参　考　資　料

目　　　　次

(一)

Railway Bridges.

The specifications prepared by Sir Benjamin Baker for the Imperial Chinese Railways.

Loading.

12. Dead Load.—The dead load must not be less than the actual weight, and shall consist of the whole weight of the steel superstructure, permanent way and ballast, if any. The weight of the ordinary permanent way, including 95 lb. rails, chairs, cross sleepers, etc., shall be taken at $1\frac{1}{2}$ cwt. per lineal foot of single line; and for an open floor the weight of the wooden cross sleepers, permanent way and guard rails shall be taken at 4 cwt. per lineal foot of single line. Where ballast is used with ordinary permanent way, the average depth shall be taken at 12 in. and assumed to weigh 120 lb. per square foot of floor.

For spans of less than 200 ft. the total dead load shall be assumed to act at the loaded chord. For spans of 200 ft. and over, the total dead load will be distributed at top and bottom chords as follows:—

(1st) On Loaded Chords:
- (a) One-half load resulting from weight of trusses.
- (b) Weight of horizontal wind bracing in plane of chords.
- (c) Weight of floor system, permanent way, etc.
- (d) One-half of load resulting from weight of cross-bracing in the case of a deck bridge.

(2nd) On Unloaded Chords:
- (a) One-half load resulting from weight of trusses.
- (b) Weight of horizontal wind bracing in plane of chords.
- (c) One-half of load resulting from weight of cross bracing in the case of a deck, or the whole of it in the case of a through bridge.

13. Live Load.—The structure shall be designed to carry a moving load for each track consisting of two engines coupled, at the head of a uniformly distributed train load.

The live-load stresses will be the maximum stresses produced by the rolling load considered as stationary or as moving in either direction. In double-track structures one track or both will be considered loaded, whichever may produce the greater stresses, and the trains will be supposed to move either in the same or in opposite directions.

The diagram of train loads shall be furnished with the inquiry and be shown upon the stress diagrams.

Where no train load is supplied with the inquiry, the live load per track of standard 4 ft. $8\frac{1}{2}$ in. gauge shall be computed as follows:—

For Main Girders:

Distributed rolling load per track = 2 tons per foot run + an excess rolling load to occupy any position on the bridge at the same time equal to $\left(20 \text{ tons} + \frac{\text{span in feet} - 10}{10}\right)$ but not greater than 30 tons.

For Cross Girders:

The load on each cross girder from each track—

For all cross girders up to 7 ft. centres = 25 tons.

For all cross girders beyond 7 ft. centres = 2 tons. per foot run of track plus an excess load of 10 tons $-\left(\frac{10 - \text{centres of cross girders in feet}}{5}\right)$ but not greater than 10 tons.

14. Wind Pressure.—The wind shall be assumed acting in either direction, horizontally, and to be blowing at a slight angle to the axis of the bridge so as to take effect on the exposed areas of the floor, and of both windward and leeward girders, except when the latter is temporarily screened by a passing train. One-half of the exposed surface of the leeward girder shall be included in the total area acted upon by the full wind pressure, except when the distance between the main girders is more than twice their depth, when the whole exposed area of leeward girder shall be taken.

With no train on the bridge the wind pressure shall be assumed to be 50 lb. per square foot, and with a train on the bridge at 30 lb. per square foot of exposed surfaces of train and bridge. The train shall be taken at 10 square feet per lineal foot, and the centre of pressure of train surface at $7\frac{1}{2}$ ft. above the rail level. The wind pressure on the train shall be treated as a moving load. The maximum stresses resulting from either condition to be taken in determining the necessary sectional areas of the parts.

In providing the necessary anchorage for the structure, the bridge shall be assumed to be covered with a train of empty passenger carriages weighing 10 cwt. per lineal foot; and in the case of a double-line bridge, the leeward track only to be loaded.

15. Momentum of Train.—Special attention shall be given to the details of the structure to provide for the longitudinal stresses resulting from the tractive force of the engines or from the sudden application of continuous brakes to the train while on the bridge, and the horizontal force resulting from such action shall be taken as one-seventh of the weight of the train.

