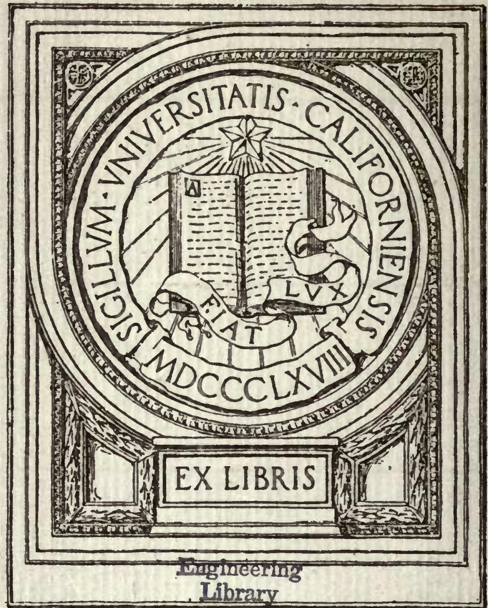
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SPECIFICATIONS FOR STEEL BRIDGES.

(*TAKEN FROM "DE PONTIBUS."*)

BY

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PREFACE.

It appears that there is considerable demand by draftsmen and computers for the specifications of "De Pontibus," but that the book is too expensive to use for specifications only; consequently the author and publishers of that work have concluded to print the said specifications, together with the tables and diagrams, separately from the other chapters—hence this little book, which it is hoped will serve the purpose of the aforesaid gentlemen at one-third of the cost of the original treatise.

A few changes in the specifications have been made in order to bring them up to date, the principal modifications being the following:

1st. The adoption of additional live loads in order to provide diagrams having engines as heavy as any yet built and even a little heavier.

2d. The increase in headroom for railway bridges from 21′ 6″ to 23′ 0″. This is to provide safety for a tall man standing with his hands over his head on a car fifteen feet high. There are such cars in actual use; and several railroad companies are now specifying the greater clearance.

3d. The adoption of rollers surrounded with oil. This is a new detail now used in the author's practice.

4th. A modification of several formulæ for man-power apparatus in rotating draw-spans. The old formulæ required more metal than is really necessary.

5th.—Some slight changes in percentages of elongation on p. 108 (De Pontibus, p. 248). These were agreed upon by conference with the representative of the largest steel-manufacturing company in America. It seems that the old requirements were a trifle too high.

6th. A modification of the requirements for tests of full-sized eyebars. This is in the nature of a compromise with the manufacturers.

7th. A small reduction in intensities of working stresses for rivets.

All other changes that have been made are too insignificant to be worth mentioning.

These specifications are used exclusively in the practice of the firm of Waddell & Hedrick; and they have been found to apply equally well to bridges of all kinds and sizes, from little ten-foot I-beam spans up to railway cantilever bridges having spans as long as sixteen hundred feet.

As the said specifications have proved so satisfactory to the author's computers and draftsmen, it is hoped that they will be equally useful to other engineers engaged in the designing of bridges.

The author desires to acknowledge here his indebtedness to his partner, Mr. Ira G. Hedrick, for valuable aid rendered him in the preparation of this work.

KANSAS CITY, MO.,
July, 1900.

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(Chapter XIV. of "De Pontibus.")

GENERAL DESCRIPTION.

MATERIALS.

All parts of the structure, except ties, foot-planks, and guard-timbers, shall, for all spans of ordinary lengths, be of medium steel, excepting only that rivets and bolts are to be of soft steel, and adjustable members of either soft steel or wrought iron. For very long spans high steel may be used for top chords, inclined end posts, pins, eye-bars in bottom chords, and those in main diagonals of panels where there is no reversion of stress when impact is included. It may be used also for the web-members of cantilever and anchor arms in cantilever bridges where the variation of stress is comparatively small and where the impact cannot be great. Excepting for purely ornamental work, cast iron will not be allowed to be used in the superstructure of any bridge, trestle, or elevated railroad, cast steel being employed wherever important castings are necessary.

CROSS-TIES, FOOT-PLANKS, AND GUARD-TIMBERS.

Cross-ties, foot-planks, and guard-timbers shall be of long-leaf, Southern yellow pine or other timber which, in the opinion of the Engineer, is equally good and serviceable. The wooden floor shall be so designed as to ensure safety from passing trains for the railroad employees. The spaces between ties shall, in general, not be less than five (5) inches nor more than six (6) inches wide. The sizes of ties shall be such as to give the requisite resistance to bending, under the assumption that the load on one pair of wheels is distributed equally over three ties, the effect of impact being considered. No tie shall be less than seven (7) or preferably eight (8) inches wide, nor less than six (6) inches deep, nor less than ten (10) feet long, except in the case of elevated railroads, where the length may be reduced to eight (8) feet for a spacing of five (5) feet between central planes of longitudinal girders.

Ties shall be dapped to a full and even bearing not less than one-half ($\frac{1}{2}$) inch onto the stringers; and each alternate tie shall be secured thereto at each end by a three-quarter ($\frac{3}{4}$) inch hook bolt, having at the hook end a square shank at least two (2) inches long to prevent the bolt from turning.

All timber bolts shall be of soft steel, with cold-pressed threads.

Outer guard-timbers shall be 6″ × 8″ laid on flat, dapped one (1) inch onto the ties, and placed so that their inner faces shall be just twelve (12) inches from the gauge-planes of rails.

Where inner guard-timbers are employed, they shall be 6″ × 8″ on flat, dapped one (1) inch onto the ties, and placed so that their outer faces shall be just five (5) inches from the gauge-planes of rails.

Each guard-rail must be bolted to each alternate tie by a three-quarter ($\frac{3}{4}$) inch screw-bolt, the head of which shall be countersunk into the wood by means of a cup-shaped washer. Each guard-timber must be spliced over a tie with a half-and-half joint of at least six (6) inches lap, through which must pass a three-quarter ($\frac{3}{4}$) inch screw-bolt.

Guard-timbers shall extend over all piers and abutments.

Steel rails or heavy steel angles well fastened to the ties may be substituted for the inner wooden guard-rails, or the inner guards may be omitted altogether if the Engineer so direct.

RERAILING APPARATUS.

At each end of every bridge or trestle, there is to be placed a rerailing apparatus that will, in the most effective manner practicable, return to the track any derailed car or locomotive that is not more than half the width of track gauge out of line.

BUCKLED-PLATE FLOORS.

If the Engineer so desire, a buckled-plate floor with ties in ballast may be used instead of the wooden floor, in which case the size of the ties may be reduced to 6″ × 8″ × 8′.

All buckled-plate floors must be thoroughly drained so as not to retain water, and the upper surface of the buckled plate must be protected from rusting by a liberal use of the best obtainable preservative coating.

SUPERELEVATION ON CURVES.

On curves the outer rail will be elevated the proper amount for the degree of curvature and for the assumed medium velocity of trains; and this elevation must be framed into ties, as no shims will be allowable anywhere under ties or rails, excepting in the case of very sharp curves requiring a superelevation exceeding three (3) inches in five (5) feet, on which long shimming timbers are to be bolted to the top flanges of the outer longitudinal girders, or short, substantial ones to tops of ties, so as to give the required superelevation.

The formula to be used for total superelevation on standard-gauge roads is

$$E = \frac{0.3277\,V^2}{R},$$

where E is the total superelevation in feet of the exterior rail above the interior rail, V is the assumed velocity of train in miles per hour, and R is the radius of the curve in feet. The total superelevation is to be obtained by depressing the inner rail and elevating the outer one equal amounts, thus preserving the grade of the centre line.

SPACING OF STRINGERS, GIRDERS, AND TRACKS.

In general, stringers for through bridges shall be spaced eight (8) feet centres or less for single-track bridges and six (6) feet six (6) inches for double-track bridges and half-through plate-girder bridges. In elevated railroads the spacing of the longitudinal girders may be made as small as five (5) feet centres.

Deck plate-girders may be spaced from six (6) feet to ten (10) feet centres, the usual distance being the nearest even foot to one tenth ($\frac{1}{10}$) of the span; but in high trestles the spacing shall, preferably, be ten (10) feet, and never less than eight (8) feet.

The standard distance between centres of tracks on tangent for surface railroads shall be thirteen (13) feet, while for elevated railroads it shall generally be twelve (12) feet.

SPACING OF TRUSSES.

From centre to centre of through-trusses the perpendicular distance shall not be less than seventeen (17) feet, or one twentieth ($\frac{1}{20}$) of the span length.

From centre to centre of deck, pin-connected, or riveted trusses the perpendicular distance shall not be less than ten (10) feet or one thirteenth ($\frac{1}{13}$) of the span length, except in the case of elevated railroads, where open-webbed, riveted girders are adopted. These may be spaced according to the directions given for plate girders.

CLEARANCES.

The clear opening on tangent shall not be less than that shown in Fig. 7.

On curved track, the horizontal distance from the centre of track to clearance line shall be increased at all points two (2) inches for each degree of curvature.

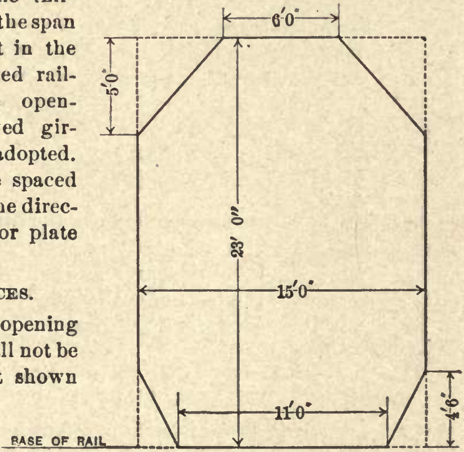


FIG. 7.

EFFECTIVE LENGTHS.

Effective lengths shall be as follows:

For pin-connected spans, the effective length shall be the distance between centres of end-pins of trusses.

For riveted girders, it shall be the distance between centres of bearing-plates.

For stringers, it shall be the distance between centres of cross-girder webs.

For cross-girders, it shall be the perpendicular distance between central planes of trusses.

For columns and posts, it shall be the greatest length between points of axis that are rigidly held in the direction in which the strength is being considered.

These effective lengths are to be used in calculating moments, stresses, and working strengths.

EFFECTIVE DEPTHS.

Effective depths shall be as follows:

For pin-connected trusses, the perpendicular distance between gravity lines of chords, which lines must pass through centres of pins.

For plate-girders and open-webbed riveted girders, the perpendicular distance between centre lines of gravity of upper and lower flanges; but never to exceed the depth from out to out of flange angles.

STYLES OF BRIDGES FOR VARIOUS SPAN LENGTHS.

For spans under fifteen (15) feet, rolled I beams.

For spans between fifteen (15) feet and eighty-five (85) feet, plate girders.

For spans between eighty-five (85) feet and one hundred and twenty-five (125) feet, "A" truss, pin-connected spans, or riveted, open-webbed girders of single cancellation.

For spans between one hundred and twenty-five (125) feet and one hundred and seventy-five (175) feet, riveted, open-webbed girders of single cancellation, or pin-connected trusses designed with special reference to extreme rigidity in all parts.

For spans exceeding one hundred and seventy-five (175) feet, pin-connected spans.

The use of pony-truss bridges of any kind is prohibited, excepting only half-through, plate-girder spans, in which the top flanges are held rigidly in place by brackets riveted to cross-girders that are spaced generally not to exceed fifteen (15) feet apart.

In general, double-track bridges shall have only two trusses, in order to avoid spreading the tracks.

FORMS OF TRUSSES.

The forms of trusses to be used are as follows:

For pin-connected spans up to one hundred and twenty-five (125) feet, the "A" truss.

For open-webbed, riveted girders, the Warren or triangular girder with verticals dividing the panels of the top chords; also the Pratt truss.

For deck-spans having top chords supporting wooden ties, the Warren or triangular girder with verticals dividing the panels of the top chords.

For spans between one hundred and twenty five (125) feet and about two hundred and fifty (250) feet, Pratt trusses with top chords either straight or polygonal,

For spans exceeding two hundred and fifty (250) feet, Petit trusses.

It is understood that these limiting lengths are not fixed absolutely, as the best limits will vary somewhat with the number of tracks and weight of trains.

MAIN MEMBERS OF TRUSS-BRIDGES.

All spans of every kind shall have end floor-beams, riveted rigidly to the trusses or girders, for supporting the stringers.

Stringers are to be riveted to the webs of the cross-girders.

In general, all trusses shall have main end posts inclined.

All trusses shall be so designed as to admit of accurate calculation of all stresses, excepting only such unimportant cases of ambiguity as that involved by using two stiff diagonals in a middle panel.

All lateral bracing and other sway-bracing shall be rigid both above and below, i.e., the sections must be capable of resisting compression, adjustable rods for such bracing being allowed only in towers of draw-spans and in lower lateral systems of deck-bridges.

The stiff diagonals of lower lateral systems, which shall be of double cancellation, shall be riveted rigidly to the stringers where they cross them, so as to transfer in an effective manner the thrust of braked trains to the truss-posts without causing a horizontal bending on the cross-girders.

All through-spans shall have stiff portal bracing at each end, connected rigidly to the inclined end posts. The said portal bracing shall be made as deep as the specified clear headroom will allow.

When the height of the trusses is great enough to permit it, there shall be used at each panel point a rigid bracing frame riveted to the top lateral strut and to the posts, and carried down to the clearance line. When the truss depth is not great enough for this detail, corner brackets of proper size, strength, and rigidity are to be riveted between the posts and the upper lateral struts.

Deck-bridges shall have stiff, diagonal braces between opposite vertical posts, which bracing, as a matter of precaution, shall have sufficient strength to carry one half of a panel-truss live load with its impact allowance; and the transverse bracing between the vertical or inclined posts at each end shall be sufficiently strong to transmit properly to the masonry one half of the wind-pressure and centrifugal load (if there be any) which is carried by the entire upper lateral system of the span.

The lower lateral systems of deck-bridges shall be made of adjustable rods in alternate panels, thus leaving every other panel unbraced, and forcing the wind-pressure from below up the vertical bracing and to the ends of the span by the upper lateral system.

Suspenders or hip verticals and two or more panel lengths of bottom chord at each end of each span shall, preferably, be made rigid members, excepting that in "A" trusses the bottom chords and centre verticals are to be of eye-bars.

All floor-beams are to be riveted to the truss-posts in truss-spans, excepting in the case of Petit trusses when the suspenders are of eye-bars. In these, floor-beam hangers may be used, provided they be made of plates or shapes, and that they be stayed at their upper ends against all possibility of rotation.

CONTINUOUS SPANS.

Except in the case of swing-bridges or cantilevers, consecutive spans are not to be made continuous over the points of support.

TRESTLE TOWERS.

As a general rule, each trestle-bent shall be composed of two columns battered from one and a half (1½) to two and a half (2½) inches to the foot, the bents being united in pairs to form towers. Each tower thus formed shall be thoroughly braced with rigid bracing on all four faces, and shall have four horizontal struts at the base. In each intermediate horizontal plane of division, formed by the panels of the tower bracing, there is to be a pair of diagonal adjustable rods to bring the columns into proper position and to retain them there.

The feet of the columns must be attached to anchorages capable of resisting twice the greatest possible uplifting; and the details of the metal-work connecting the anchor-rods to the columns must be such as to make the metal-work and pedestals act as a single piece, so that, if tested to destruction by overturning, the bent would not fail between the superstructure and the substructure.

While it is desirable to have sufficient base to prevent any tension from coming on the anchor-bolts, it is not advisable on this account to make the batter of the columns too great, especially in very high trestles.

When trestle-bents become unduly wide, a vertical column is to be placed midway between the legs so as to divide up the transverse and horizontal sway-bracing.

Care must be taken to provide properly for expansion and contraction at column feet both transversely and longitudinally.

In elevated railroads, the towers can be placed at about every fourth span or, say, every one hundred and fifty feet, or can be dispensed with altogether, when the conditions so require, by strengthening the columns properly to resist traction, thrust of braked trains, and the longitudinal component of diagonal wind-pressure.

ADJUSTABLE MEMBERS.

It is preferable to avoid altogether the use of adjustable members in trusses, as well as in sway-bracing. If the structure must be made as cheap as possible, adjustable counters may be employed ; but it is advisable to confine their use to diagonals in towers of swing-spans and in lower lateral systems of deck-bridges.

CAMBER.

All trusses must be provided with such a camber that, with the heaviest live load on the span, the total camber shall never be quite taken out by deflection. With parallel chords, sufficient camber will be obtained by making the top-chord sections longer than the corresponding bottom-chord sections by one eighth ($\frac{1}{8}$) of an inch for each ten (10) feet of length. One half of the camber after a span is swung is to be taken out of the track by dapping the ties, unless this would cut too deeply into the timber.

Plate girders and shallow, open-webbed, riveted girders should not be given any camber.

EXPANSION.

Every span must be provided with some means of longitudinal expansion and contraction due to changes of temperature over a range of one hundred and fifty (150) degrees Fahrenheit.

Spans up to eighty-five (85) feet in length, or in certain cases up to even one hundred (100) feet, may slide on planed surfaces; but those of greater length must move on nests of turned rollers. Occasionally a rocker end is permissible; but this method of expansion is always to be avoided if practicable.

ANCHORAGE.

Every span must be anchored at each end to the pier or abutment in such a manner as to prevent the slightest lateral motion, but so as not to interfere with the longitudinal motion of the trusses or girders due to changes of temperature or loading.

NAME-PLATES.

The names of the designer, manufacturer, and builder of every bridge or trestle, also the date of erection, must be attached thereto in a prominent position and in a durable manner.

LOADS.

The loads to be considered in designing bridges, trestles, and elevated railroads are the following; and all parts of same are to be proportioned to sustain properly the greatest stresses produced thereby for all possible combinations of the various loads.

A. Live Load.
B. Impact Allowance Load.
C. Dead Load.
D. Direct Wind Load.
E. Indirect Wind Load, or Transferred Load.
F. Traction Load.
G. Centrifugal Load.
H. Effects of Changes of Temperature.

In calculating the stresses caused by a uniform moving load, the load shall be assumed to cover the panel in advance of the panel point considered; but the half-panel load going to the forward panel point will be ignored; or, in other words, the uniform load will be treated as if concentrated at the various panel points.

In deck-spans on sharp curves, after the centre curve for each rail and the centre lines of the longitudinal girders are laid out, the approximate extra live load on the outer girder due to the projection of the curve of the rail beyond its centre line near mid-span is to be computed and added to the regular live load; but the corresponding excess of dead load from the flooring, being small, is to be ignored. As the superelevation provides for an equal distribution of the live load on the rails for the assumed medium velocity of trains, there will be an excess of live load on the outer girder due to the velocity being sometimes greater than this; but the said excess is so small that it is to be ignored.

The excess of live load on the inner girder, due to the velocity of train being sometimes less than that assumed for determining the superelevation, is offset by the reduced load due to the projection of the centre line of the rail near mid-span beyond the centre line of the girder; so it also is to be ignored.

LIVE LOADS.

The live load to be used in designing any railroad structure shall be taken from the "Compromise Standard System of Live Loads for Railway Bridges and the Equivalents for Same," which is given in Chapter XIX and in Plates I, II, III, and IV.

In single-track bridges but one of the seven classes of loading given can be used for any span; but in bridges having more than one track two or even three classes of loading can be used in the same span, if so desired by the Engineer: for instance, Class W could be adopted for stringers, Class X for cross-girders, and Class Y for trusses, thus utilizing the theory of probabilities.

The equivalent live loads given on the diagrams are to be used instead of the actual wheel concentrations.

For elevated railroads the live loads are generally to be very much lighter than that of Class Z of the Compromise Standard System; but the said loads will have to be determined for each individual system of elevated railroad, so as to provide for the greatest train load that can ever come upon the structure, but for no more.

IMPACT ALLOWANCE LOAD.

The impact allowance load is to be a percentage of the equivalent uniform live load, found by the formula

$$P = \frac{40000}{L + 500},$$

where P is the percentage and L the length in feet of span or portion of span that is covered by the live load, when the member considered is subjected to its maximum stress.

DEAD LOAD.

The dead load is to include the weight of all the metal and wood in the structure, excepting that of those portions resting directly on the abutments, whose weights do not affect the stresses in the trusses; also any other permanent load that may be carried by the structure.

The following unit weights are to be assumed in estimating the dead load:

Creosoted lumber four and one-half ($4\frac{1}{2}$) pounds per foot board measure.

Oak and other hard woods four and a quarter ($4\frac{1}{4}$) pounds per foot board measure.

Yellow pine three and three-quarters ($3\frac{3}{4}$) pounds per foot board measure.

White pine and other soft woods two and three-quarters ($2\frac{3}{4}$) pounds per foot board measure.

Rails and their fastenings, sixty (60) pounds per lineal foot per track.

Two thirds ($\frac{2}{3}$) of the dead load shall be assumed to be concentrated at the panel points of the lower chords in through-bridges and at those of the upper chords in deck-bridges; and one third ($\frac{1}{3}$) of the dead load at the panel points of the upper chords in through-bridges and at those of the lower chords in deck-bridges.

If in any bridge design the dead load assumed should differ from that computed from the diagram of sections and the detail drawings by an amount exceeding one (1) per cent of the sum of the equivalent live load and actual dead load, the calculations of stresses, etc., are to be made over with a new assumed dead load.

WIND LOADS.

For railroad bridges the wind loads per lineal foot of span for both the loaded and the unloaded chords are to be taken from the curves given in Plate VII.

The wind loads for the loaded chords include a pressure of three hundred (300) pounds per lineal foot on the train, the centre of which pressure is applied at a height of eight (8) feet above the base of rail.

For determining the requisite anchorage for a loaded structure, the train of empty cars shall be assumed to weigh one thousand (1000) pounds per lineal foot.

In trestle towers the columns and transverse bracing shall be proportioned to resist the following wind-pressures in addition to all other loads.

1st. When the structure is loaded, four hundred and fifty (450) pounds per lineal foot on stringers and cars, and two hundred and fifty (250) pounds for each vertical foot of each entire tower.

2d. When the structure is empty, three hundred and fifty (350) pounds per lineal foot on stringers, assumed to be concentrated one foot above the centre of stringer, and three hundred and fifty (350) pounds for each vertical foot of each entire tower.

The wind loads for longitudinal bracing are to be taken as seven tenths (0.7) of those for the transverse bracing.

In figuring greatest tension on columns and anchor-bolts, computations are to be made for both the loaded and the unloaded structure, in double-track trestles placing the train of empty cars on the leeward track.

All wind loads are to be treated as *moving loads*

INDIRECT WIND LOAD OR TRANSFERRED LOAD.

For both through and deck spans, even with polygonal top chords, the transferred load is to be assumed to produce a tension in the leeward bottom chord that is constant from end to end of span, and a similar release of tension on the windward bottom chord. For trusses with parallel chords this assumption is correct, provided that all the wind-pressure travels directly to ends of span by the horizontal bracing; while for trusses with polygonal top chords the assumption is a compromise, the travel of wind-pressure being ambiguous. The transferred load at one pedestal is to be found by multiplying one half of the total wind load on the top chord by the average truss depth and dividing the product by the perpendicular distance between central planes of trusses.

TRACTION LOAD.

The total traction load on any portion of a structure is to be taken as twenty (20) per cent of the greatest live load that can be placed on that portion of said structure.

In proportioning the towers and columns of trestles and elevated railroads, the towers and columns between consecutive expansion points are to be assumed to receive no aid from neighboring towers and columns, but must be figured for the greatest possible traction load between said consecutive expansion points.

No percentage of impact is to be added to traction loads.

CENTRIFUGAL LOAD.

The centrifugal load is to be computed for the greatest probable velocity of trains by the formula

$$C = \frac{wv^2}{32.2R},$$

where C is the centrifugal load per lineal foot, w is the equivalent live load per lineal foot, v is the velocity of train in feet per second, and R is the radius of the curve in feet.

All portions of the structure affected by the centrifugal load are to be figured to carry properly the stresses induced by the said load in addition to all other stresses to which they may be subjected.

No percentage of impact is to be added to centrifugal loads.

EFFECTS OF CHANGES OF TEMPERATURE.

In ordinary structures changes of temperature will not affect the stresses in the members, provided, of course, that proper precaution be taken to permit unrestricted expansion and contraction. But in all arches, excepting only those hinged at both ends and at the crown, the stresses caused by the assumed extreme changes of temperature must be computed and duly considered.

INTENSITIES OF WORKING-STRESSES.

The following intensities of working-stresses (i.e., pounds per square inch of cross-section) are to be used for all cases, except where wind loads are combined with other loads, under which conditions the said intensities are to be increased thirty (30) per cent. But when high steel is employed the metal is to be strained fifteen (15) per cent higher for all cases than herein specified, even after the said thirty (30) per cent has been added to allow for wind stresses.

Tension on eye-bars in bottom chords and main diagonals, and on lateral rods	18,000 pounds.
Tension on shapes in bottom chords, main diagonals and laterals, on eye-bars in suspenders and hip verticals, and on soft-steel adjustable truss members	16,000 "
Tension on net section of plate-girder flanges (assuming one eighth of the area of the web to act as a part of each flange), extreme fibres	

of rolled I beams, and on shapes in body of suspenders, hip verticals and hanger-plates (there being 50 per cent increase of net area for section through eyes)	14,000 pounds
Tension on adjustable truss members of wrought iron	13,000 "
Bending on pins	27,000 "
Bearing on pins (measured upon the projection of the semi-intrados upon a diametral plane)	22,000 "
Bearing on rivets	20,000 "
Shear on pins	15,000 "
Shear on rivets	10,000 "
Shear on webs of plate girders	10,000 "

For field-rivets the intensities for bearing and shear are to be reduced twenty (20) per cent.

Compression on top chords	$18,000 - 70\frac{l}{r}$;
Compression on inclined end posts	$18,000 - 80\frac{l}{r}$;
Compression on all other struts with fixed ends	$16,000 - 60\frac{l}{r}$;
Compression on all other struts with one or two hinged ends	$16,000 - 80\frac{l}{r}$;

where l is the unsupported length of the strut in inches and r is its least radius of gyration in inches.

Compression on end stiffeners of plate girders.	14,000 pounds.
Tension on extreme fibres of long leaf, Southern, yellow-pine timber in bending, the effect of impact being considered	2,000 "

BEARINGS UPON MASONRY.

All bed-plates must be of such dimensions that the greatest pressures on the masonry, including impact, shall not exceed those given in the following table;

Material.	Permissible Pressure per Square Inch.
Am. Nat. Cement Concrete	130 pounds.
Brickwork laid in Cement	170 "
Portland Cement Concrete	200 "
Ordinarily Good Sandstone	200 "
Extra Good Sandstone	250 "
Yellow Pine or Oak on Flat	300 "
Ordinarily Good Limestone	300 "
Extra Good Limestone	400 "
Granitoid	450 "
Granite	550 "

REVERSING-STRESSES.

In case stresses reverse, the areas required for both tension and compression, including impact in each case, are to be figured separately, and three fourths ($\frac{3}{4}$) of the smaller area is to be added to the larger area in order to obtain the total sectional area of the piece. The rivets, however, are to be figured for the sum of the two stresses, both impacts included.

The effect of reversion of stresses in case of wind loads is to be ignored when computing sectional areas of members and the number of rivets required ; but, of course, wherever reversion of stress occurs, the piece must be stiffened so as to resist compression.

NET SECTION.

The net section of any tension flange or member shall be determined by a plane cutting the member square across at any point. The greatest number of rivet-holes which can be cut by any such plane, or whose centres come nearer than two and a half ($2\frac{1}{2}$) inches to said plane, are to be deducted from the gross section when computing the net area.

BENDING MOMENTS ON PINS.

In figuring the bending moments on pins, the stresses shall be assumed as concentrated at centres of bearings.

COMBINATIONS OF STRESSES.

In the girders of plate-girder spans and of deck, open-webbed, riveted-girder spans, the only stresses that need to be considered are those caused by the live, impact, dead, and centrifugal loads.

The trusses of through-bridges will be affected by the live, impact, dead, direct wind, and indirect wind loads; and in exceptional cases also by the centrifugal load. The trusses of deck-bridges will be affected by all of these loads. In no case will the traction load affect the trusses of bridges to such an extent as to require consideration; consequently the only provision for traction load required in through and deck bridges is adequate rigid bracing to carry it from the track to the trusses without subjecting any portion of the structure to an improper loading, as, for instance, the flanges of cross-girders to horizontal bending.

In *bridges* of all kinds the various loads herein specified shall be combined without any reduction; but in *trestles*, more especially very high ones, it will be legitimate, when combining the stresses from the various loadings, to reduce some of them or even to ignore some entirely, in order to avoid proportioning for any highly improbable or impossible combination of loads. For instance, when a trestle is situated near the middle of a sharp curve or near the apex of two heavy rising grades, it would be incorrect to assume a high velocity of train. In such cases as these the element of individual judgment in combining the stresses from the various loads and in assuming the sizes of the latter cannot well be eliminated.

BENDING ON TOP CHORDS.

For combined direct stresses and bending on chords, the moment is to be computed by the compromise formula

$$M = \frac{1}{10} Wl,$$

where W is the total transverse load in pounds on the piece, including impact, and l is the length of the piece in inches.

The extreme fibre-stress for the combination shall not exceed sixteen thousand (16,000) pounds; and the moment at mid-panel is to be assumed the same in amount as that at the panel points.

Top chords subjected to transverse loading should be made as deep as economy of metal will permit.

BENDING ON INCLINED END POSTS.

In proportioning inclined end posts of trusses of through-bridges for a combination of all the loads herein specified. together with the bending caused by the wind-pressure which travels transversely down the piece to the pier or abutment, the extreme fibre may be strained thirty (30) per cent higher than the intensity specified for the direct compression, the bending moment being computed on the assumption that the inclined end post is fixed above by the portal bracing and at the bottom by its connections to the pedestal and end floor-beam, thus making the lever-arm of the moment equal to one half the length of that portion of the inclined end post lying between the centre of pedestal-pin and the centre of the lower portal strut (or, in case of plate-girder portals, the bottom of the said plate girder).

BENDING DUE TO WEIGHT OF MEMBER.

If the extreme fibre-stress resulting from the bending due to the weight only of any member does not exceed ten (10) per cent of the specified intensity of working-stress, the effect of such bending may be ignored; but, if it does so exceed, its effect must be combined with those of the other stresses, using, however, for determining the sectional area, an intensity of working-stress ten (10) per cent greater than that specified.

GENERAL LIMITS IN DESIGNING.

The following general limits shall be adhered to in designing bridges, trestles, viaducts, and the line-work of elevated railroads:

No metal less than three-eighths ($\frac{3}{8}$) of an inch in thickness shall be used except for filling-plates.

The least allowable thicknesses of webs of rolled I beams shall be as follows:

24″ I beams	$\frac{5}{8}''$	webs.
20″ "	$\frac{9}{16}''$	"
18″ "	$\frac{1}{2}''$	"
15″ "	$\frac{7}{16}''$	"
12″ "	$\frac{3}{8}''$	"

No channel less than ten (10) inches in depth shall be used, except for lateral struts, in which eight (8) inch channels may be employed.

No angles less than $3'' \times 2\frac{1}{2}'' \times \frac{3}{8}''$ shall be used, except for lacing.

No eye-bars less than four (4) inches deep or three quarters ($\frac{3}{4}$) of an inch thick shall be employed; and the depths of eyebars for chords and main diagonals shall not be less than one fifty-fifth ($\frac{1}{55}$) of the length of the horizontal projection of same.

No adjustable rod shall have less than one square inch of cross-section.

The shortest span length for trusses with polygonal top chords shall be one hundred and seventy-five (175) feet.

The limit of span length in which the stringers can be riveted continuously from end to end of span shall be two hundred (200) feet. Beyond this limit sliding bearings must be used at one or more intermediate panel points; and in no span shall there be a length of continuously riveted stringers exceeding two hundred (200) feet.

For all compression-members of trusses and for columns of viaducts and elevated railroads the greatest ratio of unsupported length to least radius of gyration shall be one hundred (100), excepting those members whose main function is to resist tension. In these the limit may be raised to one hundred and twenty (120).

The corresponding limit for all struts belonging to sway-bracing shall be one hundred and forty (140).

GENERAL PRINCIPLES IN DESIGNING ALL STRUCTURES.

In designing all structural metal-work the following principles are invariably to be observed:

1. All members must be straight between panel-points, as curved struts or ties will under no circumstances be allowed.

2. The axes of all members of trusses or girders and those of lateral systems coming together at any apex of a truss or girder must intersect at a point, whenever such an arrangement is practicable; otherwise the greatest care must be employed to ensure that all the induced stresses and bending moments caused by the eccentricity be properly provided for.

3. Truss members and portions of truss members must always be arranged in pairs symmetrically about the central plane of the truss, except in the case of single members, the axes of which lie in said central plane of truss. This applies also to the designing of open-webbed, riveted girders.

4. In proportioning main members of bridges, symmetry of section about two principal planes at right angles to each other is to be attained wherever practicable; but in designing top chords and inclined end posts this rule cannot be followed.

5. In both tension and compression members, the centre line of applied stress must invariably coincide with the axial right line passing through the centres of gravity of all cross-sections of the member taken at right angles thereto.

6. The principle of symmetry in designing must be carried even into the riveting; and groups of rivets must be made to balance about centre lines and central planes to as great an extent as is practicable.

7. In all structural metal-work, excepting only the machinery for operating movable bridges, no torsion on any

member shall be permitted, if it can possibly be avoided; otherwise, the greatest care must be taken to provide ample strength and rigidity for every portion of the structure affected by such torsion.

8. In designing all pin-connected work ample clearance for packing must be provided, and ample room must be left for assembling members in confined spaces.

9. In bridges, trestles, and elevated railroads the thrust from braked trains and the traction must be carried from the stringers or longitudinal girders to the posts or columns without producing any horizontal bending moment on the cross-girders.

10. In trestles and elevated railroads, the columns must be carried up to the tops of the cross-girders or longitudinal girders, and must be effectively riveted thereto. In no case will it be permitted to cut off the columns and rest the cross-girders or longitudinal girders on top of same.

11. Every column that acts as a beam also must have solid webs at right angles to each other, as no reliance shall be placed on lacing to carry a transverse load down the column.

