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General Specifications For Steel Railway Bridges.

American Railway Engineering Association, 1910

PART FIRST—DESIGN.

I. General.

1. The material in the superstructure shall be structural steel, except rivets, and as may be otherwise specified.

2. When alignment is on tangent, clearances shall not be less than shown on the diagram; the height of rail shall, in all cases, be assumed at 6 ins. The width shall be increased so as to provide the same minimum clearances on curves for a car 80 ft. long, 14 ft. high, and 60 ft. centre to centre of trucks, allowance being made for curvature and superelevation of rails.

3. The width centre to centre of girders and trusses shall in no case be less than one-twentieth of the effective span, nor less than is necessary to prevent overturning under the assumed lateral loading.

4. Ends of deck plate girders and track stringers of skew bridges at abutments shall be square to the track, unless a ballasted floor is used.

5. Wooden tie floors shall be secured to the stringers and shall be proportioned to carry the maximum wheel load, with 100 per cent impact, distributed over three ties, with fibre stress not to exceed 2,000 lbs. per sq. in. Ties shall not be less than 10 ft. in length. They shall be spaced with not more than 6-in. openings; and shall be secured against bunching.

II. Loads.

6. The dead load shall consist of the estimated weight of the entire suspended structure. Timber shall be assumed to weigh $4\frac{1}{2}$ lbs. per ft. B. M., ballast 100 lbs. per cu. ft., reinforced concrete 150 lbs. per cu. ft., and rails and fastenings 150 lbs. per linear ft. of track.

7. The live load, for each track, shall consist of two typical engines followed by a uniform load, according to cooper's series, or a system of loading giving practically equivalent stresses. The minimum loading to be Cooper's E-40, as shown in the following diagrams: and the diagram that gives the larger stresses to be used.

8. Heavier loadings shall be proportional to the above diagrams on the same spacing.

9. The dynamic increment of the live load shall be added to the maximum computed live-load stresses and shall be determined by the formula $I = L\frac{300}{l+300}$

where I=impact or dynamic increment to be added to live-load stress,

L=computed maximum live-load stress.

l=loaded length of track in feet producing the maximum stress in the member.

For bridges carrying more than one track, the aggregate length of all tracks producing the stress shall be used.

Impact shall not be added to stresses produced by longitudinal, centrifugal, and lateral or wind forces.

10. All spans shall be designed for a lateral force on the loaded chord of 200 lbs. per linear foot plus 10 per cent of the specified train load on one track, and 200 lbs. per linear foot on the unloaded chord; these forces being considered as moving.

11. Viaduct towers shall be designed for a force of 50 lbs. per sq. ft. on one and one-half times the vertical projection of the structure unloaded; or 30 lbs. per sq. ft. on the same surface plus 400 lbs. per linear ft. of structure applied 7 ft. above the rail for assumed wind force on train, when the structure is either fully loaded or loaded on either track with empty cars assumed to weigh 1,200 lbs. per linear ft., whichever gives the larger stress.

12. Viaduct towers and similar structures shall be designed for a longitudinal force of 20 per cent of the live load applied at the top of the rail.

13. Structures located on curves shall be designed for the centrifugal force of the live load applied at the top of the high rail. The centrifugal force shall be considered as live load and be derived from the speed in miles per hour given by the expression $60-2\frac{1}{2}D$, where "D"=degree of curve.

III. Unit Stresses and Proportion of Parts.

14. All parts of structures shall be so proportioned that the sum of the maximum stresses produced by the foregoing loads shall not exceed the following amounts in pounds per sq. in., except as modified in paragraphs 22 to 25:

15. Axial tension on net section 16,000

16. Axial compression on gross section of columns ..... $16{,}000-70\frac{l}{r}$

with a maximum of 14,000

where "l" is the length of the member in inches, and "r" is the least radius of gyration in inches.

Direct compression on steel castings 16,000

17. Bending: on extreme fibres of rolled shapes, built sections, girders, and steel castings; net section 16,000

on extreme fibres of pins 24,000

18. Shearing: shop driven rivets and pins 12,000

field driven rivets and turned bolts 10,000

plate girder webs; gross section 10,000

19. Bearing: shop driven rivets and pins 24,000

field driven rivets and turned bolts 20,000

expansion rollers; per linear inch ..... 600 d

where "d" is the diameter of the roller in inches.

on masonry 600

20. The lengths of main compression members shall not exceed 100 times their least radius of gyration, and those for wind and sway bracing 120 times their least radius of gyration.