16. Centrifugal Force.—When a bridge is on a curve, the resulting horizontal stresses due to the centrifugal action of the rolling load shall be provided for.

The centrifugal force for each degree of curvature shall be assumed to be 1 per cent.

of the maximum rolling load on all tracks for a speed of 30 miles per hour and under, and 1 per cent. shall be added for each increase in speed of 10 miles per hour.

The centrifugal force shall be assumed to act at 5 ft. above the level of the rails.

The radius in feet R shall be reduced to degrees in curvature D by the following formula: $D=\frac{5730}{R}$.

In summating the resulting stresses, the wind shall be assumed to be acting in the same direction as the centrifugal force.

Working Stresses.

17. Impact Effect.—The following working stresses have been proportioned to allow for the action of the live load on lightly-loaded girders or members of girders:—

18. Permissible Maximum Stresses.—All bridgework and trestle piers shall comply with the whole of the following conditions:—

(1st) The combined stresses, resulting from the rolling load, dead load, wind, momentum and centrifugal forces, shall not produce a greater tensile stress than one-half of the elastic limit, or equal to 27 per cent. of the minimum ultimate tensile strength of the material, nor more than the corresponding compressive, shearing, bearing and bending stresses as hereinafter set forth; but

(2nd) The combined stresses, resulting from the rolling load and dead load alone, exclusive of wind, momentum and centrifugal force, shall not produce greater tensile stresses than those tabulated below.

19. Tensile Stresses.—For Main Girders, Cross Girders and Rail Bearers of Plate Construction.

Under 20 ft. span	$4\frac{1}{2}$	tons per square inch
20 ft. and under 25 ft. span	$4\frac{3}{4}$	do.
25 ft. and under 30 ft. span	5	do.
30 ft. and under 50 ft. span	$5\frac{1}{4}$	do.
50 ft. and under 80 ft. span	$5\frac{1}{2}$	do.

For Truss and Lattice Girders.

80 ft. and under 160 ft. span:		
Bottom chords	$5\frac{1}{2}$	tons per square inch
Diagonals	$4\frac{1}{2}$ to $5\frac{1}{2}$	do.
160 ft. and under 200 ft. span:		
Bottom chords	$5\frac{3}{4}$	do.
Diagonals	$4\frac{1}{2}$ to $5\frac{3}{4}$	do.
200 ft. to 400 ft. span:		
Bottom chords	6 to 7	do.
Diagonals	$4\frac{1}{2}$ to 7	do.
All spans:		
For wind-bracing	$8\frac{1}{2}$	do.
For floor suspenders	$2\frac{1}{2}$	do.

NOTE:—The $4\frac{1}{2}$ ton stress on the diagonals will apply to those at the centre portion of the span and to the counter-bracing at the same point. The higher stresses will apply to those at the end portions of the span, where the variations of stress are not so great. Intermediate diagonals will be subject to stresses lying between the two limits.

20. Compressive Stresses.—For plate girders, the gross area of the compression flange shall not be less than that of the tension flange, nor shall the compressive stresses per square inch be more than 85 per cent. of the corresponding specified tensile stress; nor in any case shall it exceed the fraction $\left(1.0-0.006\frac{1}{w}\right)$ of the said tensile stress, where 1 is the unsupported length between cross frames or brackets and w is the width of the flange.

For truss or lattice girders, the compressive stress per square inch shall, in the case of members with riveted end connections and formed of tubular or box sections with braced sides, not exceed the fraction (0.95–0.003 r) of the corresponding specified tensile stress; not in the case of I or T section members the fraction (0.85–0.006 r) of the said stress; not in the case of members with pin end connections and formed of tubular or box sections with braced sides, the fraction (0.95–0.0045 r), where r is the ratio of the length of the unbraced portion of a member to its least radius of gyration; nor in any case shall it exceed 85 per cent. of the said tensile stress.

No compression member shall have a greater length than 120 times its least radius of gyration, or 45 times its least width, except for windbracing which may have a length not exceeding 140 times its least radius of gyration.

