x12″x12′-0″
	12′-0″	"	"	8″x14″x14′-0″

They shall be spaced 12″ between centers, notched ½″ over supports, and every fourth tie shall be fastened to the flanges of stringers by ¾″ hook bolts flattened at their lower ends to prevent turning. These bolts shall pass through the raising pieces when used, if practicable.

Ribbons. 14. There shall be an 8"x6" ribbon, of the same material as the ties, on each side of each track, with its inner face parallel to and not less than 4' 2" from the center of the track and notched 1-½" over each tie, when rails 5" high are used. When rails of less height than 5" are used, the ribbon shall be notched so that its upper surface shall be ½" below the top of the rail, or a ribbon of less height may be used.

The ribbon shall be fastened to every fourth tie (using the ties secured to the stringers by hook bolts) by ⅝" machine bolts, having a ⅛" wrought washer on the top of the ribbon, and a ½" cast washer under the tie. Ribbons shall be spliced over ties by halving horizontally with a lap of 6" Each splice shall be secured by a ⅝" bolt at center, the holes of the bolts being 11-16" in diameter. The ribbons must be continued over all piers and abutments.

15. Hook bolts and ribbon bolts are considered to be a part of the metal superstructure. See paragraph 163.

16. The standard spacing for track stringers shall be 6'-6" between centers, and the tracks will be 13'-0" between centers unless otherwise ordered. In double track metal bridges with three trusses the clearance, length of cross ties and spacing of stringers for each track shall be the same as above specified for single track bridges.

Deck Bridges. 17. In single track metal bridges, if the width between centers of trusses does not exceed 12' the cross ties may rest directly on the top chords. If of greater width, floor beams and track stringers shall be used. In plate girders having a span of 50'-0" or less, the girders shall be 6'-6" c. to c. and in longer spans 8'-0" c. to c. All girders shall be thoroughly braced laterally and transversely.

Elevation of Outer Rail. 18. The outside rail shall be elevated as required by the engineer. This will be effected by wedge-shaped ties or by raising pieces on supports as may be deemed best. If wedge-shaped ties are used, their depth at the inner support shall not be less than for bridges on tangent.

IV. LOADS.

Static Load.

19. The weights assumed for calculation shall be as follows: Rails and fastenings 100 lbs. per lineal foot of track. Timber per foot B. M., Oak, 4-½ lbs.; Yellow Pine, 4 lbs.; Wrought Iron, 3 1-3 lbs. per lineal foot for bar 1″ square. Wrought Steel, 3.4 lbs. per lineal foot for bar 1″ square. The dead load shall be assumed as concentrated 2-3 at panel points of loaded chord, and 1-3 at panel points of unloaded chord.

Moving Load.

20. The moving load shall, unless otherwise specified, be one of the loadings given in appendix, and specified on the second page hereof.

See Appendix C.

Impact.

21. The effect of impact and vibration shall be added to the maximum strains resulting from the live load, and shall be determined by the following formula:

$$I = L \frac{L}{L + D}$$

Where I = Impact.
L = Maximum live load stress.
D = Dead load stress.

The impact on floor beam hangers shall be assumed at 125%.

In computing the effect of impact in cases where the live load and dead load stresses are of opposite nature, the dead load stress shall be assumed to be zero.

Centrifugal Force.

22. Where the structure is on a curve, the effect of centrifugal force shall be considered and computed by the following formula:

$$C = \frac{W V 2}{32, 2, r.}$$

In which W = Live Load,
= Velocity in feet per second,
= Radius of curve in feet,

Note.—See Osborn's Tables for values of C for various velocities and degrees of Curvature.

Longitudinal Forces.

23. The longitudinal bracing in metal towers and the attachments of fixed ends of all girders shall be capable of resisting the momentum of train when brought to a sudden stop, the co-efficient of friction of wheels sliding upon rails, being assumed at 0.2.

Wind Forces.

24. The bottom lateral bracing in deck truss bridges and the top lateral bracing in through truss bridges shall be proportioned to resist a moving force of 150 lbs. per lineal foot for spans of 200 feet and under, and 0.4 lbs. per lineal foot for each additional foot in length over 200 feet.

25. The bottom lateral bracing in through truss bridges and the top lateral bracing in deck truss bridges shall be proportioned to resist a moving force of 450 lbs. per lineal foot for spans of 200 feet and under, and 0.4 lbs. per lineal foot for each additional foot in length over 200 feet.

26. The lateral bracing in plate girder bridges shall be proportioned to sustain a moving load of 330 lbs. per foot with 30 lbs. additional for each foot in depth of girder. Rigid cross frames shall be provided connecting the upper and lower flanges at intervals not exceeding fifteen feet, and all bracing shall be capable of transmitting compression as well as tension stresses. The lateral bracing in deck plate girder bridges will be placed in the plane of the upper flanges.

Trestles.

27. In trestle towers, the bracing and posts shall be proportioned to resist wind pressures in addition to the stresses from dead load, live load, centrifugal and traction forces, as follows:

1st. A force of 300 lbs. per lineal foot of structure applied 8′ above base of rail, and a wind pressure of 30 lbs. per sq. ft. on the exposed surfaces of all trusses, girders and towers.

2nd. A wind pressure of 50 lbs. per sq. ft. on the exposed surfaces of all trusses, girders and towers.

All trestle bracing shall preferably be composed of shapes designed to transmit compression as well as tension stresses.

28. In determining anchorage for the loaded structure, the trains shall be assumed to weigh 800 lbs. per lineal foot. **Anchorage.**

29. Lateral and longitudinal struts shall be proportioned to resist the resultant due to an initial stress of 10,000 lbs. per square inch upon all rods attached to them when this is in excess of wind stress. **Struts.**

30. Where the effect of a variation of 150 degrees F. is to produce stresses in the structure, the maximum of such stresses in each member shall be provided for. **Temperature Stresses.**

V. UNIT STRESSES.

31. All parts of the structure shall be proportioned by the following unit stresses: (See paragraph 21.)

Tension.

Wrought iron, 13,000 lbs. per square inch.

Soft steel, 15,000 lbs. per square inch.

Medium steel, 17,000 lbs. per square inch.

Compression.

32. Members with square bearings at both ends, $\dfrac{C}{1+\dfrac{l^2}{36,000\, r^2}}$ per sq. inch.

Members with square bearings at one end and pin bearings at the other, $\dfrac{C}{1+\dfrac{l^2}{24,000\, r^2}}$ per sq. inch.

