A. G. House

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"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,
1906.

By THEODORE COOPER,
Consulting Engineer.

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

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PREFACE.

The author's first railroad bridge specifications were prepared over a quarter of a century ago. From time to time these have been revised to meet the requirements of increasing train loads and the improvements in material and methods of construction. This edition is the tenth revision, seventh of those published in his own name.

While these specifications are "general" in their requirements, they are more especially intended to cover ordinary railroad bridges or those resting on two supports only. For special structures or those having special or unusual conditions and requirements, they should be supplemented by clauses suitable for the particular case.

Specifications have no executive functions. Unless intelligently supervised and executed, they have little value. The author's experience forces him to the conclusion, that plans and structures fully complying with the specifications, are limited in number; many are defective in important details.

We are now at a period, when railroads will demand bridges capable of carrying the maximum possible train loadings, not only safely, but rigidly. There will be hereafter no increasing train loads to cover or excuse the faults of design, details of construction or inferior material. Bridges of the future must be relatively better than those of the past. Any false economy by scrimping the details or using an inferior class of material will not redound to the credit of the Bridge Engineer.

N. B.—The author cannot undertake, through correspondence, to discuss, explain or instruct in regard to the use of these specifications.

General Specifications for Steel Railroad Bridges and Viaducts.

SEVENTH EDITION.

1906.

GENERAL DESCRIPTION.

1. All the structures shall be of wrought steel, as specified. (§§ 133-148) 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 bearings 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 bridges the clear width from the centre of the track to any part of the trusses shall not be less than seven (7) feet between the heights of two feet and fifteen feet 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, 57 feet c. to c. of trucks and 80 feet over all, will be as follows :

For curvature, $0.85 D$ inches on each side ;

$1.7 D$ 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.)

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

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

10. Unless otherwise specified, the form of bridge trusses Form of Trusses. may be selected by the bidder; for through bridges, the end vertical suspenders and two panels of the lower chord, at each end, shall be made rigid members. In general, all spans shall have end floor beams for supporting the stringers, (§ 14.); and all floor beams shall be riveted to the posts and vertical suspenders, above or below the pins, (§ 111), or to the chords.

11. All lateral, sway and portal bracing must be made of Lateral Bracing. shapes capable of resisting compression as well as tension, and must have riveted connections. (§§ 33, 40, 83).

12. The wooden floors will consist of transverse ties or Wooden Floor. 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 $\frac{1}{2}$ inch and 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.

13. There shall be a guard timber (scantling not less than Guard Timbers. 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 ($\frac{3}{4}$) inch bolt. All heads or nuts on upper faces of ties or guards must be countersunk below the surface of the wood. (§ 65).

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

15. The maximum strain allowed upon the extreme fibre Allowed Strain on Timber. 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.

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. (§ 5.)

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; and state kind of material to be used (§§ 138, 144).

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 $4\frac{1}{2}$ 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."

Class.	STANDARD TRAIN LOADINGS. Distances in feet.												Uniform Load.
	8	5	3	5	3	5	3	5	3	5	3	5	3
E 30	15000	30000	30000	30000	30000	30000	15000	30000	30000	30000	30000	19500	3000 lbs. per lin. ft.
E 35	17500	35000	35000	35000	35000	35000	17500	35000	35000	35000	35000	22750	3500 lbs. per lin. ft.
E 40	20000	40000	40000	40000	40000	40000	20000	40000	40000	40000	40000	26000	4000 lbs. per lin. ft.
E 45	22500	45000	45000	45000	45000	45000	22500	45000	45000	45000	45000	29250	4500 lbs. per lin. ft.
E 50	25000	50000	50000	50000	50000	50000	25000	50000	50000	50000	50000	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 E 40; and of 120,000 pounds for all classes above E 40.

For any higher train loading than E 40, all double track bridges with two trusses, for spans 150 feet and over, may be proportioned for the higher train loading on one track and E 40 loading on the second track.

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.

Lateral Forces. 24. To provide for wind 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. (§ 11.)

The bottom lateral bracing in deck bridges, and the top lateral bracing in through bridges, shall be proportioned to resist a lateral force of 200 pounds for each lineal foot for spans up to 200 feet, and 25 pounds additional for each additional 50 feet. (§ 11.)