12. In trestles and elevated railroads, every column must be anchored so firmly to its pedestal that failure by overturning or rupture could not occur in the neighborhood of the foot if the bent were tested to destruction.

13. The amount of field-riveting must be reduced to a minimum, without, however, diminishing the number of rivets requisite for strength and rigidity. Whenever it is practicable, all designs are to be made so that the field-rivets can be driven readily.

14. Rivets are not to be used in direct tension.

15. For members of any importance, more than two rivets are to be used for each connection.

16. In designing short members of open-webbed, riveted work, it is better to increase the sectional area of the piece from ten (10) to twenty-five (25) per cent beyond the theoretical requirement than to try to develop the strength by using supplementary angles at the ends to connect to the plates.

17. Star struts formed of two angles with occasional short

pieces of angle or plate for staying same are not to be used, for better results are obtained by placing the angles in the form of a T.

18. In all main members having an excess of section above that called for by the greatest combination of stresses, the entire detailing is to be proportioned to correspond with the utmost working capacity of the member, and not merely for the greatest total stress to which it may be subjected. In this connection, though, the reduced capacity of single angles connected by one leg only must not be forgotten.

19. Designs must invariably be made so that all metal-work after erection shall be accessible to the paint-brush, excepting, of course, those surfaces which are in contact with each other or with the masonry. This requirement rules out all closed columns of every type and description.

20. In general, details must always be proportioned to resist every direct and indirect stress that may ever come upon them under any probable circumstances, without subjecting any portion of their material to a stress greater than the legitimate corresponding working-stress.

21. In all designs simplicity in both main members and details is to be considered of the greatest importance.

22. In all structures rigidity is to be considered quite as important an element as mere strength.

23. Structures on skews are to be avoided whenever it is practicable to do so.

24. The use of more than a single system of cancellation in bridges shall be confined entirely to lateral systems and sway-bracing, except that at mid-panels of trusses two rigid diagonals connected at their intersection may for appearance be employed, provided that either diagonal have sufficient strength to carry the entire shear in either tension or compression, and that the adjacent vertical posts be figured accordingly.

25. The use of redundant members in structures shall not be allowed, excepting only in the case just mentioned of rigid mid-panel diagonals.

26. In all designing true economy must be given the utmost

consideration, and no useless material must be employed, every pound of metal in the structure having a legitimate function; but economy of material must not be quoted as an excuse for using inferior details or scamping the work in respect to strength, rigidity, or appearance.

27. In all structural work the subject of æsthetics must be duly considered; and all designs are to be made in harmony with the principles thereof, to as great an extent as the money available for the work will permit or as the environment of the structure calls for.

RIVETING.

The rivets used shall generally be seven eighths ($\frac{7}{8}$) inch in diameter, smaller ones being employed for small channel flanges and legs of angle-irons less than three and a half ($3\frac{1}{2}$) inches wide. In very heavy work the rivet diameter should be increased to fifteen sixteenths ($\frac{15}{16}$) inch, and in certain extreme cases to one inch.

The least diameters for rivets in flanges of channels are as follows, and the greatest diameters must not exceed the same by more than one sixteenth ($\frac{1}{16}$) of an inch:

Depth of Channel....	6″	7″	8″	9″	10″	12″	15″
Diameter of Rivet....	5/8″	5/8″	3/4″	3/4″	3/4″	3/4″	7/8″

The pitch of rivets in all classes of work in the direction of the stress shall never exceed six (6) inches, or sixteen (16) times the thickness of the thinnest outside plate, nor be less than three (3) diameters of the rivet. At the ends of compression-members it shall not exceed four (4) times the diameter of the rivets, for a length equal to twice the width of the member.

When two or more thicknesses or plate are riveted together in compression-members, the outer row of rivets shall not be more than four (4) diameters from the side edge of the plate.

No rivet-hole centre shall be less than one and a half ($1\frac{1}{2}$)

diameters from the edge of a plate, and, whenever practicable, this distance is to be increased to two (2) diameters.

The rivets when driven must completely fill the holes.

The rivet-heads must in general be round; and they must be of uniform size for the same-sized rivets throughout the work. They must be neatly made and concentric with the rivet-holes, and must thoroughly pinch the connected pieces together.

Rivets with flat heads shall be preferred to countersunk rivets; the height or thickness of the flat head shall be three eighths ($\frac{3}{8}$) of an inch.

Rivets shall not be countersunk in plates less than seven sixteenths ($\frac{7}{16}$) of an inch in thickness.

Flanges of stringers and girders carrying the vertical load from the ties shall have their rivets spaced uniformly from end to end, and at the minimum distance employed.

Whenever possible, all rivets shall be machine-driven, and the machines must be capable of retaining the applied pressure until after the upsetting is completed.

Field-riveting must be done with a button sett: the heads of the rivets must be hemispherical, and no rough edges must be left.

All rivets in splice or tension joints are to be arranged symmetrically so that each half of any tension-member or splice-plate shall have the same uncut area on each side of its centre line.

No rivet, excepting those in shoe-plates and roller or bed plates, is to have a less diameter than the thickness of the thickest plate through which it passes.

The effective diameter of any rivet shall be assumed the same as its diameter before driving; but, in making deductions for rivet-holes in tension-members, the diameter of the holes shall be assumed one eighth ($\frac{1}{8}$) of an inch larger than that of the rivet. In the effective area of riveted members, pin, bolt, and rivet holes shall be counted out for tension, and bolt and pin holes shall be counted out for compression.

DETAILS OF DESIGN FOR ROLLED I-BEAM SPANS.

Rolled I beams used as longitudinal girders shall have preferably a depth not less than one twelfth ($\frac{1}{12}$) of the span. They shall be proportioned by their moments of inertia.

I beam spans may have either one or two beams per rail. In the former case the spacing should be six (6) feet six (6) inches, and in the latter case two (2) feet six (6) inches between contiguous girders. With two lines of stringers per track, there will be required a bracing-frame at each end of span and diagonal bracing between the top flanges, unless the span be less than ten (10) feet in length, in which case the diagonals may be omitted.

With four lines of stringers per track, no diagonal bracing will be required, but three (3) bracing-frames at each end will be used, with three (3) more at mid-span when the span length exceeds ten (10) feet.

Each I beam is to have at each end a pair of stiffening angles, one of which will form a portion of the end bracing-frame. These are to fit tightly at both top and bottom against the flanges.

Under each end of each I beam there is to be riveted a bearing plate of proper area and thickness to distribute the load uniformly over the masonry, said plate being bolted effectively to the latter with due provision for expansion and contraction.

DETAILS OF DESIGN FOR PLATE-GIRDER SPANS.

Plate girders shall have preferably a depth not less than one tenth ($\frac{1}{10}$) of the span.

All plate girders, whenever it is practicable, shall be built without splices in the web; and, when such become necessary, the smallest possible number of same shall be adopted. The splice-plates and rivets for the splices shall be such as to develop in every respect the full strength of the net section of the web, the main splice-plates extending from flange to flange and having at least two (2) rows of rivets on each side of the joint. In addition to these, each flange shall be spliced by two cover-plates on top of the vertical legs of the flange angles. These must be long enough to develop by the connecting rivets at least twenty-five (25) per cent more than the full strength of their net section.

Splices in flange-plates and angles must always be avoided when sufficiently long plates and angles are procurable, which will always be the case, unless the span be abnormally long. Where flange-splices are unavoidable, they must be so located that no two pieces of either the flange or the web shall be spliced within two (2) feet of each other, and so that no flange-splice shall occur at any point where there is not an excess of sectional area above the theoretical requirements. Every non-continuous flange-piece shall be fully spliced so that the splicing plates and rivets shall have a calculated strength at least twenty-five (25) per cent greater than that of the section spliced. Field-splicing of plate girders will never be allowed for fixed spans, except in structures for foreign countries.

At least one half of every flange section must consist of angles, or else the heaviest sections of the latter must be used; and the number of cover-plates must be made as small as practicable, in no case exceeding three (3) per flange. The lengths of these cover-plates must be such as to make them project at each end not less than nine (9) inches beyond the point determined by the calculations for the requisite resistance to bending.

Where two or three cover-plates per flange are used, they shall be of equal thickness, or shall decrease in thickness outward from the angles. The cover-plates shall not extend more than four (4) inches or eight (8) times the thickness of the outer plate beyond the outer line of rivets. With cover-plates more than fourteen (14) inches wide, four (4) lines of rivets shall be used.

The compression-flanges of plate girders shall be made of the same gross section as the tension-flanges; and they shall be so stiffened laterally that the unsupported length shall never exceed twelve (12) times the width of flange.

In deck-spans there are to be bracing frames at the ends and at intermediate points not more than fifteen (15) feet apart; and there is to be an effective system of diagonal bracing of angles between the top flanges of the contiguous girders for each track.

In half-through spans the girders are to be divided up into panels generally not exceeding fifteen (15) feet in length. If a steel floor system be used, there are to be brackets of web-plates and angles at the ends of the cross-girders extending to the top flanges of the longitudinal girders, so as to stay the latter effectively; while, if a wooden floor system of ties resting on shelves or on the bottom flanges be used, there are to be steel cross-frames with solid webs, of the greatest depth obtainable, with similar brackets at their ends for the same purpose. Half-through plate-girder spans are to have a rigid, double-intersection, lower lateral system of angles riveted together by plates and angles at their intersections and to the bottom flanges of the steel stringers, if the latter be employed.

Web-stiffeners shall be placed at the ends of plate-girder spans, also at all points of concentrated loading and at intermediate points at distances not exceeding either the depth of the girder or five (5) feet, except in the case of shallow girders where the shear, including impact, does not exceed five thousand (5000) pounds per square inch of web section. Under such circumstances the spacing of intermediate stiffeners may be made as great as three (3) feet six (6) inches.

All stiffeners must bear tightly at top and bottom against the flange angles. Under end stiffeners there must be fillers flush with the flange angles, but intermediate stiffeners shall, preferably, be crimped. All stiffeners must be in pairs.

End stiffening angles shall in no case be less than 3½″ × 3½″ × ⅜″, net, and must have sufficient area to carry the entire end shear, including impact, with the specified intensity of working-stress, no reliance being placed on the fillers.

The sections of intermediate stiffening angles shall not be less than those given in the following table.

Length of Girder.	Dimensions of Angles.
Up to 50′................	3½′ × 3½″ × ⅜″
From 50′ to 70′.........	4 × 3½ × ⅜
From 70′ to 90′.........	5 × 3½ × ⅜

In proportioning the flanges of plate girders, one eighth (⅛) of the gross area of the web is to be assumed as concentrated at the centre of gravity of each flange; or, in other words, after having found the net sectional area required for the tension-flange by ignoring the resistance of the web to bending, there is to be subtracted therefrom one eighth (⅛) of the gross area of the web-plate.

At the ends of all plate girders there must be sufficient rivets in each flange to transfer properly thereto from the web the total end-shear in a distance equal to the effective depth of the girder.

At the ends of cover-plates the spacing of the rivets which attach the covers, for a length equal to at least twice the width thereof, shall be made the minimum used in the flanges.

Under each end of each plate girder there is to be riveted a bearing plate of proper area and thickness and thoroughly stiffened so as to distribute the load uniformly over the masonry, said plate being bolted effectively to the latter with due provision for expansion and contraction.

DETAILS OF DESIGN FOR OPEN-WEBBED, RIVETED GIRDER-SPANS.

All open-webbed, riveted girders for both deck and half-through bridges shall be riveted up completely in the shop, as field-riveting will be allowed only for the lateral bracing, except in structures for foreign countries.

In open-webbed, through, riveted girders, however, the connection of main members will have to be by field-rivets. In such cases all of the truss-members will have to be assembled in the shop, after which the rivet-holes for the connections shall be reamed so as to ensure perfect fitting in the field.

The use of shallow open-webbed, riveted girders shall be avoided whenever possible, for the reason that they are quite as expensive and never as satisfactory as plate girders. In case, though, of their being required, as for instance in elevated railroads occupying city streets, they are to be provided with short, substantial web-plates at the ends and at all intermediate points where connections are made to other girders.

In proportioning the web-members of such girders, the specified intensities of working stresses are to be reduced from ten (10) per cent for 6″ × 3½″ angles to twenty-five (25) per cent for equal-legged angles, with proportionate amounts for angles of intermediate inequality of legs, so as to compensate for the secondary stresses due to the eccentric grip of the rivets. In no case will it be permissible to use flats instead of angles for web-members, but tees may be employed, provided their heads be wide enough to permit of satisfactory riveted connections.

At all intersections of web-members with chords, connecting plates are to be used; for it is not permissible to attach web angles directly to chord angles without using an intermediary plate.

The exact intersection at a point of all gravity lines of girder-members assembling at any apex must be adhered to in the designing of open-webbed, riveted girders.

In designing all riveted connections, the greatest care is to be taken to make connecting plates and groups of rivets balance about centre lines of stress, especially where passing from riveted work to pin-connected, as in the case of a riveted span with hinged ends at pedestals.

In all other particulars, the designing of open-webbed, riveted work is to comply, wherever practicable and proper, with the specifications for plate-girder and pin-connected spans.

DETAILS OF DESIGNS FOR PIN-CONNECTED SPANS.

The sections of the top chords and those of the inclined end posts of through-spans shall consist generally of two built channels and a cover-plate, each channel being formed of a web and two angles, the upper one small and the lower one much larger, so as to bring the centre of gravity of the entire box section of the member as close as possible to the mid-plane of the web-plates. In no case will more than one cover-plate be allowed, and this is to be made as thin as is proper. It is permissible to substitute rolled channels for the built ones; but when this is done it is often advisable to rivet a thick narrow plate to the under side of each channel, in order to facilitate the packing and detailing of web-members by keeping the centre line of stress coincident with the gravity axis of the piece.

Main vertical posts shall, generally, be composed of two laced channels, preferably rolled ones, although built ones can be used where large sections are required.

Secondary vertical posts may be built of two rolled channels laced, or of four angles in the form of an I with a single line of lacing. These secondary vertical posts should, preferably, be riveted to the top chord instead of being pin-connected like the main vertical posts.

The channels of vertical posts may have their flanges turned either inward or outward as desired, or so as to best suit the general detailing of the truss.

Stiff bottom chords and inclined web-struts may be made of either two channels with two lines of lacing or of four angles with one line of lacing.

Upper lateral struts, overhead transverse struts, and web-stiffening struts shall, preferably, be made of four angles with one line of lacing. In case, however, the said angles be spaced very far apart, as in lateral struts connecting deep top chords, they are to be placed on the corners of a rectangle, with their legs turned inward, and laced on all four faces of the box strut thus formed.

Eye-bars are to be used for all bottom chords and main diagonals that do not require to be stiffened.

Counters, when employed, can be of either rounds, squares, or flats. These and all other adjustable members are to have their ends enlarged for the screw-threads (unless soft-steel, cold-pressed threads be used) so that the diameter at the bottom of the thread shall be one eighth ($\frac{1}{8}$) of an inch greater than that of the body of a round rod of area equal to that of the adjustable piece.

In short spans, two angles riveted back to back, or even a single large angle, may be used for lower lateral diagonals; but for long spans the diagonals are to be made of four angles in the form of an I with a single line of lacing. When two angles are used, a single plate must not be depended on to form the splice at the intersection of the diagonals, but two angles, each not less than two (2) feet long, are to be placed beneath or on top of the spliced angles, so as to form a full splice in respect to rigidity as well as strength.

Diagonals for upper lateral systems and vertical sway-bracing shall, preferably, be built of four angles in the form of an I with a single line of lacing; but, for structures where this section would involve an extravagant use of metal, two of the angles, one at top and one at bottom, may be omitted, thus making each strut consist of two angles laced, provided, of course, that where the struts cross they shall be rigidly connected by two plates of ample size. This unbalanced section for such diagonals is to be avoided whenever it can be done without undue use of metal. In no case, though, will it be permissible to use angles in tension that are not capable of resisting properly the possible compressive stresses, with due regard for the specified limit of ratio of unsupported length to least radius of gyration.

In designing transverse lateral and overhead struts and their connections it must be remembered that their main function is to hold rigidly the chords or posts to place and line, and not merely to resist as columns the greatest calculated direct stresses to which they may be subjected. For this reason such struts should have ample section for rigidity, and the connecting plates at their ends should grip both connected members effectively.

Stringers for truss-bridges shall invariably be built of plates and angles, and no cover-plates will be allowed for the flanges. Their depths shall be made not less than the most economic ones in respect to weight of metal required, provided that the bridge clearance will permit, and never less than one twelfth ($\frac{1}{12}$) of the span. No splices will be allowed in their flanges nor any in their webs, provided that sufficiently long web-plates are procurable. The compression-flanges shall be made of the same gross section as the tension-flanges; and they shall be so stiffened that the unsupported length shall never exceed twelve (12) times the width of flange.

Rigid diagonal bracing of angles is invariably to be used between the top flanges of stringers, and rigid bracing-frames are to be employed near all expansion points. If the panel length exceed thirty (30) feet, there shall be a bracing-frame at mid-length between the contiguous stringers of each track; but for all shorter panels the rigid lower lateral diagonals which are riveted to the bottom flanges will stiffen the latter sufficiently.

In respect to stiffening angles for stringers, the rules governing those for plate-girder spans are to be followed; but the end stiffeners are to be faced or otherwise treated so as to make the stringers of exact length throughout, and so as to effect a uniform bearing of the end stiffeners against the webs of the cross-girders.

In respect to proportioning of flanges and number of rivets required, the rules given for plate-girder spans are to apply also to stringers. The said rules are to apply also to cross-girders, as shall also those relating to stiffeners, splices, cover-plates, and size of compression-flanges, that are given for plate-girder spans. Wherever it is necessary to notch out the corners of the cross-girders to clear the chords, the greatest care must be taken to provide an adequate means for transferring the shear to the posts without impairing either the strength or the rigidity. If necessary, in through-bridges the web of the cross-girder can be divided into three parts so as to let the end portions project above the top flange and form brackets that will afford opportunity for using an ample number of rivets to connect to the posts, and will strengthen properly the otherwise weakened cross-girder.

In order to carry the thrust of trains from the stringers to the posts through the lower lateral diagonals, the latter and the stringers are to be made to form complete horizontal trusses by running angles between stringers at the level of the bottom flanges. In single-track bridges two pieces of angles per panel running transversely between stringers at the intersection of the latter with the diagonals will suffice; but in double-track bridges there will be required two such angles per panel between inner stringers, and four diagonal angles per panel to run from where the lateral diagonals intersect the outer stringers to where the inner stringers meet the cross-girders.

All plates, angles, and channels used in built members of trusses must, if practicable, be ordered the full length of the member; otherwise the splices must develop the full strength of the member, without any reliance being placed on the abutting ends for carrying compression.

But in total splices at the ends of sections perfect abutting of the dressed ends is to be relied upon. However, the splice-plates even there must be of ample size and strength for both rigidity and continuity.

The unsupported width of plates strained in compression, measuring between centre lines of rivets, shall not exceed thirty-two (32) times their thickness, except in the case of cover-plates for top chords and inclined end posts, where the limit may be increased to forty (40) times the thickness. Where webs are built of two or more thicknesses of plate, the rivets that are used solely for making the several thicknesses act as one plate shall in no case be spaced more than twelve (12) inches from each other or from other rivets connecting said component thicknesses together. The least allowable thickness for such compound web-plates shall be one (1) inch.

The open sides of all compression-members composed of two rolled or built channels, with or without a cover-plate, shall be stayed by tie plates at ends and by diagonal lacing-bars or lacing-angles at intermediate points. Lacing-bars may be connected to the flanges by either one or two rivets at each end; but lacing-angles, which are used for members of heavy section only, must be connected by two rivets at each end.

The tie-plates shall be placed as close as practicable to the ends of the compression-members. Their thickness shall not be less than one-fiftieth ($\frac{1}{50}$) of the distance between the centre lines of the rivets by which they are connected to the flanges, unless said tie-plates be well stiffened by angles, in which case they may be made as thin as three eighths ($\frac{3}{8}$) of an inch.

The length of a tie-plate shall never be less than its width, or one and one-half (1½) times the least dimension of strut (unless it be close to a web diaphragm of the member, in which case it may be as short as twelve (12) inches), and seldom greater than one and one-half (1½) times its width.

The thicknesses of lacing-bars shall never be less than one fiftieth ($\frac{1}{50}$) of the length between centres of the end rivets, measuring between inmost rivets in case that there be more than one rivet at each end. The smallest section for a lacing-bar shall be one and three quarter (1¾) inches by three eighths (⅜) of an inch, which size shall be used for channels under nine (9) inches deep; and the largest section shall be two and a half (2½) inches by one-half (½) inch, which size shall be used for channels fifteen (15) inches deep. For intermediate sizes of channels, the sizes of lacing-bars shall be interpolated. For all built channels of greater depth than fifteen (15) inches, and for all cases where a lacing-bar would require a greater thickness than one-half (½) inch, angle lacing is to be used, the smallest section for same being 2″ × 2½″ × ⅜″, and the largest 2½″ × 3½″ × ⅜″. For two (2) inch lacing-bars and two and a half (2½) inch lacing angles, three-quarter (¾) inch rivets are to be used; and for two and a half (2½) inch lacing-bars and three (3) inch lacing-angles seven-eighths (⅞) inch rivets are to be adopted.

In general, the inclination of lacing-bars to axis of member shall be about sixty (60) degrees; but in members of minor importance and in tension-members the said inclination may be made slightly flatter.

Pin-plates shall be used at all pinholes in built members for the double purpose of reinforcing for the metal cut away and reducing the intensity of pressure on pin and bearing to or below the specified limit. They shall be of such size as to distribute properly, through the rivets, the pressure carried by such plates to both flanges and web of each segment of the member; and they shall extend at least six (6) inches within the tie-plates of said member, so as to provide for not less than two (2) transverse rows of rivets there.

When the pin ends of compression-members are cut away into jaw-plates or forked ends, for the purpose of packing closely the various members connected by the pin, these jaw-plates or post extensions shall be considered as columns, the thickness of each of which shall be determined by the following formula:

$$p = 10{,}000 - 300\frac{l}{t};$$

where p is the greatest allowable intensity of working-stress (impact being considered); l is the unsupported length in inches, measuring from the centre of the pinhole to the centre of the first transverse line of rivets beyond the point at which the full section of the member begins; and t is the total thickness in inches of one jaw. The length l is always to be made as small as practicable; and, in cases of unavoidably long extensions, the plates are to be stiffened by an interior diaphragm composed of a web with four, or sometimes only two, angles.

It is always better, whenever practicable, to avoid cutting away the ends of channels; but, if they must be trimmed, the ends must be reinforced so that the strength of the member shall not be reduced by the trimming.

In riveted tension-members, the net section through any pinhole shall have an area fifty (50) per cent in excess of the net sectional area of the body of the member. The net section outside of the pinhole along the centre line of stress shall be at least sixty-five (65) per cent of the net section through the pinhole.

Pins are to be proportioned to resist the greatest shearing and bending produced in them by the bars or struts which they connect. No pin is to have a diameter less than eight tenths ($\frac{8}{10}$) of the depth of the deepest eye-bar coupled thereon. No truss-pin is to have a smaller diameter than three and a half ($3\frac{1}{2}$) inches, and no lateral pin, if any such be used, a diameter less than two and a half ($2\frac{1}{2}$) inches.

Lower chords are to be packed as closely as possible, and in such a manner as to produce the least bending moments on the pins; but adjacent eye-bars in the same panel must never have less than a one-half ($\frac{1}{2}$) inch space between them, in order to facilitate painting. The various members attached to any pin must be packed as closely as practicable, and all interior vacant spaces must be filled with steel fillers, where their omission would permit of motion of any member on the pin. All bars are to lie in planes as nearly as possible parallel to the central truss-plane, no divergence exceeding one eighth ($\frac{1}{8}$) of an inch to the foot being permitted.

In detailing I struts composed of four angles with a single line of lacing, the clear distance between backs of angles shall never be made less than three-quarters ($\frac{3}{4}$) of an inch, in order to permit the insertion of a small paint-brush.

The greatest allowable pressure upon expansion-rollers of fixed spans, when impact is considered, shall be determined by the equation

$$p = 600d,$$

where p is the permissible pressure in pounds per lineal inch of roller, and d is the diameter of the latter in inches. The least allowable diameter for expansion-rollers is three (3) inches.

Rollers shall be enclosed in boxes made practically dust-tight, and filled with an oil that will not congeal under any possible temperature. These boxes must be so designed as to permit of a free movement of the rollers in the longitudinal direction of span sufficient to take up the extreme variations in length due to temperature changes and deflection, and at the same time prevent any transverse motion of the end of the span.

All shoe-plates, bed-plates, and roller-plates are to be so stiffened that the extreme fibre-stress under bending, when impact is included, shall not exceed sixteen thousand (16,000) pounds.

Pedestals shall be either of cast steel or built up of plates and shapes. In built pedestals, all bearing surfaces of the base-plates and vertical bearing-plates must be planed. The vertical plates must be secured to the base by angles having at least two rows of rivets in the vertical legs; and the said vertical plates must bear properly from end to end upon the base. No base-plate, vertical plate, or connecting angle shall be less in thickness than three quarters (¾) of an inch. The vertical plates shall be of sufficient height and must contain enough metal and rivets to distribute properly the loads over the bearings or rollers. The bases of all cast-steel pedestals shall be planed so as to bear properly on the masonry or rollers. All rollers and the faces of base-plates in contact therewith are to be planed smooth, so as to furnish perfect contact between rollers and plates throughout their entire length.

All pedestals whether built or cast must have one or more diaphragms between webs, carried up as high as the general detailing will permit, so as to transmit transverse horizontal thrust to the base without overstraining the webs by bending in their weakest direction.

Heads of eye-bars are to be made of such dimensions that when the bars are tested to destruction they shall break in the body and not in the eyes; and in case of loop-eyes, so that they shall not fail in the welds. Rods with bent eyes shall not be used. In loop-eyes, the distance from the inner point of the loop to the centre of the pinhole must not be less than two and one half (2½) times the diameter of the pin, and the loop must fit closely to the pin throughout its entire semicircumference.

DETAILS OF DESIGN FOR TRESTLES AND ELEVATED RAILROADS.

The sections of main members of trestles shall, generally, be as follows: Columns, two channels laced with flanges turned either out or in, two channels with I-beam web between, four Z bars with web-plate, four Z bars with a single line of lacing inside and occasional stay-plates outside, or four angles with a single line of lacing inside; diagonals in transverse and longitudinal bracing, and all bottom horizontal bracing struts, four angles with a single line of lacing; horizontal transverse bracing struts at top of towers, bracing frames of angles; longitudinal struts at top of towers, plate girders; and longitudinal girders, plate-girder spans, or occasionally, for very long spans, open-webbed, riveted girders or pin-connected trusses.

The detailing for longitudinal girders of trestles and elevated railroads and the bracing between same shall comply with the specifications governing the designing of plate-girder spans and the floor systems of pin-connected spans.

In general, the transverse and longitudinal bracing of trestle towers shall consist of a double-cancellation system of stiff diagonals without any horizontal struts, except at the bottom between pedestals. The latter struts must be strong enough to move the column feet upon their sliding-bearings when said struts are expanded or contracted by changes of temperature. Provision must be made for holding some feet rigidly, and for sliding some in one horizontal direction only, and others in any horizontal direction, at the same time holding them all down so that they shall not be lifted perceptibly by the wind-pressure. Sliding-plates are always preferable to rollers for pedestals of trestles. They shall be planed extremely smooth, and so as to bear properly at all parts.

Occasionally, in solitary bents, it is permissible to use hinged ends for columns at pedestals; but it is generally better to make them fixed, and to figure the columns for the greatest bending produced in them by transverse loads and extreme changes of temperature.

The tops of trestle columns are to be made vertical by bending them just beneath the longitudinal girders where the latter are riveted to them; and the upper transverse struts must be made as deep as the longitudinal girders, and must be riveted effectively to the columns. Corner brackets of double webs are to be used for connecting the columns to the horizontal struts and bracing-diagonals, and at the same time to strengthen the column at the bend. Additional strengthening is to be given by using a solid web or diaphragm in the column, extending from the top thereof to a point about two (2) feet below the bend.

All splices in columns are to be full, butt splices, located preferably about two (2) feet above the points where the sway-diagonals connect, shingle-splicing being avoided because of the trouble it gives during erection.

The best span lengths for trestles are generally those which make the total cost of structure a minimum, the tower length varying from twenty (20) feet for low trestles to thirty (30) feet for very high ones, and the intermediate spans varying from thirty (30) to sixty (60) feet for the same limiting heights. Any length of girder exceeding sixty (60) feet would probably necessitate the employment of a too long, heavy, and expensive traveller, or else the use of bents of falsework between the towers.

For elevated railroads the sections of main members shall be as follows: Longitudinal girders, preferably plate girders, or, if necessary, open-webbed, riveted girders; cross-girders, plate girders; columns for structures without longitudinal or tower bracing, two channels with an I beam riveted between; and columns for structures with longitudinal or tower bracing, four Z bars with a web-plate.

All columns for elevated railroads are to have both ends fixed, being held rigidly at the top by either the longitudinal girders or by deep struts that carry the thrust of braked trains from the track to the columns, and their sectional areas are to be figured accordingly for both direct load and bending.

Longitudinal girders in elevated railroads shall, generally, be riveted into the cross-girders and not rest thereon, except under certain conditions for the sake of clearance beneath, in which case the top flanges of the half-through girders must be stayed at the ends and at intermediate points, as specified for plate-girder spans.

On all curves in elevated railroads, special lateral bracing of angles, riveted at intersections to the longitudinal girders and carried over and riveted to the columns, must be employed.

Where brackets for columns can be used advantageously in elevated-railroad work, they must be put in, and must be built of solid web plates and angles.

In general, the limiting length of structure between expansion points shall be about one hundred and fifty (150) feet. If this length be exceeded materially, the columns may have to be strengthened to resist the bending caused by changes in temperature.

All expansion-pockets are to be so detailed as to throw the load from the longitudinal girder as close as possible to the web of the cross-girder; and sufficient rivets are to be used in connecting the pocket to the cross-girder to provide for both the direct shear and the bending moment from the eccentric load.

All anchor-bolts at column feet are to extend well up above the base-plate, passing inside of a curved plate that is riveted to the column, and which supports a heavy washer-plate to receive the anchor-bolt nut. The space between the curved plate and the anchor-bolt after erection is to be filled with Portland-cement grouting.

All column feet are to be raised so far above the ground that no dirt, snow, or moisture can collect around them and remain there. The boxed spaces at column feet are to be filled with Portland-cement concrete made with small broken stone.

The bases of pedestals are always to be made large enough to prevent all possibility of settlement of foundations. In figuring the pressure on the base of the pedestals it is not sufficient to recognize only the direct live and dead loads, but it is necessary also to compute the additional unequal intensities of loading caused by both longitudinal and transverse thrusts.

SPECIFICATIONS FOR RAILROAD DRAW-SPANS.

(CHAPTER XV OF "DE PONTIBUS.")

THE specifications given in the preceding chapter for fixed spans apply also to draw-spans, except where otherwise stated in the following pages.

GENERAL DESCRIPTION.

MATERIALS.

The specifications previously given apply also to draw-spans, except that cast iron may be used for the centre castings on top of pivot-piers, for anchor-pieces in the masonry, for shafting boxes, and for rail-chairs, and some other castings of minor importance. The use of high steel for drawbridges will not be permitted.

STYLES OF BRIDGES FOR VARIOUS SPAN LENGTHS.

For spans up to one hundred and sixty (160) feet in length, plate-girder spans should be used. These may be made to act as continuous girders over the pivot-pier, or may have pin-connections over the drum, so that when the live-load is applied they will act as two separate spans. The latter style is generally preferable, because there is no tendency for the far end of the span to rise when the live load is being brought on.

For spans between one hundred and sixty (160) feet and two hundred and seventy-five (275) feet, pin-connected Pratt trusses with parallel top chords and stiff diagonals in panels where there is reversion of stress, or riveted trusses of single cancellation, are to be used.

For spans between two hundred and seventy-five (275) feet and three hundred and fifty (350) feet, pin-connected Pratt trusses with broken top chords are to be employed.

For spans of over three hundred and fifty (350) feet, pin-connected trusses with subdivided panels are to be adopted.

It is understood that these limiting lengths are not fixed absolutely, as the best limits will vary somewhat with the number of tracks and the weight of trains.

The height of towers should generally be between one sixth ($\frac{1}{6}$) and one seventh ($\frac{1}{7}$) of the total length of span, measuring from centre to centre of end-pins; although in certain cases it may, for the sake of appearance, be made a little greater. The truss depth at the inner hips should be from one ninth ($\frac{1}{9}$) to one tenth ($\frac{1}{10}$) of the total length of span. The truss depth at outer hips for spans up to four hundred (400) feet will generally be determined by the clearance required. For longer spans it should be between one fourteenth ($\frac{1}{14}$) and one fifteenth ($\frac{1}{15}$) of the total span length.

The length of the centre panel will, in most cases, be made equal to the perpendicular distance between central planes of trusses.

In spans having horizontal top chords all panels of the latter must be made of stiff members, excepting only the centre panel over the pivot-pier; and the diagonals next to the middle panel are to be tension-members.

Broken top chords must be made of stiff members from ends to inner hips, but the portion between the inner hips is to be made of eye-bars. Inclined posts extending from inner hips to drum are to be used in all cases where top chords are broken.

LOADS.

The loads to be considered in designing draw-spans are the following:

A. Live Load.
B. Impact Allowance Load.
C. Dead Load.
D. Uplift at Ends.
E. Direct Wind Load.
F. Indirect Wind Load or Transferred Load.

LIVE LOADS.

The live loads for the various parts of the structure are to be taken from the "Compromise Standard System of Live Loads for Railway Bridges," in the same manner as previously specified for fixed spans.

The live load for trusses with only one arm loaded is to be taken from the live-load curves for a span equal to the distance between the centre of the end-pin and that of the pin at the foot of the nearer tower post; but for both arms loaded the live load is to be taken for a span equal to the distance between centres of end-pins.

For only one arm loaded, the half-span is to be considered to act as a simple span on two supports; and, for both arms loaded, the entire span is to be considered continuous over four supports. The stresses due to the live load, with both arms wholly or partially loaded, are to be determined by the balanced-load method. For convenience in determining the reactions at ends and at centre supports for balanced loads the curve given on Plate IX can be used. This gives the percentage of any balanced load which is supported at the outer end of a half-span.