21. The lengths of riveted tension members in horizontal or inclined positions shall not exceed 200 times their radius of gyration about the horizontal axis. The horizontal projection of the unsupported portion of the member is to be considered as the effective length.

22. Members subject to alternate stresses of tension and compression shall be proportioned for the stresses giving the largest section. If the alternate stresses occur in succession during the passage of one train, as in stiff counters, each stress shall be increased by 50 per cent of the smaller. The connections shall in all cases be proportioned for the sum of the stresses.

23. Wherever the live- and dead-load stresses are of opposite character, only two-thirds of the dead-load stresses shall be considered as effective in counteracting the live-load stress.

24. Members subject to both axial and bending stresses shall be proportioned so that the combined fibre stresses will not exceed the allowed axial stress.

25. For stresses produced by longitudinal and lateral or wind forces combined with those from live and dead loads and centrifugal force, the unit stress may be increased 25 per cent over those given above; but the section shall not be less than required for live and dead loads and centrifugal force.

26. In proportioning tension members the diameter of the rivet holes shall be taken $\frac{1}{8}$—in. larger than the nominal diameter of the rivet.

27. In proportioning rivets the nominal diameter of the rivet shall be used.

28. Pin-connected riveted tension members shall have a net section through the pin-hole at least 25 per cent in excess of the net section of the body of the member, and the net section back of the pin-hole, parallel with the axis of the member, shall be not less than the net section of the body of the member.

29. Plate girders shall be proportioned either by the moment of inertia of their net section, or by assuming that the flanges are concentrated at their centres of gravity, in which case one-eighth of the gross section of the web, if properly spliced, may be used as flange section. The thickness of web plates shall be not less than $\frac{1}{160}$ of the unsupported distance between flange angles (see 38).

30. The gross section of the compression flanges of plate girders shall not be less than the gross section of the tension flanges; nor shall the stress per sq. in. in the compression flange of any beam or girder exceed $16{,}000-200\,\frac{l}{b}$, when flange consists of angles only or if cover consists of flat plates, or $16{,}000-150\,\frac{l}{b}$ if cover consists of a channel section, where $l=$ unsupported distance and $b=$width of flange.

31. The flanges of plate girders shall be connected to the web with a sufficient member of rivets to transfer the total shear at any point in a distance equal to the effective

depth of the girder at that point combined with any load that is applied directly on the flange. The wheel loads, where the ties rest on the flanges, shall be assumed to be distributed over three ties.

32. Trusses shall preferably have a depth of not less than one-tenth of the span. Plate girders and rolled beams, used as girders, shall preferably have a depth of not less than one-twelfth of the span. If shallower trusses, girders, or beams are used, the section shall be increased so that the maximum deflection will not be greater than if the above limiting ratios had not been exceeded.

IV. Details of Design.

General Requirements.

33. Structures shall be so designed that all parts will be accessible for inspection, cleaning, and painting.

34. Pockets or depressions which would hold water shall have drain holes, or be filled with waterproof material.

35. Main members shall be so designed that the neutral axis will be as nearly as practicable in the centre of section, and the neutral axes of intersecting main members of trusses shall meet at a common point.

36. Rigid counters are preferred; and where subject to reversal of stress shall preferably have riveted connections to the chords. Adjustable counters shall have open turnbuckles.

37. The strength of connections shall be sufficient to develop the full strength of the member, even though the computed stress is less, the kind of stress to which the member is subjected being considered.

38. The minimum thickness of metal shall be $\frac{3}{8}$—in., except for fillers.

39. The minimum distance between centres of rivet holes shall be three diameters of the rivet; but the distance shall preferably be not less than 3 ins. for $\frac{7}{8}$—in rivets and $2\frac{1}{2}$ ins. for $\frac{3}{4}$—in. rivets. The maximum pitch in the line of stress for members composed of plates and shapes shall be 6 ins. for $\frac{7}{8}$—in. rivets and 5 ins. for $\frac{3}{4}$—in. rivets. For angles with two gauge lines and rivets staggered the maximum shall be twice the above in each line. Where two or more plates are used in contact, rivets not more than 12 ins. apart in either direction shall be used to hold the plates well together. In tension members, composed of two angles in contact, a pitch of 12 ins. will be allowed for riveting the angles together.

40. The minimum distance from the centre of any rivet hole to a sheared edge shall be $1\frac{1}{2}$ ins. for $\frac{7}{8}$—in. rivets and $1\frac{1}{4}$ ins. for $\frac{3}{4}$—in. rivets, and to a rolled edge $1\frac{1}{4}$ ins. and $1\frac{1}{8}$ ins., respectively. The maximum distance from any edge shall be eight times the thickness of the plate, but shall not exceed 6 ins.