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 only 1,100 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.

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

29. When the structures are on curves, the additional effects due to the centrifugal force of trains on each track 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 (§ 109).

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, net sections:

<i>For Medium Steel.</i>		Pounds per square inch.
Floor beam hangers, when permitted (§ 94).		6,000
Longitudinal, lateral and sway bracing, for lateral forces (§§ 8, 24, 25)		18,000
Longitudinal, lateral and sway bracings, for live load (§§ 27, 29, 109).		12,000 Medium Steel.
Solid rolled beams, used as cross floor beams and stringers (§§ 45, 49).		10,000

	Pounds per square inch.	
	For live loads.	For dead loads.
Bottom flanges of plate girders (§ 46), chords and webs of lattice and pin- connected trusses.....	10,000	20,000
Verticals carrying floor beams (§ 10)....	8,000	16,000

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 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. (§ 50.)

Low Steel. 32. *Low Steel* (§ 144) may be used in tension with unit strains ten per cent. less than those allowed for *Medium Steel* (§ 138), except for eye-bars (§ 125).

33. When but one leg of a single angle is riveted to its connection the section of that leg only will be considered as effective in tension.

Net Section. 34. In members subject to tensile strains full allowance shall be made for reduction of section by rivet-holes, screw-threads, etc. (§§ 63, 64).

Compressive Strains. 35. Compression members shall be proportioned by the following allowed unit strains:

For Medium Steel.

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

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

.....
All posts of
t h r o u g h $P=8,500-45\frac{l}{r}$ for live load.
bridges.

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

All posts of
deck bridges
and trestles.

$$P = 9,000 - 40 \frac{l}{r} \text{ for live load.}$$

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

End posts are not to be considered chord segments.

Lateral struts
and rigid
bracing.

$$P = 13,000 - 60 \frac{l}{r}$$

for lateral forces (§§ 24, 25);

for live load strains use two-thirds of the
above (§§ 27, 29, 109).

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. The least width of posts
will be 10 inches.

Limitation of
Length and
Width of
Compression
Members.

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.

36. *Low Steel* (§ 144) may be used in compression with
unit strains ten per cent. less than those allowed for *Medium*
Steel. (§ 138.)

Low Steel.

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

38. All members and their connections subject to alter-
nate strains of tension and compression shall be propor-

Alternate
Strains.

tioned 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 of the members by the above-allowed unit strains. (§§ 31, 35.) The connections of such members must have the rivets and bearing areas on pins increased 50 per cent. over the usual requirements (§§ 40, 41).

Effect of Lateral
Forces on Chord
Strains.

39. The strains in the truss members or trestle posts from the assumed lateral forces need not be considered except as follows:

1st. When the strains on any member from the lateral forces 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 lateral forces, alone or in combination with other forces, can neutralize or reverse the strains in any member. (§§ 27, 28, 29.)

Rivets, Bolts
and Pins.

40. 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 $\times$ 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 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. Each connection of the bracing must have at least three rivets in plate girder spans and four rivets in truss spans and trestles.

Rivets countersunk in material of less thickness than the diameter of the rivet, shall only be given a value compared to that of a regular rivet equal to the proportion of the

thickness of the material countersunk to the diameter of the rivet.

In the case of field riveting (and for bolts as per § 65) the above-allowed shearing strains and pressures shall be reduced one-third.

Rivets and bolts must not be used in direct tension.

41. Pins shall be proportioned so that the shearing strain Pins. shall not exceed 9,000 pounds per square inch ; nor the pressure on the bearing surface of any member connected to the pin be greater per square inch than 12,500 pounds for the live load and 25,000 pounds for the dead load, (§ 68) ; 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.

42. When any member is subjected to the action of both Combined Strains. axial and bending strains, as in the case of end posts of through bridges (§ 39), 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.

43. 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.

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

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

Rolled beams used as longitudinal girders shall have, preferably, a depth not less than $\frac{1}{10}$ of the span.

46. Plate girders shall be proportioned upon the supposition that the bending or chord strains are resisted entirely Plate Girders, etc. 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. 47. 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:

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

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.

Stiffeners. 48. At any point, the combined stiffeners, fillers and in-closed web, acting together as one column, must be capable of carrying the maximum vertical shear without exceeding the allowed unit strain:

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

The stiffeners must connect to the webs by enough rivets to transfer the maximum shear to or from the webs.