DEAD LOADS.

In spans over two hundred and seventy-five (275) feet, the dead load per truss is to be increased properly from the ends towards the centre of span in order to cover the weight of the heavy truss-members, which increase in size toward the centre of the span. The division of the dead load between top and bottom chords is to be the same as specified for fixed spans.

The dead loads from tower, drum, and turntable are not to be considered as affecting the stresses in the trusses.

ASSUMED UPLIFT LOADS.

There will be a considerable uplift at the ends of the span, for they are to be brought to a firm bearing by means of the end-lifting device. The amount of this uplift per truss or girder is to be assumed as a certain proportion of the entire dead load carried by one arm of the said truss or girder when the span is being swung, which proportion is to be taken from the following table:

Spans.	Ratios of Uplift to Dead Load.
Up to 150′	$\frac{1}{3}$
150′ to 250′	$\frac{1}{4}$
250′ to 350′	$\frac{1}{5}$
350′ to 450′	$\frac{1}{6}$
Over 450′	$\frac{1}{7}$

These uplifts are to be adopted both for finding the uplift stresses in trusses and for proportioning the end-lifting machinery; provided, however, that for the latter purpose no assumed uplift be less than twenty thousand (20,000) pounds for single-track drawbridges or less than forty thousand (40,000) pounds for double-track drawbridges.

WIND LOADS.

The wind loads per lineal foot of span for both the loaded and the unloaded chords are to be the same as those specified for fixed spans, the length of span, however, being that of one arm of the draw.

When the span is open, all the wind load is to be carried to the drum through the lateral systems. When the draw is closed, the wind load is to be carried to both the ends and the centre supports, the lower lateral system and bottom chords being considered to act as a continuous girder over four supports. The reactions at the ends and the centre can be taken from the curve for balanced live loads.

INDIRECT WIND LOAD OR TRANSFERRED LOAD.

The wind load on the upper chords is to be assumed to travel through the upper lateral system to the inner hips, when the span is open, then down the inner inclined posts to the drum, thus producing a transferred load on the leeward inclined post and a released load on the windward one. As the upper lateral system is not continuous between the inner hips, none of the wind load on the upper lateral system is carried down the tower-posts, excepting that which comes on the centre panel and the two adjacent panels. In order to ensure such a distribution of the wind load it is necessary to put no diagonals in those panels of the upper lateral system which are adjacent to the inner hips and between same and the tower.

When the draw is closed, one half of the wind load on the upper lateral system of one arm is to be assumed to travel down the end inclined posts, and one half down the inner inclined posts.

The transferred-load stress on an inclined post is to be found by multiplying the wind load going to it by the average height of the top-chord panel points to which said wind load is applied, dividing the product by the perpendicular distance between central planes of trusses, and multiplying the quotient by the secant of the angle that the inclined post makes with the vertical.

The transferred-load stress on a tower-post is to be determined by multiplying the wind loads carried by the two opposite posts by the respective heights at which these loads are applied, and dividing the sum of these products by the perpendicular distance between central planes of trusses.

COMBINATIONS OF STRESSES.

In ascertaining the stresses in the trusses of swing-bridges the following conditions are to be considered:

Case No. 1. Greatest stresses, dead load only acting, bridge swinging open.

Case No. 2. Greatest stresses from assumed uplift at end of span.

Case No. 3. Greatest stresses from live load on one arm only; each arm being considered to act as a simple span on two supports.

Case No. 4. Greatest stresses from live load on both arms, the live load advancing from both ends toward the centre until the span is fully loaded; the latter being considered to act as a continuous girder over four supports.

Case No. 5. Greatest direct stresses, on the chords that carry the live load, from wind load when the bridge is open.

Case No. 6. Greatest direct stresses, on the chords that carry the live load, from wind load when the bridge is closed and wholly or partially loaded.

Case No. 7. Greatest indirect wind-load stresses or transferred-load stresses on the lower chords when the bridge is closed and wholly or partially loaded.

The first combination of these stresses includes Cases No. 1, No. 2, No. 3, and No. 4, and gives the greatest stresses for all truss members from combined live and dead loads, for which combination the regular specified intensities of working-stresses are to be used. It is to be noted that wherever the load for Case No. 2 increases the total stress on any member, its effect is to be considered; but wherever the said load decreases the total stress on any member, its effect is to be ignored. The reason for this is that the amount of uplift is a purely arbitrary assumption, which possibly may never be realized. This method of treating the uplift-load stresses causes errors on the side of safety, which do not add materially to the total weight of metal in the structure, and which tend to strengthen the lighter members of the trusses.

The second combination of these stresses includes all seven cases, but it is to be noticed that the only truss members affected by the wind loads are the inclined posts at ends and over drum, and the chords which carry the live load. In this second combination it must not be forgotten that the metal is to be strained thirty (30) per cent higher than in the first combination.

For the lateral systems the following conditions are to be considered:

For upper lateral systems of through-bridges and lower lateral systems of deck-bridges—

Case No. 1. Greatest wind-load stresses when span is swinging.

Case No. 2. Greatest wind-load stresses when span is closed and ends are raised, thus making the entire lower lateral system with the bottom chords a continuous girder with four points of support. This case does not involve the presence of any live load on the span.

For lower lateral systems of through-bridges and upper lateral systems of deck-bridges—

Case No. 3. Greatest wind-load stresses when span is swinging.

Case No. 4. Greatest wind-load stresses when span is closed and ends are raised, and with live load on one arm only, thus making the loaded chords with their lateral system a simple span with supported ends.

Case No. 5. Greatest wind-load stresses when span is closed and ends are raised, and with the live load on both arms covering same either wholly or partially, thus making the loaded chords with their lateral system a continuous girder with four (4) points of support.

The greatest stress on any lateral member found by these five conditions of wind-loading is to be used in proportioning its section, and there is to be assumed no division of the wind load between structure and train, although the failure to make said division will cause small errors on the side of safety.

DETAILS OF DESIGN FOR PLATE-GIRDER DRAW-SPANS.

Plate-girder drawbridges are to be divided into two types, viz.:

Type No. 1. Continuous girders, in which the girders act as continuous spans resting on four points of support; and

Type No. 2. Non-continuous girders, in which the two arms carry the live load independently of each other, the dead-load stresses over the pivot pier when the span is swung being carried by links.

For Type No. 1 the same combinations of stresses are to be used as specified for truss draw-spans, but it will generally be found that the wind loads do not affect the proportioning of the girders.

For Type No. 2 the loads to be considered are as follows:

Case No. 1. Dead-load stresses when the span is swung.

Case No. 2. Dead-load stresses for each arm acting independently of the other.

Case No. 3. Live-load stresses for each arm acting independently of the other.

The stresses in Cases No. 2 and No. 3 are to be combined, but those in Case No. 1 are not to be combined with either of the others, the effect of reversion of stress, however, being provided for as specified for fixed spans.

The only effect of wind load to be considered for the girders of Type No. 2 is that upon the connecting links over the turntable when the span is being rotated, for which case the amount of the wind load is to be taken at two hundred (200) pounds per lineal foot of span.

In general, the specifications for the detailing of fixed plate-girder spans are to govern the designing of plate-girder draw-spans, except as hereinafter stated.

In deck, plate-girder draw-spans the girders are to be spaced the same distance apart as specified for fixed plate-girder spans of one half the length. For half-through, plate-girder, draw-spans the girders may be spaced as closely as the previously specified clearance requirements will permit.

For deck-spans four points of support on the drum will suffice, but for half-through spans eight points will be required. The diameter of the drum is to be made as small as practicable, but never less than eight (8) feet; and the distribution of the load over the drum is to be uniform.

All girders are to be thoroughly stiffened at all points of bearing over the drum, and bearing-plates not less than one (1) inch in thickness are to be used between the drum and all girders bearing on same.

For spans of Type 1, when the length over all exceeds ninety (90) or at the utmost one hundred (100) feet, it will be necessary to splice the main girders in the field. These splices must be thoroughly made, shingle or staggered splices only being allowed; and there must be a twenty-five (25) per cent excess of strength in the details at all points thus spliced, as previously specified for fixed plate-girder spans.

Rigid bracing-frames are to be used between main girders of deck-spans at the points where the main girders bear on the drum; and heavy, rigid, plate cross-girders resting on the drum are to be used for half-through spans.

End lifts must be provided for draw-spans of Type No. 1, as hereinafter specified for truss-span drawbridges.

For spans of Type No. 2 the centre panel is to be made with pin connections, the bottom-chord pins resting in pedestals, which furnish proper bearings on the drum. The top-chord tension is to be taken up by eye-bars, which serve as toggles for raising the ends of span. These toggles are to be worked by a screw at centre of span.

The compression in bottom flanges of girders, due to dead load when the span is swung, is to be taken up by struts hinged on the bottom-chord pins.

The eye-bars of the top chords must have slotted eyes, so as to make sure that each half of the girder will act as a simple span when the live load is applied.

Proper shoes must be provided at ends of span, with grooves into which the sole-plates on ends of girders are lowered into place. These grooves should be deep enough to hold the ends of the girders securely, and the toggle at the centre must provide enough lift to clear the ends properly for turning.

All track-rails, guard-rails, and stringers must be discontinuous in the centre panel so that the toggle will be free to act.

The ends of each pair of girders over the drum must be thoroughly braced together.

The end lifting arrangement of these spans demands the most accurate shop-work; and in every case the whole span must be assembled in the shops, so that the lifting machinery can be thoroughly tested before being shipped.

DETAILS OF DESIGN FOR TRUSSES.

The details of trusses for draw-spans shall comply in general with the specifications given for trusses of fixed spans.

In trusses having broken top chords, that portion of said top chords between outer and inner hips is to be made of rigid members, and that portion between the inner hips and over the tower is to be made of eye-bars.

In pin-connected trusses with parallel chords rigid members will be required throughout the top chord, except for the centre panel, in which eye-bars are to be used. In riveted trusses stiff top chords from end to end of span are to be adopted.

The bottom chords are to be of rigid sections throughout for all spans; and for spans over three hundred (300) feet in length provision must be made near the panel points at feet of tower-posts for adjusting, by means of shimming-plates, the height of the ends of the trusses. These shimming-plates must provide an end, vertical adjustment of one (1) inch for each one hundred (100) feet of length of one arm of draw. For spans shorter than three hundred (300) feet shimming-plates beneath the end bearings will give sufficient adjustment.

Rigid portal-bracing must be used between the two inclined posts at both the inner and the outer hips. These portals are to be carried down as low as the specified clearance over tracks will permit.

In heavy spans the portal-bracing must attach to the upper and lower flanges of inclined posts, instead of lying in the gravity-planes of same.

The tower must be rigidly braced in all four faces. In the transverse planes all the diagonals and horizontal struts must, generally, be made of stiff members of box or I sections, so as to take hold of the exterior of the posts; and this sway-bracing must be carried down as low as the specified clearance will permit, so as to hold the tower-posts firmly to place and line.

In the planes of the trusses the diagonals are to be made of adjustable rods of ample section to provide for any possible unequal vertical wind-pressure when the span is open ; and the horizontal struts of box or I sections are to be rigidly attached to the columns by large plates, to which the clevises of the adjustable rods attach by means of pins.

A pair of adjustable diagonal rods or rigid struts must be used in the horizontal plane of each vertical panel of tower-bracing, so as to ensure the permanent rectangularity of the section of the tower.

All splices in top and bottom chords, inclined posts, and tower-posts are to be full splices, so as to develop the full strength of the section, even if the computed stresses do not demand such a strength of detail.

The upper lateral system between the inner and the outer hips is to be made of rigid diagonals, capable of taking both tension and compression, and transverse struts of I section, that take firm hold of the upper and lower flanges of the top chords. From inner hip to inner hip the diagonals are to be of adjustable rods ; but, as before stated, the rods are to be omitted from the panels next to the hips, so as to ensure a proper travel of the wind-loads to the pivot-pier.

The transverse sway-bracing between trusses is to be made entirely of rigid members, and is to be carried down as low as clearance requirements will permit. In long spans the lower horizontal struts of the vertical sway-bracing must take hold of the vertical posts at the flanges of same, so as to hold the said posts firmly in position.

DETAILS OF DRUM AND TURNTABLE.

The drum must be strong enough to distribute the total load from the span properly over the rollers. In general, it should be made, within reasonable limits, as deep as possible, for the cost for the extra depth will be more than offset by the saving in height of pivot-pier.

The bending moment on the drum is to be computed by the compromise formula,

$$M = \frac{l}{10} Wl,$$

where $M =$ bending moment in foot-pounds, $W =$ greatest load in pounds on one point of bearing on drum, and $l =$ distance in feet between points of bearing.

The drum is to be designed according to the specifications for ordinary plate girders. The web thereof shall have stiffeners on both sides at all points of concentration. These stiffeners must have perfect contact with the top and bottom flanges. The section required for these stiffeners is to be determined by considering the entire concentration on one point of bearing to be carried by the said stiffeners, which act as a column, fixed at both ends, with an unsupported length equal to the depth of drum. Stiffeners, each consisting of two angles, placed on opposite sides of the web must be used at intermediate points at distances not exceeding either the depth of web or three (3) feet six (6) inches.

Brackets to support the pinions gearing into the rack are to be provided on the drum. They shall be built of rolled-steel sections, and made amply strong in all directions and in every particular so as to resist the greatest thrust, wrenching, or torsion that can possibly come from the shaft. In no case are these brackets to be made of castings. The use of turned bolts for attaching the brackets to the drum will not be permitted where it is possible to drive rivets, as such bolts do not afford sufficient rigidity to prevent the connections from working loose sooner or later. The splices in the web and flanges of drum must be such as to develop the full strength of same; and the abutting ends of web and flanges must be planed smooth, and have continuous contact.

The drum must be made perfectly round, so that the centre line of web at any height will conform to the circumference of a circle; and, to preserve this form and brace the drum thoroughly, rigid radial struts are to be run from the centre casting to the drum, taking hold of the latter at each point of concentrated loading, and at intermediate points when the bearings are spaced more than eight (8) feet between centres. These radial struts must be made of four angles with solid webs or angle lacing. At the centre they are to be riveted to circular plates fitting closely around the centre casting, thus anchoring the drum firmly to the latter. Oil-grooves must be provided where these plates bear on the centre casting. Fillers are to be used beneath all stiffeners on drum.

The drum must be assembled and the bottom must then be planed smooth so as to provide an even bearing for the upper track. If it is not practicable to plane the entire drum at once, then each segment thereof is to be planed separately; but in this case the greatest care is to be taken to make the assembled parts form a perfect whole.

The least thickness of metal to be used for bottom flanges of drum shall be three quarters ($\frac{3}{4}$) of an inch, so as to provide ample metal for planing off the bottom, and that for the web and top flanges one-half ($\frac{1}{2}$) inch.

The upper track shall be made of segments of sufficient thickness to distribute the load properly between the rollers and the drum. The top face of this track shall be planed smooth so as to form close contact with the bottom flange of the drum, and the lower face shall be planed conical so as to fit closely to the conical rollers. All joints between segments are to be planed smooth and to such bevel as to ensure perfect contact with each other. These track segments are to be riveted or bolted to the bottom flanges of the drum with fifteen-sixteenths ($\frac{15}{16}$) inch rivets or bolts, placed opposite, and spaced not to exceed fifteen (15) inches between centres. The heads of these bolts or rivets are to be countersunk in the track on the side next to the rollers.

No rust-cement or any other composition is to be used between the track and the drum.

The lower track is to made strong enough to distribute the load from the rollers uniformly over the masonry. The bending moment on the lower track is to be found by the formula

$$M = \frac{1}{12} Wl$$

where $M =$ greatest bending on lower track, $W =$ total load on one roller, and $l =$ distance from centre to centre of adjacent rollers, measured on the centre line of the track.

The greatest allowable tensile stress on the extreme fibre for cast-steel track shall not exceed eight thousand (8,000) pounds per square inch, when the effect of impact is included. The lower track shall be made in segments from six (6) to eight (8) feet in length. All abutting ends of lower-track segments are to be planed smooth, are to have close contact throughout, and are to be bolted together by two bolts passing through holes in lugs cast thereon. These bolts are to be at least fifteen sixteenths ($\frac{15}{16}$) of an inch in diameter.

In no case shall the upper track be less than two and one-quarter ($2\frac{1}{4}$) inches, or the lower track less than two and one-half ($2\frac{1}{2}$) inches thick, measuring on the central cylindrical surface of the drum.

The lower track shall be anchored to the top of the pivot-pier with bolts not less than one (1) inch in diameter, nor less than fifteen (15) inches long, set in place with Portland-cement grouting. These bolts are to be made of soft steel, with cold-pressed threads and hexagonal nuts at top, and with split ends and wedges at the bottom. They are to be placed in pairs opposite on the inside and outside of the track, and are to be spaced not to exceed eighteen (18) inches between centres.

The top of the pier is to be levelled off with neat, Portland-cement mortar, and the lower track is to be set in same. It shall be made one and one-half ($1\frac{1}{2}$) or two (2) inches higher in the centre than at the edge, so that the water will drain toward the latter. A small gutter or depression in the top of the pier is to be made just inside of the lower track, and at the bottom of this depression drain-holes are to be put in, leading the water from the gutter down on the outside of the pier. These drain-holes are to be at least two (2) inches in diameter; and the tops are to be protected with screens, so as to prevent choking. They are to be spaced not to exceed ten (10) feet between centres.

The rollers shall be of cast steel, and are to be made solid, excepting only the centre hole and four or more radial holes that are left in the casting for the double purpose of reducing the weight and facilitating a rapid and uniform cooling, the said holes varying in size and number with the diameter of the roller.

The following formulæ shall be used in proportioning rollers:

For greatest total loads, including impact, with draw at rest,

$$p = 600d;$$

for loads with draw in motion,

$$p = 200d,$$

where p is the permissible pressure in pounds per lineal inch of roller, and d is its mean diameter in inches.

In no case shall the roller be less than twelve (12) inches in diameter and seven (7) inches on face.

All rollers, and the faces of the upper and lower tracks which are in contact with the rollers, are to be turned smooth to the forms of right frustums of cones, the vertices of which intersect at the centre of the drum, so that the rollers will have perfect contact with the tracks throughout their travel around the entire circumference.

A bearing is to be turned in the centre of each roller for the radial rod, and oil-holes are to be provided on both the interior and the exterior ends of the rollers, so that these bearings can be kept well lubricated.

The outer ends of the radial rods are to pass through the rollers, and the inner ends are to attach to a circular plate fitting closely around the centre casting. These radial rods are to be provided with either turnbuckles or nuts for adjusting the position of the rollers. Only square sections are to be used for the rods, and each must contain at least one square inch of section. The end of the rod passing through the roller must be upset so as to provide a turned shaft for the latter at least one and one-half (1½) inches in diameter. The outer ends of these rods are to pass through a stiff steel ring of rolled or built channel section, which is to serve as a spacer for the rollers. These channels must be made wide, but not deep, and their section is to be commensurate with the size of the turntable. They are to be held away from the rollers by friction-washers on the rods.

On the inside of the rollers collars are to be forged and turned on the radial rods to hold the said rollers in exact position on same. Turned bosses must be provided on both the inner and the outer ends of the rollers, to bear against the collars and the friction-washers.

An inner spacing-ring, of size commensurate with the magnitude of the drum, is to be attached to the radial rods. For large drums this should be in the form of a small curved plate girder lying in a horizontal plane and rigidly braced to the centre casting by radial struts that are riveted at the outer ends to the curved girder and at the inner ends to a large circular plate which fits snugly around a turned bearing on the centre casting. With this detail the radial rods are to be dispensed with, and in their stead are to be substituted heavy square bars, having their outer ends detailed as described for the radial rods, and their inner ends attached to the circular girder so as to hold the bars in a position exactly radial to the drum. These bars should not be less than two and a half (2½) inches square, and the journals should not be less than three (3) inches in diameter. There must be nuts at both ends of the bars so as to move the rollers in a radial direction, and the inner ends of the bars are to be so attached to the circular plate as to permit of the correction of any slight variation of their axes from a truly radial direction.

The centre casting must be made strong and heavy, and must be effectively anchored to the top of pier by eight (8) or more anchor-bolts not less than one and one-fourth (1¼) inches in diameter and not less than three (3) feet long. These bolts are to be made of soft steel, with cold-pressed threads and hexagonal nuts at top, and with split ends and wedges at bottom. The least allowable thickness of metal for this casting shall be one and one-half (1½) inches. The base shall be true and level; and an even bearing shall be secured by bedding in neat, Portland-cement mortar. For heavy draws this centre casting is to be set well into the masonry, then grouted in place.

All bearings for plates which rotate on this casting are to be turned smooth, and are to be provided with suitable oil-grooves, so they can be easily oiled.

Spans resting on drums of small diameter in proportion to the span length are to be anchored to the pivot-pier by means of a large anchor-rod in centre of pier, extending down ten (10) or fifteen (15) feet into same. This rod shall pass through the centre casting and through a box girder over the centre of the drum, which girder shall rivet into either the transverse or the longitudinal girders. The lower end of the rod shall pass through a heavy cast-iron anchor-piece embedded in the concrete of the pier. Both ends of the rod shall be provided with nuts for adjustment, and all details shall be made strong enough to develop the full strength of the anchor-rod. The upper nut shall be almost, but not quite, in contact with a large washer-plate that rests on the box girder. The size of the anchor-rod is to be determined by assuming an unbalanced upward wind load of five (5) pounds per square foot on the total area of the horizontal projection of one arm of the span.

The cap-plate for holding down the top connection-plate for the radial struts is to be attached to the top of the centre casting by means of a bolt tapped into same. This bolt is to be at least one and one-quarter (1¼) inches in diameter.

The rack for turning the span is to be made in short sections, not over four feet long, so that in case of breakage only a small portion of the rack need be replaced. These rack segments are to be bolted to the lower track with tap-bolts not less than fifteen sixteenths ($\frac{15}{16}$) of an inch in diameter, and spaced not to exceed fifteen (15) inches between centres. There must be enough of them in any case in any one segment of the track to resist, with a good margin for contingencies, the entire shear (including that due to the rotating moment) caused by the effort of the pinion or pinions that engage with said segment. The least allowable thickness of metal in the rack shall be one and one-eighth (1⅛) inches. The ends of the rack segments are to be planed so as to secure close contact, and the abutting ends are to be bolted together with turned bolts at least seven eighths (⅞) of an inch in diameter.

The bottom of the rack and that portion of lower track upon which the rack bears are to be planed smooth. The width of the base of the rack shall be at least two thirds (⅔) of its height; and ribs bracing the vertical portion to the base shall be provided at distances not exceeding eighteen (18) inches.

Drainage-holes not less than three fourths (¾) of an inch in diameter, spaced not more than two (2) feet between centres, shall be bored in the lower-track segments, starting just back of the rack and leading to the outside of the track.

The girders over the drum shall be so arranged as to distribute the load over it properly. The number of bearing points required will depend upon the length of span, the distance from centre to centre of trusses, the total load to be carried, and the economical size of pivot-pier. The arrangement of the supporting girders in turn depends upon the number of bearing points to be used. For ordinary single-track bridges up to three hundred (300) feet in length a very good arrangement of girders over drum is secured by making the diameter of the drum and the length of centre panel equal to the distance from centre to centre of trusses; then the middle points of both the longitudinal and the transverse girders will be directly over the web of the drum, thus furnishing four points of bearing. Four more points of bearing are secured by putting in short diagonal girders, which connect to both transverse and longitudinal girders and bear on the drum at their centres. This arrangement gives in all eight (8) points of support.

The longitudinal, transverse, and diagonal girders over the drum shall be so designed that their rigidities will be such that when deflected under the load the extreme fibre-stress will be about the same in all the said girders.

The bottom-chord stresses in the centre panel can either be carried by the longitudinal girders, or the bottom-chord sections can be continued through the centre panel, the longitudinal girders being placed above them, and steel chairs being inserted beneath their centres to furnish bearings on the drum. In case that the bottom-chord stresses are carried by the longitudinal girders, ample provision must be made for them, as well as for the bending stresses, in designing the sections for these girders. Where the clearance over the waterway will permit, metal can be saved by letting the top flange of the longitudinal girder form the bottom chord of the truss.

In any arrangement of girders over the drum, bearing-plates at least one (1) inch thick must be used between the top flange of the drum and the bottom flanges of the girders, in order to make the points of concentration well defined, and so as to transmit the load properly from girders to drum.

All girders bearing on the drum are to have stiffeners on both sides of their webs at all points of concentration; and in no case are the stiffeners to be crimped, but are to have fillers beneath. They must have close bearings at top and bottom flanges, and are to be proportioned in the same manner as previously specified for those on the drum.

The rollers, tracks, drum, and girders over drum shall be completely assembled in the shop before shipment, all holes being reamed to fit and the sections being match-marked. Every roller must have a true bearing on both the upper and the lower tracks during a complete revolution of the draw.

Before the assembling of the rollers is done there must be marked on both the upper and the lower track segments a circle of the same diameter, which circles will come a trifle inside of the exterior ends of all rollers; then, after the turntable is perfectly adjusted, each roller is to be marked where these circles touch it. After the turntable is disconnected each roller is to be set up properly in a lathe, and the exterior periphery is to be chamfered off exactly to the points marked, so that when the turntable is set up in the field, if the exterior of each roller is brought exactly to the circles on the two tracks, the rollers will all be in their proper positions. These lines on the tracks will serve also afterwards to line up the rollers whenever the turntable is to be adjusted.

MACHINERY FOR TURNING THE SPAN AND LIFTING THE ENDS OF SAME

POWER.

When a draw-span is to be opened frequently, some kind of mechanical power must be used. The kind of power best adapted to any particular span depends upon a number of conditions, more especially the location of the bridge.

A gasoline-engine is an economic and convenient form of power for small spans which do not require more than twelve (12) or fifteen (15) horse-power to operate.

Duplicate electric motors, where direct connections can be made with electric-light or street-railway power-plants, are very efficient, convenient, and reliable; but in no case is it safe to depend upon storage-batteries for power. The use of electric motive power is therefore confined to bridges located in or near towns or cities.

Where over twelve (12) or fifteen (15) horse-power is required for operating the spans, and where electrical connections cannot be made, the steam-engine is the best form of power to use, except possibly in some special cases where water-power can be had conveniently.

Except in the case of short, light drawbridges, whenever mechanical power is employed it is necessary to apply the same to the rack by two pinions located diametrically opposite each other. If with this arrangement the tooth-pressure be still too high, it will be necessary to replace each pinion by a pair of pinions located as close together as practicable. With pinions located far apart some kind of an equalizer must be employed to divide the work equally between them, on account of the unavoidable, slight irregularities in the tooth-spacing of the entire rack. When electrical power is adopted, the equalizing may be done by means of electrical connections between the duplicate motors; but with any other power a mechanical equalizer between the two radial shafts must be employed. There will be no equalizing needed between the two pinions of each pair, on account of their being placed so close together.

With the equalizing arrangement just specified, it is legitimate to assume an equal division of work among all the pinions that engage the rack.

No matter what mechanical power be used, all spans must be provided also with hand-operating machinery.

METHOD OF DETERMINING POWER REQUIRED FOR OPERATING THE SPAN AND LIFTING THE ENDS.

The power required for turning any span is to be determined by the following formula:

$$\text{H.P.} = \frac{.0125\,Wv}{550} \qquad (1)$$

where $W =$ total load on rollers in pounds, and $v =$ velocity on pitch-circle of rack in feet per second. The value of v is to be determined by the formula

$$v = \frac{\pi D}{4t},$$

where $D =$ diameter of pitch-circle of rack, and $t =$ assumed time in seconds for turning the draw through one fourth ($\frac{1}{4}$) of a revolution. This method gives the power required under ordinary conditions; but it is always necessary to figure also the power required to open the span against an assumed unbalanced wind-pressure. This is to be determined as follows:

The unbalanced wind-pressure on one arm is to be taken at five (5) pounds per square foot of the exposed surface of the floor and both trusses.

Let $P =$ total unbalanced wind load on one arm in pounds, and $v =$ velocity of travel of its centre of pressure in feet per second; then

$$\text{H.P.} = \frac{Pv}{550}. \qquad (2)$$

The value of v is to be determined by assuming a certain time t, in seconds, for turning the draw one fourth ($\frac{1}{4}$) of a revolution. Let l = distance in feet of the centre of pressure on one arm from the centre of the drum; then

$$v = \frac{\pi l}{2t}. \tag{3}$$

For *Mechanical-power Turning-machinery* the greatest H.P. required is to be determined as follows:

Case I.—(*a*) By Formula (1) determine the H.P. required for turning the span in the least time in which it is probable that the said span will ever need to be opened.

Case II.—(*a*) By Formula (1) determine the H.P. required for turning the span in twice the time assumed in Case I. (*b*) By Formula (2) determine the H.P. required for operating the draw against the unbalanced wind load in twice the time assumed in Case I, and add together the two amounts of H.P. determined by (*a*) and (*b*). The sum will be the greatest H.P. required for Case II.

The greatest pressure on the teeth and torsion on shafts found for these two cases are to be used, the metal being strained on the extreme fibre as hereinafter specified; but the said teeth and shafting must also be figured on the assumptions that the entire available capacity of the machinery is required merely to hold the draw from turning under an excessive unbalanced wind-pressure, and that under these conditions the metal is strained twice as high as hereinafter specified.

For *Hand Turning-machinery* the H.P. required to turn the span in the *least time* in which it is probable that it will ever need to be opened by man-power is to be found by the formula previously specified; then the number of men required to perform this work is to be determined by assuming that six (6) men are equivalent to one H.P. In proportioning all parts of the hand-operating machinery there shall be assumed on the levers as many men as are required by the above method, each man exerting a horizontal thrust of one hundred and twenty (120) pounds. Under such conditions the metal is to be strained the same as hereinafter specified for machinery operated by mechanical power under extraordinary conditions.

DETAILS OF MACHINERY.

OPERATING MACHINERY.

All gear-wheels are to be of cast steel with cut gears. To determine the size of any gear-wheel, the tooth-pressure on the pitch-circle is first to be found as follows:

For gears moved by mechanical power only,

$$P = 550 \frac{H.P.}{v},$$

where $H.P.$ = horse-power to be transmitted by gear, v = velocity in feet per second at its pitch-circle, and P = tooth-pressure in pounds.

For gears moved by hand-power,

$$P = 120NM,$$

where N = number of men, M = multiple of lever over gear under consideration, and P = tooth-pressure.

Having thus determined the tooth-pressure, the pitch can be found by the following formula:

$$p = .025 \sqrt{\tfrac{2}{3}P},$$

for gears in which the face is equal to $2\frac{1}{2}$ times the pitch, where p = pitch, and P = total tooth-pressure.

This allows an extreme fibre-stress on the teeth of eight thousand (8,000) pounds per square inch, which is to be the standard intensity for all teeth under ordinary conditions of operation. Bevel-gears are to be considered as only three fourths ($\frac{3}{4}$) as strong as spur-gears of the same pitch and face. The use of bevel-gears with very thin teeth will not be allowed, even though they be of standard pattern; but special bevel-gears with thicker teeth than usual will have to be manufactured.

All gears are to be key-seated and finished in accordance with the practice of the best machine-shops. All pinions gearing into the rack and into the large spur-wheels are to be shrouded on top, and the extra strength obtained by this shrouding is not to be counted upon in proportioning the size of the teeth of the pinion.

All shafting is to be of cold-rolled steel, and is to be provided with couplings, collars, and keys for gears.

All couplings must be strong enough to develop the full strength of the shafting, and must be keyed to the same, flange-couplings being preferred. All couplings are to be placed as near the bearings as practicable.

Suitable collars are to be used wherever they are necessary to hold the shafting from moving longitudinally.

The greatest allowable length of any shaft between centres of bearings is to be determined by the formula

$$L = 75 \sqrt[3]{d^2},$$

where $L =$ the unsupported length in inches, and $d =$ diameter of shaft in inches.

The diameter required for any shaft is to be determined by the following formula:

$$d = 4\sqrt[3]{\frac{H.P.}{N}},$$

where $d =$ diameter required, $H.P. =$ the horse-power to be transmitted, and $N =$ the number of revolutions per minute. This will allow for all bending that will come on any well-designed and properly supported shaft under ordinary conditions, and provides for an extreme fibre-stress of about twelve thousand (12,000) pounds per square inch, under the assumption that the twisting moment and the bending moment are about equal.

Every shaft, however, after being designed by the preceding formula must be checked as follows, and if found weak must be strengthened properly either by increasing the diameter or by reducing the lever arm or arms of the bending moment.

First, find the twisting moment and the bending moment (including that caused by the weight of the shaft itself) by computing the tooth-pressure, which is the force producing directly these moments, calling the twisting moment T and the bending moment M. The equivalent twisting moment for a combination of these two moments is given by the equation

$$T' = M + \sqrt{M^2 + T^2},$$

where T' is the equivalent twisting moment.

The corresponding extreme fibre-stress is to be found by the equation

$$f = 5.1\frac{T'}{d^3},$$

where d is the diameter of the shaft, and f is the extreme fibre-stress. This should never exceed twelve thousand (12,000) pounds per square inch for all ordinary conditions of operation, or twenty-four thousand (24,000) pounds per square inch for the unusual conditions of the machinery stalled by the unbalanced wind-pressure when working at its utmost capacity, or for operation by man-power.

In no case is any shaft of less than two and one-quarter ($2\frac{1}{4}$) inches in diameter to be used for any part of the machinery of draw-spans.

Suitable cast-iron boxes are to be provided for all bearings. All boxes, bearings, couplings, collars, etc., are to be made in accordance with the best machine-shop practice. The boxes for the line of shafting running to ends of span are to have wooden shims beneath them so that the shaft can be aligned perfectly after the span is swung.

The hand-power turning-machinery is to be so arranged that the levers can be applied conveniently to shafts near the centre of span for both the turning and the end-lifting machinery. Shafts must also be provided for applying the hand-power levers to the end-lifting machinery at each end of the span. Suitable hand-levers are to be provided for as many men as are required for operating the draw. These levers are to be constructed entirely of steel, excepting only the small wooden quarter-rounds at the ends by which the men take hold.