Members with pin bearings at both ends, $\dfrac{C}{1+\dfrac{l^2}{18{,}000\, r^2}}$ per sq. inch.

In which C = 13,000 for wrought iron.
" C = 15,000 " soft steel.
" C = 17,000 " medium steel.
" l = length between supports in inches.
" r = least radius of gyration in inches.
" l/r shall not exceed 100 for main members and 120 for subordinate members.

NOTE.—Values of $\frac{l^2}{r^2}$ may be taken from Osborn's Tables.

Bending.

33. Pins, closely packed, medium steel, 25,000 lbs. per square inch.

Bearing.

34. Pins ....22,000 lbs. per square inch.
Rivets ....20,000 lbs. per square inch.

Shearing.

35. Pins, medium steel......11,000 lbs. per square inch.
Rivets ....10,000 lbs. per square inch
On webs of plate girders soft steel.. 9,000 lbs.
Medium steel...10,000 lbs.

Field Rivets.

36. The number of rivets thus found shall be increased 20% for rivets driven in field.

Wind Stresses.

37. The same permissible stress shall also be used for members subject to wind stresses, centrifugal force and momentum of train. No allowance will be made for the wind stress when combined with stress from dead and live load, unless the combined stress exceed by 25 per cent. the stress from dead and live load only, in which case the combined stress will be used with a unit stress 25 per cent. greater than above given.

Alternate Stresses.

38. Members subject to alternate stresses of tension and compression in immediate succession, shall be so proportioned that the total sectional area is equal to the sum of the areas required for each stress. (See paragraph 21).

The strength of the connections shall be proportionately increased.

39. Members subjected to combined bending and direct stresses must be proportioned for the combined stresses. Combined Stress.

40. The timber parts of the structure shall be proportioned by the following unit stresses, given in pounds per square inch. Timber.

SPECIES	Transverse Loading.	End Bearing.	Short Columns l equal to or less than 12 d.	Bearing Across Fibre.	Shear Along Fibre
1. White Oak	1400	1400	1000	600	300
2. Long Leaf Pine	1600	1600	1000	350	200
3. White Pine	1000	1000	700	200	150

41. Columns whose length exceeds 12 times their least side shall be proportioned by the following formula: Timber Columns.

$$P = \frac{C}{1 + \frac{l^2}{1,000\, d^2}}$$

Where P = Unit load on column.
C = Unit load as given above for short columns.
l = Length of column between supports, in inches.
d = Least side of column, in inches.

VI. GENERAL DETAILS.

42. When the track is on a curve, both inner and outer trusses or girders are to be alike and to be figured for the proportion of the live load given by the formula: Track on Curve.

$$w = \frac{m + b}{2\,b} P$$

Where
W = load going to either trusses.
m = center ordinate to curve.
b = width c. to c. of trusses.
P = the live load at panel point considered.

Net Section. 43. The net section of any tension member or flange shall be determined by a plane, cutting the member square across at any point. The greatest number of rivet holes which can be cut by this plane, or come within an inch of it, are to be deducted from the gross section.

Pins and Rivets. 44. In deducting rivet holes to obtain the net section of riveted tension members, the rivet hole shall be taken with a diameter one-eighth (1/8) inch larger than the undriven rivet for rivets with full heads, and one-fourth (1/4) inch larger for countersunk rivets in plates 5/8" or less in thickness.

Effective Diameter of Rivets. 45. The effective diameter of the driven rivet shall be assumed the same as its diameter before driving.

46. Where rivets are countersunk the bearing of the head shall not be counted.

Minimum Number of Rivets. 47. No connection shall be made with less than three (3) rivets.

Pitch of Rivets. 48. The pitch of rivets shall not exceed 6 inches, nor be less than three diameters of the rivet. At the ends of compression members the pitch shall not exceed four diameters of the rivet for a length equal to twice the depth of the member, and in the flanges of girders and chords carrying floor the pitch shall not exceed 4 inches.

Distance from Center of Rivet to Edge of Plate. 49. The distance from center of rivet to edge of plate shall not be less than 1-1/4 inches, except in bars under 2-1/2 inches wide. When practicable it shall be at least two diameters of the rivet. It shall not exceed eight times the thickness of the plate.

Distance Between Rivets in Compression Members. 50. The distance between rivets for plates strained in compression shall not exceed sixteen times the thickness of plate in line of stress, nor forty times the thickness at right angles to line of stress.

Rollers. 51. All bridges exceeding 80 feet in length shall have hinged bolsters at each end and at one end nests of turned friction rollers of steel bearing upon planed surfaces. The rollers shall not be less than 4" in diameter, and the pressure per lineal inch of roller shall not exceed 500 times the diameter of roller in inches. For bridges under 80 feet in length, one end shall be free to move upon planed surfaces.

Least Thickness of Plates.

52. No plate or shape shall be less than 3/8 inch thick for main members, or 5-16 inch thick for wind bracing, lattice bars, etc.

Length of Compression Members.

53. Compression members shall not exceed in length 40 times their least width nor 100 times the least radius of gyration for main members, and 120 times the least radius of gyration for subordinate members. "Main Members" shall include all elements of trusses, posts of towers or bents, and all other members directly acted upon by the live load. "Subordinate Members" shall include lateral systems, sway bracing, and all other members not directly acted upon by the live load.

54. The several segments or parts of a compression member shall be proportionately as strong as the member taken as a whole.

Stay Plates

55. Stay plates shall have a thickness of not less than one-fortieth (1-40) the unsupported width. They shall be not less than twelve (12) inches long, nor less than the greatest width of the member. "By length of stay plate is meant the dimension parallel to the axis of the member."

Lacing.

56. Lacing shall never make an angle of less than 60° with the axis of the member. If clear width between segments exceed 12 inches the member shall be double latticed, and the latticing shall never make an angle of less than 45° with the axis of the member.

Tension Members.

57. Long vertical tension members will preferably be stiffened.

Eye Bars.

58. Heads of eye bars shall be so proportioned as to develop the full strength of the bar. The heads shall be formed by upsetting and forging, and in no case will welding be allowed. (See paragraph 101.)

59. Eye bars must be perfectly straight before boring and bars working together shall be piled and clamped together and bored in one operation.