41. The diameter of the rivets in any angle carrying calculated stress shall not exceed one-quarter the width of the leg in which they are driven. In minor parts $\frac{7}{8}$—in. rivets may be used in 3—in. angles, and $\frac{3}{4}$—in. rivets in $2\frac{1}{2}$—in. angles.

42. Rivets carrying calculated stress and whose grip exceeds four diameters shall be increased in number at least one per cent for each additional $\frac{1}{16}$ in. of grip.

43. The pitch of rivets at the ends of built compression members shall not exceed four diameters of the rivets, for a length equal to one and one-half times the maximum width of member.

44. In compression members the metal shall be concentrated as much as possible in webs and flanges. The thickness of each web shall be not less than one-thirtieth of the distance between its connections to the flanges. Cover plates shall have a thickness not less than one-fortieth of the distance between rivet lines.

45. Flanges of girders and built members without cover plates shall have a minimum thickness of one-twelfth of the width of the outstanding leg.

46. The open sides of compression members shall be provided with lattice and shall have tie-plates as near each end as practicable. Tie-plates shall be provided at intermediate points where the lattice is interrupted. In main members the end tie-plates shall have a length not less than the distance between the lines of rivets connecting them to the flanges, and intermediate ones not less than one-half this distance. Their thickness shal not be less than one-fiftieth of the same distance.

47. The latticing of compression members shall be proportioned to resist the shearing stresses corresponding to the allowance for flexure for uniform load provided in the column formula in paragraph 16 by the term $70\ \frac{l}{r}$. The minimum width of lattice bars shall be $2\frac{1}{2}$ ins. for $\frac{7}{8}$—in. rivets, $2\frac{1}{4}$ ins. for $\frac{3}{4}$—in. rivets, and 2 ins. if $\frac{5}{8}$—in. rivets are used. The thickness shall not be less than one-fortieth of the distance between end rivets for single lattice and one-sixtieth for double lattice. Shapes of equivalent strength may bs used.

48. Three-fourths-inch rivets shall be used for latticing flanges less than $2\frac{1}{2}$ ins. wide, and $\frac{3}{4}$—in. for flanges from $2\frac{1}{2}$ to $3\frac{1}{2}$ ins. wide; $\frac{7}{8}$—in. rivets shall be used in flanges $3\frac{1}{2}$ ins. and over, and lattice bars with at least two rivets shall be used for flanges over 5 ins. wide.

49. The inclination of lattice bars with the axis of the member shall be not less than 45 degrees, and when the distance between rivet lines in the flanges is more than 15 ins., if single rivet bar is used, the lattice shall be double and riveted at the intersection.

50. Lattice bars shall be so spaced that the portion of the flange included between their connections shall be as strong as the member as a whole.

51. Abutting joints in compression members when faced for bearing shall be spliced on four sides sufficiently to hold the connecting members accurately in place. All other joints in riveted work, whether in tension or compression, shall be fully spliced.

52. Pin-holes shall be reinforced by plates where necessary, and at least one plate shall be as wide as the flanges will allow and be on the same side as the angles. They shall contain sufficient rivets to distribute their portion of the pin pressure to the full cross-section of the member.

53. Forked ends on compression members will be permitted only where unavoidable;

where used, a sufficient number of pin plates shall be provided to make the jaws of twice the sectional area of the member. At least one of these plates shall extend to the far edge of the farthest tie-plate, and the balance to the far edge of the nearest tie-plate, but not less than 6 ins. beyond the near edge of the farthest plate.

54. Pins shall be long enough to insure a full bearing of all the parts connected upon the turned body of the pin. They shall be secured by chambered nuts or be provided with washers if solid nuts are used. The screw ends shall be long enough to admit of burring the threads.

55. Members packed on pins shall be held against lateral movement.

56. Where members are connected by bolts, the turned body of these bolts shall be long enough to extend through the metal. A washer at least $\frac{1}{4}$ in. thick shall be used under the nut. Bolts shall not be used in place of rivets except by special permission. Heads and nuts shall be hexagonal.

57. Where splice plates are not in direct contact with the parts which they connect, rivets shall be used on each side of the joint in excess of the number theoretically required to the extent of one-third of the number for each intervening plate.

58. Rivets carrying stress and passing through fillers shall be increased 50 per cent in number; and the excess rivets, when possible, shall be outside of the connected member.

59. Provision for expansion to the extent of $\frac{1}{8}$—in. for each 10 ft. shall be made for all bridge structures. Efficient means shall be provided to prevent excessive motion at any one point.