All machinery shall be so arranged that the span can be turned completely around in either direction, and so that it is reversible in every particular.

END-LIFTING APPARATUS.

The ends are to be lifted and locked by means of a toggle mechanism to be operated by screws at each end of the span. The entire machinery is to be made strong enough, with the previously specified intensities of working-stresses, to exert an upward force on each end of each truss equal to the assumed uplift in case of mechanical power; or to transmit to the end rollers the greatest force that the men can exert on the hand levers, assuming that as many men will be applied thereto as are required for the turning-machinery, and that each man exerts a horizontal thrust of one hundred and twenty (120) pounds, straining the metal twice as high as in the case where the power is mechanical.

In case of mechanical power, all the teeth and shafting must also be figured on the assumption that the entire available capacity of the machinery is required merely to start motion, and that under this condition the metal is strained twice as high as herein specified.

The size of screw required is to be determined by the following formula:

$$d = .02\sqrt{P},$$

where d = diameter of screw at base of threads, and P = axial pressure on screw.

The axial pressure is to be determined for the two following cases, the greater pressure thus found being adopted:

Case I.—

$$P = \frac{2Rh'}{h},$$

where R = total assumed upward reaction at one end of span, h' = greatest rise of ends when end lifts are applied, and h = travel of nut on screw necessary to produce the rise h'.

The factor two (2) is used to allow one hundred (100) per cent for friction.

Case II.—

$$P = 60MN,$$

where $M =$ the number of pounds pressure the screw will exert for one pound applied on the lever, and $N =$ number of men on said lever. By using eighty (80) instead of one hundred and twenty (120) in the above formula, there is made an allowance of fifty (50) per cent for friction, which is certainly lower than it will ever be under ordinary working conditions.

Assuming the coefficient of friction low in this case makes an error on the side of safety.

For all ordinary conditions, Case II will give the greater value for P. The threads are to be standard square threads, and the nuts which work on them are to be made long enough to keep the greatest working unit pressure on said threads down to five hundred (500) pounds per square inch

All links used in the toggle mechanism are to be proportioned by the formula

$$p = 10,000 - \frac{300l}{t},$$

where $l =$ greatest unsupported distance between fillers, except in links in which only one filler is used between two flats, when it is to be taken as the entire distance from centre to centre of end-pins, $t =$ thickness of each link, and $p =$ the intensity of working compressive stress.

In no case is the diameter of any pin used in a toggle to be less than two and a half ($2\frac{1}{2}$) inches.

Rail lifts are to be provided in connection with the end-lifting toggle, and the mechanism therefor is to be so designed that the rails will not begin to rise until the end rollers have been drawn from their bearings on the end shoes. The rails shall be lifted so as to clear by one (1) inch all parts over which they must pass in turning, under the assumption that the temperature of the top chords is higher by thirty (30) degrees Fahrenheit than that of the bottom chords.

Suitable guide-chairs for the rails near the ends of the span are to be provided beneath the same on at least fifteen (15) ties from each end of the span. These chairs must be either spiked or bolted to the ties, and must hold the rails firmly in place. Guide-rods such as are employed in ordinary switch-work are to be used every six feet between the portions of the rails resting in the guide-chairs.

The strength of all parts of the rail-lifting machinery is to be determined by computing the force necessary to deflect the two rails the required amount in a distance of twenty (20) feet, and adding fifty (50) per cent thereto for friction.

If considered necessary for any particular span, latches are to be provided for holding the ends in place ; but under ordinary conditions the track-rails and the end rollers are all that will be required.

In double-track drawbridges special attention must be paid to the designing of not only the lifting-gear, but also the trusses themselves, in order to ensure that, under the most unfavorable circumstances possible, there shall be no lifting of the ends of trusses off their supports. If such a lifting were possible, the result would certainly be the derailment of an entering train, and consequently disaster to the span. To prevent such uplifting the trusses must be deep and very rigid, and the lift of the ends must be from one (1) to two (2) inches, according to the length of the span.

SHOES AND END-BEARING ROLLERS.

Rollers are to be provided beneath the end-pins of trusses and attached to the span by means of links which form a part of the toggle. The rollers must be bored so as to fit over the pins at the bottom of the links. Both the pins and the inside of the rollers must be finished very smooth; and provision must be made for oiling the bearings between them. The allowable intensity for bearing between rollers and pins shall be ten thousand (10,000) pounds per square inch of horizontal projection of pin inside of the roller.

No roller shall be less than six (6) inches in diameter, and the pins inside of same shall not be less than three and seven-sixteenths ($3\frac{7}{16}$) inches net in diameter. The play between rollers and their pins shall not be over one thirty-second ($\frac{1}{32}$) of an inch. The links forming the support for the ends of trusses are to be proportioned by the formula

$$p = 10{,}000 - 300\frac{l}{t},$$

where p = intensity of working compressive stress, l = greatest unsupported length of one link, and t = thickness of same.

In all drawbridges where, on account of infrequent operation combined with great changes in temperature and great length of arms, there is a tendency to drag the rollers longitudinally on their bearings, the detailing of the link supports must be such as to provide sufficient rigidity to overcome the friction of the rollers on their bearings, and thus permit the lifting apparatus to accommodate itself to extreme changes of temperature without overstraining any of its parts.

The bearings for rollers on the shoes shall be cupped one-eighth ($\frac{1}{8}$) inch or more in depth so as to provide ample bearing area, using an intensity of ten thousand (10,000) pounds, impact being included in the calculated load. The shoes to receive the end rollers may be made of either cast or structural steel, and are to be anchored firmly to the masonry. The two shoes at one end of span are to be connected to each other by means of adjustable rods not less than one and one-half ($1\frac{1}{2}$) inches in diameter, and strong enough to take up the entire thrust from the toggle.

Shimming-plates varying in thickness from one fourth ($\frac{1}{4}$) to one half ($\frac{1}{2}$) of an inch and of a total depth of not less than three (3) inches are to be used beneath the shoes so as to provide adjustment for the ends of the span.

Shoulders must be provided on the shoes to furnish a bearing for the rollers when they are lowered by the toggle. Each shoulder must be turned so as to fit the roller exactly, when the axis of the pin through the said roller is in the vertical plane of the truss. The height of these shoulders above the bottom of the rollers shall be about one third of the diameter of said rollers, but never enough to involve the possibility of collision with the draw-span during its revolution and when the top chords thereof are thirty (30) degrees Fahrenheit warmer than the bottom chords.

All parts of the end-lifting machinery must be finished in accordance with the best machine-shop practice, and all sliding surfaces shall be provided with oil-holes that are easily accessible.

In all cases end floor-beams with double webs shall be used, in order to provide proper support for the end-lifting machinery.

Whenever spans are to be floored for highway traffic, all keyholes for applying hand-levers are to be provided with suitable cast-iron caps.

Whenever practicable, the end-lifting toggle machinery is to be assembled in the shops to make sure that it will work satisfactorily.

HOUSES AND SUPPORTS.

Wherever mechanical power of any kind is to be used for operating any draw-span, a suitable house is to be provided for same. The size of the house required will depend upon the kind of power to be used, and the amount thereof. All parts of the house shall be durable and strong, and shall be finished in a first-class and workmanlike manner. A sufficient number of windows is to be put in to light properly all parts of the building. The house shall be placed high enough in the tower to give the required clearance beneath its supports, and, where shallow trusses are used, it shall be placed entirely above the span. The supports for the house shall be designed to carry the weight of the latter and that of all machinery to be placed therein, together with a proper allowance for live load. In general, steel beams shall be used for the joists supporting the floor, and all parts of the latter shall be made strong enough to carry three hundred and fifty (350) pounds per square foot.

The weight of the house and its machinery must always be considered in proportioning all parts of the structure which will be affected by these loads, whether the span is to be provided with mechanical power at first or not, as it may become necessary later on to put it in. The wind load on the house must also be considered in proportioning the tower posts and all bracing between them.

CAMBER AND DEFLECTION.

The lengths of all truss members shall be such that when the assumed uplift is applied at the ends of the span, and when the greatest live load is on the structure, the centre lines of the bottom chords from end to end of span will lie in a horizontal plane. The vertical movement of the ends, from the condition of no stress in the chords, when the weight of the finished span is supported on the falsework, to the condition of the span swung, must be very carefully figured, as upon this will depend the camber increments or decrements in lengths of members, the clearances, adjustments, etc.

GENERAL SPECIFICATIONS GOVERNING THE DESIGNING OF STEEL HIGHWAY BRIDGES AND VIADUCTS.

(CHAPTER XVI OF "DE PONTIBUS.")

GENERAL DESCRIPTION.

CLASSIFICATION.

HIGHWAY bridges shall be divided into three classes, viz., Class A, which includes those that are subject to the *continued* application of heavy loads; Class B, which includes those that are subject to the *occasional* application of heavy loads; and Class C, which includes those for ordinary, light traffic.

In general it may be stated that bridges of Class A are for densely populated cities; those of Class B for smaller cities and manufacturing districts; and those of Class C for country roads.

MATERIALS.

All parts of the structure, excepting the flooring or paving, shall, for all spans of ordinary lengths, be of medium steel, excepting only that rivets and bolts are to be of soft steel, and adjustable members of either soft steel or wrought iron. For very long spans high steel may be used for top chords, inclined end posts, pins, and eye-bars in bottom chords and in main diagonals of panels where there is no reversion of stress when impact is included. Cast iron will not be allowed to be used in the superstructure of any highway bridge or trestle, except for purely ornamental work, cast steel being employed wherever important castings are necessary.

JOISTS, PLANKS, GUARD-TIMBERS, AND WOODEN HAND-RAILS.

Joists, planks, guard-rails, hand-rails, and all other timber portions of the structure shall be of long-leaf, Southern, yellow pine, or other timber which, in the opinion of the Engineer, is equally good and serviceable.

The sizes of the timber joists shall be such as to give the requisite resistance to bending, the effect of impact being considered; but no joist shall be less than three (3) inches wide or twelve (12) inches deep.

As a rule the depth of a joist shall not exceed four (4) times its width. Otherwise, the joists shall be properly bridged at distances not exceeding eight (8) feet.

They shall be proportioned by the formula

$$M = \frac{1}{6} Rbd^2,$$

where M is the greatest bending moment in inch-pounds upon a joist, R is the intensity of working-stress in pounds, b the width of the joist in inches, and d the depth of same in inches.

Joists shall be dapped at least one-half (½) inch upon their bearings, and shall have their tops brought to exact level before the planks are laid thereon.

They shall be spaced not to exceed two (2) feet between centres; shall, preferably, lap by each other so as to extend over the full width of the floor-beam; and shall be separated half an inch, so as to permit the circulation of air. The outside joists, however, shall abut so as to provide flush surfaces from end to end of span.

Floor-planks for the main roadway shall be at least three (3) inches thick and from eight (8) to ten (10) inches wide, and shall be laid with one-quarter (¼) inch openings. Each plank shall be spiked to each joist on which it rests by two (2) seven (7) inch cut spikes, the holes for which shall be bored in order to avoid splitting the timber, or else by two (2) seven (7) inch wire nails.

Whenever a wearing-floor is used, the lower planks must be planed on the upper side and sized to a uniform thickness, and the wearing-floor must be planed on the lower side so as to ensure a perfect bearing between upper and lower floors.

Floor-planks for footwalks shall be at least two (2) inches thick and not much more or less than six (6) inches wide, and shall be laid with one-half (½) inch openings. Each of said planks shall be spiked to each joist upon which it rests by two (2) six (6) inch cut spikes, the holes for same being bored.

All planks shall be laid with the heart side down.

There shall be a wheel-guard of a scantling not less than four (4) inches by six (6) inches on each side of the roadway to prevent wheel hubs from striking the trusses. It is to be laid on its flat, and blocked up from the floor by shims at least one (1) foot long, six (6) inches wide, and two (2) inches thick, spaced not more than seven (7) feet between centres, each shim being spiked to the floor by four (4) four-and-a-half (4½) inch cut spikes. The guard-rails are to be bolted to the floor through the centre of each shim by a three-quarter (¾) inch bolt, which must also pass through the joist beneath. When the guard-rails are bolted to the wooden hand-rail posts, the bolt-heads are to be countersunk into the guard-rail, so as to make a flush surface on the inner face of same. The joints in the guard-rail are to be lap-joints, at least six (6) inches long, each located symmetrically over the middle of a shim. When a bridge is on a heavy grade, the inner, upper corners of the guard-rails are to be covered with steel angles fastened to the timber by countersunk screws, spaced about eighteen (18) inches apart, so as to protect the guard-rails from the injurious effects of using them instead of wheel-brakes for heavily-loaded wagons.

When wooden hand-rails are employed, they are to be made of pine, the posts being 4″ × 6″ × 4′ 6″ to 5′, with two (2) runs of 2″ × 6″ timbers—one on its flat and the other below on edge to support the first for a hand-rail—and one (1) run of 2″ × 12″ hub-plank.

The posts are to be spaced not to exceed ten (10) or, preferably, eight (8) feet apart. The hand-railing is to be firmly attached to the bridge, and rigidly braced. When the rigidity of a hand-railing is dependent upon that of the outer joists, the latter must be properly bridged and stiffened. Any other wooden hand-railing of equal strength and rigidity, and which is satisfactory to the Engineer, will, however, be accepted.

When iron hand-railing is employed, it is to be of a firm, substantial pattern, pleasing to the eye, and rigidly attached to the trusses or floor-beams. Both through and deck bridges are to be provided with a hand-rail on each side, not less than three and a half (3½) feet high above the floor. In case there be any liability of a horse jumping over this railing, its height must be increased to four and a half (4½) or five (5) feet. There must be a hand-rail on the outside of each sidewalk, not less than three and a half (3½) feet in height above the floor.

FLOORING ON APPROACHES.

All floor-timbers, guards, and railings shall extend over all piers and abutments, and make suitable connection with the embankments at the ends of the structure. Aprons or cover-joints of steel plate shall be provided at the ends of spans, if required. The floors of the sidewalks shall extend to and connect with the floor of the main roadway, so as to leave no open space between them.

STREET–RAILROAD TRACKS.

Should there be one or more street-railroad tracks crossing the bridge, there must be directly under each rail a joist or stringer, properly proportioned to resist the effect of the total maximum load on the rail ; and the bending effect of the concentrated loads upon the floor-beams must be duly considered.

The rails shall be so laid as to offer as little obstruction as possible to the wheels of vehicles.

PAVED FLOORS.

Where paved floors are adopted, the pavement shall be of the best of its kind, and shall be built according to the latest and most approved specifications. Paved floors are always to be supported by steel stringers, preferably of rolled I beams, spaced generally not to exceed three (3) feet six (6) inches between centres. For asphalt or stone-block pavements, a buckled-plate floor, with concrete thereon, shall be used. The surface of the pavement must be thoroughly drained so as not to retain water, and the upper surface of the buckled plate, before it is covered with the concrete, must be protected from rusting by a liberal use of the best obtainable preservative coating.

When wooden-block paving is adopted, it may rest on a timber floor from four (4) to five (5) inches thick, which in turn rests on and is spiked to timber shims that are bolted effectively to the steel stringers.

All paved floors must be pitched so as to drain transversely to the structure; but plank floors need not be pitched, as the water will drain through the quarter-inch openings.

CLEARANCES.

The smallest allowable clear roadway shall be twenty (20) feet, measured between inclined end posts, excepting for cheap country bridges, where it may be reduced to eighteen (18) feet, or even to fourteen (14) feet, in case that the bridge be so short that no provision need be made for teams passing thereon.

The smallest allowable clear headway shall be fourteen (14) feet, except for bridges in cities where the ordinances require a greater height. The corner brackets may, however, encroach on the specified clear headway, provided they do not extend either laterally or downward more than five (5) feet.

EFFECTIVE LENGTHS AND DEPTHS.

See Specifications for Railroad Structures.

STYLES OF BRIDGES FOR VARIOUS SPAN LENGTHS.

In general, spans of and below twenty (20) feet are to consist of rolled beams or simply wooden joists; spans from twenty (20) to sixty (60) feet, of plate girders; spans from sixty (60) to ninety (90) feet, of open-webbed, riveted girders of single cancellation, or pin-connected "A" trusses; and spans exceeding ninety (90) feet, of pin-connected trusses.

The use of pony-truss bridges of any kind is prohibited, excepting only half-through, plate-girder spans, in which the top flanges are held rigidly in place by brackets riveted to cross-girders that are spaced generally not to exceed fifteen (15) feet apart.

FORMS OF TRUSSES.

The forms of trusses to be used are as follows:

For pin-connected spans up to ninety (90) feet, the "A" truss.

For open-webbed, riveted girders, the Warren or Triangular girder, with verticals dividing the panels; also the Pratt truss.

For deck-spans carrying joists on the top chords, the Warren or Triangular girder with verticals dividing the panels of the top chords.

For spans between ninety (90) feet and about two hundred and fifty (250) feet, Pratt trusses with top chords either straight or polygonal.

For spans exceeding two hundred and fifty (250) feet, Petit trusses.

It is understood that these limiting lengths are not fixed absolutely, as the best limits will vary somewhat with the width of bridge and the live load to be carried.

MAIN MEMBERS OF TRUSS-BRIDGES.

All spans of every kind shall have end floor-beams, riveted rigidly to the trusses or girders, for supporting the joists or stringers.

Steel stringers are, preferably, to be riveted to the webs of the cross-girders, but wooden joists are generally to rest on top of the latter.

In general, all trusses shall have main end posts inclined.

All trusses shall be so designed as to admit of accurate calculations of all stresses, excepting only such unimportant cases of ambiguity as occur when two stiff diagonals are used in a middle panel.

In important bridges with steel stringers, all lateral bracing and other sway-bracing shall be rigid above and below: i.e. the sections must be capable of resisting compression, adjustable rods for such bracing being allowed only in towers of draw-spans and in the lower lateral systems of deck-bridges; but, in cheap country bridges, the lateral and other sway diagonals may be adjustable rods.

The stiff diagonals of lower lateral systems, which shall be of double cancellation, shall be riveted rigidly to all the steel stringers where they cross them.

In the trusses of important bridges counterbracing the web shall be effected by using stiff diagonals, but in cheap bridges it may be done by using counters of adjustable rods.

All through-spans shall have portal bracing at each end, carried as low as the specified clear headroom will allow. The portal struts shall be riveted rigidly to the web or both flanges of the inclined end posts. Riveting portals to one flange only will not be allowed.

When the height of the trusses is great enough to permit, transverse, vertical sway-bracing shall be employed; otherwise, corner brackets of proper size, strength, and rigidity are to be riveted between the posts and the upper lateral struts.

Deck-bridges shall, as a matter of precaution, have sway-diagonals between opposite vertical posts of sufficient strength to carry one half of a panel-truss live load with its impact allowance; and the transverse bracing between the vertical or inclined posts at each end of span shall be sufficiently strong to transmit properly to the masonry one half of the total wind-pressure carried by the upper lateral system of the span.

The lower lateral systems of deck-bridges may be made of adjustable rods in alternate panels, thus leaving every other panel unbraced, and forcing the wind-pressure from below up the vertical bracing and to the ends of the span by the upper lateral system.

In important bridges, suspenders or hip verticals and two or more panel lengths of bottom chord at each end of span shall, preferably, be made rigid members, except that eye-bars are to be used for bottom chords of "A" truss bridges.

All floor-beams are to be riveted to the truss-posts in truss-spans, excepting in the case that eye-bars be used for suspenders or hip verticals. In such cases floor-beam hangers may be used, provided they be made of plates or shapes, and that they be stayed at their upper ends against all possibility of rotation.

CONTINUOUS SPANS.

See Specifications for Railroad Structures.

TRESTLE-TOWERS.

In general, the descriptive specifications for railroad trestles are to be followed in designing highway trestles or viaducts, except that in cheap structures all sway-diagonals of towers may be made of adjustable rods, with horizontal struts at the panel points, provided that the struts be rigidly riveted to the columns.

CAMBER.

All trusses must be provided with such a camber that, with the heaviest live load on the span, the total camber shall never be quite taken out by deflection. With parallel chords, sufficient camber will be obtained by making the top-chord sections longer than the corresponding bottom-chord sections by five thirty-seconds ($\frac{5}{32}$) of an inch for each ten (10) feet of length.

Plate girders and shallow, open-webbed, riveted girders should not be given any camber.

EXPANSION, ANCHORAGE, AND NAME PLATES.

See Specifications for Railroad Structures.

LOADS.

The loads to be considered in designing highway bridges and trestles are the following; and all parts of same are to be proportioned to sustain properly the greatest stresses produced thereby for all possible combinations of the various loads, excepting only that the live load and wind load cannot act together, unless the structure carry an electric railway; for the reason that no person would venture on the bridge when even one half of the assumed wind-pressure is acting.

A. Live Load.
B. Impact Allowance Load.
C. Dead Load.
D. Direct Wind Load.
E. Indirect Wind Load or Transferred Load.
F. Effects of Changes of Temperature.

When a highway bridge carries an electric railway, it shall be proportioned also for—

G. Traction Load, and,
H. Centrifugal Load.

In calculating the stresses caused by a uniform moving load, the load shall be assumed to cover the panel in advance of the panel point considered; but the half-panel load going to the forward panel point will be ignored; or, in other words, the uniform load will be treated as if concentrated at the various panel points.

LIVE LOADS.

The uniformly distributed live loads per square foot of floor, including the entire clear widths of both main roadway and footwalks, shall be taken from the curve diagram shown on Plate V.

In applying these curves the span lengths used shall be as follows:

For stringers and joists, a single panel length; for floor-beams and single panel suspenders with their corresponding primary-truss struts, two (2) panel lengths; for hip verticals of Petit trusses, four (4) panel lengths; and for main-truss members, the length of span loaded when the member under consideration receives its maximum stress.

In the case of bridges with exterior sidewalks, one sidewalk only and the roadway are to be considered loaded when proportioning the beam-hangers and *primary* truss members of all bridges, and when proportioning the main-truss members of all spans less than one hundred (100) feet for bridges of Class A, and of all spans less than eighty (80) feet for bridges of Classes B and C. In all other cases both of the sidewalks and the roadway are to be considered loaded. The eccentric loading increases the live load per truss. But, when a bridge has only one exterior sidewalk, the effect of the eccentric loading is to be considered to act upon the whole of the nearer truss, and the sidewalk is to be considered empty when calculating the stresses in the farther truss. Floor-beams of bridges with one or two exterior sidewalks are to be proportioned on the assumption that, first, the main roadway is loaded, and the sidewalk or sidewalks are empty; and, second, that the main roadway is empty, and the sidewalk or sidewalks are loaded, due account being taken of the effect of reversing stresses as hereafter specified.

In addition to the preceding loads, the floor, joists, floor-beams, beam-hangers, and primary-truss members are to be proportioned for the following concentrated loads, which are, however, supposed to occupy a whole panel length of the main roadway to the exclusion of the other live loads there (excepting only the electric-railway live load).

CLASS A.

A road-roller weighing thirty thousand (30,000) pounds, of which twelve thousand (12,000) pounds are concentrated upon the roller in front of the machine, and nine thousand (9000) pounds on each of the wheels at the rear, the distance between the central planes of these wheels being five (5) feet, and that between their axis and the axis of the front roller eleven (11) feet. The width of the front roller is to be four (4) feet, and that of each rear wheel one foot eight inches (1′ 8″).

CLASS B.

A concentrated load of sixteen thousand (16,000) pounds equally distributed upon two pairs of wheels, the axes of which are eight (8) feet apart, and the central planes of the wheels six (6) feet apart.

CLASS C.

A concentrated load of ten thousand (10,000) pounds distributed in the same manner as for Class B.

The road-roller load is assumed to be equally divided between all of the joists that it can cover, and the wheel loads for Classes B and C equally between two joists.

In case that the highway bridge or trestle carries a single-track line of electric road, that one of the four car or train loads, shown on Plate VI, which most closely approximates to the greatest railway load that will be carried by the structure is to be adopted, and is to be assumed to occupy ten (10) feet in width of the entire clear roadway of the span to the exclusion of all other live loads on said ten (10) feet, except as hereinafter specified for floor-beams and primary-truss members.

The equivalent uniformly distributed live loads, given by the curves on Plate VI, are to be used when making computations instead of the concentrations just specified.

The impact allowance for these electric railway loads is to be taken from the Specifications for Railroad Structures.

The floor system and primary-truss members are to be figured for these electric train loads when passing either the road-roller or the heavy wagon-load; and the trusses as a whole are to be figured for a uniform load found by combining the equivalent electric load, considering it to occupy ten (10) feet of roadway, together with its impact allowance, with the regular uniform live load per square foot of floor on the remaining width of clear roadway, together with its proper impact allowance, provided that the equivalent live load per lineal foot for the cars, plus the proper impact allowance, exceed the regular live load for a ten (10) foot width of roadway, plus its proper impact allowance. If it do not so exceed, the regular uniform live load is to be employed.

IMPACT-ALLOWANCE LOAD.

The impact-allowance load is to be a percentage of the uniform live load, found by the formula

$$P = \frac{10000}{L + 150},$$

where P is the percentage and L the length in feet of span or portion of span that is covered by the live load, when the member considered is subjected to its maximum stress.

DEAD LOAD.

See Specifications for Railroad Structures.

WIND LOADS.

For highway structures the wind loads per lineal foot of span for both the loaded and the unloaded chords are to be taken from the curves shown on Plate VIII.

This diagram was figured for a clear roadway of twenty (20) feet. For wider structures, the wind loads are to be increased two (2) per cent for each foot of width in excess of twenty (20).

The wind loads given on the diagram have been computed from detailed designs for simple spans up to seven hundred and fifty (750) feet in length, but beyond this limit they have been assumed; consequently, in designing spans of greater length than this, it will be necessary to check the assumed wind-pressure after the sections are proportioned, using an intensity of twenty-five (25) pounds per square foot.

The intensities employed in preparing the curves varied from forty (40) pounds for very short spans to twenty-five (25) pounds for very long ones.

For viaducts, the wind-pressure on the empty structure is to be assumed as three hundred (300) pounds per lineal foot on the spans at the level of the floor, and two hundred and fifty (250) pounds for each vertical foot of each entire tower.

The wind loads for longitudinal bracing are to be taken as seven tenths (0.7) of those for the transverse bracing.

For viaducts carrying electric trains, the wind loads are to be taken from the Specifications for Railroad Structures.

All wind loads are to be treated as *moving loads.*

INDIRECT WIND LOAD OR TRANSFERRED LOAD.

See Specifications for Railroad Structures.

TRACTION LOAD.

See Specifications for Railroad Structures.

CENTRIFUGAL LOAD.

See Specifications for Railroad Structures.

EFFECTS OF CHANGES OF TEMPERATURE.

See Specifications for Railroad Structures.

INTENSITIES OF WORKING-STRESSES.

See Specifications for Railroad Structures.

BEARINGS UPON MASONRY.

See Specifications for Railroad Structures.

REVERSING-STRESSES.

See Specifications for Railroad Structures.

NET SECTION.

See Specifications for Railroad Structures.

BENDING MOMENTS ON PINS.

See Specifications for Railroad Structures.

COMBINATIONS OF STRESSES.

The Specifications for Railroad Structures under this heading are to be followed, with this exception: in bridges and viaducts that do not carry trains, the live load and the wind load are assumed not to act simultaneously.

BENDING ON TOP CHORDS.

See Specifications for Railroad Structures.

BENDING ON INCLINED END POSTS.

The Specifications for Railroad Structures under this heading are to be followed, with this exception: in bridges that do not carry trains, the live load and the wind load are assumed not to act simultaneously.

BENDING DUE TO WEIGHT OF MEMBER.

See Specifications for Railroad Structures.

GENERAL LIMITS IN DESIGNING.

The following general limits shall be adhered to in designing highway bridges and viaducts:

The perpendicular distance between central planes of trusses shall never be less than one twentieth ($\frac{1}{20}$) of the span.

The length of any bracket cantilevered beyond a truss or girder shall never exceed one half of the perpendicular distance between the central planes of adjacent trusses or girders, unless there be more than two trusses to the span.

No metal less than five sixteenths ($\frac{5}{16}$) of an inch in thickness shall be used, except for filling-plates; and in important bridges this limit shall be increased to three eighths ($\frac{3}{8}$) of an inch.

The least allowable thicknesses of webs of rolled I beams shall be as follows:

24″ I beams	$\frac{9}{16}$″	webs.
20 " "	$\frac{1}{2}$	"
18 " "	$\frac{7}{16}$	"
15 " "	$\frac{3}{8}$	"
12 " "	$\frac{5}{16}$	"

No channel less than six (6) inches in depth shall be used except for lateral struts, in which five (5) inch channels may be employed.

No angles less than $2\frac{1}{2}'' \times 2\frac{1}{2}'' \times \frac{5}{16}''$ shall be used except for lacing.

No eye-bars less than three (3) inches deep or five eighths ($\frac{5}{8}$) of an inch thick shall be employed; and the depths of eye-bars for chords and main diagonals shall not be less than one sixtieth ($\frac{1}{60}$) of the horizontal length of same.

No adjustable rod shall have less than three quarters ($\frac{3}{4}$) of a square inch of cross-section.

The shortest span length for trusses with polygonal top chords shall be one hundred and sixty (160) feet.

The limit of span length in which steel stringers can be riveted continuously from end to end of span shall be two hundred (200) feet. Beyond this limit sliding-bearings must be used at one or more intermediate panel points; and in no span shall there be a length of continuously riveted stringers exceeding two hundred (200) feet.

For all compression-members of trusses and for columns of viaducts the greatest ratio of unsupported length to least radius of gyration shall be one hundred and twenty (120), excepting those members whose main function is to resist tension. In these the limit may be raised to one hundred and fifty (150).

The corresponding limit for all struts belonging to sway-bracing shall also be one hundred and fifty (150).

GENERAL PRINCIPLES IN DESIGNING ALL HIGHWAY STRUCTURES.

See Specification for Railroad Structures.

RIVETING.

In general, the specifications for riveting given for railroad structures shall apply also to highway structures, except that in the latter the diameters for rivets may be reduced to three quarters ($\frac{3}{4}$) of an inch for ordinary work.

DETAILS OF DESIGN FOR ROLLED I-BEAM SPANS.

Rolled I beams used as longitudinal girders shall have, preferably, a depth not less than one fifteenth ($\frac{1}{15}$) of the span. They shall be proportioned by their moments of inertia. The spacing shall generally not exceed three (3) feet six (6) inches.

Provided that wooden shims be bolted to the top flanges for spiking the planks thereto, no sway-bracing will be required; but otherwise it must be used. Each I beam is to have at each end a pair of stiffening angles, fitting tightly at both top and bottom to the flanges, to carry the load to the masonry and to form part of the end bracing-frames. Each pair of girders is to have a bracing-frame at each end; and under each end of each I beam there is to be riveted a bearing-plate of proper area and thickness (never less than five eighths [$\frac{5}{8}$] inch) to distribute the load uniformly over the masonry, said plate being bolted effectively to the latter, with due provision for expansion and contraction.

DETAILS OF DESIGN FOR PLATE-GIRDER SPANS.

In designing plate-girder spans for highway structures, the corresponding specifications for railroad structures are to be followed, except that the depths of girders shall preferably be not less than one twelfth ($\frac{1}{12}$) of their span, that metal five-sixteenths ($\frac{5}{16}$) inch thick may be used, and that the stiffening angles may be made as small as two and a half ($2\frac{1}{2}$) by two and a half ($2\frac{1}{2}$) inches.

DETAILS OF DESIGN FOR OPEN-WEBBED, RIVETED GIRDER SPANS.

See Specifications for Railroad Structures.

DETAILS OF DESIGN FOR PIN-CONNECTED SPANS.

The sections of top chords and inclined end posts of through-spans shall consist, generally, of two rolled or built channels and a single cover-plate. In the case of built channels, the section of the member must be so proportioned as to bring its centre of gravity as near as possible to the middle of the webs.

Main vertical posts shall generally be composed of two laced channels, preferably rolled ones, although built channels may be used where large sections are required.

Secondary vertical posts may be made of two rolled channels laced, or of four angles in the form of an I with a single line of lacing. These secondary vertical posts should be riveted to the top chords instead of being pin-connected thereto, as in the case of the main vertical posts.

The channels of vertical posts may have their flanges turned either inward or outward, as desired, or so as best to suit the general detailing of the truss.

Stiff bottom chords and inclined web-struts may be made of either two channels with two lines of lacing or of four angles with one line of lacing, the use of trussed eye-bars for struts being prohibited.

Upper lateral struts, overhead transverse struts, and web-stiffening struts shall preferably be made of four angles with one line of lacing. In case, however, the said angles be spaced very far apart, as in lateral struts connecting deep top chords, they are to be placed on the corners of a rectangle, with their legs turned inward, and laced on all four faces of the box strut thus formed.

Eye-bars are to be used for all bottom chords and main diagonals that do not require to be stiffened.

Counters, when employed, can be of either rounds, squares, or flats. These and all other adjustable members are to have their ends enlarged for the screw-threads (unless soft-steel, cold-pressed threads be used), so that the diameter at the bottom of the thread shall be one eighth ($\frac{1}{8}$) of an inch greater than that of the body of a round rod of area equal to that of the adjustable piece.

Diagonals for upper lateral systems and vertical sway-bracing shall, preferably, be built of four angles in the form of an I, with a single line of lacing; but for structures where this section would involve an extravagant use of metal, two of the angles, one at the top and one at the bottom, may be omitted, thus making each strut consist of two angles laced, provided, of course, that where the struts cross they shall be rigidly connected by two plates of ample size. This unbalanced section for such diagonals is to be avoided whenever it can be done without undue use of metal. In no case, though, will it be permissible to use angles in tension that are not capable of resisting properly the possible compressive stresses, with due regard for the specified limit of ratio of unsupported length to least radius of gyration.

In cheap highway bridges the lateral diagonals may be made of adjustable rods with right and left clevises at their ends, by which they are to be connected through pins to corner-plates that are riveted to both the lateral strut and the truss member. The ordinary detail consisting of two or three short pieces of angle riveted on top of the cover-plate, and between two of which the rod lies, will not be permitted. Where adjustable rods are employed, the struts to the ends of which they attach must be figured for a total compressive stress equal to the sum of the components (in the direction of said strut) of the greatest allowable working-stresses on all of the adjustable rods meeting at one end of said strut. While this method gives an excessive stress for the strut, the effect will be a desirable error on the side of safety and rigidity.