The latticing of compression members shall be proportioned for a transverse shear at any point in their length equal to not less than $2\frac{1}{2}$ per cent. of the axial load on the member. This shearing force shall be considered as divided between all transverse parallel stiffening planes in proportion to their distances from the neutral axis of the member.

The width of flat bar lacings shall not be less than three times the nominal diameter of the rivets connecting them to the main member. Their thickness shall not be less than one-fortieth of the minimum distance between the centres of rivets in the case of single latticing and one-sixtieth for double latticing, riveted at the intersection. Angle, tee, channel or tube sections of equivalent strength may be substituted for flats.

21. Alternating Stresses.—Members subject to alternate tension and compression shall be proportioned as struts, to resist the greater stress added to one-half of the lesser stress, except in the case of wind-bracing, where the member shall be proportioned to resist the greater stress. The sum of the stresses shall be used in designing the connections.

22. Shearing, Bearing and Bending Stresses.—The shearing, bearing and bending stresses per square inch shall not exceed the following limits:

(1) In Truss or Lattice Girders, and all Web or Flange Joints in Plate Girders.

(a) For shop-driven rivets and turned bolts or pins of a driving fit.

Shearing stress .... $\frac{3}{4}$ of the permissible maximum tensile stress per square inch in the girder or member.

Bearing stress .... $1\frac{1}{2}$ do.

Bending stress .... $1\frac{1}{2}$ do.

(b) For field connections increase the number of rivets and black bolts by 15 per cent. and 20 per cent. respectively.

(2) In Plate Girders.

Shearing stress in rivets............	$\frac{7}{8}$ of the permissible maximum tensile stress per square inch in the girder.	
Shearing stress in web plate	$\frac{1}{2}$	do.
Bearing stress on rivets............	$1\frac{3}{4}$	do.

(3) Bending Stress on Members Subject to Direct Tensile or Compressive Stresses.

Where such stresses occur the member shall be proportioned to the algebraic sum of the stresses resulting from the direct stresses and three-fourths of the maximum bending stress, and the stress per square inch shall not exceed that permitted for the direct stresses. The member shall be considered as a beam freely supported at the ends, and the bending moment at the ends shall be considered equal to that in the centre but in opposite direction.

23. Rollers and Bedplates.—The pressure in pounds per lineal inch on rollers of rolled steel shall not exceed 560 d, where d equals the diameter of the rollers in inches; in the case of live rollers under swing bridges the pressure shall not exceed two-thirds of this amount.

Bedplates and rockers shall be of sufficient area and strength to distribute the load over the masonry without exceeding a pressure of 16 tons per square foot for hard stone, of 20 tons per square foot for granite, and 15 tons per square foot for cement concrete (6 to 1), and 18 tons per square foot for cement concrete (4 to 1).

24. Wrought Ironwork.—Where wrought iron is used for any girder or member of a bridge, the working stresses shall be 80 per cent. of those specified in the case of steel for members subject to tensile and bending stresses, and for short compression members; 85 per cent. for long compression members, and 90 per cent. for members subject to shearing and bearing stresses.

25. Wind and Centrifugal Force.—Where the stresses resulting from the dead and live loads are combined with those due to the wind alone, or with the wind and cetrifugal force, the preceding working stresses per square inch may be increased 25 per cent., but in no case shall they exceed 27 per cent. of the minimum ultimate tensile strength of the material.

26. Connections.—Connections shall be proportioned to develop the full strength of the member, notwithstanding that the calculated stress may be less.

NOTE.—Where bridges or trestles have to be constructed to the requirements of the British Board of Trade or Ministry of Transport, the loading, unit stresses and details of construction shall comply with Specification No. 153 (1922-3), of the British Engineering Standards Committee.

Structural Details.

27. Types of Bridges.—For spans of 16 ft. and under, rolled beams may be used; for spans from 16 ft. to 80 ft., plate girders shall be used; for spans from 80 ft. to 200 ft., riveted truss or lattice girders shall be used; and above 200 ft., either riveted or pin-connected truss or lattice girders may be used.