Rolled Beams. 49. Rolled beams shall be proportioned (§§ 31, 45) by their moments of inertia.

Counters. 50. 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 inches, or else must be capable of carrying all the counter live load in that panel. (§ 92.)

51. Counters shall be provided and proportioned so that either a future increase of 25 per cent. in the specified live load, or the maximum loading E 50, shall not in any case increase the allowed unit strain more than 25 per cent.

DETAILS OF CONSTRUCTION.

Details. 52. 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.

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

54. The pitch of rivets in all classes of work shall never Riveting. exceed 6 inches, or sixteen times the thinnest outside plate, nor be less than three diameters of the rivet. (§§ 81, 96.)

55. The rivets used shall generally be $\frac{7}{8}$ inch diameter for main members of the trusses and floor, and not less than $\frac{3}{4}$ for lateral or other bracing.

56. 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.

57. 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.

58. 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.

59. 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.

60. 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.

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

62. 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.

63. 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 mem-

bers, the diameter of the rivet-holes will be assumed as $\frac{1}{8}$ inch larger than the undriven rivets.

64. 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 zig-zag 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.

Bolts. 65. 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.

66. All nuts must be of hexagonal shape. (§ 93.)

Splices. 67. All joints in riveted tension members must be fully and symmetrically spliced.

68. Riveted tension members shall have an effective section through the pin-holes one-third in excess of the net section of the member, and back of the pin at least 60 per cent. of the net section through the pin-hole (§ 41).

Abutting Joints. 69. 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.

70. In compression members, abutting joints with un-tooled 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. 71. The webs of plate girders must be spliced at all joints by a plate on each side of the web.

Stiffeners. 72. 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. (§§ 47, 48.)

73. 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.

74. 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 $\frac{1}{8}$ inch below the face of these angles, at any point. (§§ 75, 158.) Web Plates.

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

76. 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

77. 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.

78. 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. Lattice Girders.
(§ 97.)

79. 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.

80. 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.

81. 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 3 inches apart.

Thickness of Metal.

82. 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.

Limitation of Angles and Channels.

83. Connection angles for stringers or floor beams shall have no leg less than $3\frac{1}{2}$ inches or be of less thickness than $\frac{1}{2}$ inch. (§ 102.)

No angle less than $3 \times 2\frac{1}{2}$ inches shall be used for bracing.

The width of channels used for bracing shall not be less than 6 inches for single or 8 inches for double track bridges.

Eye-Bars.

84. 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.)

85. 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.

86. The bars must be bored to lengths not varying from the calculated lengths more than $\frac{1}{84}$ of an inch for each 25 feet of total length.

87. 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.

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

Pins.

89. The pins shall be turned straight and smooth; chord pins shall fit the pin-holes within $\frac{1}{80}$ 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.

90. The diameter of the pin shall not be less than eight-

tenths the width of the largest 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.

91. All bars with screw ends shall be upset at the ends, Upset Ends. so that the diameter at the bottom of the threads shall be $\frac{1}{8}$ inch larger than any part of the body of the bar.

92. Where closed sleeve nuts are used on adjustable Adjustable Members. members the effective length of thread shall be legibly stamped at the screw ends of each bar. Adjustable counters to be avoided where practicable.

93. Screw threads must be of the United States standard, except at the ends of the pins, and except for rods over $1\frac{3}{8}$ in. diameter, where they shall be six threads to the inch.

94. In special cases, where floor beam hangers may be Hangers. permitted, they must be rigidly attached to the trusses and be so arranged as to stay the floor beams firmly against rotation or end motion. (§ 10.)

95. Compression members shall be of steel, and of ap- Compression Members. proved forms. (§ 35.)

96. 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.

97. The open sides of all compression members shall be Latticing. 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 $\frac{1}{8}$ or double lattice bars connected by a rivet at the intersection not less than $\frac{1}{8}$ of the distance between the rivets connecting them to the members. They shall be in-

clined 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 least width of the member plus nine inches.

98. 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. (§ 41.) 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. (§ 97.)

99. 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.

100. In compression chord sections and end posts, the material must be mostly 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 § 80. (§ 42.)

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

Floor Beams
and Stringers.