In designing transverse lateral and overhead struts and their connections, it must be remembered that their main function is to hold rigidly the chords or posts to place and line, and not merely to resist as columns the greatest calculated direct stresses to which they may be subjected. For this reason such struts should have ample section for rigidity, and the connecting plates at their ends should grip both connected members effectively.

Where built stringers are used for the floor system, they shall be made without cover-plates, and generally of the economic depth in respect to total weight of metal, but never less in depth than one fifteenth ($\frac{1}{15}$) of the span. No splices will be allowed in their flanges nor any in their webs, provided that sufficiently long web-plates are procurable. The compression-flanges shall be made of the same gross section as the tension-flanges, and they shall be so stiffened that the unsupported length shall never exceed sixteen (16) times the width of flange. Rigid diagonal bracing of angles is to be used between the top flanges of such stringers, unless they be held rigidly in place by the flooring; and rigid bracing-frames are to be employed between the ends of adjacent stringers at all expansion points. Where such stringers are used, the lower lateral system must invariably consist of rigid sections, each piece being riveted to each stringer where it crosses the same.

In respect to stiffening angles for stringers, the rules governing those for plate-girder spans are to be followed; but the end stiffeners are to be faced or otherwise treated so as to make the stringers of exact length throughout, and so as to effect a uniform bearing of the end stiffeners against the webs of the cross-girders.

In respect to the proportioning of flanges and number of rivets required, the rules given for plate-girder spans are to apply also to stringers. The said rules are to apply to cross-girders, as shall also those relating to stiffeners, splices, cover-plates, and size of compression-flanges, that are given for plate-girder spans. Wherever it is necessary to notch out the corners of the cross-girders to clear the chords, the greatest care must be taken to provide an adequate means for transferring the shear to the posts without impairing either the strength or the rigidity. If necessary, in through-bridges, the web of the cross-girder may be divided into three parts so as to let the end portions project above the top flange and form brackets that will afford opportunity for using an ample number of rivets to connect to the posts, and will strengthen properly the otherwise weakened cross-girder.

All plates, angles, and channels used in built members of trusses must, if practicable, be ordered the full length of the member; otherwise the splices must develop the full strength of the member without any reliance being placed on the abutting ends for carrying compression.

But in total splices at the ends of sections perfect abutting of the dressed ends is to be relied upon. However, the splice-plates even there must be of ample size and strength for both rigidity and continuity.

The unsupported width of plates strained in compression, measuring between centre lines of rivets, shall not exceed thirty-two (32) times their thickness, except in the case of cover-plates for top chords and inclined end posts, where the limit may be increased to forty (40) times the thickness. Where webs are built of two or more thicknesses of plate, the rivets that are used solely for making the several thicknesses act as one plate shall in no case be spaced more than (12) inches from each other, or from other rivets connecting said component thicknesses together. The least allowable thickness for such compound web-plates shall be one (1) inch.

The open sides of all compression-members composed of two rolled or built channels, with or without a cover-plate, shall be stayed by tie-plates at ends and by diagonal lacing-bars or lacing angles at intermediate points. Lacing-bars may be connected to the flanges by either one or two rivets at each end; but lacing angles, which are used for members of heavy section only, must be connected by two rivets at each end.

The tie-plates shall be placed as close as practicable to the ends of the compression-members. Their thickness shall not be less than one fiftieth ($\frac{1}{50}$) of the distance between the centre lines of the rivets by which they are connected to the flanges, unless said tie-plates be well stiffened by angles, in which case they may be made as thin as three eighths ($\frac{3}{8}$) of an inch. The length of a tie-plate shall never be less than its width, or one and one-half ($1\frac{1}{2}$) times the least dimension of strut (unless it be close to a web diaphragm of the member, in which case it may be made as short as twelve (12) inches), and seldom greater than one and one-half ($1\frac{1}{2}$) times its width.

The thicknesses of lacing-bars shall never be less than one fiftieth ($\frac{1}{50}$) of the length between centres of the end rivets, measuring between inmost rivets in case that there be more than one rivet at each end.

The smallest section for a lacing-bar shall be one and three-quarter ($1\frac{3}{4}$) inches by five sixteenths ($\frac{5}{16}$) of an inch, which size may be used for channels under eight (8) inches deep; and the largest section shall be two and a half ($2\frac{1}{2}$) inches by seven-sixteenths ($\frac{7}{16}$) inch, which size shall be used for channels fifteen (15) inches deep. For intermediate sizes of channels, the sizes of lacing-bars shall be interpolated. For all built channels of greater depth than fifteen (15) inches, and for all cases where a lacing-bar would require a greater thickness than seven sixteenths ($\frac{7}{16}$) of an inch, angle lacing is to be used, the smallest section for same being 2″ × $2\frac{1}{2}$″ × $\frac{5}{16}$″, and the largest $2\frac{1}{2}$″ × $3\frac{1}{2}$″ × $\frac{3}{8}$″.

In general, the inclination of lacing-bars to axis of member shall be about sixty (60) degrees; but for members of minor importance the said inclination may be made slightly flatter.

Pin-plates shall be used at all pinholes in built members, for the double purpose of reinforcing for the metal cut away and reducing the intensity of pressure on pin and bearing to or below the specified limit. They shall be of such size as to distribute properly, through the rivets, the pressure carried by such plates to both flanges and web of each segment of the member, and shall extend at least six (6) inches within the tie-plates of said member, so as to provide for not less than two (2) transverse rows of rivets there.

When the pin ends of compression-members are cut away into jaw-plates or forked ends, for the purpose of packing closely the various members connected by the pin, these jaw-plates or post extensions shall be considered as columns, the thickness of each of which shall be determined by the following formula:

$$p = 10{,}000 - 300\frac{l}{t};$$

where p is the greatest allowable intensity of working-stress (impact being considered); l is the unsupported length in inches, measuring from the centre of the pinhole to the centre of the first transverse line of rivets beyond the point at which the full section of the member begins; and t is the total thickness in inches of one jaw. The length l is always to be made as small as practicable, and in cases of unavoidably long extensions the plates are to be stiffened by an interior diaphragm composed of a web with four, or sometimes only two, angles.

It is always better, whenever practicable, to avoid cutting away the ends of channels; but, if they must be trimmed, the ends must be reinforced so that the strength of the member shall not be reduced by the trimming.

In riveted tension members the net section through any pinhole shall have an area fifty (50) per cent in excess of the net sectional area of the body of the member. The net section outside of the pinhole along the centre line of stress shall be at least sixty-five (65) per cent of the net section through the pinhole.

Pins are to be proportioned to resist the greatest shearing and bending produced in them by the bars or struts which they connect. No pin is to have a diameter less than eight tenths ($\frac{8}{10}$) of the depth of the deepest eye-bar coupled thereon. No pin is to have a smaller diameter than two and a half ($2\frac{1}{2}$) inches.

Lower chords are to be packed as closely as possible, and in such a manner as to produce the least bending moments on the pins; but adjacent eye-bars in the same panel must never have less than one-half ($\frac{1}{2}$) inch space between them, in order to facilitate painting. The various members attached to any pin must be packed as closely as practicable, and all interior vacant spaces must be filled with steel fillers, where their omission would permit of motion of any member on the pin. All bars are to lie in planes as nearly as possible parallel to the central truss plane.

In detailing I struts composed of four angles with a single line of lacing, the clear distance between backs of angles shall never be made less than three quarters ($\frac{3}{4}$) of an inch, in order to permit the insertion of a small paint-brush.

The greatest allowable pressure upon expansion-rollers of fixed spans, when impact is considered, shall be determined by the equation

$$p = 600d,$$

where p is the permissible pressure in pounds per lineal inch of roller, and d is the diameter of the latter in inches. The least allowable diameter for expansion-rollers is two and a quarter ($2\frac{1}{4}$) inches.

Rollers shall be enclosed in boxes made practically dust-tight and filled with an oil that will not congeal under any possible temperature. These boxes must be so designed as to permit of the free movement of the rollers in the longitudinal direction of span sufficient to take up the extreme variations in length due to temperature changes and deflection, and at the same time prevent any transverse motion of the end of span.

All shoe-plates, bed-plates, and roller-plates are to be so stiffened that the extreme fibre-stress under bending, when impact is included, shall not exceed sixteen thousand (16,000) pounds per square inch.

Pedestals shall be either of cast steel or built up of plates and shapes. In built pedestals, all bearing-surfaces of the base-plates and vertical bearing-plates must be planed. The vertical plates must be secured to the base by angles having at least two rows of rivets in the vertical legs; and the said vertical plates must bear properly from end to end upon said base. No base-plate, vertical plate, or connecting angle shall be less than five-eighths ($\frac{5}{8}$) of an inch in thickness. The vertical plates shall be of sufficient height, and must contain enough metal and rivets to distribute properly the loads over the bearings or rollers. The bases of all cast-steel pedestals shall be planed so as to bear properly on the masonry or rollers.

All rollers and the faces of base-plates in contact therewith are to be planed smooth, so as to furnish perfect contact between rollers and plates throughout their entire length.

Heads of eye-bars are to be made of such dimensions that, when the bars are tested to destruction, they shall break in the body and not in the eyes; and, in the case of loop eyes, so that they shall not fail in the welds. Rods with bent eyes shall not be used. In loop eyes, the distance from the inner point of the loop to the centre of the pinhole must not be less than two and one half ($2\frac{1}{2}$) times the diameter of the pin, and the loop must fit closely to the pin throughout its semi-circumference.

DETAILS OF DESIGN FOR VIADUCTS.

The specifications for the "Details of Design for Trestles and Elevated Railroads" are in general to be followed as far as they will apply in the designing of highway viaducts, the principal variation being that, for cheap structures, adjustable rods with clevises may be substituted for the stiff diagonals in the four faces of the braced towers, by adding, of course, horizontal struts at the panel points of the transverse and longitudinal bracing. These struts must be riveted to the columns by means of wide plates to which the clevises attach, and must never be pin-connected. Corner horizontal plates are to be employed for attaching the horizontal adjustable rods by means of clevises, each of said plates being riveted to both a transverse and a longitudinal bracing strut.

The detailing for the longitudinal girders of viaducts and the bracing between same shall comply with the specifications for detailing highway plate or open-webbed, riveted girder spans; and the specifications for wooden floor system, paving, hand-rails, etc., shall be the same for highway viaducts as for highway bridges.

SPECIFICATIONS FOR HIGHWAY DRAW-SPANS.

(CHAPTER XVII OF "DE PONTIBUS.")

THESE specifications will be given principally by reference to the previous specifications for Railroad Structures, Highway Bridges, and Railroad Draw-Spans.

GENERAL DESCRIPTION.

CLASSIFICATION.

See Specifications for Highway Bridges.

MATERIALS.

See Specifications for Railroad Draw-spans.

JOISTS, PLANKS, GUARD-TIMBERS, AND WOODEN HAND-RAILS.

See Specifications for Highway Bridges.

FLOORING ON APPROACHES.

See Specifications for Highway Bridges.

STEEL RAILROAD TRACKS

See Specifications for Highway Bridges.

PAVED FLOORS.

See Specifications for Highway Bridges.

CLEARANCES

See Specifications for Highway Bridges.

EFFECTIVE LENGTHS AND DEPTHS.

See Specifications for Railroad Structures.

STYLES OF BRIDGES FOR VARIOUS SPAN LENGTHS.

For spans up to one hundred and forty (140) feet in length, plate-girder spans are to be used. These plate-girder spans may be made to act as continuous girders over the pivot-pier, or may have pin-connections over the drum, so that when the live load is applied they will act as two separate spans. The former style is generally preferable as a matter of economy in time of operation, there being no important reason for raising the ends to any great extent, as there is in the case of railroad draw-spans.

For spans between one hundred and forty (140) and two hundred and twenty-five (225) feet, pin-connected Pratt trusses with parallel chords are to be used.

For spans between two hundred and twenty-five (225) feet and three hundred (300) feet, pin-connected Pratt trusses with broken top chords are to be employed.

For spans of over three hundred (300) feet, pin-connected trusses with subdivided panels are to be adopted.

It is understood that these limiting lengths are not fixed absolutely, as the best limits will vary somewhat with the width of bridge and the live load to be carried.

The proper truss depths for all cases cannot well be specified, as they will depend upon various considerations, such as appearance, economy, width of structure, etc.

In all cases the top chords are to be of rigid members, and inclined posts are to be used at ends and over drum, as specified for railroad draw-spans.

MAIN MEMBERS OF TRUSS DRAW-SPANS.

See Specifications for Highway Bridges.

LOADS.

See Specifications for Railroad Draw-Spans.

LIVE LOADS.

See Specifications for Highway Bridges; and, for the manner of applying live loads to draw-spans, see Specifications for Railroad Draw-Spans.

IMPACT-ALLOWANCE LOAD.

See Specifications for Highway Bridges.

DEAD LOAD.

See Specifications for Railroad Structures.

ASSUMED UPLIFT STRESSES.

See Specifications for Railroad Draw-Spans.

The inferior limit of uplift for designing the machinery of light highway drawbridges is to be taken at ten thousand (10,000) pounds at each of the four corners of the span.

WIND LOADS.

See Specifications for Highway Bridges. For method of using the wind loads, see Specifications for Railroad Draw-Spans.

INDIRECT WIND LOAD OR TRANSFERRED LOAD.

See Specifications for Railroad Structures. For method of dealing with this load, see Specifications for Railroad Draw-Spans.

INTENSITIES OF WORKING-STRESSES.

See Specifications for Railroad Structures.

BEARINGS UPON MASONRY.

See Specifications for Railroad Structures.

REVERSING STRESSES.

See Specifications for Railroad Structures.

NET SECTION.

See Specifications for Railroad Structures.

BENDING MOMENTS ON PINS.

See Specifications for Railroad Structures.

COMBINATIONS OF STRESSES.

See Specifications for Railroad Draw-Spans.

It is to be observed, however, that, for spans which do not carry trains, the live load and the wind load are assumed not to act simultaneously.

BENDING ON TOP CHORDS.

See Specifications for Railroad Structures.

BENDING ON INCLINED END POSTS.

The Specifications for Railroad Structures under this heading are to be followed with this exception : in bridges that do not carry trains, the live load and the wind load are assumed not to act simultaneously.

BENDING DUE TO WEIGHT OF MEMBER

See Specifications for Railroad Structures.

GENERAL LIMITS IN DESIGNING.

See Specifications for Highway Bridges.

GENERAL PRINCIPLES IN DESIGNING.

See Specifications for Railroad Structures.

RIVETING.

See Specifications for Highway Bridges.

DETAILS OF DESIGN FOR PLATE-GIRDER DRAW-SPANS.

The specifications for the corresponding item in the Specifications for Railroad Draw-Spans are to be followed, with the following exceptions:

1st. The perpendicular distances between central planes of girders will be made to suit the general requirements; and, 2d. At least eight (8) points of support on the drum will be needed.

DETAILS OF DESIGN FOR PIN-CONNECTED DRAW-SPANS.

The specifications for the corresponding item in the Specifications for Highway Bridges are to be followed, and in addition thereto those given under the heading "Details of Design for Trusses of Draw-Spans" in the Specifications for Railroad Draw-Spans are to be employed, except that the use of adjustable members for lateral diagonals will be permitted in the case of cheap highway draw-spans.

DETAILS OF DRUMS AND TURNTABLES.

In general the Specifications for the corresponding item in the Specifications for Railroad Draw-Spans shall be followed, except that, for light, highway draws, the limiting thicknesses, etc., may be reduced to the following:

Top flanges and webs of drums—three eighths ($\frac{3}{8}$) of an inch.

Bottom flanges of drums—five eighths ($\frac{5}{8}$) of an inch.

Upper track segments—one and three-quarter ($1\frac{3}{4}$) inches.

Lower track segments—two (2) inches.

Bearing-plates over drum—three quarters ($\frac{3}{4}$) of an inch.

Centre casting on pivot-pier—one (1) inch.

Anchor-bolts for same—one and one-eighth ($1\frac{1}{8}$) inches in diameter and two and a half ($2\frac{1}{2}$) feet long.

Rollers—ten (10) inches in diameter and six (6) inches face.

MACHINERY FOR TURNING THE SPAN AND LIFTING THE ENDS OF SAME.

See Specifications for Railroad Draw-Spans.

METHOD OF DETERMINING POWER REQUIRED FOR OPERATING THE SPAN AND LIFTING THE ENDS.

See Specifications for Railroad Draw-Spans.

DETAILS OF MACHINERY.

OPERATING MACHINERY.

See Specifications for Railroad Draw-Spans.

END-LIFTING APPARATUS.

See Specifications for Railroad Draw-Spans.

SHOES AND END-BEARING ROLLERS.

See Specifications for Railroad Draw-Spans.

HOUSES AND SUPPORTS.

See Specifications for Railroad Draw-Spans.

CAMBER AND DEFLECTION.

See Specifications for Railroad Draw-Spans.

GENERAL SPECIFICATIONS GOVERNING THE MANUFACTURE, SHIPMENT, AND ERECTION OF STEEL BRIDGES, TRESTLES, VIADUCTS, AND ELEVATED RAILROADS.

(CHAPTER XVIII OF "DE PONTIBUS.")

DRAWINGS.

As soon as practicable after the signing of the contract for building the structure, complete detail drawings will be furnished by the Engineer, and from these the Contractor is to prepare his shop drawings, complying carefully therewith and making no changes without the written consent of the Engineer. The working drawings are to be sent in triplicate for the approval of the Engineer and his principal Shop Inspector, who will retain two sets and return the third after checking same and marking thereon any changes or corrections desired; after which a corrected set of shop drawings shall be sent without delay by the Contractor to the Engineer. The approval of said working drawings by the Engineer will not relieve the Contractor from the responsibility of any errors thereon.

The drawings furnished by the Engineer shall be checked carefully by the Contractor before beginning work. Should any errors be discovered, the Engineer's attention shall be called to same, and corrections will be made, after which the Contractor shall be responsible for all errors which may occur or which may have occurred. The Engineer shall have the right to alter as he may see fit the preliminary plans, if further investigation of the conditions affecting the proposed structure so warrant; and he shall be at liberty to make minor changes in all plans during construction without any extra charge for same being made by the Contractor unless, in the opinion of the Engineer, the Contractor be really entitled to extra compensation on account of such changes.

The Contractor shall furnish without charge as many sets of shop drawings as the Engineer and other officers of the company may deem necessary for their use during construction or for record.

INSPECTION.

The inspection and tests of metal will be made promptly on its being rolled or cast, and the quality will be determined before it leaves the rolling-mill or foundry. The inspection of workmanship will be made as the manufacture of the material progresses, and at as early a period as the nature of the work will permit.

All facilities for inspection of material and workmanship shall be furnished by the Contractor; and the Engineer and his inspectors shall have free access to any of the works in which any portion of the material is being made.

The Contractor shall give the Inspector due notice when any material is ready for inspection. Any delay on the part of the Inspector shall be reported to the Engineer, but no material will be accepted which has not been passed upon by the authorized representative of the Engineer.

METAL.

Unless otherwise specified, all metal shall, for all spans of ordinary length, be medium steel; excepting only that rivets and bolts are to be of soft steel, and adjustable members of either soft steel or wrought iron.

For very long, fixed spans, high steel may be used for top chords, inclined end posts, pins, and eye-bars in bottom chords and in main diagonals of panels where there is no reversion of stress, when impact is included. It may be used also for the web members of cantilever arms and anchor arms of cantilever bridges, where the variation of stress is comparatively small, and where the impact cannot be great.

Except for purely ornamental work and a few minor details of the operating machinery of drawbridges, cast iron will not be allowed to be used in the superstructure of any bridge, trestle, viaduct, or elevated railroad, cast steel being employed wherever important castings are necessary.

ROLLED STEEL.

All steel shall be manufactured by either the acid or the basic open-hearth process, and must be uniform in character for each specified kind. Any attempt to substitute Bessemer or any other steel for the open-hearth product will be considered as a violation of the contract and a good and sufficient reason for cancelling the same.

All plates shall be rolled from slabs. These slabs shall be made by a separate operation, by rolling an ingot and cutting off the scrap. The original ingot shall have at least twice the cross-sectional area of the slab, and the latter shall be at least six times as thick as the plate.

All finished material coming from the mills must be free from seams, flaws, or cracks, and must have a clean, smooth finish.

COMPOSITION OF ROLLED STEEL.

The greatest allowable percentages of certain principal ingredients of the various kinds of rolled steel shall be as given in the following table:

Ingredients.	Percentages.		
	Soft Steel.	Medium Steel.	High Steel.
Phosphorus (acid steel)..	0.05	0.06	0.07
Phosphorus (basic steel)	0.03	0.04	...
Sulphur....	0.04	0.05	0.05
Silicon................ ...	0.04	0.05	0.06
Manganese.........	0.60	0.70	0.80

These percentages apply to drillings taken from the edges of plates and the exterior of shapes, bars, or flats. If, however, the drillings be taken from the middle of plates or the heart of other sections, the percentages given in the table are to be increased twenty-five (25) per cent. Special chemical analyses are to be made whenever the Inspector deems them to be necessary as a supplement to the other tests.

IDENTIFICATION.

Each ingot shall be stamped or marked plainly with its proper melt-number; and this melt-number must be stamped or painted plainly on all blooms, billets, or slabs made from such ingots in order to identify the material throughout its various processes of manufacture; and the melt-number must be stamped plainly on each piece of finished material. Rivet and lacing steel, and small pieces for pin-plates and stiffeners, may be shipped in bundles, securely wired together, with the blow or melt number on a metal tag attached.

GENERAL PROVISIONS ON METHODS OF TESTING.

Rivet-rods and other rounds are to be tested in the form in which they leave the rolls, without machining.

Test-pieces from angles, plates, shapes, etc., shall be rectangular in shape, with a cross-sectional area of preferably about one half (½) of a square inch, but not less, and shall be taken so that only two sides are machine-finished, the other two having the surface which was left by the rolls.

Should fracture occur outside of the middle third of the gauge length, the test is to be discarded as worthless if it falls below the standard.

If any test-piece have a manifest flaw, its test shall not be considered.

In case that one test-piece falls slightly below the requirements in any particular, the Inspector may allow the re-testing of the lot or heat by taking four (4) additional tests from the said lot or heat; and, if the average of the five (5) shall show that the steel is within the requirements, the metal may be accepted; otherwise it shall be rejected.

Drillings for chemical analysis may be taken either from the preliminary test-piece or from the finished material.

The speed of the machine for breaking test-pieces shall not be less than one-quarter (¼) inch per minute, nor more than three (3) inches per minute.

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 the material is to be annealed or otherwise treated before use, the specimens representing such material may be similarly treated before testing; but they shall also give standard elongation, reduction, and fracture before annealing.

TENSILE STRENGTH.

The ultimate tensile strength per square inch on test-pieces for all three kinds of rolled steel used in structural metal-work shall be as follows:

Soft steel	50,000 lbs. to 60,000 lbs.
Medium steel ...	60,000 lbs. to 70,000 lbs.
High steel	70,000 lbs. to 80,000 lbs.

ELASTIC LIMITS.

The least allowable elastic limits obtained from test-pieces and determined in the usual manner by the drop of the beam shall be as follows:

Soft steel	30,000 lbs. per square inch.
Medium steel...	35,000 lbs. per square inch.
High steel	40,000 lbs. per square inch.

ELONGATION.

The percentages of elongation shall be obtained from the test-pieces after breaking on an original length of eight (8) inches, in which length must occur the curve of reduction from stretch on both sides of the point of fracture. The least allowable elongations for the various kinds of rolled structural steel shall be as follows:

Shape.	Percentage of Elongation.		
	Soft Steel.	Medium Steel.	High Steel.
Rounds (excepting pins)	26	24	—
Pins	—	20	16
Angles and bars	26	24	20
Plates under 40″ wide	—	24	20
Plates 40″ to 70″ wide, and webs of beams and channels	—	23	19
Plates over 70″ wide	—	21	—
Flanges of beams and channels	—	20	18

REDUCTION OF AREA.

The reduction of area, measured on test-pieces, for the various kinds of rolled structural steel shall be as follows:

Shape.	Percentage of Reduction of Area.		
	Soft Steel.	Medium Steel.	High Steel.
Rounds (excepting pins)	50	44	38
Pins	—	40	34
Angles and bars	48	40	34
Plates under 40″ wide	—	40	34
Plates 40″ to 70″ wide, and webs of beams and channels	—	38	34
Plates over 70″ wide	—	37	—
Flanges of beams and channels	—	36	30

BENDING TESTS.

Specimens of soft steel shall be capable of bending to one hundred and eighty (180) degrees and closing down flat upon themselves, without cracking, when either hot, cold, or quenched.

Specimens of medium steel, when heated to a dark orange and cooled in water at seventy (70) degrees Fahrenheit, or when cold or hot, shall be capable of bending one hundred and eighty (180) degrees around a circle whose diameter is equal to the thickness of the test-piece, without showing signs of cracking on the convex side of the bend.

Specimens of high steel when quenched in a similar manner shall be capable of bending ninety (90) degrees around a circle whose diameter is equal to twice the thickness of the test-piece, and one hundred and eighty (180) degrees, either hot or cold, without showing signs of cracking on the convex side of the bend.

DRIFTING TESTS.

Punched rivet-holes in medium steel, pitched two (2) diameters from a sheared edge, must stand drifting until their diameters are fifty (50) per cent greater than those of the original holes, and must show no signs of cracking the metal.

High steel must stand the same test, except that the increase in diameter is to be twenty-five (25) per cent instead of fifty (50) per cent.

FRACTURE.

All broken test-pieces for all three classes of steel must show a silky fracture of uniform color.

NUMBER OF TEST-PIECES.

At least three (3) tensile tests and three bending tests shall be made on specimens from different ingots of each melt, except in the case of small melts, for which the number may be reduced to two (2) or even to one (1), according to the judgment of the Inspector. The bending tests may, if desired, be made on the broken test-pieces of the tension tests. If material of various shapes is to be made from the same melt, the specimens for testing are to be so selected as to represent the different shapes rolled from such melt.

All tests are to be made by the Contractor for the Inspector without charge.

The Inspector will be permitted considerable latitude in respect to the number of tests required, reducing same when the metal runs uniformly and increasing same when it does not.

Lots for testing shall not exceed twenty (20) tons in weight; and plates rolled in universal mill or in grooves, or sheared plates, shall each constitute a separate lot, as shall also the angles, channels, or beams.

TESTS OF FULL-SIZED EYE-BARS.

Full-sized eye-bars may be tested to destruction, provided notice be given in advance of the number and size required for this purpose, so that the material can be rolled at the same time as that required for the structure. The number of tests of full-sized eye-bars will depend upon the size of the order and upon the regularity of the results of the tests. In general, for small orders, the number of tests shall be about three (3) per cent of the number of eye-bars in the order, but never less than two bars for an order for a single span. For large orders the number of tests shall be about two (2) per cent of the number of eye-bars in the order. Should the Inspector find the bars to be very uniform in strength, elasticity, and ductility, and fully up to the specifications, he will be at liberty to reduce the number of tests of full-sized bars. In the case of testing long bars, it will be allowable to choose a bar at random from a number of finished bars, cut it in two, and upset the cut end of each piece, thus making two test-bars.

Full-sized bars of medium steel must show an ultimate tensile strength of at least fifty-six thousand (56,000) pounds per square inch. The elongation shall not be less than fourteen (14) per cent in a gauged length of ten (10) feet; and the elastic limit shall not be less than fifty (50) per cent of the ultimate strength of the bar.

For high steel the limits just specified shall be changed as follows:

Ultimate strength, 65,000 pounds.
Elongation, twelve (12) per cent.
Elastic limit, fifty (50) per cent.

Any lot of steel bars which meets the requirements of the preceding paragraph shall be accepted, if none of the bars which break in the eye show an ultimate strength, elastic limit, or elongation less than that specified for the body of the bar, unless one fourth (¼) of the full-sized samples so tested break in the eye. In case of failure to meet any of these requirements, the lot from which the sample bars were taken will be rejected.

All full-sized sample bars which break at less than the ultimate strength specified, or do not otherwise fill the specifications, shall be at the expense of the Contractor; unless, in case of those that break in the eye, he shall have made objection in writing to the form or dimensions of the heads before making the eye-bars. All others shall be paid for by the purchaser at the contract price of finished metal-work on cars at shops, less the scrap value of the broken bars.

PIN METAL.

Pins up to six (6) inches in diameter may be rolled, but above that diameter they shall be forged. The rounds from which the pins are to be turned must be true, straight, and free from all injurious flaws or cracks. All forged pins shall be reduced from a single bloom or ingot until perfect homogeneity is secured throughout the whole mass. The blooms shall have at least three (3) times the sectional area of the finished pins. No forging shall be done below a red heat.

VARIATION IN WEIGHT.

Except in the case of sheared plates ordered to gauge, a variation in cross-section or weight of rolled material of more than two (2) per cent from that specified may be cause for rejection. For the said sheared plates the permissible excess variation shall run from four (4) per cent for plates five eighths (⅝) of an inch or more in thickness to eight (8) per cent for plates three eighths (⅜) of an inch or less in thickness, the variations for intermediate thicknesses being directly interpolated.

Should the shipping weight of any entire order exceed by more than one (1) per cent the weight computed from the approved shop drawings, the amount in excess of the said one (1) per cent will not be paid for, unless in the entire order the weight of plates exceeding thirty-six (36) inches wide be greater than thirty (30) per cent of the whole, in which case the allowable variation shall be increased to two (2) per cent.

WROUGHT IRON.

All wrought iron, if any be used, must be of the best quality obtainable, tough, ductile, fibrous, and of a uniform quality; also straight, smooth, and free from cinder-pockets or injurious flaws, buckles, blisters, or cracks. No steel scrap shall be used in its manufacture.

The tensile strength, determined from test-pieces in the same manner as specified for steel, shall not fall below fifty thousand (50,000) pounds per square inch; and the elastic limit shall not be less than twenty-six thousand (26,000) pounds per square inch. The elongation, determined in the same manner as specified for steel, shall not be less than twenty (20) per cent.

All wrought iron must bend cold one hundred and eighty (180) degrees, without sign of fracture, to a curve the inner radius of which equals the thickness of the piece tested. Soft steel is to be used instead of wrought iron wherever practicable.

CAST IRON.

Except where chilled iron is specified, all castings shall be of tough, gray iron, free from injurious cold-shuts or blowholes, true to pattern, and of a workmanlike finish. Sample-pieces one (1) inch square, cast from the same heat of metal in sand-moulds, shall be capable of maintaining on a clear span of four (4) feet six (6) inches a central load of five hundred (500) pounds when tested in the rough bar. All castings shall be straight and out of wind, with proper and approved uniform thickness of metal, and shall have perfect, sharp, and clean lines, angles, and mouldings, all re-entrant angles being properly filleted.

CAST STEEL.

All steel castings shall be made of acid open-hearth steel containing from twenty-five hundredths (0.25) to four tenths (0.4) per cent of carbon, and not more than the following percentages of other ingredients:

Phosphorus,	five hundredths (0.05).
Sulphur,	five hundredths (0 05).
Manganese,	eight tenths (0.8).

The ultimate tensile strength shall run from sixty-five thousand (65,000) to seventy-five thousand (75,000) pounds per square inch; the elastic limit shall not be less than one half (½) of the ultimate strength; and the elongation of test specimens in two (2) inches shall not be less than fifteen (15) per cent for fixed castings or seventeen (17) per cent for movable castings.

All steel castings shall be carefully and uniformly annealed, and shall be true to drawings, smooth, clean, and free from blowholes, sponginess, and all other defects. All corners therein shall be properly filleted.

TESTS OF ROLLERS FOR DRAW-SPANS.

The Contractor shall make, at his own expense, under the direction of the Engineer or his duly authorized representative, for each draw-span, tests, not exceeding three (3) in number, of full-sized cast rollers; also any tests of specimens of the metal for the same that may be considered necessary by the Engineer to determine its quality.

OTHER TESTS OF FULL-SIZE MEMBERS OR DETAILS.

The Contractor shall make, at his own expense, under the direction of the Engineer or his Inspector, such other tests of full-size members or details as the Engineer may prescribe, provided that the said members or details are similar to those used on the work, and provided that the total cost to the Contractor of such extra tests does not exceed one quarter of one per cent (0.25%) of the total contract price of the work.

WORKMANSHIP.

All metal shall be carefully straightened before being turned over to the shops.

All workmanship shall be first-class in every particular, and all portions of metal-work exposed to view shall be neatly finished.

All idle corners of plates and angles, such for instance as the ends of the unconnected legs of angle lacing, shall be neatly chamfered off at an angle of about forty-five (45) degrees, so as to give a sightly finish to the work and to avoid bending of said corners during shipment and erection.

As far as practicable, all parts shall be so constructed as to be accessible for inspection and painting.

All punched work shall be so accurately done that, after the various component pieces are assembled and before the reaming is commenced, forty (40) per cent of the holes can be entered easily by a rod of a diameter one sixteenth ($\frac{1}{16}$) of an inch less than that of the punched holes; eighty (80) per cent by a rod of a diameter one eighth ($\frac{1}{8}$) of an inch less than same; and one hundred (100) per cent by a rod of a diameter one quarter ($\frac{1}{4}$) of an inch less than same. Any shopwork not coming up to this requirement will be subject to rejection by the inspector.

SHEARED EDGES.

All sheared and hot-cut edges shall have not less than one quarter ($\frac{1}{4}$) inch of metal removed by planing to a smooth, finished surface. Lacing-bars, fillers, stay-plates, and stringer-bracing connecting plates only will be exempt from this requirement.

RE-ENTRANT CORNERS.

No sharp or unfilleted re-entrant corners will be allowed anywhere in the work.

ANNEALING.

In all cases where a steel piece in which the full strength is required has been partially heated or bent, the whole piece must be subsequently annealed. In pieces of secondary importance, where the bending is slight, said bending is to be made cold, and no annealing in such cases will be required. Crimped web-stiffeners will not require annealing.

All eye-bars shall be carefully and uniformly annealed at a dark orange heat.

RIVETS.