60. Eye bars shall not be less than five-eighths (5/8) inch thick, and preferably not less than one-fifth (1-5) the width of the bar.

Riveted Tension Members.

61. Riveted tension members shall have an excess of section of twenty-five (25) per cent. through pin holes and net section at all other points. Pin plates shall also be proportioned for bearing on pins. The material back of pins shall be proportioned for double shear, using for working length the distance from back of pin to end of plate. But the length of plate back of pin shall not be less than two and one-half (2½) inches.

Rods.

62. All rods with screw ends shall be upset at the ends so that the area at the root of the thread shall exceed by seventeen (17) per cent. the area of the rod.

63. All rods with welded heads must be of wrought iron.

Loop Eyes.

64. When loop eyes are used, the loop must be so designed as to develop the full strength of the bar.

The eyes must be reamed, and give full bearing on the pins.

Area of Rods.

65. No lateral or diagonal rod shall be less than one square inch in area.

Screw Ends

66. Screw threads shall be cut according to U. S. standard, except in ends of pins.

Washers and Nuts.

67. Washers and nuts shall have a uniform bearing. All nuts shall be easily accessible with a wrench for the purpose of adjustment, and shall be effectively checked after the final adjustment. All parts working together or parts of one member of the truss must be equally strained.

Bolts.

68. All bolts must be of neat length and have a washer under head and nut when they are in contact with wood. Washers and nuts shall have a uniform bearing. All nuts

shall be easily accessible with a wrench for the purpose of adjustment, and shall be effectively checked after the final adjustment.

Rivets shall be used in preference to bolts to resist shearing stresses.

When bolts are unavoidable they must be turned to a driving fit and have a washer under each and every nut. Bearing on threads will not be allowed.

Bolts with hexagonal nuts shall in general be used, and round-headed bolts will not be allowed.

69. All spaces which would otherwise permit the lodgment of water must be drained or filled with water-proof material. **Drainage.**

VII. I BEAMS.

70. I beams will be connected together in groups of two or three for each rail, have a ¾ inch sole plate and ¾ inch bed plate at each end, and be secured at each end to masonry by two 1″ anchor bolts, which shall enter the masonry at least 9 inches. Sheet lead ⅛ inch thick to be shipped, boxed, with girders and to be placed between bed plates and masonry. When ends rest on timber wall plates, the loose bed plate can be omitted.

71. When two or three "I" beams form a compound girder they will be connected together at intervals of about 3 feet, by means of vertical I beam separators riveted to their webs.

The standard width center to center of "I" girders will be 4 feet 11 inches and I beam separators will be not less than 20″ deep when two beams are used, and 10″ deep when three beams are used.

There will be a strut at each end, and a system of angle bracing between the girders.

VIII. PLATE GIRDERS.

Calculation.

72. The length of the span shall be considered as the distance between centers of end bearings, and the depth which shall preferably be not less than 1-10 of the span, shall be taken as the distance between centers of gravity of the flanges, unless this exceeds the depth from back to back of angles, in which case this latter depth shall be taken.

Flanges.

73. The compression flanges of plate girders and beams shall be made of the same gross section as the tension flanges, and they shall be stayed transversely when their length is more than twenty times their width.

Webs.

74. One-sixth of the web may only be considered as available gross area in each flange when the web sheet is not spliced. All joints shall be spliced by a plate on each side of the web and these plates shall have a double line of rivets on each side of the joint.

Stiffeners.

75. All web plates shall be stiffened at both edges of end bearings, and at all points of local concentrated loadings. Intermediate stiffeners shall be used if the ratio of unsupported depth of web to the thickness is greater than fifty.

76. Stiffeners shall be in pairs, and spaced so the shear per foot shall not exceed the safe shear given by the formula.

$$\frac{20000 \times 12\,t}{1 + \frac{d^2}{3000\,t^2}}$$

Where t = the thickness of web plate in inches

d = the clear distances between supports in inches.

NOTE.— See Osborn's Tables for safe resistance of web plate against buckling.

The maximum spacing of stiffeners shall not exceed six (6) feet.

77. There shall be at least two pair of stiffeners over the end bearings, the projecting legs of which shall be as wide

as flange angles will permit. These four stiffeners, including their fillers, shall take care of the maximum end shear.

78. Intermediate stiffeners shall not be less than given below:

For Webs 4 feet and under..........3½ x 3 x 5-16
For Webs 4 feet to 7 feet..............3½ x 3½ x ⅜
For Webs over 7 feet....................5 x 3½ x ⅜

79. Fillers, unless ruled otherwise for special cases, shall be placed under all stiffeners, the thickness being equal to the thickness of the flange angles. **Fillers.**

80. Six inch legs and over will in all cases be connected to the web plates by two rows of staggered rivets, the pitch of rivets shall not be less than 2-¼″ nor more than 4-½″.

81. Not less than one-half the total area of the flanges shall be concentrated in the angles, or the largest size angles shall be used.

82. Through plate girders or lattice girders shall be stayed by stiffened gussets at each floor beam or transverse strut.

83. Plate girders shall be cambered ¼″ for each 25 feet in length, unless otherwise specified. **Camber.**

IX. STRINGERS AND FLOOR BEAMS.

84. Stringers shall generally be placed 6 feet 6 inches, center to center; shall be as deep as practicable, consistent with economy, and shall preferably be riveted to the webs of floor beams.

The span length shall be taken as the distance between centers of floor beams.

85. When lengths exceed 12 feet or twelve times flange widths, stringers will have their upper flanges connected by a system of angle bracing, angles to be not less than 3-½x3x5-16, with at least three ⅞ inch rivets in connection. Cross frames to be placed near outer ends of end stringers.

Bracing will be required in all cases where alignment is on curve.

86. Floorbeams will be riveted to the webs of plate girders or to the posts of through truss bridges, preferably above the pin in the latter case.

The span length shall be taken as the distance center to center of trusses.

Floorbeam hangers shall be avoided when possible. (See paragraph 21.)

87. All bridges shall preferably have end floorbeams and when distance from center of end floorbeams to back wall equals or exceeds 18″, brackets shall be provided in line with stringers.

88. Connection angles of stringers to floorbeams and of floorbeams to truss, shall not be less than 3½x3½x9-16, and the webs of all stringers and floorbeams shall be faced true and square.