60. Spans of 80 ft. and over, resting on masonry, shall have turned rollers or rockers at one end; and those of less length shall be arranged to slide on smooth surfaces. These expansion bearings shall be designed to permit motion in one direction only.

61. Fixed bearings shall be firmly anchored to the masonry.

62. Expansion rollers shall be not less than 6 ins. in diameter. They shall be coupled together with substantial side bars, which shall be so arranged that the rollers can be readily cleaned. Segmental rollers shall be geared to the upper and lower plates.

63. Bolsters or shoes shall be so constructed that the load will be distributed over the entire bearing. Spans of 80 ft. or over shall have hinged bolsters at each end.

64. Wall plates may be cast or built up; and shall be so designed as to distribute the load uniformly over the entire bearing. They shall be secured against displacement.

65. Anchor bolts for viaduct towers and similar structures shall be long enough to engage a mass of masonry the weight of which is at least one and one-half times the uplift.

66. Bridges on an inclined grade without pin-shoes shall have the sole plates beveled so that the masonry and expansion surfaces may be level.

Floor Systems.

67. Floor-beams shall preferably be square to the trusses or girders. They shall be

riveted directly to the girders or trusses or may be placed on top of deck bridges.

68. Stringers shall preferably be riveted to the webs of all intermediate floor-beams by means of connection angles not less than $\frac{1}{2}$ in. in thickness. Shelf angles or other supports provided to support the stringer during erection shall not be considered as carrying any of the reaction.

69. Where end floor-beams cannot be used, stringers resting on masonry shall have cross frames near their ends. These frames shall be riveted to girders or truss shoes where practicable.

Bracing.

70. Lateral, longitudinal, and transverse bracing in all structures shall be composed of rigid members.

71. Through truss spans shall have riveted portal braces rigidly connected to the end posts and top chords. They shall be as deep as the clearance will allow.

72. Intermediate transverse frames shall be used at each panel of through spans having vertical truss members where the clearance will permit.

73. Deck spans shall have transverse bracing at each end proportioned to carry the lateral load to the support.

74. The minimum-sized angle to be used in lateral bracing shall be $3\frac{1}{2}$ by 3 by $\frac{3}{8}$ ins. Not less than three rivets through the end of the angles shall be used at the connection.

75. Lateral bracing shall be far enough below the flange to clear the ties.

76. The struts at the foot of viaduct towers shall be strong enough to slide the movable shoes when the track is unloaded.

Plate Girders.

77. If desired, plate-girder spans over 50 ft. in length shall be built with camber at a rate of $\frac{1}{16}$—in. per 10 ft. of length.

78. Where flange plates are used, one cover plate of top flange shall extend the whole length of the girder.

79. There shall be web stiffeners, generally in pairs, over bearings, at points of concentrated loading, and at other points where the thickness of the web is less than $\frac{1}{60}$ of the unsupported distance between flange angles. The distance between stiffeners shall not exceed that given by the following formula, with a miximum limit of six feet (and not greater than the clear depth of the web):

$$d=\frac{t}{40}\ (12{,}000-s),$$

where d=clear distance, between stiffeners of flange angles.

t=thickness of web.　　s=shear per sq. in.

The stiffeners at ends and at points of concentrated loads shall be proportioned by the formula of paragraph 16, the effective length being assumed as one-half the depth of

girders. End stiffeners and those under concentrated loads shall be on fillers and have their outstanding legs as wide as the flange angles will allow and shall fit tightly against them. Intermediate stiffeners may be offset or on fillers, and their outstanding legs shall be not less than one-thirtieth of the depth of girder plus 2 ins.

80. Through plate girders shall have their top flanges stayed at each end of every floor beam, or, in case of solid floors, at distances not exceeding 12 ft., by knee braces or gusset plates.

Trusses.

81. Truss spans shall be given a camber by so proportioning the length of the members that the stringers will be straight when the bridge is fully loaded.

82. Hip verticals and similar members, and the two end panels of the bottom chords of single track pin-connected trusses, shall be rigid.

83. The eye-bars composing a member shall be so arranged that adjacent bars shall not have their surfaces in contact; they shall be as nearly parallel to the axis of the truss as possible, the maximum inclination of any bar being limited to one inch in 16 ft.

84. Pony trusses shall be riveted structures, with double webbed chords, and shall have all web members latticed or otherwise effectively stiffened.

PART SECOND—MATERIALS AND WORKMANSHIP.