Rivets when driven must completely fill the holes, have full heads concentric with the rivet-holes, and be machine-driven whenever practicable. The machine must be capable of retaining the applied pressure after the upsetting is completed.

The rivet-heads must be full and neatly finished, of approved hemispherical shape, in full contact with the surface, or be countersunk when so required, and of a uniform size for the same-sized rivets throughout the work; and they must pinch the connected pieces thoroughly together. Flattened heads may be used in certain places, if necessary for clearance. Except where shown otherwise on the drawings, all rivet diameters are to be seven eighths (⅞) of an inch. No loose or imperfect rivets will be allowed to remain in any part of the metal-work.

RIVET-HOLES.

Rivet-holes must be accurately spaced; the use of drift-pins will be allowed only for bringing together the several parts forming a member, and they must not be driven with such force as to distort the metal about the holes. The distance between the edge of any piece and the centre of a rivet-hole must never be less than one and a half (1½) inches, excepting for lattice bars, small angles, and where especially shown otherwise on the Engineer's drawings; and, wherever practicable, this distance shall be at least two (2) diameters of the rivet.

PUNCHING AND REAMING.

All rivet-holes in steel-work, if punched, shall be made with a punch one-eighth ($\frac{1}{8}$) inch in diameter less than the diameter of the rivet intended to be used, and shall be reamed to a diameter one-sixteenth ($\frac{1}{16}$) inch greater than that of the said rivet.

Before this reaming takes place all the pieces to be riveted together shall be assembled and bolted into position, then the reaming shall be done; for one of the principal objects of this clause in relation to subpunching is to ensure the correct matching of rivet-holes, and the avoidance of holes of excessive diameter. Said clause also ensures the removal of most, if not all, incipient cracks started by the process of punching.

All reaming is to be done by means of twist-drills, the use of tapered reamers being prohibited, except where twist-reamers cannot be employed. All holes must be at right angles to surface of member, and all sharp or raised edges of holes under heads must be slightly rounded off before the rivets are driven.

All holes for field-rivets, excepting those for lateral and sway-bracing, when not drilled to an iron template, shall be reamed while the connecting parts are temporarily assembled.

Punching shall not be permitted in any piece in which the thickness of the metal exceeds the diameter of the cold rivet that is to be used; but all such pieces shall be drilled solid.

BUILT MEMBERS.

Built members must, when finished, be true and free from twists, kinks, buckles, or open joints between the component pieces.

All abutting surfaces of compression-members must be planed or turned to even bearings so that they shall be in as perfect contact throughout as can be obtained by such means; and all such finished surfaces must be protected by white lead and tallow before shipment from the shop.

The ends of all webs and chord or flange angles that abut against other webs must be faced true and square or to exact bevel; and the end-stiffeners must be placed perfectly flush with these planed ends, so as to afford a proper bearing. Filling-plates beneath end-stiffening angles must be practically flush with said angles, and must in no case project outside of same at the bearings. If a good and satisfactory job of work cannot be obtained by this method, the end-stiffening angles shall be made one eighth ($\frac{1}{8}$) of an inch thicker, and the entire ends shall be planed after the stiffening angles are riveted on.

No web-plate will be allowed to project beyond the flange angles, or to recede more than one eighth ($\frac{1}{8}$) of an inch from faces of same.

All filling and splice plates in riveted work must fit at their ends to the flanges sufficiently close to be sealed, when painted, against the admission of water; but they need not be tool-finished, unless so specially indicated either on the drawings or in the specifications. Edges of spliced web-plates must be faced so as to provide close contact throughout the entire depth.

EYE-BARS.

Except in the case of loop-eyes, no weld will be allowed in the body of the eye-bars. The heads of the eye-bars 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 one thirty-second ($\frac{1}{32}$) of an inch below and one sixteenth ($\frac{1}{16}$) of an inch above that specified, and in diameter of one fourth ($\frac{1}{4}$) of an inch in either direction. Eye-bars must be perfectly straight before boring.

Loop-eyes shall invariably be made of wrought iron, as steel cannot be relied upon to afford a proper weld.

PINHOLES.

All pinholes must be bored truly parallel and at right angles to the axes of the members, unless otherwise shown on the drawings; and, in pieces not adjustable for length, no variation of more than one thirty-second ($\frac{1}{32}$) of an inch will be allowed in the length between centres of pinholes.

Pinholes in eye-bars must be in the centre of the heads, and on the centre line of the bars.

Bars, which are to be placed side by side in the structure, shall be bored at the same temperature, and shall be of such equal length that, when placed in a pile, the pin at each end will pass through the holes at the same time without forcing.

PINS.

All pins shall be turned accurately to a gauge, and shall be finished perfectly round, smooth, and straight. All pins up to three and one-half ($3\frac{1}{2}$) inches in diameter shall fit the pinholes within one fiftieth ($\frac{1}{50}$) of an inch, and all pins over three and one-half ($3\frac{1}{2}$) inches in diameter shall fit their holes within one thirty-second ($\frac{1}{32}$) of an inch.

The Contractor must provide steel pilot-nuts for all pins to preserve the threads while said pins are being driven.

TURNED BOLTS.

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

TURNBUCKLES, NUTS, THREADS, AND WASHERS.

All sleeve-nuts, turnbuckles, and clevises must be made so strong and stiff that they will be able to resist without rupture the ultimate pull of the bars which they connect, and without distortion the greatest twisting force to which they could ever be subjected. They must be made so that the threaded lengths of the rods engaged can be verified.

The dimensions of all square and hexagonal nuts, except those on the ends of pins, shall be such as to develop the full strength of the body of the adjustable member. No round-headed bolts will be allowed.

Washers and nuts must have uniform bearing.

Cast or wrought iron washers must be used under the heads of all timber bolts when the bearing is on the wood.

All threads, except those on the ends of pins, must be of the United States standard. Each adjusting nut must be provided with an effective nut-lock or check-washer.

ROLLERS.

Rollers shall be turned accurately to a gauge, and must be finished perfectly round, and to the correct diameter or diameters, from end to end. The tongues and grooves in plates and rollers must fit snugly, so as to prevent lateral motion. Roller-beds must be planed.

ANCHOR-BOLTS.

All bed-plates and bearings must be fox-bolted to the masonry or attached to concrete by anchor-plates. The Contractor must furnish all bolts, drill all holes, and set the bolts to place with Portland-cement grouting.

All anchor-bolts are to be of soft steel with cold-pressed threads; and the threaded portion of all such bolts tested to destruction shall develop a greater strength than that of the unthreaded portion of same. The lengths of the nuts for all adjustable rods must always be great enough to develop the full strength of the rod.

All anchor-bolts are to be thoroughly oiled but not painted before shipment; and the exposed portions thereof, after erection, are to receive two coats of paint at the same time the rest of the metal-work receives its two coats.

NAME-PLATES.

A name-plate of neat design and finish, giving the name of the Contractor and the date of erection, shall be firmly attached to each end of every through-bridge, and to some prominent place or places in all other structures.

PAINTING.

All metal-work before leaving the shop shall be thoroughly cleansed from all loose scale, rust, and dirt, and shall then be given one coat of the best carbon primer or any other priming-coat required by the Engineer, which coat shall be thoroughly dried before the metal-work is loaded for shipment. It is absolutely essential that the entire surface of the metal-work be thoroughly cleansed by the most effective known methods, such as the use of wire-brushes, then the painter's torch, and in certain cases the application of a strong caustic solution, followed by scraping, washing with clean water, and drying.

In riveted work all surfaces coming in contact shall be extra well painted before being riveted together. Bottoms of bedplates, bearing-plates, and any other parts which are not accessible for painting after erection shall have three coats of paint, one at the shop, the other two in the field, before erection. Pins, bored pinholes, turned friction-rollers, and all other polished surfaces shall be coated with white lead and tallow before shipment from the shop.

After the structure is erected the metal-work shall be thoroughly cleansed from mud, grease, or any other objectionable material that may be found thereon, then thoroughly and evenly painted with two (2) coats of paint of any kind that the Engineer may adopt.

All three coats of paint given to the metal-work are to be of distinctly different shades or colors ; and the second coat must be allowed to dry thoroughly before the third coat is applied.

No thinning of paint with turpentine, benzine, or other thinner will be allowed without special written permission from the Engineer.

No painting is to be done in wet or freezing weather.

All painting is to be done in a thorough and workmanlike manner, to the satisfaction of the Engineer, and no paint whatever is to be used on the structure without first being approved by the Engineer.

All the materials for painting shall be subject at all times to the closest inspection and chemical analysis; and the detection of any inferior quality of such material, in either shop or field, shall involve the rejection of all such suspected material at hand and the scraping and repainting of those portions of the work which, in the opinion of the Engineer, were defectively painted on account of such inferior material.

All recesses which would retain water or through which water could enter must be filled with thick paint or some water-proof cement before receiving final painting. All surfaces so close together as to prevent the insertion of paint-brushes must be painted thoroughly by using a piece of cloth instead of the brush.

SHIPPING.

All parts shall be loaded carefully so as to avoid injury in transportation, and shall be at the Contractor's risk until erected and accepted.

In shipping long plate girders great care is to be taken to distribute the weight properly over the two cars that support them, and to provide means for permitting the cars to pass around curves without disturbing the loading. In both the handling and shipment of metal-work every care is to be taken to avoid bending or straining the pieces or damaging the paint. All pieces bent or otherwise injured will be rejected.

TIMBER.

All timber must be of the best quality, sawed true and out of wind, full size, and free from wind-shakes, large or loose knots, decayed wood, sap, worm-holes, or any other defect that would impair its strength or durability.

ERECTION.

The Contractor shall furnish all staging and falsework, and shall erect, adjust, and paint all of the metal-work ready for the timber-floor. He shall also furnish and lay the latter and put on the track-rails, unless there be a written agreement to the contrary.

The Contractor shall employ suitable mechanics for every kind of mechanical work, and shall, at the request of the Engineer, discharge any workman whom the said Engineer shall deem incompetent, negligent, or untrustworthy.

All material of whatever kind shall be subject to inspection and approval at any time during the progress and until the final completion of the work ; and the entire work shall be constructed in a substantial and workmanlike manner, and to the satisfaction and acceptance of the Engineer.

DEFECTIVE WORK.

The Contractor, upon being so directed by the Engineer, shall remove, rebuild, or make good, without charge, any work which the said Engineer may consider to be defectively executed. The fact that any defective material in the structure had been previously accepted by the oversight of the Company's engineers or inspectors shall not be considered a valid reason for the Contractor's refusing to remove it or make it good. And until such defective work is removed and made good, the Engineer shall deduct from the partial payments or the final payment, as the case may be, whatever sum for such defective work as may, in his opinion, appear just and equitable.

DIRECTIONS TO CONTRACTOR.

In case that the Contractor shall not be present upon the work at any time when it may be necessary for the Engineer to give instructions, the foreman in charge for the time being shall receive and obey any orders that the Engineer may give.

The Contractor shall commence work at such points as the Engineer may direct, and shall conform to his directions as to the order and time in which the different parts of the work shall be done, as well as to the force required to complete the work at the date specified.

CLOSING THOROUGHFARES.

The Contractor and his employees shall so conduct their operations as not to close any thoroughfare by land or water without the written consent of the proper authorities of such thoroughfare.

RESPONSIBILITY FOR ACCIDENTS.

The Contractor shall assume and be responsible for all accidents to men, animals, and materials before the acceptance of the structure; and must remove at his own expense all falsework, rubbish, or other useless material caused by his operations; and such work shall be included as a part of the work to be performed.

The Contractor shall place sufficient and proper guards for the prevention of accidents, and shall put up and maintain at night suitable and sufficient lights.

DAMAGES.

The Contractor shall indemnify and save harmless the Company against all claims and demands of all parties whatsoever for damages or compensation for injuries arising from any obstructions created by the Contractor or his employees, or from any neglect or omission to provide proper lights and signals during the construction of the work.

ALTERATION OF PLANS.

The Engineer shall have the power to vary, extend, increase, or diminish the quantity of the work, or to dispense with a portion thereof during its progress without impairing the contract; and no allowance will be made the Contractor except for the work actually done. In case any change involve the execution of work of a class not herein provided for, the Contractor shall perform the same and be paid the actual cost thereof plus the percentage for profit agreed upon in the contract. In this case the Contractor must furnish the Engineer with satisfactory vouchers for all labor and material expended on the work.

STRICTNESS OF INSPECTION.

All materials and workmanship will be thoroughly and carefully inspected, and the Contractor will be held at all times to the spirit of the specifications; but nothing will be done by the Company's engineers or inspectors to give the Contractor needless worry or annoyance, the intent of both specifications and inspection being simply to obtain for the Company work that will be first-class in every particular and a credit to every one connected with its designing and construction.

SPIRIT OF THE SPECIFICATIONS.

The nature and spirit of these specifications are to provide for the work herein enumerated to be fully completed in every detail for the purpose designed; and it is hereby understood that the Contractor, in accepting the contract, agrees to furnish any and every thing necessary for such construction, notwithstanding any omission in the drawings or specifications.

ENGINEER.

Whenever in these specifications the term "Engineer" is employed, it is understood that it is to mean the . ... Engineer of the .... Company or the duly authorized representative of same.

TENDERS.

Tenders for all work, whenever it is practicable, shall be made on schedule prices, lump-sum bids being accepted only for such parts as steam or electric machinery, which could not well be paid for by the pound.

All tenders are to be made in strict accordance with the plans and specifications submitted to bidders by the Engineer; and no bids based upon suggested changes in same will be considered.

In awarding contracts, preference will be given to those bidders in whose shops the piece-work system is least employed.

THE COMPROMISE STANDARD SYSTEM OF LIVE LOADS FOR RAILWAY BRIDGES AND THE EQUIVALENTS FOR SAME.

(CHAPTER XIX OF "DE PONTIBUS.")

IN 1893 the author published a small pamphlet, now out of print, which bore the above title. Its contents are reproduced here instead of in a second edition. The various steps taken in its preparation were as follows:

In 1891 the author presented to the American Society of Civil Engineers a paper entitled "Some Disputed Points in Railway-Bridge Designing," in which he advocated the adoption of a few standard train-loads for railroad bridges, instead of the almost innumerable ones then in use, offered a set of loads for discussion, and urged that the "Equivalent Uniform-Load Method" of computing stresses be adopted instead of the burdensome method of wheel concentrations that had been in vogue for the preceding ten years. This paper received a very thorough discussion, from which it was evident that bridge engineers and railroad engineers, as a whole, would be glad to settle upon a few standard loadings, and to adopt some simple equivalent method of computing stresses. Most of those who desired the abandonment of the "Concentrated Wheel-load Method," advocated the adoption of the "Equivalent Uniform-Load Method," but a few favored either the "Single" or the "Double Concentration Method," with a constant car-load.

This paper, with the discussions, was published in the February and March 1892 number of the *Transactions* of the American Society of Civil Engineers, and was reviewed very generally by the technical press, attention being paid principally to the subject of equivalent loads. These reviews started a series of letters by the author and others, that were printed at first in the *Railroad Gazette*, and later also in the *Engineering Record*, in which letters the subject of equivalents was thoroughly and exhaustively treated. These proved that the "Equivalent Uniform-Load Method" gives results which are accurate enough for all practical purposes, and that neither the "Single Concentrated-Load Method" nor the "Double Concentrated-Load Method" gives results coinciding at all closely with those found by the theoretically exact method of "Wheel Concentrations."

In November 1892 the author sent a circular letter to all the chief engineers of railroads in the United States and Canada who were members (in any grade) of the American Society of Civil Engineers, and to every other member of that society connected with or specially interested in the designing, building, or operating of railroad bridges. This letter solicited a ballot on certain "Disputed Points in Railway Bridge Designing," foremost among which were those of standard live loads and a simple equivalent method for computation. The number of responses received was as great as could have been expected; and the result was that about eighty-two per cent of those who voted favored and eighteen per cent opposed the adoption of "a Standard System of Live Loads for Railway Bridges" similar to that proposed by the author. Eighty-two per cent also of those who voted were in favor of abandoning the "Concentrated Wheel-Load Method," and eighteen per cent were in favor of retaining it. Of the former, seventy-eight per cent favored the "Equivalent Uniform-Load Method," and twenty-two per cent were in favor of either the "Single" or the "Double Concentration Method." A number of gentlemen who responded made valuable suggestions in respect to the standard system of live loads propounded, and by the aid of these the author prepared a proposed "Compromise Standard System of Live Loads for Railway Bridges," and submitted the same, as before, for final ballot in May 1893.

The number of replies received showed that great interest was taken in the question; and the result of the ballot was ninety per cent in favor and ten per cent opposed to the proposed standard.

Next the pamphlet was published and distributed quite generally among those engineers interested in the subject of bridges, a copy being sent not only to every one who had replied to the ballots, but also to every railroad chief engineer in the United States, Canada, and Mexico whose address was given in Poor's Manual. To these chief engineers there was also sent another circular letter with a ballot that read as follows:

I Agree
Do Not Agree to use the "Compromise Standard System of Live Loads for Railway Bridges" when calling for bids on railroad-bridge work, or when having plans prepared for railroad bridges.

I Agree
Do Not Agree to specify that the "Equivalent Uniform-Load Method" is to be used in computing stresses in the bridges that are to be designed for my road.

Signature of Voter.

....

Chief Engineer of the

....

Over one hundred chief engineers thus addressed voted in favor of both propositions, and very few were opposed.

The pamphlet has now been in use more than four years, and has been in such demand that the first edition (a large one) has been exhausted. All those who have used its methods indorse heartily both the loads specified and the Equivalent Uniform-Load Method.

METHOD OF UTILIZING THE EQUIVALENT LOADS.

In calling for bids on bridge-work to be accompanied with designs for the structures, a railroad engineer can nominate any bridge specifications whatsoever, standard or otherwise, and at the same time specify that the live loads are to be taken from the "Compromise Standard System," and that the "Equivalent Loads" thereof are to be employed.

In this "System" will be found from "Class Z" to "Class T," inclusive, a close approximation to any live load that an engineer is likely to want to use; and if, for a certain car-load, some engineer should prefer a heavier or lighter engine-loading, he can obtain practically what he wishes by specifying that one class is to be used for floor systems and primary-truss members, and another class for main-truss members. The author does not advise this, however, except in the case of double-track bridges, where it would be advantageous to use a certain class for floor systems and primary-truss members, and a lighter class for the trusses, because the chances of there being two, full, maximum train-loads on the span at the same time are generally very small. It might be well to carry this idea even further by specifying, for instance, "Class V" for stringers, "Class W" for floor-beams and primary-truss members, and "Class X" for main-truss members of double-track bridges. Such a method would be in accordance with the theory of probabilities; but it would not apply to single-track bridges, for which the locomotive and car loads of the "Compromise Standard System" have been properly adjusted.

The "Equivalent Uniform-Load Method" reduces to a minimum the labor of making computations of stresses in bridges. The correctness of this statement will be rendered evident by the ensuing explanations of the use of the method. As for its exactness, if any-one has any doubt whatsoever about its closeness of approximation to the theoretically correct method of wheel-concentrations, let him read the author's letter in the *Railroad Gazette* of July 28, 1893. An inspection of Table I of that communication shows that no reasonable man can object to the "Equivalent Uniform-Load Method" because of its want of exactness.

In designing a bridge, one commences naturally with the stringers, then passes to the floor-beams; and afterwards to the trusses; so let us follow this order.

STRINGERS.

From Plate III find the equivalent live load per lineal foot for a span equal to the panel length, add to same the assumed weight per foot of two stringers and the floor they support, and divide the sum by two, calling the result w; then find the total bending moment at mid-span by substituting in the well-known formula,

$$M = \frac{1}{8}wl^2,$$

where l is the panel length in feet, and M is the required moment in foot pounds.

Should the total end shear be required, it can be found for each stringer by adding together the end shear given on Pl. II and the total weight of one stringer with the floor that it carries, and dividing the sum by two.

FLOOR-BEAMS.

In proportioning a floor-beam, the important thing to ascertain is the total concentration at the point where two stringers meet. The live-load concentration is to be found by multiplying together the panel length and the equivalent uniform load per lineal foot given on Pl. III *for a span equal to twice the panel length*, and dividing the product by two. It is unnecessary to describe here how the dead-load concentration at each stringer support is to be found. Nor is it necessary to do more than merely mention that the live-load concentration obtained for the floor-beam is the same as that required in finding stresses in primary-truss members.

TRUSSES.

These can be divided into two kinds, viz., those with equal panels and parallel chords, and those in which the panel lengths are unequal, or the chords are not parallel, or both. In the first case, the stresses can be determined most expeditiously by substitution in tabulated formulæ, and in the second case by the graphical method.

Case I.

From Plate IV find the equivalent uniform live load per lineal foot for the given span length and multiply same by the panel length, calling the product L. For single-track bridges this must be divided by two. All the live-load stresses in main-truss members of single-intersection bridges can be found by substituting this value of L in Table XVII.

Just here it is proper to remark that the "Equivalent Uniform-Load Method" is not applicable to trusses of multiple intersection; but the most approved modern practice in bridge-engineering does not countenance the building of trusses or girders having more than a single system of cancellation. The "Equivalent Uniform-Load Method" does, however, apply to trusses with divided panels, such as the Petit truss; but as this style of truss nowadays involves almost invariably a polygonal top chord, its treatment herein will come under

Case II.

Where trusses have unequal panels or chords not parallel, the first step to take is the finding of all the dead-load stresses by the graphical method, starting from one end of the span and working towards the middle, where the last stress is checked by the method of moments, and the correctness of the entire graphical work is thereby proved.

The next step is to find from Pl. IV., as in Case I, the equivalent live-load per lineal foot for the span, and therefrom the value of the panel-truss live-load L. Next set a slide-rule for the ratio of dead load per lineal foot and the equivalent live load per lineal foot for the span, and, by referring to the dead-load stresses already found, read off from the rule all of the live-load stresses in chords and inclined end posts.

Next assume that there is an upward reaction at one end of the span equal to 1,000 pounds, 10,000 pounds, or 100,000 pounds (according to the size of the bridge), caused by a load placed at the first panel point from the other end of the span, then find graphically the stress in each web-member from end to end of span, caused by this assumed upward reaction.

Then calculate the value of the live-load reaction for the maximum stress in each web-member by means of the slide-rule and the following formula and table, in which n is the number of panels in the span, n' is the number of the panel point at the head of the train, counting from the loaded end of the span, and C is the coefficient of $\frac{L}{n}$.

Live-load reaction for the head of train at $n' = C \times \frac{L}{n}$.

n'	C	n'	C	n'	C	n'	C
1	1	7	28	13	91	19	190
2	3	8	36	14	105	20	210
3	6	9	45	15	120	21	231
4	10	10	55	16	136	22	253
5	15	11	66	17	153	23	276
6	21	12	78	18	171	24	300

Then, still using the slide-rule, find the greatest live-load stress in each web-member by the following equation:

$$\text{Stress required} =$$
$$\text{Stress from Assumed Reaction} \times \frac{\text{Actual Reaction}}{\text{Assumed Reaction}}.$$

Where the panels are divided as in the Petit truss, and where inclined subposts are employed, the *tensile* stress in the *upper* half of each main diagonal thus found will have to be corrected by subtracting therefrom a stress equal to $\frac{L}{2}$ sec. A, where A is the inclination of the diagonal to the vertical. But when inclined subties are used instead of inclined subposts, the correction just referred to will apply only to the *compressive* stresses in the *lower* halves of the main diagonals. The reason for making this correction, as will be at once evident to any one who is accustomed to finding stresses in Petit trusses, is that the method above outlined ignores the subdivision of the panels when ascertaining by graphics the stresses caused by the assumed upward reaction.

In comparing the equivalent loads for spans of one hundred feet, given on Pl. III, with those given on Pl. IV, an apparent discrepancy will be noticed. This is due to the fact that Pl. III is for plate-girder spans, for which the equivalent loads were obtained from the bending moment at mid-span; while Pl. IV is for truss-spans, for which the equivalent loads are the average of those at all of the panel points.

In computing the equivalent loads for Pls. III and IV, it was assumed that cars may precede as well as follow the locomotives.

Since De Pontibus was published, it has become necessary to add Classes Q, R, and S to the "Compromise Standard System" in order to be not only abreast of the times, but also slightly in the lead thereof; for there has appeared lately a tendency to specify exceedingly heavy live loads for railway bridges, because, probably, several excessively heavy locomotives have been manufactured recently.

Pls. I, II, III, and IV of this book show the new classes of loading, their end shears and their equivalent uniform loads.

TABLES.

TABLE I.

COEFFICIENTS OF IMPACT FOR RAILWAY BRIDGES.

I = Impact.
L = Length of Span in Feet.

$$I = \frac{400}{L + 500}.$$

L	I	L	I	L	I
1	0.7984	50	0.7273	99	0.6678
2	0.7968	51	0.7260	100	0.6667
3	0.7952	52	0.7247	105	0.6612
4	0.7936	53	0.7233	110	0.6557
5	0.7921	54	0.7220	115	0.6504
6	0.7905	55	0.7207	120	0.6452
7	0.7889	56	0.7194	125	0.6400
8	0.7874	57	0.7181	130	0.6349
9	0.7858	58	0.7169	135	0.6299
10	0.7843	59	0.7156	140	0.6250
11	0.7828	60	0.7143	145	0.6202
12	0.7812	61	0.7130	150	0.6154
13	0.7797	62	0.7117	155	0.6107
14	0.7782	63	0.7105	160	0.6061
15	0.7767	64	0.7092	165	0.6015
16	0.7752	65	0.7080	170	0.5970
17	0.7737	66	0.7067	175	0.5926
18	0.7722	67	0.7055	180	0.5882
19	0.7707	68	0.7042	185	0.5839
20	0.7692	69	0.7030	190	0.5797
21	0.7678	70	0.7018	195	0.5755
22	0.7663	71	0.7005	200	0.5714
23	0.7648	72	0.6993	210	0.5634
24	0.7634	73	0.6981	220	0.5556
25	0.7619	74	0 6968	230	0.5480
26	0.7605	75	0.6957	240	0.5405
27	0.7590	76	0.6944	250	0.5333
28	0.7576	77	0.6932	260	0.5263
29	0.7561	78	0.6920	270	0.5195
30	0.7547	79	0.6908	280	0.5128
31	0.7533	80	0.6897	290	0.5063
32	0.7519	81	0.6885	300	0.5000
33	0.7505	82	0.6873	325	0.4848
34	0.7491	83	0.6861	350	0.4706
35	0.7477	84	0.6849	375	9.4571
36	0.7463	85	0.6838	400	0.4444
37	0.7449	86	0.6826	450	0.4211
38	0.7435	87	0.6814	500	0.4000
39	0.7421	88	0.6803	550	0.3810
40	0.7407	89	0.6791	600	0.3636
41	0.7394	90	0.6780	650	0.3478
42	0.7380	91	0.6768	700	0.3333
43	0.7367	92	0.6757	750	0.3200
44	0.7353	93	0.6745	800	0.3077
45	0.7339	94	0.6734	850	0.2963
46	0.7326	95	0.6723	900	0.2857
47	0.7313	96	0.6711	950	0.2759
48	0.7299	97	0.6700	1000	0.2667
49	0.7286	98	0.6689		

TABLE II.

COEFFICIENTS OF IMPACT FOR HIGHWAY BRIDGES.

I = Impact.
L = Length of Span in Feet.

$$I = \frac{100}{L + 150}.$$

L	I	L	I	L	I
1	0.6623	50	0.5000	99	0.4016
2	0.6579	51	0.4975	100	0.4000
3	0.6536	52	0 4951	105	0.3922
4	0.6494	53	0.4926	110	0.3846
5	0.6452	54	0.4902	115	0.3774
6	0.6410	55	0.4878	120	0.3704
7	0.6369	56	0.4854	125	0.3636
8	0.6329	57	0.4831	130	0.3571
9	0.6289	58	0.4808	135	0.3509
10	0.6250	59	0.4785	140	0.3448
11	0.6211	60	0.4762	145	0.3389
12	0.6173	61	0.4739	150	0.3333
13	0.6134	62	0.4717	155	0.3279
14	0.6098	63	0.4695	160	0.3226
15	0.6061	64	0.4673	165	0.3175
16	0.6024	65	0.4651	170	0.3125
17	0.5988	66	0.4630	175	0.3077
18	0.5952	67	0.4608	180	0.3030
19	0.5917	68	0.4587	185	0 2985
20	0.5882	69	0.4566	190	0.2941
21	0.5848	70	0.4546	195	0.2899
22	0.5814	71	0.4525	200	0 2857
23	0.5780	72	0.4505	210	0.2778
24	0.5747	73	0.4481	220	0.2703
25	0.5714	74	0.4464	230	0.2632
26	0.5682	75	0.4444	240	0.2564
27	0.5650	76	0.4425	250	0.2500
28	0.5618	77	0.4405	260	0.2439
29	0.5586	78	0.4386	270	0.2381
30	0.5556	79	0.4367	280	0.2326
31	0.5525	80	0.4348	290	0.2273
32	0.5495	81	0.4329	300	0.2222
33	0.5465	82	0.4310	325	0.2105
34	0.5435	83	0.4292	350	0.2000
35	0.5405	84	0.4274	375	0.1905
36	0.5376	85	0.4255	400	0.1818
37	0 5348	86	0.4237	450	0.1667
38	0.5319	87	0.4219	500	0.1539
39	0.5291	88	0.4202	550	0.1429
40	0.5263	89	0.4184	600	0.1333
41	0.5236	90	0.4167	650	0.1250
42	0.5208	91	0.4149	700	0.1176
43	0.5181	92	0.4131	750	0.1111
44	0.5155	93	0.4115	800	0.1053
45	0.5128	94	0.4098	850	0.1000
46	0.5102	95	0.4082	900	0.0952
47	0.5076	96	0.4065	950	0.0909
48	0.5051	97	0.4049	1000	0.0870
49	0.5025	98	0.4033		

TABLE III.

INTENSITIES FOR INCLINED END POSTS.

$$P = 18{,}000 - 80\frac{l}{r}.$$

$\frac{l}{r}$	P	$\frac{l}{r}$	P	$\frac{l}{r}$	P	$\frac{l}{r}$	P	$\frac{l}{r}$	P
1	17920	25	16000	49	14080	73	12160	97	10240
2	17840	26	15920	50	14000	74	12080	98	10160
3	17760	27	15840	51	13920	75	12000	99	10080
4	17680	28	15760	52	13840	76	11920	100	10000
5	17600	29	15680	53	13760	77	11840	101	9920
6	17520	30	15600	54	13680	78	11760	102	9840
7	17440	31	15520	55	13600	79	11680	103	9760
8	17360	32	15440	56	13520	80	11600	104	9680
9	17280	33	15360	57	13440	81	11520	105	9600
10	17200	34	15280	58	13360	82	11440	106	9520
11	17120	35	15200	59	13280	83	11360	107	9440
12	17040	36	15120	60	13200	84	11280	108	9360
13	16960	37	15040	61	13120	85	11200	109	9280
14	16880	38	14960	62	13040	86	11120	110	9200
15	16800	39	14880	63	12960	87	11040	111	9120
16	16720	40	14800	64	12880	88	10960	112	9040
17	16640	41	14720	65	12800	89	10880	113	8960
18	16560	42	14640	66	12720	90	10800	114	8880
19	16480	43	14560	67	12640	91	10720	115	8800
20	16400	44	14480	68	12560	92	10640	116	8720
21	16320	45	14400	69	12480	93	10560	117	8640
22	16240	46	14320	70	12400	94	10480	118	8560
23	16160	47	14240	71	12320	95	10400	119	8480
24	16080	48	14160	72	12240	96	10320	120	8400

TABLE IV.

INTENSITIES FOR TOP-CHORD COMPRESSION-MEMBERS.

$$P = 18,000 - 70\frac{l}{r}.$$

$\frac{l}{r}$	P	$\frac{l}{r}$	P	$\frac{l}{r}$	P	$\frac{l}{r}$	P	$\frac{l}{r}$	P
1	17930	25	16250	49	14570	73	12890	97	11210
2	17860	26	16180	50	14500	74	12820	98	11140
3	17790	27	16110	51	14430	75	12750	99	11070
4	17720	28	16040	52	14360	76	12680	100	11000
5	17650	29	15970	53	14290	77	12610	101	10930
6	17580	30	15900	54	14220	78	12540	102	10860
7	17510	31	15830	55	14150	79	12470	103	10790
8	17440	32	15760	56	14080	80	12400	104	10720
9	17370	33	15690	57	14010	81	12330	105	10650
10	17300	34	15620	58	13940	82	12260	106	10580
11	17230	35	15550	59	13870	83	12190	107	10510
12	17160	36	15480	60	13800	84	12120	108	10440
13	17090	37	15410	61	13730	85	12050	109	10370
14	17020	38	15340	62	13660	86	11980	110	10300
15	16950	39	15270	63	13590	87	11910	111	10230
16	16880	40	15200	64	13520	88	11840	112	10160
17	16810	41	15130	65	13450	89	11770	113	10090
18	16740	42	15060	66	13380	90	11700	114	10020
19	15670	43	14990	67	13310	91	11630	115	9950
20	16600	44	14920	68	13240	92	11560	116	9880
21	16530	45	14850	69	13170	93	11490	117	9810
22	16460	46	14780	70	13100	94	11420	118	9740
23	16390	47	14710	71	13030	95	11350	119	9670
24	16320	48	14640	72	12960	96	11280	120	9600

TABLE V.