X. TRUSSES AND TOWERS.

Unsymmetrical Sections.

89. Unsymmetrical chord sections composed of two rolled or riveted channels and one plate shall be so proportioned that the centers of pins in abutting members shall be in the same line and the eccentricity may be made sufficient to counteract the bending stress due to the weight of the member or provision must be made for it, as in top chords and end posts. The material shall be concentrated mostly in the channels.

H—Sections.

90. H-shaped sections, if exceeding ten inches in depth, shall have tie plates at ends holding them truly square.

Top Laterals.

91. The top lateral struts shall be of the full depth of the chord and shall be securely riveted thereto. The top lateral rods, if used, shall be attached to the lateral gusset plates, which shall be securely riveted to the top chord.

92. For spans of 200 feet and under, each portal frame shall consist of four angles riveted to the end posts and connected by diagonal latticing. The latticing shall be flat bars if the depth of the portal does not exceed two feet and angles if of greater depth. Portals

For spans exceeding 200 feet in length the portal frames may consist of top and bottom struts connected by cross braces.

93. In through bridges, when the depth of truss is between 25 and 30 feet, knee braces shall be used at each vertical post; when the depth exceeds 30 feet sub-struts and overhead diagonal rods or lattice struts of angles shall be used at each vertical post. Cross Bracing.

94. There shall be built or cast steel bolsters at each end of span, securely anchored to the masonry, provision to be made for expansion. Anchor bolts shall be set in Portland cement. (See paragraph 163.) Bolsters and Anchors.

95. Long tension members shall be clamped together at intersection to prevent rattling. Posts and struts shall be in one length without splice. Long Members.

96. Struts composed of two channels latticed shall preferably have the webs of the channels vertical with the clear distance between webs such that the radius of gyration of the member with reference to an axis parallel to the webs of the channels shall not be less than the radius of gyration of the channels. Provision must be made for drainage where necessary. Struts.

97. The legs of trestle bents shall generally have a batter of one horizontal to six vertical.

98. The bents shall be united in pairs to form towers, and each tower thus formed shall be thoroughly braced in all directions. Lateral and longitudinal struts shall be provided at bottom and at each intermediate joint; also at top in the absence of floorbeams or girders acting as such. Towers.

99. Each leg shall be securely anchored to its pedestal, provision being made for expansion.

Chords.

100. If the length of the panel, divided by the least radius of gyration of the top chord is less than the length of span divided by the radius of gyration of the top chords, considered as a trussed column, the latter shall be used in finding the area of top chord sections.

Eyebars.

101. Eye bars shall be closely packed, and as nearly parallel as possible, the greatest allowable inclination of any bar being limited to 1 inch in 10 feet. (See paragraph 60.)

102. Screw ends of pins must project at least 1/4" beyond nuts, to permit upsetting in the field.

Camber.

103. Trusses shall have just sufficient camber to bring the joints of the compression chord to a true square bearing when the truss is fully loaded. Each member of the truss shall be lengthened or shortened in proportion to the street to which it is subject under a full dead and full live load, so that under the full loading each member will be strained to its normal length.

Eyebars and Pins.

104. The center of bearings of the stressed members are to be considered as the points of application of loads on pins when determining bending moments. The diameter of the pins shall not be less than 3/4 of the width of widest bar attached. Heads of eye bars must not be less in strength than body of bar.

XI. RIVETED WORK.

Soft Steel.

105. All holes in tension members of all thicknesses less than three-fourths (3/4) inch shall be either punched one-eighth (1/8) inch smaller than the rivet required and reamed to one-sixteenth (1-16) inch larger, or they may be drilled from the solid.

106.. All holes in tension members of all thicknesses three-fourths (3/4) inch or greater shall be drilled from the solid.

107. All holes in compression members of all thicknesses less than three-fourths (3/4) inch shall be punched full size.

108. All holes in compression members of all thicknesses three-fourths (¾) inch or greater shall be drilled from the solid.

109. All holes in metal less than three-fourths (¾) inch thick shall be either punched one-eighth (⅛) inch smaller than the rivet required and reamed to one-sixteenth (1-16) inch larger, or they may be drilled from the solid. **Medium Steel.**

110. All holes in metal three-fourths (¾) inch or greater in thickness shall be drilled from the solid.

111. Reamed work is not required for fillers, lace bars, transverse, diagonal or lateral bracing, except to make holes true and square to members.

112. When plates are drilled as assembled, they must be separated after being drilled and cleaned of clippings forced between them by the drill. The square shoulders of all rivet holes under rivet heads must have a fillet of one-thirty-second (1-32) inch neatly removed.

113. Every built member or girder must be true and out of wind, neatly finished to length, and field driven rivets of all main girder connections shall be laid out with templates and accurately drilled, so as to pass the rivets cold.

114. Power riveting shall be used wherever possible. All rivets must have neatly capped full heads. Tightening loose rivets by recupping or "setting up" will not be allowed; they must be cut out and redriven, whether in shop or field. Rivets must be properly heated and driven to completely fill the holes. No loose rivets allowed.

See paragraph 68. **Bolts.**

XII. QUALITY OF MATERIAL.

A. WROUGHT IRON.

115. Wrought iron shall be made by the puddling process or rolled from fagots or piles made up from No. 1 wrought iron scrap, alone or with muck bar added. **Manufacture.**

Physical Properties. 116. The minimum physical qualities required shall be as follows:

Tensile strength, pounds per sq. inch.............48,000
Yield point, pounds per sq. inch...............25,000
Elongation, per cent. in 8 inches.................. 20

117. In sections weighing less than 0.654 pounds per lineal foot the percentage of elongation required shall be 15 per cent.

Cold Bending Tests. 118. Cold bending tests shall be made on specimens cut from the bar as rolled. The specimen shall be bent through an angle of 180 degrees by a succession of light blows.

Nicking Test. 119. When nicked and bent, it shall show a generally fibrous fracture, free from course crystalline spots. Not over 10 per cent. of the fractured surface shall be granular.

Hot Bending Tests. 120. Hot bending tests shall be made on specimens cut from the bar as rolled. The specimens, heated to a bright red heat, shall be bent through an angle of 180 degrees by a succession of light blows and without hammering directly on the bend.

121. If desired, a bar shall be worked and welded in the ordinary manner without showing signs of red-shortness.

Yield Point. 122. The yield point shall be determined by the careful observation of the drop of the beam or halt in the gauge of the testing machine.