V. Material.

85. Steel shall be made by the open-hearth process.

86. The chemical and physical properties shall conform to the following limits:

Elements Considered	Structural Steel	Rivet Steel	Steel Castings
Phosphorus, max. Basic	0.04 per cent	0.04 per cent	0.05 per cent
Phosphorus, max. Acid	0.06 „ „	0.04 „ „	0.08 „ „
Sulphur, maximum.....	0.05 „ „	0.04 „ „	0.05 „ „
Ultimate tensile strength Pounds per square inch	Desired 60,000 1,500,000	Desired 50,000 1,500,000	Not less than 65,000
Elong., min. %, in. 8″, Fig. 1 ..	Ult. ten. str'gth	Ult. ten. str'gth	15 per cent
Elong., min. %, in. 2″, Fig. 2..	22		
Character of Fracture	Silky	Silky	Silky or fine granular
Cold Bends without Frac	180° flat	180° flat	90° $d=3t$

The yield point, as indicated by the drop of beam, shall be recorded in the test reports.

87. In order that the ultimate strength of full-sized annealed eye-bars may meet the requirements of paragraph 163, the ultimate strength in test specimens may be determined by the manufacturers; all other tests than those for ultimate strength shall conform to the above requirements.

88. If the ultimate strength varies more than 4,000 lbs. from that desired, a retest shall be made on the same gauge, which, to be acceptable, shall be within 5,000 lbs. of the desired ultimate.

89. Chemical determinations of the percentages of carbon, phosphorus, sulphur, and manganese shall be made by the manufacturer from a test ingot taken at the time of the pouring of each melt of steel, and a correct copy of such analysis shall be furnished to the engineer or his inspector. Check analyses shall be made from finished material, if called for by the purchaser, in which case an excess of 25 per cent above the required limits will be permitted.

90. Plate, shape, and bar specimens for tensile and bending tests shall be made by cutting coupons from the finished product, which shall have both faces rolled and both edges milled to the form shown by Fig. 1; or with both edges parallel; or they may be turned to a diameter of $\frac{3}{4}$ in. for a length of at least 9 ins., with enlarged ends.

91. Rivet rods shall be tested as rolled.

92. Pin and roller specimens shall be cut from the finished rolled or forged bar, in such manner that the centre of the specimen shall be 1 in. from the surface of the bar. The specimen for tensile test shall be turned to the form shown by Fig. 2. The specimen for bending test shall be 1 in. by $\frac{1}{2}$—in. in section.

93. For steel castings the number of tests will depend on the character and importance of the castings. Specimens shall be cut cold from coupons moulded and cast on some portion of one or more castings from each melt or from the sink heads, if the heads are of sufficient size. The coupon or sink head, so used, shall be annealed with the casting before it is cut off. Test specimens to be of the form prescribed for pins and rollers.

94. Rolled steel shall be tested in the condition in which it comes from the rolls.

95. At least one tensile and one bending test shall be made from each melt of steel as rolled. In case steel differing $\frac{3}{8}$ in. and more in thickness is rolled from one melt, a test shall be made from the thickest and thinnest material rolled.

96. A deduction of 1 per cent. will be allowed from specificed percentage for elongation, for each $\frac{1}{8}$ in. in thickness above $\frac{3}{4}$ in.

97. Bending tests may be made by pressure or by blows. Plates, shapes, and bars less than 1 in. thick shall bend as called for in paragraph 86.

98. Full-sized material for eye-bars and other steel 1 in. thick and over, tested as rolled, shall bend cold 180 degrees around a pin, the diameter of which is equal to twice the thickness of the bar, without fracture on the outside of bend.

99. Angles $\frac{3}{4}$ in. and less in thickness shall open flat, and angles $\frac{1}{2}$ in. and less in thickness shall bend shut, cold, under blows of a hammer, without sign of fracture. This test shall be made only when required by the inspector.

100. Rivet steel, when nicked and bent around a bar of the same diameter as the rivet rod, shall give a gradual break and a fine silky uniform fracture.

101. Finished material shall be free from injurious seams, flaws, cracks, defective edges, or other defects, and have a smooth, uniform, and workmanlike finish. Plates 36

ins. in width and under shall have rolled edges.

102. Every finished piece of steel shall have the melt number and the name of the manufacturer stamped or rolled upon it. Steel for pins and rollers shall be stamped on the end. Rivet and latice steel and other small parts may be bundled with the above marks on an attached metal tag.

103, Material which, subsequent to the above tests at the mills, and its acceptance there, develops weak spots, brittleness, cracks, or other imperfections, or is found to have injurious defects, will be rejected at the shop and shall be replaced by the manufacturer at his own cost.