28. Minimum Sections.—No shape weighing less than $5\frac{1}{2}$ lb. per lineal foot shall be used, nor any plate or bar less than $\frac{5}{16}$ in. in thickness when both sides are accessible for painting, nor less than $\frac{3}{8}$ in. when only one side is accessible for painting. The web plate of plate girders shall not be less than $\frac{3}{8}$ in. in thickness. The unsupported width of any plate subjected to compression shall not exceed thirty times its thickness, except in the case of flange plates of trough-shaped booms and posts, where it may be forty times its thickness. No angle less than 3 in. by 2 in. shall be used in the main members of girders or trusses, or in any member having rivets $\frac{7}{8}$ in. in diameter. No angle less than $2\frac{1}{2}$ in. by 2 in. shall be used in any part of a bridge structure.

End angles connecting rail bearers or cross-girders shall not be less than $\frac{3}{4}$ of thickness of the web plates.

Bedplates shall not be less than $\frac{3}{4}$ in. in thickness.

No eye bars less than $\frac{3}{4}$ in. nor over 2 in. in thickness shall be used. The minimum section shall be 4 in. by $\frac{3}{4}$ in. The depth of eye bars for chords and main diagonals shall not be less than $\frac{1}{55}$ of the length of the horizontal projection of the distance between the points of support.

No main pins shall be less than $3\frac{1}{2}$ in. in diameter, nor less than three-quarters of the width of the widest bar attached to them.

29. Rivets.—The pitch of rivets in the direction of the stress shall not exceed 8 in. in any case, nor be more than sixteen times the thickness of the thinnest outside plate or angle bar, nor be less than 3 diameters, and not more than forty times the thickness of the thinnest outside plate at right angles to the stress. The distance from the centre of the rivet or bolt hole to the edge of a plate or bar shall not be less than $1\frac{1}{2}$ diameters in the case of machined or rolled edges, nor $1\frac{3}{4}$ diameters in the case of sheared edges, nor exceed eight times the thickness of the plate.

At the ends of plate girder flange plates the pitch of rivets shall not exceed $4\frac{1}{2}$ diameters for a length sufficient to provide a number of rivets whose combined sectional areas shall be equal to the net sectional area of the flange plate. The flange plate shall be of such length that one-half of these rivets shall be beyond the theoretical end of the plate. Where webs are built up of two or more plates, the rivets, which are used solely for making the several thicknesses act as one plate, shall not be spaced more than 12 in. apart. Such compound web plates shall not be used where the total thickness is less than 1 in.

At the ends of the riveted columns or struts for a length equal to $1\frac{1}{2}$ times the width of the member, the pitch of the rivets shall not exceed $4\frac{1}{2}$ diameters.

30. Provision for Temperature.—Freedom for expansion and contraction due to change of temperature shall be provided in all spans at the rate of 1 in. for every 100 ft. in length.

Bridges shall be provided with suitable bearing plates riveted to the flanges and bolted through the bedplates to the masonry at one end, and be free to move longitudinally at the other end. Suitable expansion bearings shall be provided at one end of each span.

The expansion bearings shall be so designed as to permit of inspection and lubrication.

They shall permit of a free movement in a longitudinal direction sufficient to take up the extreme variations in length due to temperature changes and deflection, and at the same time to prevent any transverse motion or uplifting of the end of the span.

31. Camber.—Bridges of 100 ft. span and upwards shall be constructed with a camber of 1 in. for every 100 ft. in length. With parallel chords sufficient camber may be obtained by making the top chord sections longer than the corresponding bottom chord sections by $\frac{1}{8}$ in. for every 10 ft. of length.

Plate girders less than 80 feet in length shall not be given any camber.

32. Joints.—The butting ends of all spliced members, whether in tension or compression, shall bear evenly throughout their whole faces and be fully covered and riveted to transmit the whole stress through the splice. Web splices shall have double covers of sufficient width to admit of sufficient rivets to transmit the whole of the shearing stress at the joint.

Symmetrical covers shall have a sectional area at least 5 per cent. in excess of the section covered and 10 per cent. for unsymmetrical covers. The centre of gravity of the covers shall coincide as nearly as possible with the centre of gravity of the section covered.