102. 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. (§ 83.)

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

Pin-Holes.

104. 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.

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

106. 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 lateral forces. (§§ 4, 11, 24.) Transverse
Diagonal
Bracing.

107. 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.

108. Pony riveted trusses and girders shall be stayed by knee braces or gusset plates at the ends and at intermediate points.

109. All deck girders shall have transverse braces at the ends. All deck bridges shall have transverse bracing at each panel point, of sufficient strength to carry half the maximum strain increment due to lateral and centrifugal forces. This bracing shall be proportioned in double-track bridges to resist the unequal loading of the trusses, with one track loaded.

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

111. At all points where floor beams, portals or other bracing connect with the posts or chords, proper diaphragms must be inserted to distribute the loads and forces over the full section of these posts or chords. Diaphragms.

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

113. All bed-plates must be of such dimensions that the greatest pressure upon the pedestal stone shall not exceed 250 pounds per square inch. Their upper bearing surfaces should, preferably, be at least six inches above the masonry. Bed-Plates.

114. All bridges over 80 feet span shall have hinged bolsters at both ends, and at one end nests of turned friction rollers. Friction Rollers.

tion rollers or rockers running between planed surfaces. These rollers shall not be less than $4\frac{7}{8}$ inches diameter for spans 100 feet or less, and for greater spans this minimum diameter shall be increased in proportion of 1 inch for each 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 drained and cleaned.

115. 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.

116. 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.

117. 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.

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

118. 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; and must be inserted at least six diameters into the masonry. The contractor must furnish all bolts, drill all holes and set bolts to place with sulphur or Portland cement.

119. 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.

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

121. The lower struts in trestle towers must be capable Trestle Towers. 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.

122. All joints in the tower columns shall be fully spliced for all possible tension strains, and to hold the parts firmly in position. (§§ 25, 69.)

123. Tower footings, pedestals 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. (§ 28.)

124. All workmanship shall be first class in every particular. Workmanship.

125. All eye-bars must be made of Medium Steel. (§§ 138-142.)

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

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

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

129. The steel (§§ 138-144) may be used in tension with- Reaming. out reaming of punched holes up to $\frac{1}{8}$ inch in thickness, and may be used in compression without reaming for all thicknesses of metal which will stand the drifting test. (§ 146.) In all other cases, the steel must have all holes drilled or reamed to a diameter $\frac{1}{8}$ inch larger than the punched holes.

Planing of
Edges.

Similarly, the sheared edges must be planed off to a depth of $\frac{1}{8}$ inch, so as to remove all the sheared surface of the metal, wherever reaming of punched holes is required.

130. 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 low steel in connection with compression members of medium steel.

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

Pilot Nuts. 132. Pilot nuts must be used during the erection to protect the threads of the pins.

QUALITY OF MATERIAL.

STEEL.

133. All steel must be made by the Open Hearth process. The phosphorus must not exceed 0.08 of one per cent. for steel made by the acid method, or 0.04 for steel by the basic method.

134. The steel must be uniform in character for each specified kind. The finished bars, plates and shapes must be free from injurious seams or flaws, cracks on the faces or corners, or other defects, 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.

135. 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.

136. 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

* 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.

or otherwise treated before use, the specimen representing such material may be similarly treated before testing for tensile strength.

The elongation shall be measured on an original length of 8 inches. At least two test pieces shall be taken from each melt or blow of finished material, one for tension and one for bending. (Art. 153.)

137. 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.

138. **Medium Steel** shall have an ultimate strength, when Medium Steel. tested in samples of the dimensions above stated, of 60,000 to 70,000 pounds per square inch, an elastic limit of not less than one-half of the ultimate strength, and a minimum elongation of 20 per cent. in 8 inches. But for eye-bar material, not over 20 per cent. of the material must run below 62,000 or above 68,000 pounds per square inch. Steel for pins may have a minimum elongation of 15 per cent.

139. 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.

140. Eye-bar material, $1\frac{1}{2}$ inches and less in thickness, Eye-Bars. 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 $\frac{1}{4}$ of an inch increase of thickness, to a minimum of 18 per cent. No bars over 2 inches in thickness will be used, except by special permission.

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. Full sized material for eye-bars shall bend cold 180° to a curve, whose inner radius is equal to the thickness of the material, without fracture on the outside of the bend.