104. A variation in cross-section or weight of each piece of steel of more than $2\frac{1}{2}$ per cent from that specified will be sufficient cause for rejection, except in case of sheared plates, which will be covered by the following permissible variations, which are to apply to single plates, when ordered to weight:

105. Plates $12\frac{1}{2}$ lbs. per sq. ft. or heavier:

(a) Up to 100 ins. wide, $2\frac{1}{2}$ per cent above or below the prescribed weight.

(b) One hundred inches wide and over, 5 per cent above or below.

106. Plates under $12\frac{1}{2}$ lbs. per sq. ft.:

(a) Up to 75 ins. wide, $2\frac{1}{2}$ per cent above or below.

(b) Seventy-five inches and up to 100 ins. wide, 5 per cent above or 3 per cent below.

(c) One hundred inches wide and over, 10 per cent above or 3 per cent below.

107. Plates when ordered to gauge will be accepted if they measure not more than 0.01 in. below the ordered thickness.

108. An excess over the nominal weight, corresponding to the dimensions on the order, will be allowed for each plate, if not more than that shown in the following table, 1 cu. in. of rolled steel being assumed to weigh 0.2833 lb.:

Thickness Ordered	Nominal Weights	Width of Plate			
		Up to 75″	75″ and Up to 100″	100″ and Up to 115″	Over 115″
Ins.	Lbs.	%	%	%	%
$\frac{1}{4}$	10.20	10	14	18	—
$\frac{5}{16}$	12.75	8	12	16	—
$\frac{3}{8}$	15.30	7	10	13	17
$\frac{7}{16}$	17.85	6	8	10	13
$\frac{1}{2}$	20.40	5	7	9	12
$\frac{9}{16}$	22.95	$4\frac{1}{2}$	$6\frac{1}{2}$	$8\frac{1}{2}$	11
$\frac{5}{8}$	25.50	4	6	8	10
Over $\frac{5}{8}$	——	$3\frac{1}{2}$	5	$6\frac{1}{2}$	9

109. Except where chilled iron is specified, castings shall be made of tough gray iron, with sulphur not over 0.10 per cent. They shall be true to pattern, out of wind and

free from flaws and excessive shrinkage. If tests are demanded, they shall be made on the "Arbitration Bar" of the American Society for Testing Materials, which is a round bar $1\frac{1}{4}$ ins. in diameter and 15 ins. long. The transverse test shall be made on a supported length of 12 ins. with load at middle. The minimum breaking load so applied shall be 2,900 lbs., with a deflection of at least $\frac{1}{10}$ in. before rupture.

110. Wrought-iron shall be double-rolled, tough, fibrous, and uniform in character. It shall be thoroughly welded in rolling and be free from surface defects. When tested in specimens of the form of Fig. 1, or in full-sized pieces of the same length, it shall show an ultimate strength of at least 50,000 lbs. per sq. in., an elongation of at least 18 per cent. in 8 ins., with fracture wholly fibrous. Specimens shall bend cold, with the fibre, through 135 degress, without sign of fracture, around a pin the diameter of which is not over twice the thickness of the piece tested. When nicked and bent, the fracture shall show at least 90 per cent fibrous.

VI. Inspection and Testing at the Mills.

111. The purchaser shall be furnished complete copies of mill orders, and no material shall be rolled nor work done before the purchaser has been notified where the orders have been placed, so that he may arrange for the inspection.

112. The manufacturer shall furnish all facilities for inspecting and testing the weight and quality of all material at the mill where it is manufactured. He shall furnish a suitable testing machine for testing the specimens, as well as prepare the pieces for the machine, free of cost.

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

VII. Workmanship.

114. All parts forming a structure shall be built in accordance with approved drawings. The workmanship and finish shall be equal to the best practice in modern bridge works. Material arriving from the mills shall be protected from the weather and shall have clean surfaces before being worked in the shops.

115. Material shall be thoroughly straightened in the shop, by methods that will not injure it, before being laid off or worked in any way.

116. Shearing and chipping shall be neatly and accurately done and all portions of the work exposed to view neatly finished.

117. The size of rivets called for on the plans shall be understood to mean the actual size of the cold rivet before heating.

118. When general reaming is not required, the diameter of the punch shall not be more than $\frac{1}{16}$ in. greater than the diameter of the rivet; nor the diameter of the die more than $\frac{1}{8}$ in. greater than the diameter of the punch. Material more than $\frac{3}{4}$ in. thick shall be subpunched and reamed or drilled from the solid.

119. Punching shall be accurately done. Drifting to enlarge unfair holes will not be allowed. If the holes must be enlarged to admit the rivet, they shall be reamed. Poor matching of holes will be cause for rejection.