33. Handrails.—Where handrails are required on bridges, they shall be constructed at least $4\frac{1}{2}$ ft. high above rail level of two lines of gas pipes of 1 in. internal diameter, with suitable standards not more than 5 ft. apart, or of open lattice work of plates $\frac{1}{4}$ in. in thickness, suitably stiffened.

34. Trough Flooring.—Where trough flooring is used for bridge floors, it shall be designed on the assumption that the wheel loads are distributed over 5 ft. run of the floor if the sleepers are parallel with the flutes of the troughs, and 10 ft. if they are at right angles to the flutes, without the fibre stress exceeding that specified for the span. A suitable stiffening girder shall be used in the centre of the span where the troughs carry a double track.

35. Wind-Bracing and Cross-Bracing.—Wind-bracing and cross-bracing between main girders or struts shall be formed of rigid members capable of resisting tension or compression.

General Data Assumed for Calculations.

36. Effective Spans, Lengths and Depths.—For the purposes of calculating the moments, stresses, shears and working strengths, the effective lengths and depths shall be taken as follows:—

For Main Girders.—The centres of bearing plates in the case of riveted plate or truss girders, and the centres of end pins in the case of pin-connected trusses.

For Cross Girders.—The centres of the main longitudinal girders or trusses.

For Rail Girders.—The centres of cross girders.

For Struts.—The centres of the vertical web plates of booms with riveted connections and the centres of pins with pin connections, where the web consists of a single system, but where the web consists of more than one system the length shall be taken between the points of intersection or between the points of intersection and the centre of vertical web plates or pin.

For Compression Flange and End Posts.—Between the points of intersection of the vertical or horizontal bracing with the flanges in weakest plane of bending. In unbraced compression flanges the effective length shall be taken as three-quarters of the total length.

Bending in Pins.—Between centres of bearings.

Effective Depths.—The effective depths of riveted plate or truss girders shall be taken as the centre of gravity of the upper and lower flanges, and, in the case of pin-connected trusses, the centres of pins, but not in any case to be more than the distance over the angles connecting the vertical web plates with the horizontal flange plates. The depth between the centres of the horizontal rows of rivets shall be used in calculating the horizontal shearing forces on the rivets connecting the flange angles to the web plates in plate girders.

37. Sectional Areas.—The net sectional area shall be taken for all tension members, and shall be determined by a plane cutting the member square across at any point. The greatest number of holes which can be cut by any such plane, or whose centre measured diagonally is less than 40 per cent. greater than the distance between the gauge lines shall be deducted from the gross section when computing the net area.

The gross sectional area shall be taken for all compression members.

The bearing and shearing areas of rivets shall be calculated on the diameter of the hole.

The shearing stress on the web plates of plate girders shall be calculated on the gross sectional area of the full depth of the plate.

In plate girders the flanges shall be calculated as resisting the whole of the bending stresses and web plates the whole of the shearing stresses, but one-eighth of the web plates may be included in the estimated sectional areas of the flanges, if the web plates are suitably covered to transmit horizontal stresses.

In deducting area for snap-headed rivets or turned bolts the diamater of the hole shall be taken, for countersunk rivets, one-eighth of an inch larger than the diameter of the holes; and for holes of black bolts, a hole one-eighth of an inch larger than the nominal diameter of the bolt shall be taken.

38. Loads.—All dead loads shall be assumed to be evenly distributed in the case of plate girders, except the load brought on the main longitudinal girders from the cross girders when they exceed 10 ft. centres. In the case of lattice or truss girders the dead load shall be assumed to be collected at the panel joints.

Live loads shall, in the case of lattice or truss girders, be considered to cover the panel in advance of the panel joint being considered, but the half load will be ignored in the calculations.

39. Riveting in Webs.—In calculating shearing and bearing stresses on web rivets of plate girders, the whole of the shear acting on the side of the panel next the abutment shall be considered as being transferred into the flange angles in a distance equal to the effective depth of the girder, with a deduction for the bending stress carried by the web plate.

Provision shall be made for local shear from heavy wheel loads, and the rivet spacing in top flanges of deck plate girders and rail bearers shall not exceed 4 in.