143. 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. (§ 138.)

Low Steel. *144. **Low Steel** shall have an ultimate strength, on same sized samples, of 55,000 to 65,000 pounds per square inch, an elastic limit not less than one-half the ultimate strength, and a minimum elongation of 23 per cent. in 8 inches.

145. 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.

Drifting. 146. For both kinds of steel, $\frac{5}{8}$ inch or less in thickness, rivet holes punched as in ordinary practice (§§ 55, 56, 57), must stand drifting to a diameter one-third greater than that of 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.

Rivet Steel. 147. **Rivet Steel** shall have an ultimate strength of 48,000 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.

148. The steel for rivets must, under the above bending test (145), stand closing solidly together without sign of fracture. When nicked and bent around a bar of its own diameter it shall break gradually and give a fine, uniform, silky fracture.

Variation in Size. 149. 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. 150. Steel castings will be used for drawbridge wheels, track segments and gearing. (Art. 1.)

* Use permitted, but not recommended.

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.

151. Except where cast steel or chilled iron is required, Cast Iron. 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.

152. The timber shall be strictly first-class Timber.

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.

153. All facilities for inspection of the materials and Inspection. 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.

154. 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.

155. 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 test, it will be considered rejected material, and be solely at the cost of the contractor.

PAINTING.

Painting. 156. All metal work (except § 159) before leaving the shop shall be thoroughly cleaned from all loose scale and rust and oil, and be given one good coating of pure raw linseed oil, well worked into all joints and open spaces.

157. In riveted work the surfaces coming in contact shall each be painted before being riveted together. Bottoms of bed-plates, bearing-plates, tooled ends and joints of chords and posts, 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.

158. 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.

159. 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. 160. 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.

161. 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.

162. 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.

163. 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 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.

All plans, including working drawings, must be submitted Export Work. 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 legibly 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 legibly 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 (§ 132) for all pins shall be sent with the pins.

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.

CHANGES AND ADDITIONS

MADE IN

THIS EDITION.

§§ 5, 10, 14, 20, 23, 24, 26, 29, 31, 32, 33, 35, 36, 38, 39, 40,
41, 48, 51, 55, 68, 81, 83, 90, 93, 94, 108, 109, 111, 113, 114,
118, 123, 129, 133, 134, 138, 140, 142, 144, 146, 147, 148, 156,
157, Table III.

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CONTENTS

BY

THE EDITOR

THE EDITOR'S NOTE
ON THE JOURNAL OF THE
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1908

APPENDIX.

TABLE I.
MAXIMUM MOMENTS *M*, END SHEARS *S*, AND FLOOR-BEAM REACTIONS
R, PER TRACK, FOR LOADING E 40, FOR GIRDER BRIDGES.