Finish. 123. All wrought iron must be practically straight, smooth, free from cinder spots or injurious flaws, buckles, blisters or cracks. As the thickness of bars approaches the maximum that the rolls will produce the same perfection of finish will not be required as in thinner ones.

In flat and square bars one-thirty-second (1-32) inch variation either way from the size ordered will be allowed.

In round iron one one-hundredth (1-100) inch variation either way from the size ordered will be allowed.

B. CAST IRON.

124. Castings shall be of tough, gray iron, free from injurious cold shuts or blow holes, and of smooth, workmanlike finish.

One sample bar, one inch square, about five feet long, cast in sand mould, shall be furnished from each cast. This sample bar shall be capable of sustaining on a clear span of four and one-half (4½) feet, a central load of 500 pounds when tested in the rough bar.

C. WROUGHT STEEL.

125. All steel shall be open hearth, made at works of established reputation, which have been successfully manufacturing steel for at least one year. **Kind.**

126. If made in an acid furnace, the amount of phosphorous and sulphur in the finished product shall not exceed eight one-hundredths (.08) of one per cent. and six one-hundredths (.06) of one per cent., respectively. **Acid Open Hearth.**

127. If made in a basic furnace, the amount of phosphorus or sulphur shall not exceed six one-hundredths (.06) of one per cent. **Basic Open Hearth.**

128. The tensile strength, elastic limit, elongation and reduction of area shall be determined from a standard test piece cut from the finished material and planed or turned parallel for at least ten (10) inches of its length, the piece to have as nearly one-half (½) square inch sectional area as practicable, and the elongation to be measured on an original length of eight (8) inches. **Test Pieces.**

Specimens for bending tests shall be cut from the finished section and shall be of the same form as those used for tensile tests.

129. Three specimens, two for tensile tests and one for bending test, shall be furnished from each melt, except where a melt is rolled into widely varying sections, when each of such widely varying sections shall be represented by at least one test. **Number of Tests.**

Where only a small portion of a melt is rolled into the order covered by these specifications, it is left to the discretion of the engineer or his authorized representative to reduce the number of tests.

If the manufacturer so desires, the bending tests may be made on the broken tensile test pieces instead of on specimens as specified above.

Full Size Test.

130. Eyebars shall be of medium steel. Full-sized tests shall show twelve and one-half (12½) per cent. elongation in fifteen feet of the body of the eyebar, and the tensile strength shall not be less than 55,000 pounds per square inch. Eyebars shall be required to break in the body, but should an eyebar break in the head, and show twelve and one-half (12½) per cent. elongation in fifteen feet and the tensile strength specified, it shall not be cause for rejection, provided that not more than one-third (1-3) of the total number of eyebars tested break in the head.

The engineer will notify the contractor of the number of full sized eyebar tests required.

All bars which do not meet the requirements of the specifications shall be at the expense of the contractor, all others shall be paid for by the purchaser, at the contract price of finished metal work on cars at shops, less the scrap value of the broken bars. (See paragraph 161.)

131. Material which is to be used without annealing or further treatment is to be tested in the condition in which it comes from the rolls. When material is to be annealed or otherwise treated before use, the specimen representing such material is to be similarly treated before testing.

Grades.

132. Steel shall be of three grades: Medium, soft and rivet.

Medium Steel.

133. Specimens from finished material, cut to size specified above, shall have an ultimate tensile strength of not less than 60,000 nor more than 70,000 pounds per square inch; and elastic limit of not less than 35,000 pounds per square inch, and an elongation of not less than twenty-two (22) per cent.

This grade of steel to bend cold 180 degrees over a mandrel, the diameter of which is equal to the thickness of the piece tested, without a crack or flaw on the outside of the bent portion.

134. Specimens from finished material, cut to size specified above, shall have an ultimate tensile strength of not less than 52,000 nor more than 62,000 pounds per square inch; and an elastic limit of not less than 32,000 per square inch; and an elongation of not less than twenty-five (25) per cent. **Soft Steel.**

This grade of steel must stand bending cold 180 degrees and close down flat on itself without sign of fracture on convex side of curve.

135. Specimens cut to size specified above shall have an ultimate tensile strength of not less than 50,000 nor more than 60,000 pounds per square inch; an elastic limit of not less than 30,000 pounds per square inch, and an elongation of not less than twenty-six (26) per cent. **Rivet Steel.**

136. All blooms, billets or slabs shall be examined for surface defects, flaws or blow holes before being rolled into the finished sections, and such chippings and alterations made as will insure solidity in the rolled sections. **Chippings and Alterations.**

137. Every finished piece of steel shall be stamped with the melt number, and steel for pins shall have the number stamped on the ends. Rivet and lacing steel, and small pieces for pin plates and stiffeners, may be shipped in bundles, securely wired together, with the melt number on a metal tag attached. **Branding.**

138. The chemical analysis for carbon, phosphorus and sulphur of each melt must be furnished to the engineer or his representative at the mill, before any of the material rolled from said melt is shipped from the mill. **Chemical Analysis.**

139. Finished material must present a smooth, clean surface, free from cracks, buckles, flaws, ragged edges, or any other defects, and must be straight throughout and true to section. **Finish.**

140. A variation of more than two and one-half ($2\frac{1}{2}$) per cent. from ordered weight will be considered cause for rejection. **Variation in Weight.**

For all plates ordered to gauge, there will be permitted an average excess of weight over that corresponding to the dimensions on the order equal in amount to that specified in following table:

THICKNESS OF PLATE. Inch.	WIDTH OF PLATE.		
	Up to 75 inches. Per cent.	75 to 100 inches. Per cent.	Over 100 inches. Per cent.
¼	10	14	18
5-16	8	12	16
⅜	7	10	13
7-16	6	8	10
½	5	7	9
9-16	4½	6½	8½
⅝	4	6	8
Over ⅝	3½	5	6½

Shipments.

141. Shipments of material from the mills will not be permitted until after the tests have been made. Copies of all shipping invoices must be furnished to the engineer or his representative at the mill as shipments are made.