INTENSITIES FOR INTERMEDIATE POSTS AND SUB-DIAGONALS WITH ONE OR TWO HINGED ENDS.

$$P = 16{,}000 - 80\frac{l}{r}.$$

$\frac{l}{r}$	P	$\frac{l}{r}$	P	$\frac{l}{r}$	P	$\frac{l}{r}$	P	$\frac{l}{r}$	P
1	15920	25	14000	49	12080	73	10160	97	8240
2	15840	26	13920	50	12000	74	10080	98	8160
3	15760	27	13840	51	11920	75	10000	99	8080
4	15680	28	13760	52	11840	76	9920	100	8000
5	15600	29	13680	53	11760	77	9840	101	7920
6	15520	30	13600	54	11680	78	9760	102	7840
7	15440	31	13520	55	11600	79	9680	103	7760
8	15350	32	13440	56	11520	80	9600	104	7680
9	15280	33	13360	57	11440	81	9520	105	7600
10	15200	34	13280	58	11360	82	9440	106	7520
11	15120	35	13200	59	11280	83	9360	107	7440
12	15040	36	13120	60	11200	84	9280	108	7360
13	14960	37	13040	61	11120	85	9200	109	7280
14	14880	38	12960	62	11040	86	9120	110	7200
15	14800	39	12880	63	10960	87	9040	111	7120
16	14720	40	12800	64	10880	88	8960	112	7040
17	14640	41	12720	65	10800	89	8880	113	6960
18	14560	42	12640	66	10720	90	8800	114	6880
19	14480	43	12560	67	10640	91	8720	115	6800
20	14400	44	12480	68	10560	92	8640	116	6720
21	14320	45	12400	69	10480	93	8560	117	6640
22	14240	46	12320	70	10400	94	8480	118	6560
23	14160	47	12240	71	10320	95	8400	119	6480
24	14080	48	12160	72	10240	96	8320	120	6400

TABLE VI.

INTENSITIES FOR COLUMNS OF VIADUCTS AND ELEVATED RAILROADS AND FOR ALL LATERAL STRUTS AND OTHER COMPRESSION MEMBERS WITH FIXED ENDS, EXCEPTING CHORDS OF TRUSSES.

$$P = 16{,}000 - 60\frac{l}{r}.$$

$\frac{l}{r}$	P	$\frac{l}{r}$	P	$\frac{l}{r}$	P	$\frac{l}{r}$	P	$\frac{l}{r}$	P	$\frac{l}{r}$	P
1	15940	26	14440	51	12940	76	11440	101	9940	126	8440
2	15880	27	14380	52	12880	77	11380	102	9880	127	8380
3	15820	28	14320	53	12820	78	11320	103	9820	128	8320
4	15760	29	14260	54	12760	79	11260	104	9760	129	8260
5	15700	30	14200	55	12700	80	11200	105	9700	130	8200
6	15640	31	14140	56	12640	81	11140	106	9640	131	8140
7	15580	32	14080	57	12580	82	11080	107	9580	132	8080
8	15520	33	14020	58	12520	83	11020	108	9520	133	8020
9	15460	34	13960	59	12460	84	10960	109	9460	134	7960
10	15400	35	13900	60	12400	85	10900	110	9400	135	7900
11	15340	36	13840	61	12340	86	10840	111	9340	136	7840
12	15280	37	13780	62	12280	87	10780	112	9280	137	7780
13	15220	38	13720	63	12220	88	10720	113	9220	138	7720
14	15160	39	13660	64	12160	89	10660	114	9160	139	7660
15	15100	40	13600	65	12100	90	10600	115	9100	140	7600
16	15040	41	13540	66	12040	91	10540	116	9040	141	7540
17	14980	42	13480	67	11980	92	10480	117	8980	142	7480
18	14920	43	13420	68	11920	93	10420	118	8920	143	7420
19	14860	44	13360	69	11860	94	10360	119	8860	144	7360
20	14800	45	13300	70	11800	95	10300	120	8800	145	7300
21	14740	46	13240	71	11740	96	10240	121	8740	146	7240
22	14680	47	13180	72	11680	97	10180	122	8680	147	7180
23	14620	48	13120	73	11620	98	10120	123	8620	148	7120
24	14560	49	13060	74	11560	99	10060	124	8560	149	7060
25	14500	50	13000	75	11500	100	10000	125	8500	150	7000

TABLE VII.

CENTRIFUGAL FORCE IN PERCENTAGES OF LIVE LOAD.

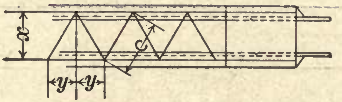
$C.F. = \frac{V^2 \times 100}{32.2 \times R}$. V = Velocity in feet per second. R = Radius in feet.

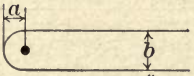
Degree.	Velocity in Miles per Hour.								
	10	15	20	25	30	35	40	50	60
1	0.12	0.26	0.46	0.73	1.05	1.43	1.87	2.91	4.20
2	0.23	0.53	0.93	1.46	2.10	2.86	3.73	5.82	8.40
3	0.35	0.79	1.40	2.19	3.15	4.28	5.60	8.74	12.59
4	0.47	1.05	1.86	2.92	4.20	5.71	7.46	11.65	16.78
5	0.58	1.31	2.33	3.65	5.25	7.14	9.33	14.57	20.99
6	0.70	1.57	2.79	4.37	6.30	8.56	11.19	17.48	25.17
7	0.82	1.84	3.26	5.10	7.34	9.99	13.05	20.39	29.36
8	0.93	2.10	3.73	5.82	8.39	11.42	14.91	23.30	33.55
9	1.05	2.36	4.19	6.55	9.43	12.84	16.77	26.20	37.74
10	1.16	2.62	4.66	7.28	10.48	14.26	18.63	29.11	41.92
11	1.28	2.89	5.12	8.00	11.52	15.68	20.49	32.01	
12	1.40	3.11	5.58	8.73	12.59	17.11	22.35	34.89	
13	1.51	3.40	6.05	9.45	13.61	18.53	24.20		
14	1.63	3.66	6.51	10.17	14.65	19.94	26.05		
15	1.74	3.92	6.97	10.90	15.70	21.36	27.90		
16	1.86	4.18	7.43	11.62	16.73	22.77			
17	1.98	4.44	7.90	12.34	17.77	24.19			
18	2.09	4.70	8.36	13.06	18.81	25.60			
19	2.21	4.96	8.82	13.79	19.85	27.00			
20	2.32	5.22	9.28	14.51	20.88	28.42			
21	2.44	5.48	9.74	15.22	21.91	29.82			
22	2.55	5.74	10.20	15.94	22.95	31.23			
23	2.66	5.99	10.65	16.65	23.97	32.63			
24	2.78	6.25	11.11	17.37	25.00	34.02			
25	2.89	6.51	11.57	18.08	26.02	35.42			
26	3.01	6.76	12.02	18.79	27.05	36.81			
27	3.12	7.02	12.47	19.50	28.07	38.20			
28	3.23	7.27	12.93	20.20	29.09	39.59			
29	3.34	7.53	13.37	20.91	30.11	40.97			
30	3.46	7.78	13.83	21.62	31.12	42.35			
31	3.57	8.03	14.28	22.32	32.13	43.73			
32	3.68	8.29	14.73	23.03	33.15	45.11			
33	3.80	8.54	15.18	23.72	34.16	46.49			
34	3.91	8.79	15.62	24.42	35.16	47.85			
35	4.02	9.04	16.07	25.12	36.15	49.20			
36	4.13	9.29	16.51	25.81	37.16	50.57			
37	4.24	9.54	16.95	26.50	38.15	51.92			
38	4.35	9.79	17.39	27.19	39.14	53.27			
39	4.46	10.04	17.84	27.88	40.14	54.62			
40	4.57	10.28	18.27	28.57	41.12	55.97			
41	4.68	10.53	18.71	29.24	42.10	57.30			
42	4.79	10.77	19.15	29.93	43.09	58.66			
43	4.90	11.02	19.58	30.61	44.08	59.99			
44	5.01	11.26	20.01	31.29	45.04	61.29			
45	5.11	11.50	20.41	31.95	46.00	62.61			
46	5.22	11.74	20.87	32.63	46.97				
47	5.33	11.99	21.30	33.30	47.95				
48	5.44	12.23	21.73	33.98	48.92				
49	5.54	12.46	22.15	34.63	49.85				
50	5.65	12.71	22.58	35.30	50.82				

NOTE.—The stepped line shows the limiting percentages for a superelevation of 4″ for outer rail.

TABLE VIII.

SIZES AND WEIGHTS OF STAY-PLATES AND LACING-BARS FOR ORDINARY POSTS.



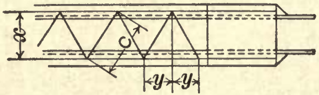


$a = \frac{b}{2} + \frac{1''}{4}$

Depth of Channel.	x	y	C	Size of Lacing-bar.	Size of Stay-plate.	Weight of Lacing in pounds per Ft. of Col.	Weight of One Stay-plate in pounds.	Size of Rivet.
6″	5″	3″	$5\frac{27}{32}''$	$1\frac{1}{4}'' \times \frac{3}{8}''$	$6\frac{7}{8}'' \times \frac{3}{8}'' \times 9''$	13.22	6.58	⅝″
	6	4	$7\frac{7}{32}$	" "	$7\frac{7}{8} \times \frac{3}{8} \times 9$	11.45	7.53	
	7	4	$8\frac{1}{16}$	" "	$8\frac{7}{8} \times \frac{3}{8} \times 12$	12.39	11.32	
	8	$4\frac{1}{2}$	$9\frac{3}{16}$	" "	$9\frac{7}{8} \times \frac{3}{8} \times 12$	12.13	12.60	
	9	$5\frac{1}{4}$	$10\frac{13}{32}$	" "	$10\frac{7}{8} \times \frac{3}{8} \times 15$	11.42	17.34	
	10	$5\frac{3}{4}$	$11\frac{17}{32}$	" "	$11\frac{7}{8} \times \frac{3}{8} \times 15$	11.31	18.93	
7″	5	3	$5\frac{27}{32}$	" "	$7 \times \frac{3}{8} \times 9$	13.22	6.70	
	6	4	$7\frac{7}{32}$	" "	$8 \times \frac{3}{8} \times 9$	11.45	7.65	
	7	4	$8\frac{1}{16}$	" "	$9 \times \frac{3}{8} \times 12$	12.39	11.48	
	8	$4\frac{1}{2}$	$9\frac{3}{16}$	" "	$10 \times \frac{3}{8} \times 12$	12.13	12.75	
	9	$5\frac{1}{4}$	$10\frac{13}{32}$	" "	$11 \times \frac{3}{8} \times 15$	11.42	17.54	
	10	$5\frac{3}{4}$	$11\frac{17}{32}$	" "	$12 \times \frac{3}{8} \times 15$	11.31	19.13	
8″	6	4	$7\frac{7}{32}$	$2'' \times \frac{3}{8}''$	$8 \times \frac{3}{8} \times 9$	13.45	7.65	¾″
	7	4	$8\frac{1}{16}$	" "	$9 \times \frac{3}{8} \times 12$	14.52	11.48	
	8	$4\frac{1}{2}$	$9\frac{3}{16}$	" "	$10 \times \frac{3}{8} \times 12$	14.19	12.75	
	9	$5\frac{1}{4}$	$10\frac{13}{32}$	" "	$11 \times \frac{3}{8} \times 15$	13.34	17.54	
	10	$5\frac{3}{4}$	$11\frac{17}{32}$	" "	$12 \times \frac{3}{8} \times 15$	13.18	19.13	
	11	$6\frac{1}{4}$	$12\frac{21}{32}$	" "	$13 \times \frac{3}{8} \times 18$	13.05	24.87	
9″	7	4	$8\frac{1}{16}$	" "	$9\frac{1}{8} \times \frac{3}{8} \times 12$	12.39	11.64	

TABLE VIII—*Continued.*

SIZES AND WEIGHTS OF STAY-PLATES AND LACING-BARS FOR ORDINARY POSTS.

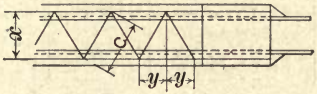


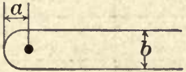
$a = \frac{b}{2} + \frac{1''}{4}$

Depth of Channel.	x	y	C	Size of Lacing-bar.	Size of Stay-plate.	Weight of Lacing in pounds per Ft. of Col.	Weight of One Stay-plate in pounds.	Size of Rivet.
9″	8″	4½″	$9\frac{3}{16}$″	2″ × ⅜″	10⅛″ × ⅜″ × 12″	14.19	12.91	¾″
	9	5¼	$10\frac{13}{32}$	" "	11⅛ × ⅜ × 15	13.34	17.76	
	10	5¾	$11\frac{17}{32}$	" "	12⅛ × ⅜ × 15	13.18	19.32	
	11	6¼	$12\frac{21}{32}$	" "	13⅛ × ⅜ × 18	13.05	25.11	
	12	7	$13\frac{29}{32}$	" "	14⅛ × ⅜ × 18	12.56	27.02	
10″	8	4½	$9\frac{3}{16}$	2¼″ × ⅜″	10¼ × ⅜ × 12	16.03	13.07	
	9	5¼	$10\frac{13}{32}$	" "	11¼ × ⅜ × 15	15.53	17.94	
	10	5¾	$11\frac{17}{32}$	" "	12¼ × ⅜ × 15	14.98	19.53	
	11	6¼	$12\frac{21}{32}$	" "	13¼ × ⅜ × 18	14.74	25.35	
	12	7	$13\frac{29}{32}$	" "	14¼ × ⅜ × 18	14.19	27.26	
	13	7½	15	" "	15¼ × ⅜ × 21	14.07	34.04	
	14	8	16⅛	" "	16¼ × ⅜ × 21	14.00	36.26	
	15	8¾	17⅜	" "	17¼ × ⅜ × 24	13.62	44.00	
12″	8	4½	$9\frac{3}{16}$	" "	10⅝ × ⅜ × 12	16.03	13.55	
	9	5¼	$10\frac{13}{32}$	" "	11⅝ × ⅜ × 15	15.53	18.55	
	10	5¾	$11\frac{17}{32}$	" "	12⅝ × ⅜ × 15	14.98	20.13	
	11	6¼	$12\frac{21}{32}$	" "	13⅝ × ⅜ × 18	14.74	26.06	
	12	7	$13\frac{29}{32}$	" "	14⅝ × ⅜ × 18	14.19	27.98	
	13	7½	15	" "	15⅝ × ⅜ × 21	14.07	31.88	

TABLE VIII—*Continued.*

SIZES AND WEIGHTS OF STAY-PLATES AND LACING-BARS FOR ORDINARY POSTS.





$$a = \frac{b}{2} + \frac{1''}{4}$$

Depth of Channel.	x	y	C	Size of Lacing-bar.	Size of Stay-plate.	Weight of Lacing in pounds per Ft. of Col.	Weight of One Stay-plate in pounds.	Size of Rivet.
12″	14″	8″	16⅛″	2¼″ × ⅜″	16⅝″ × ⅜″ × 21″	14.00	37.10	¾″
	15	8¾	17⅜	" "	17⅝ × ⅜ × 24	13.62	41.97	
	16	9½	18⅝	" "	18⅝ × ⅜ × 24	13.30	47.50	
15″	9	5¼	10 13/32	2½ × ⅜	12 × ⅜ × 15	17.66	19.13	⅞″
	10	5¾	11 17/32	" "	13 × ⅜ × 15	17.38	20.73	
	11	6¼	1′ 0 21/32	" "	14 × ⅜ × 18	17.14	26.79	
	12	7	1 1 29/32	" "	15 × ⅜ × 18	16.44	28.71	
	13	7½	1 3	" "	16 × ⅜ × 21	16.27	35.70	
	14	8	1 4⅛	" "	17 × ⅜ × 21	16.15	37.94	
	15	8¾	1 5⅜	" "	18 × ⅜ × 24	15.68	45.92	
	16	9½	1 6⅝	" "	19 × ⅜ × 24	15.28	48.45	
	18	10½	1 8 27/32	3 × 7/16	21 × ⅜ × 27	21.15	60.25	
	20	11½	1 11 1/16	" ½	23 × 7/16 × 30	23.92	85.60	
	22	12¾	2 1 7/16	" 9/16	25 × 7/16 × 33	26.31	102.30	
	24	13¾	2 3 21/32	" "	27 × ½ × 36	26.25	137.75	
	26	15	2 6 1/32	1 ∠ 3″ × 2½″ × ⅜″	29 × 9/16 × 39		180.18	
	28	16¼	2 8⅜	" "	31 × 9/16 × 42		207.48	
	30	17¼	2 10 19/32	" "	33 × ⅝ × 45		263.03	

TABLE IX.

BENDING MOMENTS ON PINS.

Diam. of Pin.	Moments in In.-lbs. for Fibre Stress of		Diam. of Pin.	Moments in In.-lbs. for Fibre Stress of		Diam. of Pin.	Moments in In.-lbs. for Fibre Stress of	
	27,000 lbs. per sq. in.	35,100 lbs. per sq. in.		27,000 lbs. per sq. in.	35,100 lbs. per sq. in.		27,000 lbs. per sq. in.	35,100 lbs. per sq. in.
2″	21200	27570	6⅞″	861300	1119700	11⅝″	4164500	5413900
2⅛	25500	33200	7	909100	1181800	11¾	4300000	5590000
2¼	30200	39300	7⅛	958800	1246400	11⅞	4439300	5771100
2⅜	35500	46200	7¼	1010100	1313100	12	4580500	5954700
2½	41400	53800	7⅜	1063300	1382300	12⅛	4725000	6142500
2⅝	47900	62300	7½	1118300	1453800	12¼	4872700	6334500
2¾	55100	71700	7⅝	1175100	1527500	12⅜	5023600	6530700
2⅞	63000	81900	7¾	1233900	1604100	12½	5177200	6730400
3	71600	93100	7⅞	1294500	1682700	12⅝	5334700	6935100
3⅛	80800	105000	8	1357200	1764400	12¾	5494000	7142200
3¼	91000	118300	8⅛	1421800	1848300	12⅞	5657300	7354500
3⅜	101900	132500	8¼	1488500	1935100	13	5823600	7670700
3½	113600	147700	8⅜	1557000	2024100	13⅛	5993200	7791200
3⅝	126300	164200	8½	1627800	2116100	13¼	6166000	8015800
3¾	139800	181700	8⅝	1700700	2210900	13⅜	6342300	8245000
3⅞	154200	200500	8¾	1775700	2308400	13½	6521700	8478200
4	169600	220500	8⅞	1853000	2408900	13⅝	6704600	8716000
4⅛	186100	241900	9	1932300	2512100	13¾	6890900	8958200
4¼	203500	264500	9⅛	2013900	2618100	13⅞	7080500	9204700
4⅜	222000	288600	9¼	2097900	2727300	14	7273800	9455900
4½	241500	314000	9⅜	2184300	2839600	14⅛	7470000	9711000
4⅝	262200	340900	9½	2272900	2954800	14¼	7670700	9971900
4¾	284100	369300	9⅝	2363600	3072700	14⅜	7874000	10236200
4⅞	307100	399200	9¾	2457000	3194100	14½	8081100	10505400
5	331300	430700	9⅞	2552500	3318300	14⅝	8292000	10779600
5⅛	356800	463900	10	2650900	3446200	14¾	8506400	11058300
5¼	383600	498700	10⅛	2751300	3576700	14⅞	8724500	11341900
5⅜	411600	535100	10¼	2854400	3710700	15	8946200	11630100
5½	441000	573300	10⅜	2960300	3848400	15½	9871200	12832600
5⅝	471800	613300	10½	3068600	3989200	16	10857200	14114400
5¾	504000	655200	10⅝	3179500	4133400	16½	11907300	15479500
5⅞	537500	698700	10¾	3292900	4280800	17	13022900	16929800
6	572500	744300	10⅞	3409600	4432500	17½	14206300	18468200
6⅛	609200	792000	11	3528100	4586500	18	15459100	20096800
6¼	647100	841200	11⅛	3649900	4744900	18½	16783500	21818600
6⅜	686700	892700	11¼	3774300	4906600	19	18181300	23635700
6½	728000	946400	11⅜	3901500	5072000	19½	19654600	25551000
6⅝	770700	1001900	11½	4031400	5240800	20	21205800	27567500
6¾	815300	1059800						

Note.—27000 lbs. is the allowable stress, excluding wind.
35100 lbs. is the allowable stress. including wind.

TABLE X.

BEARING ON PINS.

Diam. of Pin.	Bearing.		Diam. of Pin.	Bearing.	
	22000 Lbs. per Sq. In.	28600 Lbs. per Sq. In.		22000 Lbs. per Sq. In.	28600 Lbs. per Sq. In.
2″	44000	57200	7″	154000	200200
2⅛	46800	60800	7⅛	156800	203800
2¼	49500	64400	7¼	159500	207400
2⅜	52300	67900	7⅜	162300	210900
2½	55000	71500	7½	165000	214500
2⅝	57800	75100	7⅝	167800	218100
2¾	60500	78700	7¾	170500	221700
2⅞	63300	82200	7⅞	173300	225200
3	66000	85800	8	176000	228800
3⅛	68800	89400	8⅛	178800	232400
3¼	71500	93000	8¼	181500	236000
3⅜	74300	96500	8⅜	184300	239500
3½	77000	100100	8½	187000	243100
3⅝	79800	103700	8⅝	189800	246700
3¾	82500	107300	8¾	192500	250300
3⅞	85300	110800	8⅞	195300	253800
4	88000	114400	9	198000	257400
4⅛	90800	118000	9⅛	200800	261000
4¼	93500	121600	9¼	203500	264600
4⅜	96300	125100	9⅜	206300	268100
4½	99000	128700	9½	209000	271700
4⅝	101800	132300	9⅝	211800	275300
4¾	104500	135900	9¾	214500	278900
4⅞	107300	139400	9⅞	217300	282400
5	110000	143000	10	220000	286000
5⅛	112800	146600	10⅛	222800	289600
5¼	115500	150200	10¼	225500	293200
5⅜	118300	153700	10⅜	228300	296700
5½	121000	157300	10½	231000	300300
5⅝	123800	160900	10⅝	233800	303900
5¾	126500	164500	10¾	236500	307500
5⅞	129300	168000	10⅞	239300	311000
6	132000	171600	11	242000	314600
6⅛	134800	175200	11⅛	244800	318200
6¼	137500	178800	11¼	247500	321800
6⅜	140300	182300	11⅜	250300	325300
6½	143000	185900	11½	253000	328900
6⅝	145800	189500	11⅝	255800	332500
6¾	148500	193100	11¾	258500	336100
6⅞	151300	196600	11⅞	261300	339600

NOTE.—22000 lbs. per sq. in. is the allowable stress excluding wind.
28600 " " " " " " " " including "

TABLE XI.

INTENSITIES FOR FORKED ENDS AND EXTENSION-PLATES OF COMPRESSION-MEMBERS.

Formula: $P = 10000 - 300\frac{l}{t}$.

$\frac{l}{t}$	P	$\frac{l}{t}$	P	$\frac{l}{t}$	P
1	9700	11	6700	21	3700
2	9400	12	6400	22	3400
3	9100	13	6100	23	3100
4	8800	14	5800	24	2800
5	8500	15	5500	25	2500
6	8200	16	5200	26	2200
7	7900	17	4900	27	1900
8	7600	18	4600	28	1600
9	7300	19	4300	29	1300
10	7000	20	4000	30	1000

TABLE XII.

SHEARING AND BEARING VALUES OF RIVETS.

Diameter of Rivet.	Single Shear. 10000 S 8000 F	Bearing Values	Shop or Field.	Bearing Values for Different Thicknesses of Plates.											
				$\frac{1}{4}''$	$\frac{5}{16}''$	$\frac{3}{8}''$	$\frac{7}{16}''$	$\frac{1}{2}''$	$\frac{9}{16}''$	$\frac{5}{8}''$	$\frac{11}{16}''$	$\frac{3}{4}''$	$\frac{13}{16}''$	$\frac{7}{8}''$	$\frac{15}{16}''$
$\frac{1}{2}''$	S : 1963	20000	S	2500	3125	3750	4375								
	F : 1570	16000	F	2000	2500	3000	3500								
$\frac{5}{8}$	S : 3068	20000	S	3125	3906	4687	5469	6250	7031						
	F : 2454	16000	F	2500	3125	3750	4375	5000	5625						
$\frac{3}{4}$	S : 4418	20000	S	3750	4687	5625	6562	7500	8437	9375	10312				
	F : 3534	16000	F	3000	3750	4500	5250	6000	6750	7500	8250				
$\frac{7}{8}$	S : 6013	20000	S	4375	5469	6562	7656	8750	9844	10938	12031	13125	14219		
	F : 4810	16000	F	3500	4375	5250	6125	7000	7875	8750	9625	10500	11375		
$\frac{15}{16}$	S : 6903	20000	S	4687	5859	7031	8203	9375	10547	11719	12891	14062	15234	16406	
	F : 5522	16000	F	3750	4687	5625	6562	7500	8437	9375	10312	11250	12187	13125	
1	S : 7854	20000	S	5000	6250	7500	8750	10000	11250	12500	13750	15000	16250	17500	18750
	F : 6283	16000	F	4000	5000	6000	7000	8000	9000	10000	11000	12000	13000	14000	15000

S : Shop-driven rivets. *F* : Field-driven rivets.

TABLE XIII.

COEFFICIENTS OF W TAN θ FOR BOTH COMPRESSION AND TENSION STRESSES IN BOTTOM CHORDS OF THROUGH-BRIDGES AND TOP CHORDS OF DECK-BRIDGES, DUE TO WIND LOADS APPLIED TO SAID CHORDS, WHEN THE LATERAL SYSTEM IS OF DOUBLE CANCELLATION.

Number of Panels in Span.	Number of Panel from End of Span.												
	1	2	3	4	5	6	7	8	9	10	11	12	13
4	¾	1¾											
5	1	2½	3										
6	1¼	3¼	4¼										
7	1½	4	5½	6									
8	1¾	4¾	6¾	7¾									
9	2	5½	8	9½	10								
10	2¼	6¼	9¼	11¼	12¼								
11	2½	7	10½	13	14½	15							
12	2¾	7¾	11¾	14¾	16¾	17¾							
13	3	8½	13	16½	19	20½	21						
14	3¼	9¼	14¼	18¼	21¼	23¼	24¼						
15	3½	10	15½	20	23½	26	27½	28					
16	3¾	10¾	16¾	21¾	25¾	28¾	30¾	31¾					
17	4	11½	18	23½	28	31½	34	35½	36				
18	4¼	12¼	19¼	25¼	30¼	34¼	37¼	39¼	40¼				
19	4½	13	20½	27	32½	37	40½	43	44½	45			
20	4¾	13¾	21¾	28¾	34¾	39¾	43¾	46¾	48¾	49¾			
21	5	14½	23	30½	37	42½	47	50½	53	54½	55		
22	5¼	15¼	24¼	32¼	39¼	45¼	50¼	54¼	57¼	59¼	60¼		
23	5½	16	25½	34	41½	48	53½	58	61½	64	65½	66	
24	5¾	16¾	26¾	35¾	43¾	50¾	56¾	61¾	65¾	68¾	70¾	71¾	
25	6	17½	28	37½	46	53½	60	65½	70	73½	76	77½	78
26	6¼	18¼	29¼	39¼	48¼	56¼	63¼	69¼	74¼	78¼	81¼	83¼	84¼

TABLE XIV.

COEFFICIENTS OF $\frac{W \sec \theta}{n}$ (WHERE n = NO. OF PANELS IN SPAN) FOR WIND-LOAD STRESSES IN THE DIAGONALS OF LATERAL SYSTEMS OF SINGLE CANCELLATION. THESE COEFFICIENTS APPLY TO LATERAL SYSTEMS COMPOSED OF INTERSECTING DIAGONAL RODS OR OF SINGLE DIAGONAL STRUTS.

No. of Panels in Span.	Number of Panel from End of Span.												
	1	2	3	4	5	6	7	8	9	10	11	12	13
4	6	3											
5	10	6	3										
6	15	10	6										
7	21	15	10	6									
8	28	21	15	10									
9	36	28	21	15	10								
10	45	36	28	21	15								
11	55	45	36	28	21	15							
12	66	55	45	36	28	21							
13	78	66	55	45	36	28	21						
14	91	78	66	55	45	36	28						
15	105	91	78	66	55	45	36	28					
16	120	105	91	78	66	55	45	36					
17	136	120	105	91	78	66	55	45	36				
18	153	136	120	105	91	78	66	55	45				
19	171	153	136	120	105	91	78	66	55	45			
20	190	171	153	136	120	105	91	78	66	55			
21	210	190	171	153	136	120	105	91	78	66	55		
22	231	210	190	171	153	136	120	105	91	78	66		
23	253	231	210	190	171	153	136	120	105	91	78	66	
24	276	253	231	210	190	171	153	136	120	105	91	78	
25	300	276	253	231	210	190	171	153	136	120	105	91	78
26	325	300	276	253	231	210	190	171	153	136	120	105	91

NOTE.—For the stresses in diagonals of lateral systems of double cancellation, *i.e.*, those systems in which the diagonals are composed of intersecting struts, divide the coefficients in the above table by two.

TABLE XV.

COEFFICIENTS OF *W* TAN θ FOR COMPRESSION-STRESSES IN WINDWARD BOTTOM CHORDS OF THROUGH-BRIDGES, AND WINDWARD TOP CHORDS OF DECK BRIDGES, DUE TO WIND LOADS APPLIED DIRECTLY TO SAID CHORDS, WHEN THE LATERAL SYSTEM IS OF SINGLE CANCELLATION. THE TENSILE STRESSES IN LEEWARD CHORDS ARE NUMERICALLY EQUAL TO THE COMPRESSION STRESSES GIVEN IN THE TABLE FOR ONE PANEL NEARER END OF SPAN.

No. of Panels in Span.	Number of Panel from End of Span.												
	1	2	3	4	5	6	7	8	9	10	11	12	13
4	1½	2											
5	2	3	3										
6	2½	4	4½										
7	3	5	6	6									
8	3½	6	7½	8									
9	4	7	9	10	10								
10	4½	8	10½	12	12½								
11	5	9	12	14	15	15							
12	5½	10	13½	16	17½	18							
13	6	11	15	18	20	21	21						
14	6½	12	16½	20	22½	24	24½						
15	7	13	18	22	25	27	28	28					
16	7½	14	19½	24	27½	30	31½	32					
17	8	15	21	26	30	33	35	36	36				
18	8½	16	22½	28	32½	36	38½	40	40½				
19	9	17	24	30	35	39	42	44	45	45			
20	9½	18	25½	32	37½	42	45½	48	49½	50			
21	10	19	27	34	40	45	49	52	54	55	55		
22	10½	20	28½	36	42½	48	52½	56	58½	60	60½		
23	11	21	30	38	45	51	56	60	63	65	66	66	
24	11½	22	31½	40	47½	54	59½	64	67½	70	71½	72	
25	12	23	33	42	50	57	63	68	72	75	77	78	78
26	12½	24	34½	44	52½	60	66½	72	76½	80	82½	84	84½

TABLE XVI.

INTENSITIES OF WORKING-STRESSES FOR VARIOUS MATERIALS.

TENSION-STRESSES.

Eye-bars	18000 lbs. per sq. in.
Shapes	16000 " " " "
Flanges of floor-beams and stringers (counting in ⅛ of web)	14000 " " " "
Hip verticals (eye-bars)	16000 " " " "
" " (shapes) and hanger-plates *	14000 " " " "
Adjustable members, soft steel	16000 " " " "
" " wrought iron	13000 " " " "
Lateral rods	18000 " " " "
" shapes	16000 " " " "

COMPRESSION-STRESSES.

Top-chords	18000 lbs. − $70\frac{l}{r}$ per sq. in.
Inclined end posts	18000 lbs. − $80\frac{l}{r}$ " " "
Intermediate posts and subdiagonals	16000 lbs. − $80\frac{l}{r}$ " " "
Lateral struts (no impact for wind loads)	16000 lbs. − $60\frac{l}{r}$ " " "
Columns of viaducts (fixed ends)	16000 lbs. − $60\frac{l}{r}$ " " "

(l = unsupported length; r = radius of gyration, both in same unit.)

End stiffeners in plate-girders	14000 lbs " " "
Forked ends and extension-plates	10000 lbs. − $300\frac{l}{t}$ " " "

(l = length in inches from centre of pinhole to first rivet beyond point where full section of member begins; t = thickness of plate.)

Rollers, allowing for impact, static load	600d per lin. in.
" " " " moving load	200d " " "

(d = diameter of rollers in inches.)

SHEARING-STRESSES.

Webs of plate-girders, medium steel, net section	10000 lbs. per sq. in.
Rivets	10000 " " " "
Pins	15000 " " " "

BENDING-STRESSES.

Extreme fibre of rolled sections of medium steel, impact included	16000 lbs. per sq. in.
Extreme fibre of timber beams, impact included	2000 " " " "

---

* Increase net section through eye 50 per cent over that of body of member.

TABLE XVI—(*Continued.*)

INTENSITIES OF WORKING-STRESSES FOR VARIOUS MATERIALS.

BEARING-STRESSES.

Rivets	20,000 lbs. per sq. in.
Chord pins	22,000 " " " "
Lateral pins	28,600 " " " "

Impact, railway bridges, $I = \frac{400}{L + 500}$.

Impact, highway bridges, $I = \frac{100}{L + 150}$.

(L = Length in feet of span.)

For reversing-stresses figure the areas required for both tension and compression and add ¾ of the lesser area to the greater.

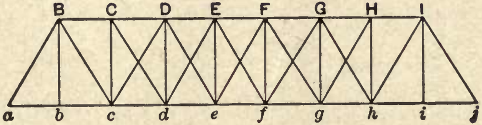
For combined dead, live, and wind load stresses strain 30 per cent higher than for dead and live load only.

The effect of reversion of stresses in case of wind loads is to be ignored.

No impact is to be added for centrifugal and traction loads.

TABLE XVII.

MAXIMUM STRESSES UNDER DEAD AND LIVE LOADS IN PRATT TRUSSES.



W = Dead Load per panel.
L = Live Load per panel.

For any other truss, letter vertices in manner shown.

The Live and Dead Loads are uniform per foot of span.

Panels of through and deck bridges are of equal length.

The Dead Load is assumed as concentrated at lower vertices of trusses for through-bridges and at upper vertices of trusses for deck-bridges.