40. Vertical Cross-Bracing Between Struts.—The vertical cross-bracing between struts shall be proportioned to carry 50 per cent. of the panel load due to wind, and the struts shall be calculated to resist any bending stresses from the wind loads.

Rolled I Beam Spans.

41. Depth.—Rolled joists used as longitudinal girders shall, preferably, have a depth of not less than one-twelfth of the span.

42. Construction with Open Floor.—Rolled joist spans may be constructed with either one or two joists per rail.

With single joists per rail the spacing should be $6\frac{1}{2}$ ft. centres, with rigid cross struts and diagonal bracing between the top flanges, unless the span is under 10 ft., when the diagonal bracing may be omitted.

With two joists per rail the spacing should not exceed $2\frac{1}{2}$-ft. centres for the two joists under the rail. No diagonal bracing is required, but the rigid cross struts must extend across the four joists under each track at the ends of the spans and also at mid-span when the length of span exceeds 10 ft.

43. Construction with Plated Floor.—Rolled joist spans with plated floor riveted to the top flanges may be constructed with either one or two joists per rail spaced at the same centres as with the open floor.

44. General.—Each joist shall have at each end a pair of end stiffening angles riveted to the web and fitted tightly between the top and bottom flanges.

Suitable bearing plates to distribute the load on the abutments shall be provided at each end of the joists.

Where handrails are required they shall be carried on suitable longitudinal rolled joists, and shall be either of gas tubes with standards or of plate construction as required.

Plate Girder Spans.

45. Depth.—Plate girders shall, preferably, have a depth of from one-tenth to one-twelfth of the span.

46. Splices.—All plate girders, whenever it is practicable, shall be built without splices; but, where this is unavoidable, the smallest number of splices shall be adopted.

47. Flanges.—Whenever practicable, at least one-half of the flange section shall be contained in the angles, or else the heaviest section of angles shall be used, and the number of flange plates reduced to a minimum. To obtain an even distribution of stress over the cross section of the flange plates, they shall not project more than 8 in. or sixteen times their thickness beyond the outer line of rivets through the flange angles.

The compression flange shall be stiffened laterally by cross-bracing frames in the case of deck spans, and triangular brackets extending from the top flange to each cross girder

Rail bearers shall be placed under each rail and riveted to the cross girder webs. The deck shall be covered with buckled plates, riveted to the floor girders and to suitable intermediate supports. The buckled plates shall not be less than $\frac{5}{16}$ in. in thickness, with a buckle of at least $2\frac{1}{2}$ in., and preferably placed with the buckle downwards. Suitable provision shall be made for draining the floor of the accumulation of rain water.

Horizontal diagonal bracing shall be fixed between the top booms of main girders of the necessary strength to transmit the wind pressure safely to the portal bracing between the end posts, and of sufficient rigidity and stiffness to keep the booms in line. Where there is an open floor, rigid horizontal diagonal bracing shall be fixed between the bottom booms of main girders to transmit the lateral stresses to the piers or abutments. The lower diagonal bracing shall be rigidly secured to the rail bearers, so as to transmit the longitudinal thrust due to train momentum through the diagonals to the main girders and to relieve the cross girders of horizontal bending.

Cross-bracing of the maximum depth permissible with the required headroom shall be fixed between the tops of struts, with knee brackets riveted at top corners to struts and cross-bracing and at bottom corners to struts and cross girders, so that a rigid frame is formed at each strut or vertical suspender.

Portal bracing of the maximum depth permissible with the required headroom shall be riveted to the end posts. Rigid knee brackets shall be riveted to the portal bracing and end posts. In determining the sectional area of the end posts, provision must be made for the bending stresses due to the wind pressure. The end posts shall be considered as fixed at the ends, and the leverage from bottom of end post to underside of portal bracket reduced by one-half.

52. General Proportions.—The depth of main and cross girders shall not be less than one-tenth of the span and shall, preferably, be one-eighth. Rail bearers shall have a depth of not less than one-twelfth of their span.

The centres of the main girders shall not be less than one-twentieth of the span, and the height of main girders not more than three times the width between their centres.