D. CAST STEEL.

142. Steel castings shall be made of a first class quality of open-hearth steel, sound, smooth, true to pattern, and free from blow holes, flaws and warps. All steel castings shall be thoroughly annealed at a temperature sufficiently high to make a blue scale, and when tested in three-quarter (¾) inch round turned test pieces, cut from castings, or from extensions cast to the castings, shall show an ultimate strength of from 65,000 to 75,000 pounds per square inch, and an elongation of not less than fifteen (15) per cent. in two (2) inches, and including the break.

E. PAINT.

Quality of Paint.

143. All paint for use in the "first coat" shall be of the best quality of graphite paint or of carbon primer, of a manufacture acceptable to the engineer.

144. All paint for use in the "finish coats" shall be of a quality and color specified on the second page hereof.

145. All surfaces that are inaccessible after being riveted, or after erection, shall have, before assembling or before erection, two (2) coats of pure red lead and boiled linseed oil, mixed in the proportion of eighteen (18) lbs. of lead to one (1) gallon of oil. **Inaccessible Surfaces.**

All bolts which are to remain permanently in the structure are to be dipped in "first coat," as described above.

146. As soon as shop work is complete, the material shall be thoroughly cleaned from all scale, rust, grease or other foreign matter, and given one coat of "first coat," as described above. **First Coat.**

147. Erection marks shall be made on the painted surface and not on the bare metal and then oiled over. **Erection Marks.**

148. After erection and before applying the finish coats, the material shall again be retouched and field rivets shall be painted with the "first coat," as described above; the field rivets shall be painted as soon as practicable after driving. **Retouching and Finish Coats.**

149. All metal work shall, after erection, be thoroughly cleansed from mud, grease or any other objectionable material that may be found thereon (wire brushes or scrapers shall be used when necessary or required by the engineer), and painted with two (2) coats of "finish coat," as specified above. **Finishing Coats.**

No painting will be allowed in wet or freezing weather, and all surfaces must be dry when paint is applied.

150. All turned or planed surfaces shall be coated with a mixture of white lead and tallow before being exposed to the weather. **Turned and Planed Surfaces.**

151. All paint and oil used for the structure shall be especially purchased, and the contractor will furnish the engineer with copies of all orders for same; and until all **Copies of Orders.**

such copies have been received by the engineer, no paint shall be applied.

F. TIMBER.

152. All timber shall be of the best quality of the kind specified, cut from sound, live timber, free from loose or rotten knots, worm holes, wind shakes or splits, reasonably well seasoned, straight grained, square edged, and free from any defect calculated to impair its strength or durability. Sap wood shall not be allowed in more than ten (10) per cent. of the pieces of one kind, and no piece will be accepted showing sap covering more than one-fourth (¼) the width of the piece on any face at any point, nor more than half the thickness of any plank at its edge, at any point.

XIII. WORKMANSHIP.

153. All workmanship must be strictly first class.

154. All members that may become bent or in any way injured in transportation or erection, or from any cause, must be repaired, straightened and made good to the satisfaction of the engineer.

155. All plates and shapes shall be carefully straightened before the work is laid out. and all work must be finished in a neat and workmanlike manner. The edges of sheared steel plates in main members shall be carefully faced or planed to effectively remove defects caused by shearing.

Annealing.

156. No forging or other work must be performed on any material at a temperature as low as a blue heat, and all steel forged work must be afterward thoroughly and uniformly annealed by heating throughout to a uniform dark red heat and being allowed to cool slowly.

Appearance.

157. Due regard must be had for the neat and attractive appearance of the finished structure; and details of workmanship of an unsightly character will not be allowed.

XIV. INSPECTION AND TESTS.

158. All material shall be subject to inspection and tests at mills and shops during the various processes of manufacture, and free access must be permitted for the Railway Company's engineer or inspectors at any works where material is in process of manufacture. A notice of at least one week must be given to the Railway Company when its inspector may be on hand for the performance of his duties. **Mill and Shop Inspection.**

159. All materials and workmanship shall be subject to inspection and rejection of the Railway Company's engineer; and all materials condemned by him shall be immediately removed from the work.

160. The inspection of the work shall not relieve the contractor of his obligation to perform sound and reliable work, as herein provided. And all work of whatever kind which, during its progress, and before it is finally accepted may become damaged from any cause, shall be replaced by good, sound work, satisfactory to the Railway Company's engineer. **Inspection not to Relieve Contractor.**

161. The contractor shall furnish the engineer or his inspector all necessary facilities for making the tests specified herein.

XV. ERECTION.

162. The contractor shall erect the bridge complete, in a thoroughly workmanlike manner and ready for the ties, and to the lines and grades furnished by the Railway Company's engineer. **Erection.**

163. The contractor for superstructure shall furnish and put in place all stone bolts and anchors for attaching the iron or steel work to the masonry. He will drill all the necessary holes in the masonry and set all bolts in neat Portland cement of a brand satisfactory to the Railway Company's engineer. When the requirements of the contract demand that the bolts or anchors be built in the masonry the contractor for the superstructure shall furnish **Anchor Bolts.**

said bolts and anchors and deliver them at the bridge site at such time as may be ordered by the Railway Company's engineer, but he will not be required to place them. (See paragraph 15.)

Lines, Grades, Etc.

164. All lines and grades are to be given by the Railway Company's engineer.

165. The stakes and marks given by the Railway Company's engineer must be carefully preserved by the contractor, who shall give the engineer all necessary assistance and facilities for the establishment of the lines and grades, and the measuring up of the work.

Unloading.

166. All material shall be unloaded at the bridge site with care and piled on skids well above the level of the ground.

False Work.

167. The contractor shall furnish and erect all false work, staging and scaffolding, and all tools and erection plant necessary to do the work thoroughly and expeditiously, and he shall remove the same as fast as the advance of the work will permit.

168. Before placing any false work, the contractor shall submit to the engineer for his approval, duplicate drawings, showing the location of all bents, and the placing of falsework other than such as is approved shall not be allowed.

Permits and Licenses.

169. The contractor shall give to the proper authorities all requisite notices relating to the work in his charge, and obtain all official permits and licenses for temporary obstructions, and pay all proper fees for same; and he shall pay for any other legal charges from city, town or county officers.

Damages.

170. The contractor shall pay all damages or losses or claims recovered that the owner may be made liable for, and save the owner harmless in all things from any accident which may happen or arise by reason of failure, neglect or refusal on his part or that of anyone in his employ to take all necessary precaution to prevent the same,

and also arising from any and all encroachments or trespassing on the neighboring property.