120. Where subpunching and reaming are required, the punch used shall have a diameter not less than $\frac{3}{16}$ in. smaller than the nominal diameter of the rivet. Holes shall then be reamed to a diameter not more than $\frac{1}{16}$ in. larger than the nominal diameter of the rivet. (See 135.)

121. When general reaming is required it shall be done after the pieces forming one built member are assembled and so firmly bolted together that the surfaces shall be in close contact. If necessary to take the pieces apart for shipping and handling, the respective pieces reamed together shall be so marked that they may be reassembled in the same position in the final setting up. No interchange of reamed parts will be permitted.

122. Reaming shall be done with twist drills and without using any lubricant.

123. The outside burrs on reamed holes shall be removed to the extent of making a $\frac{1}{16}$ in. fillet.

124. Riveted members shall have all parts well pinned up and firmly drawn together with bolts, before riveting is commenced. Contact surfaces to be painted (See 152.)

125. Lattice bars shall have neatly rounded ends, unless otherwise called for.

126. Stiffeners shall fit neatly between flanges of girders. Where tight fits are called for, the ends of the stiffeners shall be faced and shall be brought to a true contact bearing with the flange angles.

127. Web splice plates and fillers under stiffeners shall be cut to fit within $\frac{1}{8}$ in. of flange angles.

128. Web plates of girders, which have no cover plates, shall be flush with the backs of angles or project above the same not more than $\frac{1}{8}$ in., unless otherwise called for. When web plates are spliced, not more than $\frac{1}{4}$-in. clearance between ends of plates will be allowed.

129. The main sections of floor-beams and stringers shall be milled to exact length after riveting and the connection angles accurately set flush and true to the millled ends or if required by the purchaser, the milling shall be done after the connection angles are riveted in place, milling to extend over the entire face of the member. The removal of more than $\frac{3}{32}$ in. from the thickness of the connection angles will be cause for rejection.

130. Rivets shall be uniformly heated to a light cherry red heat in a gas or oil furnace so constructed that it can be adjusted to the proper temperature. They shall be driven by pressure tools wherever possible. Pneumatic hammers shall be used in preference to hand driving.

131. Rivets shall look neat and finished, with heads of approved shape, full, and of equal size. They shall be central on shank and grip the assembled pieces firmly. Recupping and calking will not be allowed. Loose, burned, or otherwise defective rivets shall be cut out and replaced. In cutting out rivets, great care shall be taken not to injure the adjacent metal. If necessary, they shall be drilled out.

132. Wherever bolts are used in place of rivets which transmit shear, the holes shall be reamed parallel and the bolts shall make a driving fit, with the threads entirely outside of the holes. A washer not less than $\frac{1}{4}$ in. thick shall be used under nut.

133. The several pieces forming one built member shall be straight and fit closely together, and finished members shall be free from twists, bends, or open joints.

134. Abutting joints shall be cut or dressed true and straight and fitted close together, especially where open to view. In compression joints, depending on contact bearing, the surfaces shall be truly faced, so as to have even bearings after they are riveted up complete and when perfectly aligned.

135. Holes for floor-beam and stringer connections shall be subpunched and reamed according to paragraph 120, to a steel templet not less than one inch thick. If required, all other field connections, except those for laterals and sway bracing, shall be assembled in the shop and the unfair holes reamed; and when so reamed the pieces shall be match-marked before being taken apart.

136. Eye-bars shall be straight and true to size, and shall be free from twists, folds in the neck or head, or any other defect. Heads shall be made by upsetting, rolling, or forging. Welding will not be allowed. The form of heads will be determined by the dies in use at the works where the eye-bars are made, if satisfactory to the engineer, but the manufacturer shall guarantee the bars to break in the body when tested to rupture. The thickness of head and neck shall not vary more than $\frac{1}{16}$ in. from that specified. (See 163).

137. Before boring, each eye-bar shall be properly annealed and carefully straightened. Pin-holes shall be in the centre line of bars and in the centre of heads. Bars of the same length shall be bored so accurately that, when placed together, pins $\frac{1}{32}$ in. smaller in diameter than the pin-holes can be passed through the holes at both ends of the bars at the same time without forcing.

138. Pin-holes shall be bored true to gauges, smooth and straight; at right angles to the axis of the member and parallel to each other, unless otherwise called for. The boring shall be done after the member is riveted up.

139. The distance centre to centre of pin-holes shall be correct within $\frac{1}{32}$ in., and the diameter of the holes not more than $\frac{1}{50}$ in. larger than that of the pin, for pins up to 5 in. diameter, and $\frac{1}{32}$ in. for larger pins.