53. Construction of Main Girders.—The booms and end posts shall, preferably, be of trough section. The top booms and end posts shall have edge angles riveted to the edge of the vertical plates of the troughs. Suitable plate diaphragms shall be riveted between the vertical side plates of booms. The width of booms shall not be less than one-fifteenth of the unsupported distance or one-forty-fifth of the length. Provision shall be made for draining the trough booms of the accumulation of rain water.

Struts shall, generally, be of four angles, with or without side plates and a web plate; but where lacing bars are substituted for the web plate, they shall conform to the rules of lacing bars for compression members.

Ties shall, as far as practicable, be constructed of rigid members, but they may be of rolled flat bars, except near the centre, where they must be formed of rigid members. Counter-bracing shall be of similar construction to the centre ties. Distance pieces shall be used between the plates forming long ties to reduce vibration.

in through spans, at intervals of not more than fifteen times its width. The length of the compression flange shall not exceed forty-five times its width.

Main girders of plate construction shall, preferably, have one flange plate extending from end to end in the compression flange.

48. Web Plates and Stiffeners.—Web plates shall have angle-bar stiffeners riveted on both sides at the ends and inner edges of the bearing plates, and at all points of local and concentrated loads, and also at points throughout the length of the girder, generally not farther apart than the depth of the girder, with a maximum spacing of 6 ft., when the thickness of the web is less than one-sixtieth of the unsupported distance between the flange angles.

All stiffeners shall bear tightly and top at bottom against the flange angles. All stiffeners over the bearing plates shall have packings under them of the same thickness as the flange angles and as wide as the stiffener angles, but intermediate stiffeners shall, preferably, be joggled over the flange angles unless the latter exceed $\frac{5}{8}$-in. in thickness. Where practicable, stiffeners shall be placed at web joints. The stiffeners and the rivets connecting them to the web plate should be of sufficient area to take at least one-half of the vertical shear at the point of attachment of stiffeners to web plate.

Stiffening angles over the bearing plates shall in no case be less than $3\frac{1}{2}$ in. by $3\frac{1}{2}$ in. by $\frac{3}{8}$ in., but must have sufficient area to carry the entire shear without exceeding the specified intensity of working stress, no reliance being placed on the packings. They shall be proportioned as struts having a length equal to the depth of the girder.

The combined width over the outstanding legs of intermediate stiffeners shall not be less than one-tenth of the depth of the girder plus 2 inches, and the thickness shall not be less than three-fourths of the thickness of the web plate or one-twelfth of the outstanding leg of the stiffener.

Girders will be neatly finished at the ends. They will, generally, have a plate, corresponding in width to the flange plates, riveted to the end angles.

49. Cross-Bracing and Deck Spans.—Cross-bracing, consisting of complete frames, shall be used at the ends and at intermediate points where needed for wind and centrifugal force.

50. Lateral Bracing.—In spans with open floors, horizontal diagonal bracing shall extend from end to end of sufficient section to resist the wind and centrifugal force. This bracing shall, preferably, be of rigid members. In plated floors this diagonal bracing may be omitted.

Riveted Truss or Lattice Girders.—Through Bridges.

51. General Design.—The main girders of through bridges shall, preferably, be of the single intersection type, with inclined end posts and ties and vertical struts and suspenders.

Cross girders shall be riveted to the vertical struts and suspenders, and a cross girder shall be secured to ends of main girders to support the rail bearers.

The open side of long compression members shall be stayed with intermediate tie plates or bracing where necessary. The tie plates shall have a thickness of not less than one-fiftieth of their unsupported width, except where they are stiffened with angle bars, when they may be $\frac{5}{16}$ in. The length of tie plates at the ends of laced struts or lateral bracing shall not be less than the vertical side plates of the main booms.

The latticing of compression members shall be proportioned for a transverse shear at any point in their length equal to not less than $2\frac{1}{2}$ per cent. of the axial load on the member. This shearing force shall be considered as divided between all transverse parallel stiffening planes in proportion to their distances from the neutral axis of the member.