171. All refuse material and rubbish that may accumulate during the progress of the work shall be removed from time to time, and upon completion of the work all surplus material, falsework and rubbish shall be removed from the vicinity of the structure as may be directed by the Railway Company's engineer. **Refuse Material and Rubbish.**

172. When the erection is done by the Railway Company, the contractor shall furnish all necessary pilot nuts for erection, to be returned to contractor in as good condition as when received, when erection is completed.

XVI. NAME PLATES.

173. Two name plates of suitable size and design, and which may be required to be of aluminum or bronze, shall be provided and securely fastened at points to be designated by the engineer. The plates shall be inscribed as directed by the engineer.

XVII. GENERAL.

174. The structure shall be built under the direction of the engineer in charge, in accordance with the general drawings, and will include all work of any description, whether specifically set forth herein or on the drawings, or not, to make the work herein provided for complete, to the entire satisfaction of the Railway Company.

175. All fees or royalties for any patented invention, article or arrangement that may be used upon or in any manner connected with the construction, erection of the work, or any part thereof, embraced in these specifications, shall be included in the price mentioned in the contract; and the contractor shall protect and hold harmless the Railway Company against any and all demands for such fees, royalties or claims, and before the final payment or settlement is made on account of the contract, the contractor must **Patented Devices.**

furnish acceptable proof of a proper and satisfactory release from all such claims.

Subletting

176. No part of the work shall be sublet, nor shall the contract for the whole or any portion of the work be assigned unless by written consent of the Railway Company's engineer.

Employees.

177. Should any disorderly or incompetent person be employed upon the work, he shall upon notice from the Railway Company's engineer be discharged and not employed again without his permission.

Changes.

178. The work shall be done substantially in accordance with the accepted plans, details and directions by the engineer, and in accordance with these specifications, but the right is reserved by the Railway Company, without incurring any liability therefor, to make such changes in the said general or detail plans and in the specifications as its engineer may deem necessary for the convenience, safety and stability of the work, or as shall be deemed advisable or desirable by him, to make the same a satisfactory piece of work.

179. The right is also reserved by the Railway Company, without incurring any liability therefor, beyond the contract price, except as hereinafter provided, to increase or diminish the amount of labor or material, or both, herein provided for, within such limits as shall be deemed necessary by said engineer to make said work, when completed, a satisfactory piece of work.

180. But if any such change in any of the said general or detailed plans, or in the specifications, shall, in the opinion of the Railway Company's engineer, materially increase the actual cost of performing the labor necessary to construct the portions of the work thereby changed, beyond what such labor would have cost, if performed without such change, then the contractor shall receive the amount of such increased cost, as determined by the engineer, with ten (10) per cent. thereof additional, such percentage to be for and in lieu of profits; any decrease in such cost, as

determined by the engineer, shall inure to the benefit of the Railway Company.

181. And if by any such change in any of the said general or detail plans, or in these specifications, any material is used in the structure, the cost of which is, in the opinion of the Railway Company's engineer, in excess of that herein provided for, the contractor shall receive such excess of cost, as determined by the said engineer, and ten (10) per cent. thereof additional, such percentage to be for and in lieu of profits; any decrease of such cost, as determined by said engineer, shall inure to the benefit of the Railway Company.

Claims.

182. The contractor shall make no claim against the Railway Company for damages or losses occasioned by the elements or from any causes for which the Railway Company is not responsible. No claim for extra work not provided for in the plans and specifications will be allowed unless a written order to perform such work shall have been given by the Railway Company's engineer, and all claims for such work shall be presented in writing for settlement in the monthly estimate next after such work shall have been performed. Claims by the contractor for damages by reason of any detention on the part of the Railway Company will not be allowed, but any such detention shall make a corresponding extension of the time for completion of the contract.

Commencement of Work.

183. The work herein provided for shall be commenced upon any part or portion of the same, as the Railway Company's engineer may direct, within ten (10) days after receipt of written notice from the engineer so to do.

Prosecution of Work.

184. The work shall be prosecuted continuously and in the most energetic, expeditious and workmanlike manner, with the largest force of all classes of workmen that can be worked to advantage, and the contractor shall supply sufficient plant to work at such places and at as many places as the Railway Company's engineer may direct until the whole shall have been completed; or work upon any part or portion of the structure shall at any time be wholly or partially suspended or discontinued by order of the engineer, when-

ever in his opinion the best interests of the owner or the progress of the work upon other parts or portions of the structure may demand it.

Completion of Work.

185. The entire work herein provided for shall be prosecuted in such manner that the whole shall be complete and ready for acceptance by the Railway Company at or before the time specified on the first page hereof, or in the event that the contractor fail to complete the work within such specified time, he will be liable for any and all damage which the Railway Company may suffer in consequence of the delay; provided that any mutual agreement, set forth in the contract of which these specifications form a part, relating to damages for delay of completion after the specified time or to awards for completion before the specified time, shall be and remain in full force and effect.

186. If at any time during the progress of the work it should appear by the report of the engineer that the force employed, the quantity or quality of tools or appliances provided, or that the progress or character of the work or material furnished are not respectively such as, in the opinion of the engineer, will insure the completion of the work under this contract within the time specified, or not in accordance with the specifications, then in that case the Railway Company may serve written notice on the contractor and sureties to at once supply such increase of force, appliances or tools, and to cause such improvement to be made in the character of the work or materials, as will be required to make the same conform to these specifications and the requirements of the engineer; and if, on the expiration of three (3) days after the service of such written notice upon the contractor and sureties personally, or by leaving same or mailing same for them at last known addresses, the contractor shall have failed to furnish to the Railway Company satisfactory evidence of his efforts, ability and intentions to remedy the specified deficiencies, the Railway Company may thereupon enter and take possession of the said work or any part thereof, with tools, materials, plant, appliances, houses, machinery

and other appurtenances thereon, hold the same as security for any and all damage or liabilities that may arise by reason of the nonfulfillment of this contract within the time specified, and, furthermore, may employ the said tools and other appurtenances, materials, and such other means as it may deem proper to complete the work at the expense of the contractor, and may deduct the cost of the same from any payment then due or thereafter falling due to the contractor for this work; and, in case the contractor shall not complete the work within the time specified, and the Railway Company shall, notwithstanding such failure, permit the contractor to proceed with and complete the said work as if such time had not elapsed, said permission shall not be deemed a waiver in any respect by the Railway Company of any forfeiture or liability for damages or expenses thereby incurred, arising from such non-completion of said work within the specified time, but such liability shall continue in full force against the contractor and his sureties as if such permission had not been given.