140. Pins and rollers shall be accurately turned to gauges and shall be straight and smooth and entirely free from flaws.

141. Screw threads shall make tight fits in the nuts and shall be U. S. standard, except above the diameter of $1\frac{3}{8}$ in., when they shall be made with six threads per inch.

142. Steel, except in minor details, which has been partially heated, shall be properly annealed.

143. Steel castings shall be free from large or injurious blow-holes and shall be annealed.

144. Welds in steel will not be allowed.

145. Expansion bed plates shall be planed true and smooth. Cast wall plates shall be planed top and bottom. The finishing cut of the planing tool shall be fine and correspond with the direction of expansion.

146. Pilot and driving nuts shall be furnished for each size of pin, in such numbers as may be ordered.

147. Field rivets shall be furnished to the amount of 15 per cent, plus ten rivets in excess of the nominal number required for each size.

148. Pins, nuts, bolts, rivets and other small details shall be boxed or crated.

149. The scale weight of every piece and box shall be marked on it in plain figures.

150. Payment for pound price contracts shall be by scale weight. No allowance over 2 per cent of the total weight of toe structure as computed from the plans will be allowed for excess weight.

VIII. Shop Painting.

151. Steel work, before leaving the shop, shall be thoroughly cleaned and given one good coating of pure linseed oil, or such paint as may be called for, well worked into all joints and open spaces.

152. In riveted work, the surfaces coming in contact shall each be painted before being riveted together.

153. Pieces and parts which are not accessible for painting after erection, including tops of stringers, eye-bar heads, ends of posts and chords, etc., shall have an additional coat of paint before leaving the shop.

154. Painting shall be done only when the surface of the metal is perfectly dry. It shall not be done in wet or freezing weather, unless protected under cover.

155. Machine-finished surfaces shall be coated with white lead and tallow before shipment or before being put out into the open air.

IX. Inspection and Testing at the Shops.

156. The manufacturer shall furnish all facilities for inspecting and testing the weight and quality of workmanship at the shop where material is manufactured. He shall furnish a suitable testing machine for testing full-sized members, if required.

157. The purchaser shall be notified well in advance of the start of the work in the shop, in order that he may have an inspector on hand to inspect material and workmanship.

158. When an inspector is furnished by the purchaser, he shall have full access, at all times, to all parts of the shop where material under his inspection is being manufactured.

159. The inspector shall stamp each piece accepted with a private mark. Any piece not so marked may be rejected at any time and at any stage of the work. If the inspector, through an oversight or otherwise, has accepted material or work which is defective or contrary to the specifications, this material, no matter in what stage of completion, may be rejected by the purchaser.

160. The purchaser shall be furnished complete shop plans.

161. Complete copies of shipping invoices shall be furnished to the purchaser with each shipment. These shall show the scale weights of individual pieces.

X. Full-Sized Tests.

162. Full-sized tests on eye-bars and similar members, to prove the workmanship, shall be made at the manufacturer's expense, and shall be paid for by the purchaser at contract price, if the tests are satisfactory. If the tests are not satisfactory, the members represented by them will be rejected.

163. In eye-bar tests, the minimum ultimate strength shall be 55,000 lbs. per sq. in. The elongation in 10 ft., including fracture, shall be not less than 15 per cent. Bars shall generally break in the body and the fracture shall be silky or fine granular, and the elastic limit as indicated by the drop of the mercury shall be recorded. Should a bar break in the head and develop the specified elongation, ultimate strength, and character of fracture, it shall not be cause for rejection, provided not more than one-third of the total number of bars break in the head. (See 136.)

ADDENDUM TO GENERAL SPECIFICATIONS FOR STEEL RAILWAY BRIDGES.

Points to be Specifically Determined by Buyers When Soliciting Proposals for Steel Railway Bridges.

When general detail drawings are not furnished for the use of bidders specific answers should be given to questions a, b, and c, below.

Specific answers should also be given to questions d, e, and f, if the class of work described in any of the paragraphs there referred to is desired. If these features are not specifically demanded, the unbracketed paragraphs will be construed to define the kind of work desired.

(a) What class of live load shall be used? (Pars. 7 and 8.)

(b) Shall linseed oil or paint be used? If paint, what kind? (Par. 151.)

(c) Shall contractor furnish floor bolts?

(d) Shall general reaming be done? (Part. 121.)

(e) Shall field connections be assembled at the shop? (Par. 135.)

(f) Shall floor connection angles be milled after riveting? (Par. 129.)

Extract from Modern Framed Structures.