Span <i>L</i> , Ft.	Max. mom. <i>M</i> , Ft.-lbs.	Max. end shear <i>S</i> , Lbs.	Max. floor reac. <i>R</i> , Lbs.	EQUIVALENT UNIFORM LOAD.		
				<i>M</i> , Lbs.	<i>S</i> , Lbs.	<i>R</i> , 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	93 800	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	10 530	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	8 750	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,	6 060	6 970	.....
52.....	2 030 000	178 500	233,500	6 010	6 870	.....
54.....	2 162 000	182 400	.....	5 980	6 760	.....
56.....	2 304 000	186 000	.....	5 840	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	6 500	.....
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	253 600	.....	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., <i>M</i> , Ft.-lbs.	Max. shears, <i>S</i> , Lbs.	Equiv. unif. load.			Max. mom., <i>M</i> , Ft.-Lbs.	Max. shear, <i>S</i> , Lbs.	Equiv. unif. load.		
			<i>M</i> , Lbs.	<i>S</i> , Lbs.				<i>M</i> , Lbs.	<i>S</i> , Lbs.	
10...	125 000	70 000	10 000	14 000	E 40	150 000	84 000	12 000	16 800	E 50
11...	145 500	72 700	9 630	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	
15...	240 000	80 000	8 540	10 670		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	E 35	404 200	101 100	8 960	10 600	E 41
20...	361 200	85 000	7 220	8 500		433 500	102 000	8 660	10 300	
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	E 30					
28...	558 000	89 350	5 700	6 380						
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 driver.	Total load on drivers.	Load per 2 drivers.	Load per foot for all drivers.	Load per foot for tender.	Load per whole engine.	Load per foot for tender.	Equivalent typical engine.
<i>Passenger Engines:</i>	Tons.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	
C. M. & St. P. R. R.	172	218 000	125 600	47 500	142 000	16 000	11 360	7 000	6 750	5 720	E. 40
N. Y. C. & H. R. R. R.	169	194 500	144 000	49 000	148 000	14 200	8 760	8 000 ¹	7 250	5 710	" 45
C. B. & O. R. R.	183	212 500	154 000	51 380	154 000	15 300	11 560	7 500 ²	6 920	5 890	" 46
D. L. & W. R. R.	160	201 000	120 000	52 000	154 000	14 360	10 740	8 000 ³	7 580	6 300	" 50
A. T. & St. Fe R. R., oil burning....	201	226 700	176 000	50 630	151 900	14 800	11 120	7 500 ⁴	7 400	6 100	" 50*
L. S. & M. S. R. R.	194 ¹	233 000	155 000 ²	55 330	166 000	15 800	11 860	8 000 ³	6 800	6 200	" 50*
Cooper's E. 40.....	142	180 000	104 000	50 000	160 000	16 666	10 666	6 500	7 326	5 916	E. 38 to E. 40 for short spans.
<i>Freight Engines:</i>											
L. V. R. R., 1100 class.....	156	185 000	117 000	42 750	171 000	15 785	10 523	6 500	7 671	5 707	E. 40
L. E. R. R., H. B.	151.3	198 000	104 600	45 600	177 000	13 665	10 114	6 400	7 627	5 327	" 45
L. E. & W. R. R., Brooks.....	135.5	205 000	108 000	46 000	184 000	18 100	12 000	6 400	8 307	6 130	" 45
M. St. P. & S. M. R. R., Decapod..	167	214 000	123 000	42 000 ²	180 000	15 500 ³	9 328	6 600	7 943	6 590	" 46
Ill. Cen. R. R.	172.5	222 200	133 700	50 000 ²	183 200	16 500	12 267	7 382	8 702	6 045	" 46
L. V. R. R., Class 661.....	170.5	227 000	132 000	52 165	204 200	20 781	13 350	7 389	9 525	6 735	" 50
Union R. R., 1885	169	220 000	114 000	57 000	177 500	17 600	11 250	7 200 ⁴	8 383	6 085	" 50
N. T. & H. R. R., 1065.....	183.4	227 500	134 300	40 800	177 500	17 600	11 250	7 200 ⁴	8 383	6 085	" 50
A. T. & St. Fe R. R., Decapod	203.7	257 800	143 000	54 800	207 800	20 440	11 200	7 600	8 570	6 740	" 50*
Malles Articulated, B. & O. R. R.	228.7	324 500	143 000	55 700	207 800	22 300	16 725	7 600	10 300	7 390	" 50*
P. B. & L. E. R. R., 150.....	197.2	230 300	141 100	57 500	225 200	23 000 ²	14 444	6 000	10 274	6 730	" 50*
Cooper's E. 50.....	177.5	225 000	130 000	60 000	200 000	20 000	13 333	8 125	9 782	7 305	

* Slightly exceeds E 50 for very short spans only.

RELATIVE COST OF BRIDGES

Built Under These Specifications

FOR THE

DIFFERENT CLASSES OF LOADINGS.

The increased cost and weight of metal 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 typical of those in use on the principal railroads of the United States at the beginning of the Twentieth Century.

As far as the effects upon the bridges are concerned, these engines are represented by the typical train loadings of these specifications, E 38 to E 50.

The heavier of these engines are close to the possible maximum, considering the limitations of the permissible cross section of existing railroads, fixed wheel base and the mechanical details of design and proportions.

There are now in general use 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. There are special cars which have, when fully loaded, 50,000 pounds on each axle, but such cars would never be put together in series. It is recommended that train loading E 40 be the *minimum* adopted by any railroad in North America carrying general traffic. Train load E 50, under the requirements of these specifications, will, in the opinion of the author, be sufficient to provide for any possible future loading. Many important systems have already adopted it as their standard loading.

THEODORE COOPER.

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