Estimates and Payments.

187. Approximate estimates will be made monthly by the Railway Company's engineer if requested by the contractor, upon the amount of acceptable material delivered at the bridge site or erected in place, and also reasonable estimates will be allowed at the discretion of the engineer upon acceptable material delivered at the shops in reasonable amounts and proper condition.

Ninety (90) per cent. of the amounts of such estimates will be paid in cash within fifteen (15) days after approval of such estimates by the Railway Company provided no legal restraints are placed upon such owner preventing such payment. The remaining ten (10) per cent. will be paid within fifteen days after the final completion and acceptance by the Railway Company of all the work herein specified, provided the same is free from all claims for labor and material under these specifications, which might in any manner become a lien upon said structure or a claim upon the Railway Company.

Comply with All Laws.

188. The contractor shall be required to comply with all federal, state, city, town or other laws and statutes in force in

the locality, and it is understood and agreed that the contract of which these specifications are a part, is made and executed subject to the terms and conditions of any and all such laws. The contractor will be expected to inform himself regarding such laws, and to govern himself accordingly.

Special Clauses.

189. All the written part of these specifications and any special clauses attached hereto, and referring to this structure, are to be considered as a part hereof, and shall be as carefully noted and as strictly followed as if printed herein.

Plans and Specifications.

190. The plans and specifications are intended to be explanatory of each other, but should any discrepancy appear, or any misunderstanding arise as to the import of anything contained in either, the interpretation of the Railway Company's engineer shall be final and binding on the contractor; and all directions and explanations required, alluded to or necessary to complete any of the provisions of these specifications, and give them due effect, will be given by the engineer.

Engineer.

191. The term "engineer," as herein used, is understood to mean the chief engineer in charge of the work, and the work at all times shall be under his control, and the decisions of said engineer upon all questions as to estimates or the determination of the quantity or quality of the work, and on all other questions herein left to his discretion, shall be final and conclusive.

The above constitute the specifications referred to in the contract of the undersigned with

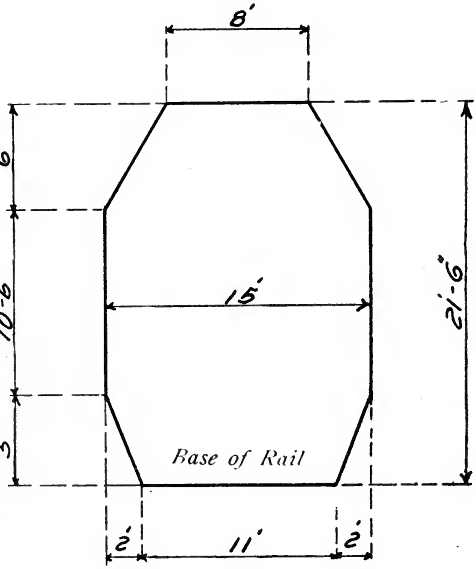
....

dated ....

Contracting firm ....

By ....

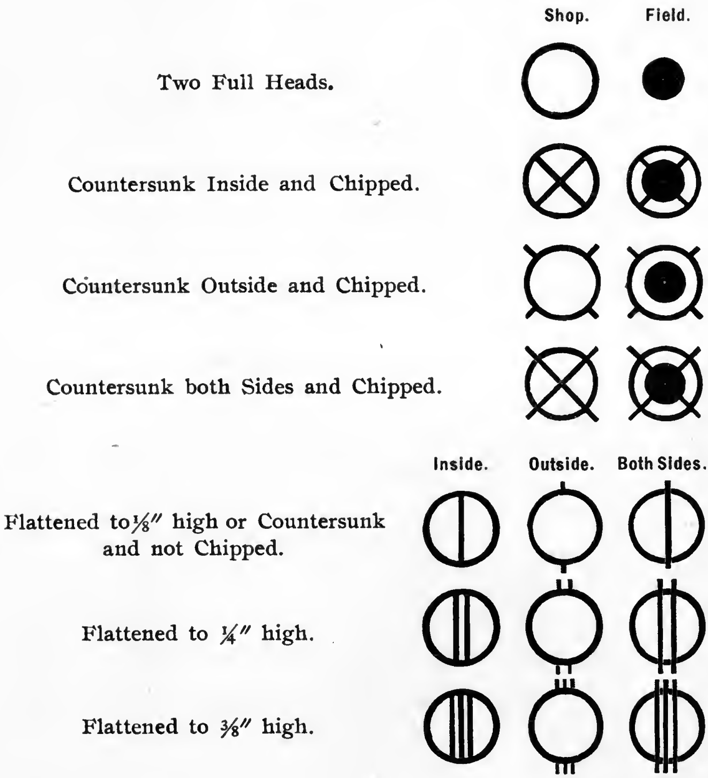
APPENDIX A.



CLEARANCE DIAGRAM FOR THROUGH BRIDGES.

Appendix B.

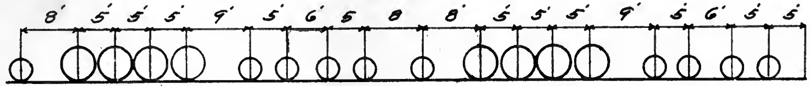
CONVENTIONAL SIGNS FOR BRIDGE RIVETS.



Appendix C.

Cooper's Standard Loading.

Distances in feet.



Class																			Uniform Load.
E 50	25000	50000	50000	50000	50000	32500	32500	32500	32500	25000	50000	50000	50000	50000	32500	32500	32500	32500	5000 lbs. per lin. ft.
E 45	22500	45000	45000	45000	45000	29250	29250	29250	29250	22500	45000	45000	45000	45000	29250	29250	29250	29250	4500 lbs. per lin. ft.
E 40	20000	40000	40000	40000	40000	26000	26000	26000	26000	20000	40000	40000	40000	40000	26000	26000	26000	26000	4000 lbs. per lin. ft.
E 30	15000	30000	30000	30000	30000	19500	19500	19500	19500	15000	30000	30000	30000	30000	19500	19500	19500	19500	3000 lbs. per lin. ft.
E																			