The width of flat bar lacings shall not be less than three times the nominal diameter of the rivets connecting them to the main member. Their thickness shall not be less than one-fortieth of the minimum distance between the centres of rivets in the case of single latticing and one-sixtieth for double latticing, riveted at the intersection. Angle, tee, channel or tube sections of equivalent strength may be substituted for flats.

The distance between connections of lacing bars shall not exceed eight times the least width of the segments connected.

Vertical suspenders shall be composed of rigid members, and shall be proportioned to take three-quarters of the stress as a compressive stress.

All sections shall, as far as possible, be symmetrical about the centre line of stress, and all rivets grouped symmetrically about the same line.

Where angle bars connected by one blade are used as ties, the sectional areas shall be taken as follows:—For equal sides angle bars, 75 per cent. of net sectional area, for angle bars with sides in the proportion of 2 to 1 and connected by longer side, 90 per cent.; intermediate size shall be interpolated.

54. Construction of Floor Girders.—Cross girders and rail bearers shall, preferably, be composed of four angles and a web plate without flange plates and the details shall, generally, conform to the rules for plate girders.

Half Through Bridges.

55. General.—The details shall, generally, conform to the requirements for through bridges, but all struts shall be formed with plate webs and knee brackets of the largest dimensions permissible with the required clearances shall be riveted to each strut and cross girder.

Deck Bridges.

56. General.—The details shall, generally, conform to the requirements for through bridges. Rigid cross frames and diagonal bracing shall be provided as for deck plate girders.

Workmanship.

57. General.—The whole of the workmanship shall be of the highest class and equal to the requirements for first-class bridge-work, as given in British Engineering Standards

Association Specification No. 153.

58. Planing, Machining and Fitting of Sheared Edges.—The ends of all girders that butt or fit against other webs shall be finished true and square or to exact level required, so as to give a good bearing, and end angles shall be flush with ends of web plates.

All packings and cover plates must fit sufficiently close to the flanges at their ends to be sealed against the admission of water when painted.

All web stiffeners shall be fitted to bear tightly against the flange angles.

59. Punching, Drilling and Riveting.—All rivet, bolt and pin holes shall be drilled, except for floor plates and lacing bars, when they may be punched.

All rivet holes shall be $\frac{1}{16}$ in. larger in diameter than the nominal size of rivet.

Rivets must completely fill the holes and have large cup heads, and be machine driven wherever practicable. Countersinking shall be neatly done.

60. Eyebars.—Eyebars shall be formed without welding and shall be slightly stronger in the head than in the body of the bar.

The heads shall be made by upsetting, rolling or forging into shape. A variation from the specified dimensions of the heads will be allowed, in thickness of $\frac{1}{32}$ in. below and $\frac{1}{16}$ in. above that specified and in diameter $\frac{1}{4}$ in. in either direction.

Eyebars must be perfectly straight before boring. All eyebars shall be annealed.

61. Loop Ends to Bars.—Where unavoidable, welding will be allowed to form the loop ends of minor bracing bars.

62. Screw Ends to Bars.—All screw ends to bars shall be at least $\frac{1}{16}$ of an inch larger at the base of the thread than in the body of the bar and the enlarged ends shall be formed without welding.

An increased diameter of one-eighth of an inch over the net size shall be taken in the case of bars used without enlarged ends.

63. Riveted Tension Bars.—Riveted tension bars with pin connections shall have a net area through pin-hole of not less than one and a half times the net area in the body of the bar and between the pin-hole and the end of the bar of at least four-fifths of the net area. Sufficient rivets shall be provided to make the thickening plates at the pin-hole effective.

The length from edge of pin-hole to the end of tension bar shall not be less than the diameter of the pin.

64. Pins.—All pins shall be turned straight and smooth to a gauge and shall fit the pin-holes to $\frac{1}{50}$ in. They shall be turned to a smaller diameter at the ends for the thread and driven to place with a pilot nut where necessary to preserve the threads.

65. Rollers and Bedplates.—Rollers shall be turned accurately to gauge and be finished perfectly round and to the correct diameter from end to end. The tongues and grooves in the plates and rollers must fit closely to prevent lateral motion.

Roller beds and expansion bearings shall be planed with the cut of the tool in the direction of movement.