Member.	12-panel Truss.	11-panel Truss.	10-panel Truss.	9-panel Truss.	8-panel Truss.	Multiply by
aB	W 5.5 + L 5 5	W 5 + L 5	W 4.5 + L 4.5	W 4 + L 4	W 3.5 + L 3.5	Length of member divided by depth of truss.
Bc	“ 4.5 + “ $\frac{55}{12}$	“ 4 + “ $\frac{45}{11}$	“ 3 5 + “ 3.6	“ 3 + “ $\frac{28}{9}$	“ 2.5 + “ $\frac{21}{8}$	
Cd	“ 3.5 + “ $\frac{45}{12}$	“ 3 + “ $\frac{36}{11}$	“ 2.5 + “ 2.8	“ 2 + “ $\frac{21}{9}$	“ 1.5 + “ $\frac{15}{8}$	
De	“ 2.5 + “ $\frac{36}{12}$	“ 2 + “ $\frac{28}{11}$	“ 1.5 + “ 2.1	“ 1 + “ $\frac{15}{9}$	“ 0.5 + “ $\frac{10}{8}$	
Ef	“ 1.5 + “ $\frac{28}{12}$	“ 1 + “ $\frac{21}{11}$	“ 0.5 + “ 1 5	“ 0 + “ $\frac{10}{9}$	−“ 0.5 + “ $\frac{6}{8}$	
Fg	“ 0.5 + “ $\frac{21}{12}$	“ 0 + “ $\frac{15}{11}$	−“ 0.5 + “ 1.0	− “ 1 + “ $\frac{6}{9}$	−“ 1.5 + “ $\frac{3}{8}$	
Gh	−“ 0.5 + “ $\frac{15}{12}$	− “ 1 + “ $\frac{10}{11}$	−“ 1.5 + “ 0.6	− “ 2 + “ $\frac{3}{9}$		
Hi	−“ 1.5 + “ $\frac{10}{12}$	− “ 2 + “ $\frac{6}{11}$				

MAXIMUM STRESSES UNDER DEAD AND LIVE LOADS IN PRATT TRUSSES—*Continued.*

Member.		12-panel Truss.	11-panel Truss.	10-panel Truss.	9-panel Truss.	8-panel Truss.	Multiply by
	abc	*W* 5.5 + *L* 5.5	*W* 5 + *L* 5	*W* 4.5 + *L* 4.5	*W* 4 + *L* 4	*W* 3.5 + *L* 3.5	Panel length divided by depth of truss.
BC	*cd*	“ 10.0 + “ 10.0	“ 9 + “ 9	“ 8.0 + “ 8.0	“ 7 + “ 7	“ 6.0 + “ 6.0	
CD	*de*	“ 13.5 + “ 13.5	“ 12 + “ 12	“ 10.5 + “ 10.5	“ 9 + “ 9	“ 7.5 + “ 7.5	
DE	*ef*	“ 16.0 + “ 16.0	“ 14 + “ 14	“ 12.0 + “ 12.0	“ 10 + “ 10	“ 8.0 + “ 8.0	
EF	*fg*	“ 17.5 + “ 17.5	“ 15 + “ 15	“ 12.5 + “ 12.5			
FG		“ 18.0 + “ 18.0					
Through	Deck						
	Cc	“ 4.5 + “ $\frac{55}{12}$	“ 4 + “ $\frac{45}{11}$	“ 3.5 + “ 3.6	“ 3 + “ $\frac{28}{9}$	“ 2.5 + “ $\frac{21}{8}$	Unity.
Cc	*Dd*	“ 3.5 + “ $\frac{45}{12}$	“ 3 + “ $\frac{36}{11}$	“ 2.5 + “ 2.8	“ 2 + “ $\frac{21}{9}$	“ 1.5 + “ $\frac{15}{8}$	
Dd	*Ee*	“ 2.5 + “ $\frac{36}{12}$	“ 2 + “ $\frac{28}{11}$	“ 1.5 + “ 2.1	“ 1 + “ $\frac{15}{9}$	“ 0.5 + “ $\frac{10}{8}$	
Ee	*Ff*	“ 1.5 + “ $\frac{28}{12}$	“ 1 + “ $\frac{21}{11}$	“ 0.5 + “ 1.5	“ 0 + “ $\frac{10}{9}$	−“ 0.5 + “ $\frac{6}{8}$	
Ff	*Gg*	“ 0.5 + “ $\frac{21}{12}$	“ 0 + “ $\frac{15}{11}$	−“ 0.5 + “ 1.0			
Gg		−“ 0.5 + “ $\frac{15}{12}$					

Member.		7-panel Truss.	6 panel Truss.	5-panel Truss.	4-panel Truss.	3-panel Truss.	Multiply by
	aB	*W* 3 + *L* 3	*W* 2.5 + *L* 2.5	*W* 2 + *L* 2.0	*W* 1.5 + *L* 1.5	*W* 1 + *L* 1	Length of member divided by depth of truss.
	Bc	“ 2 + “ $\frac{15}{7}$	“ 1.5 + “ $\frac{10}{8}$	“ 1 + “ 1.2	“ 0.5 + “ $\frac{3}{4}$	“ 0 + “ $\frac{1}{3}$	
	Cd	“ 1 + “ $\frac{10}{7}$	“ 0.5 + “ 1.0	“ 0 + “ 0.6	−“ 0.5 + “ $\frac{1}{4}$		
	De	“ 0 + “ $\frac{6}{7}$	−“ 0.5 + “ 0.5	− “ 1 + “ 0.2			
	Ef	− “ 1 + “ $\frac{3}{7}$					
	abc	“ 3 + “ 3	“ 2.5 + “ 2.5	“ 2 + “ 2	“ 1.5 + “ 1.5	“ 1 + “ 1	Panel length div. by depth of truss.
BC	*cd*	“ 5 + “ 5	“ 4.0 + “ 4.0	“ 3 + “ 3	“ 2.0 + “ 2.0	“ 1 + “ 1	
CD	*de*	“ 6 + “ 6	“ 4.5 + “ 4.5				
Through	Deck						
	Cc	“ 2 + “ $\frac{15}{7}$	“ 1.5 + “ $\frac{10}{8}$	“ 1 + “ 1.2	“ 0.5 + “ $\frac{3}{4}$		Unity.
Cc	*Dd*	“ 1 + “ $\frac{10}{7}$	“ 0.5 + “ 1.0	“ 0 + “ 0.6	−“ 0.5 + “ $\frac{1}{4}$		
Dd	*Ee*	“ 0 + “ $\frac{6}{7}$	−“ 0.5 + “ 0.5				

TABLE XVIII.

SUPERELEVATIONS OF OUTER RAIL ON CURVES.

$$E = \frac{.3277V^2}{R}.$$

E = Elevation in feet.
V = Velocity in miles per hour.
R = Radius in feet.

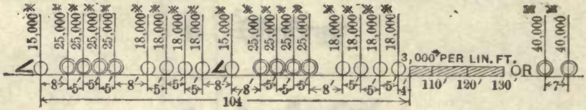
Degree.	Speed in Miles per Hour.											Degree.
	10	15	20	25	30	35	40	45	50	55	60	
1	1/16"	1/8"	1/4"	7/16"	5/8"	13/16"	1 1/16"	1 3/8"	1 11/16"	2 1/16"	2 1/2"	1
2	1/8	5/16	9/16	7/8	1 1/4	1 11/16	2 3/16	2 3/4	3 7/16	4 1/8	4 15/16	2
3	3/16	7/16	13/16	1 5/16	1 7/8	2 1/2	3 5/16	4 1/8	5 1/8	6 3/16	7 3/8	3
4	1/4	5/8	1 1/16	1 11/16	2 1/2	3 3/8	4 3/8	5 9/16	6 13/16	8 1/4	9 3/4	4
5	3/8	3/4	1 3/8	2 1/8	3 1/16	4 3/16	5 7/16	6 7/8	8 1/2	10 1/4	12 1/16	5
6	7/16	15/16	1 5/8	2 9/16	3 11/16	5.0	6 9/16	8 1/4	10 1/4	13 5/8		
7	1/2	1 1/16	1 15/16	3.0	4 5/16	5 13/16	7 5/8	9 9/16	11 3/4			
8	9/16	1 1/4	2 3/16	3 3/8	4 7/8	6 9/16	8 11/16	10 1/8				
9	5/8	1 3/8	2 1/2	3 13/16	5 1/2	7 1/2	9 3/4	12 3/16				
10	11/16	1 9/16	2 3/4	4 1/4	6 1/8	8 5/16	10 3/4					
11	3/4	1 11/16	3.0	4 11/16	6 3/4	9 1/8	11 13/16					
12	13/16	1 7/8	3 5/16	5 1/8	7 5/16	9 15/16	12 13/16					
14	15/16	2 3/16	3 13/16	5 15/16	8 9/16	11 1/2						
16	1 1/16	2 1/2	4 3/8	6 13/16	9 11/16	13 1/16						
18	1 1/4	2 3/4	4 15/16	7 5/8	10 7/8							
20	1 3/8	3 1/16	5 7/16	8 1/2	12.0							
24	1 5/8	3 11/16	6 1/2	10 1/16								
30	2.0	4 9/16	8 1/16	12 7/16								
40	2 11/16	6.0	10 9/16									

PLATE

AXLE CONCENTRATIONS
FOR
THE COMPROMISE STANDARD SYSTEM
OF
LIVE LOADS FOR RAILWAY BRIDGES.

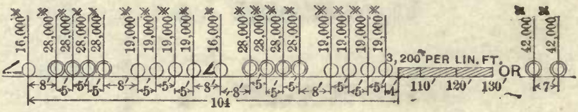
CLASS Z.

TOTAL WEIGHT OF ONE ENGINE AND TENDER=93.5 TONS.



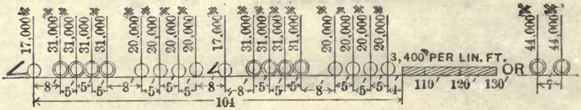
CLASS Y.

TOTAL WEIGHT OF ONE ENGINE AND TENDER= 102 TONS.



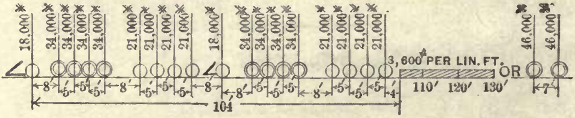
CLASS X.

TOTAL WEIGHT OF ONE ENGINE AND TENDER=110.5 TONS.



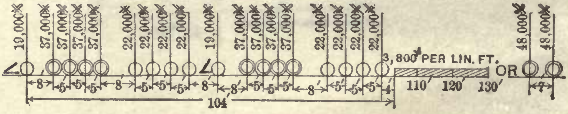
CLASS W.

TOTAL WEIGHT OF ONE ENGINE AND TENDER =119 TONS.



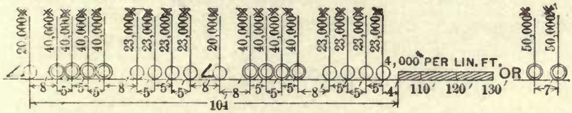
CLASS V.

TOTAL WEIGHT OF ONE ENGINE AND TENDER=127.5 TONS.



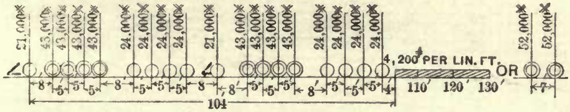
CLASS U.

TOTAL WEIGHT OF ONE ENGINE AND TENDER = 136 TONS.



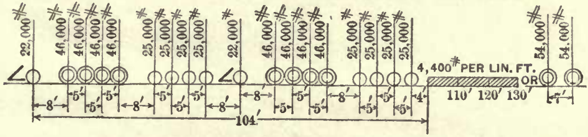
CLASS T.

TOTAL WEIGHT OF ONE ENGINE AND TENDER = 144.5 TONS.



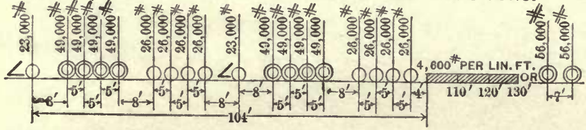
CLASS S.

TOTAL WEIGHT OF ONE ENGINE AND TENDER = 153 TONS.



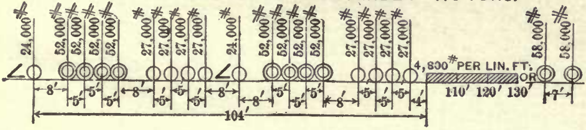
CLASS R.

TOTAL WEIGHT OF ONE ENGINE AND TENDER = 161.5 TONS.



CLASS Q.

TOTAL WEIGHT OF ONE ENGINE AND TENDER = 170 TONS.



N.B. These concentrated loads are to be employed only as a standard of reference, and are the loads which were used in obtaining the data for plotting the curves on Plates, Nos. 2, 3 & 4. For finding stresses use the equivalent loads given by said curves.

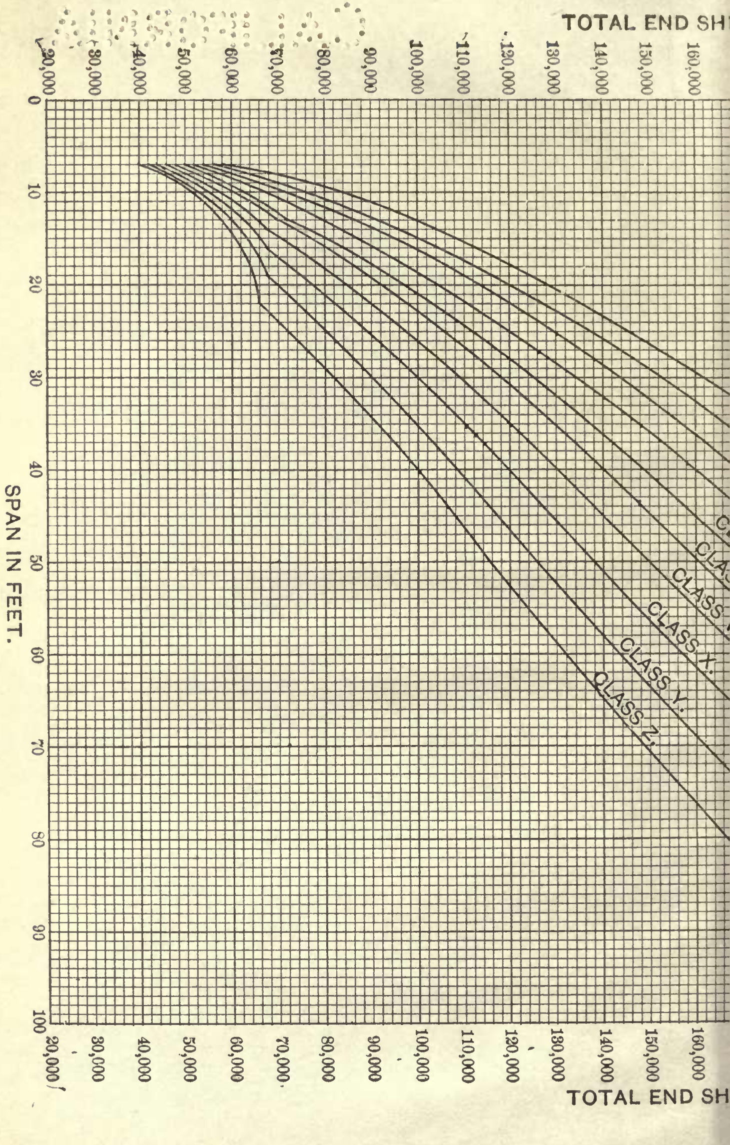

TOTAL END SH
20,000
30,000
40,000
50,000
60,000
70,000
80,000
90,000
100,000
110,000
120,000
130,000
140,000
150,000
160,000
0
10
20
30
40
50
60
70
80
90
100
SPAN IN FEET.
CLASS X.
CLASS Y.
CLASS Z.
CLASS
CLAS
20,000
30,000
40,000
50,000
60,000
70,000
80,000
90,000
100,000
110,000
120,000
130,000
140,000
150,000
160,000
TOTAL END SH

PLATE II.

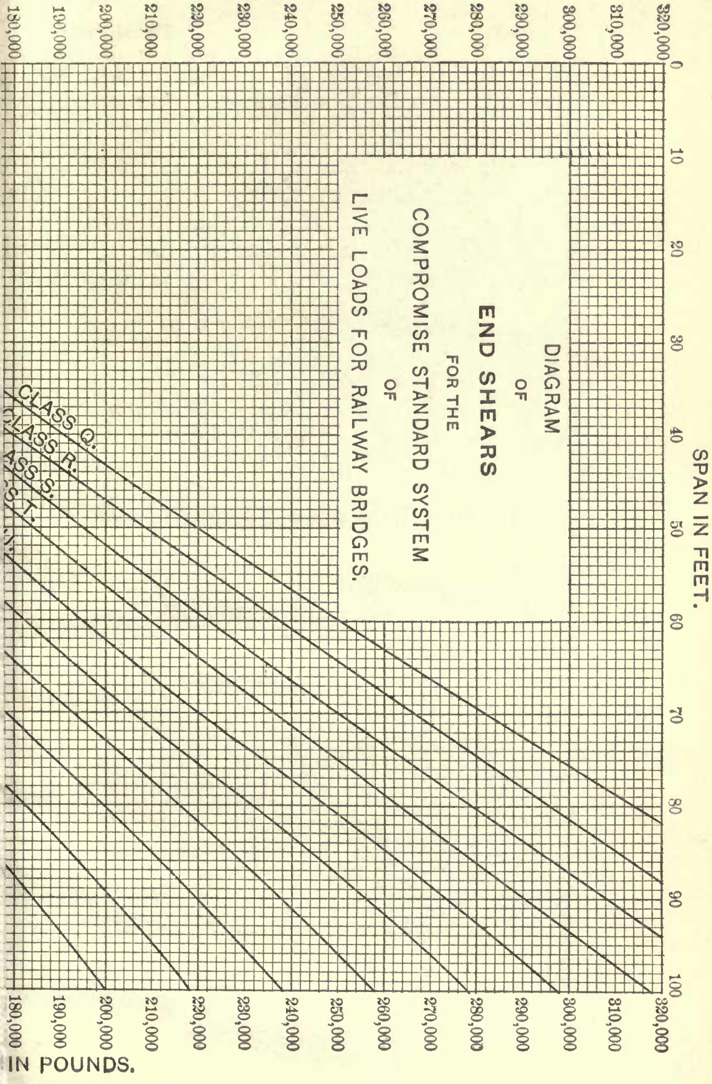
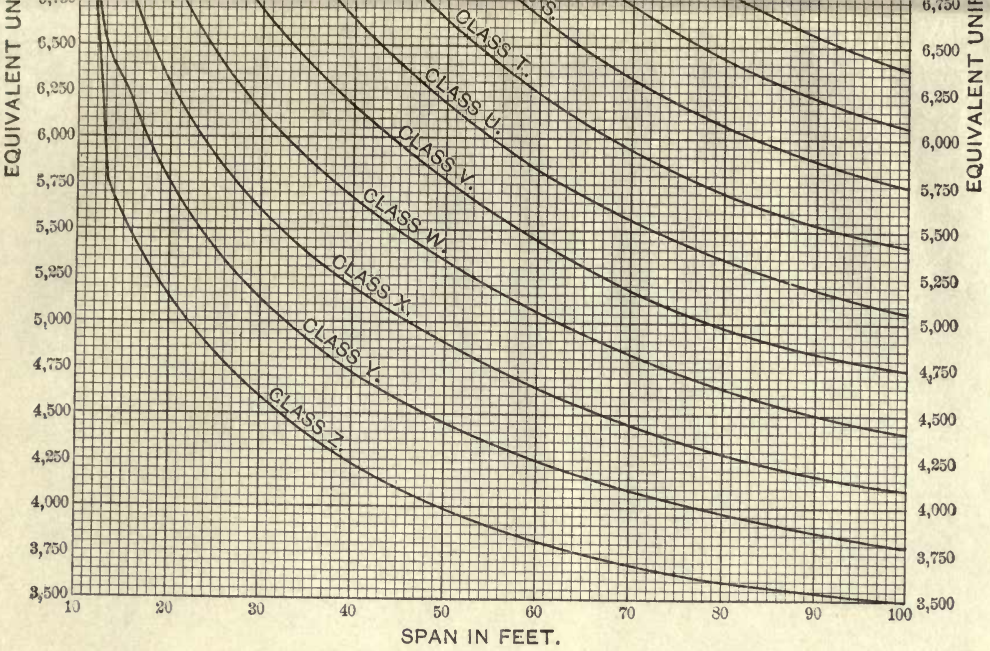


DIAGRAM OF **END SHEARS** FOR THE COMPROMISE STANDARD SYSTEM OF LIVE LOADS FOR RAILWAY BRIDGES.



N.B. FOR PANELS OR SPANS SHORTER THAN 10′, USE ONE OF THE AXLE LOADS OF THE ALTERNATIVE LOADING (PLACING THE WHEEL AT MID-LENGTH) AND THE FORMULA $M = \frac{1}{4} WL$.

PLATE III.

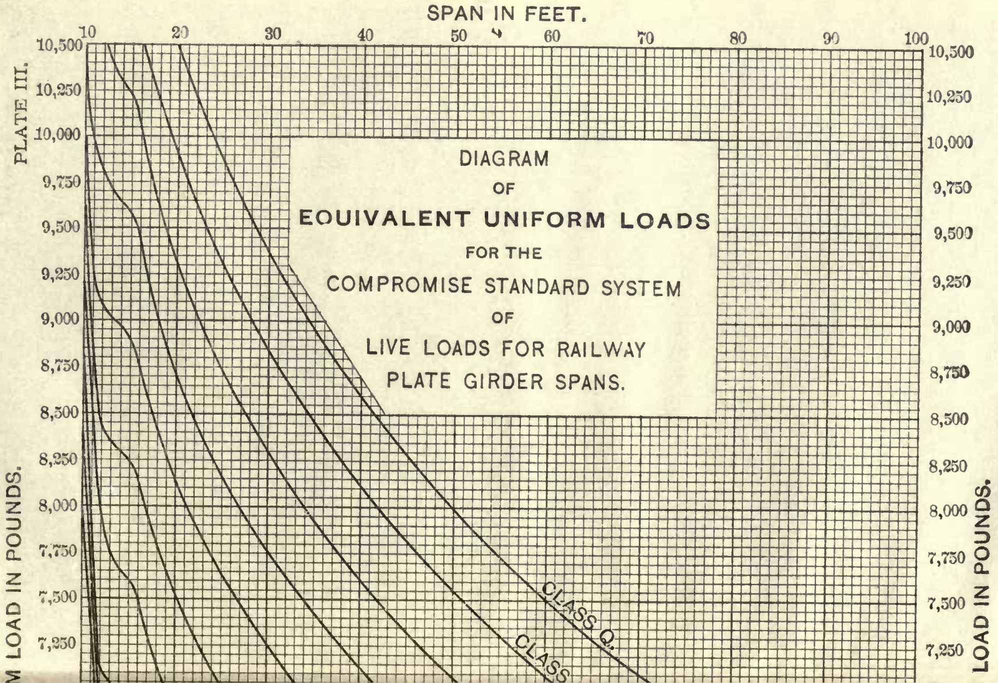


DIAGRAM
OF
EQUIVALENT UNIFORM LOADS
FOR THE
COMPROMISE STANDARD SYSTEM
OF
LIVE LOADS FOR RAILWAY
PLATE GIRDER SPANS.

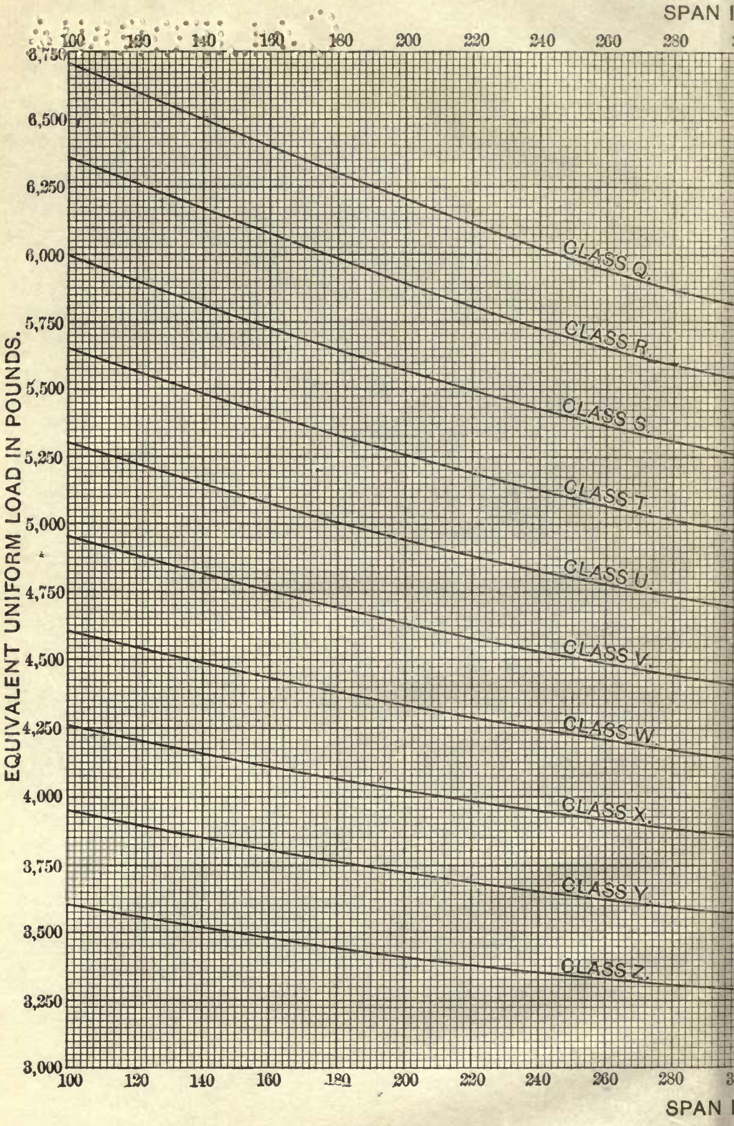

SPAN I
100
120
140
160
180
200
220
240
260
280
EQUIVALENT UNIFORM LOAD IN POUNDS.
6,750
6,500
6,250
6,000
5,750
5,500
5,250
5,000
4,750
4,500
4,250
4,000
3,750
3,500
3,250
3,000
CLASS Q.
CLASS R.
CLASS S.
CLASS T.
CLASS U.
CLASS V.
CLASS W.
CLASS X.
CLASS Y.
CLASS Z.
100
120
140
160
180
200
220
240
260
280
SPAN I

PLATE IV.

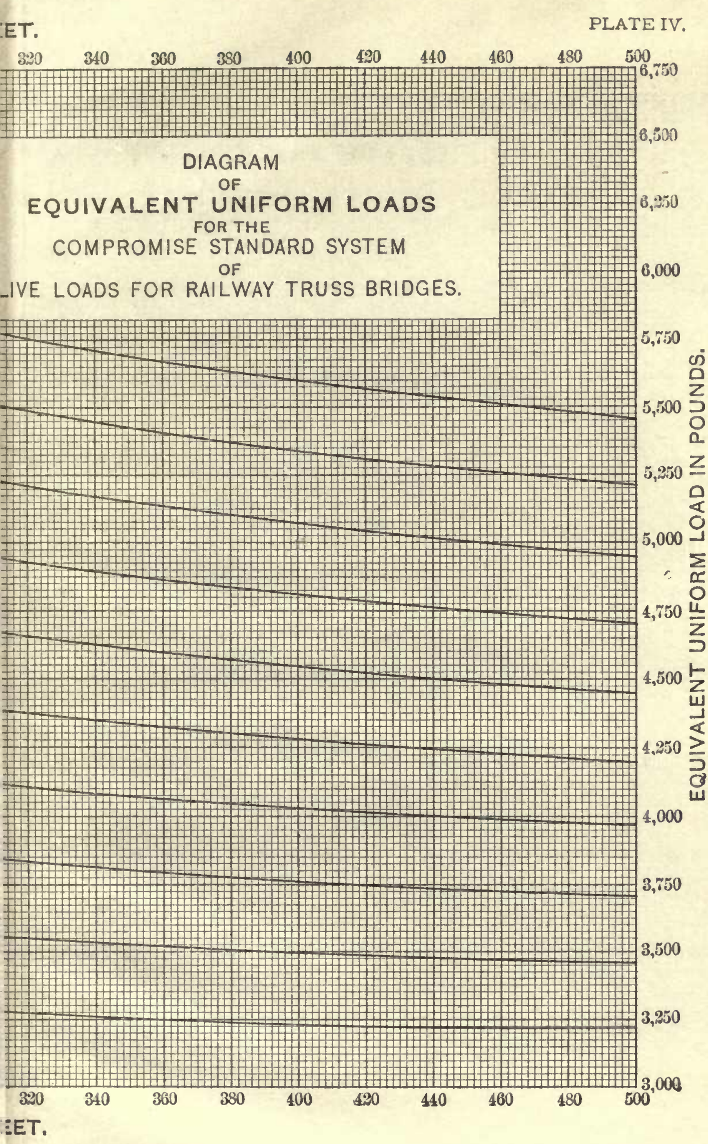


DIAGRAM
OF
EQUIVALENT UNIFORM LOADS
FOR THE
COMPROMISE STANDARD SYSTEM
OF
LIVE LOADS FOR RAILWAY TRUSS BRIDGES.

PLATE V.

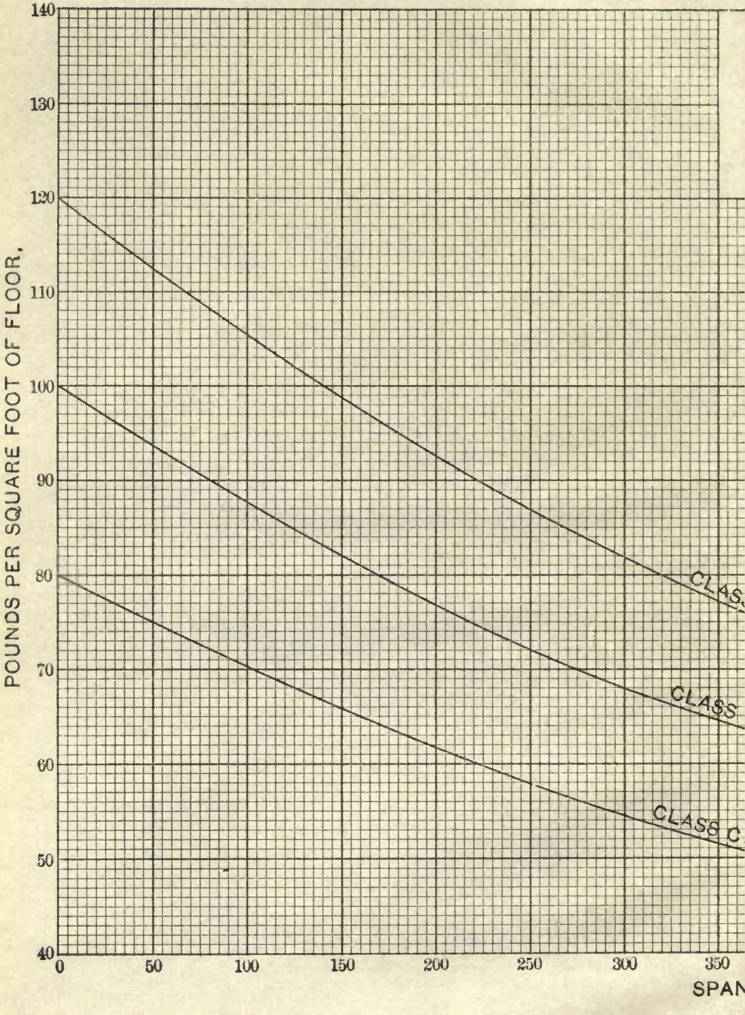
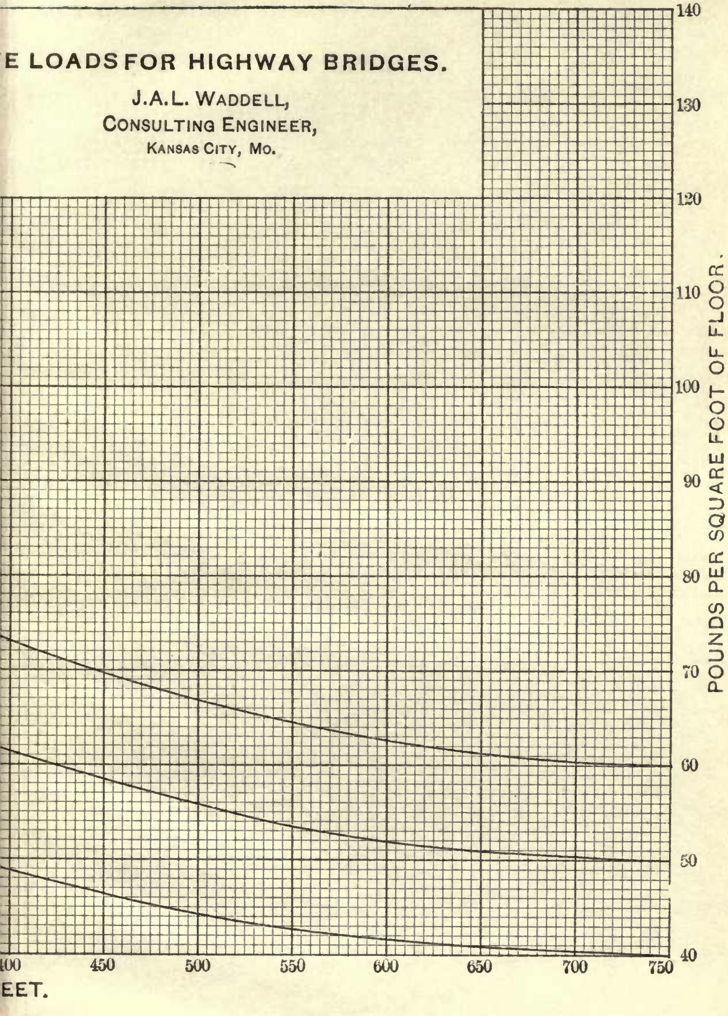

POUNDS PER SQUARE FOOT OF FLOOR.
140
130
120
110
100
90
80
70
60
50
40
0
50
100
150
200
250
300
350
SPAN
CLAS
CLASS
CLASS C

PLATE V.


E LOADS FOR HIGHWAY BRIDGES.
J.A.L. WADDELL,
CONSULTING ENGINEER,
KANSAS CITY, MO.
140
130
120
110
100
90
80
70
60
50
40
POUNDS PER SQUARE FOOT OF FLOOR.
400
450
500
550
600
650
700
750
EET.

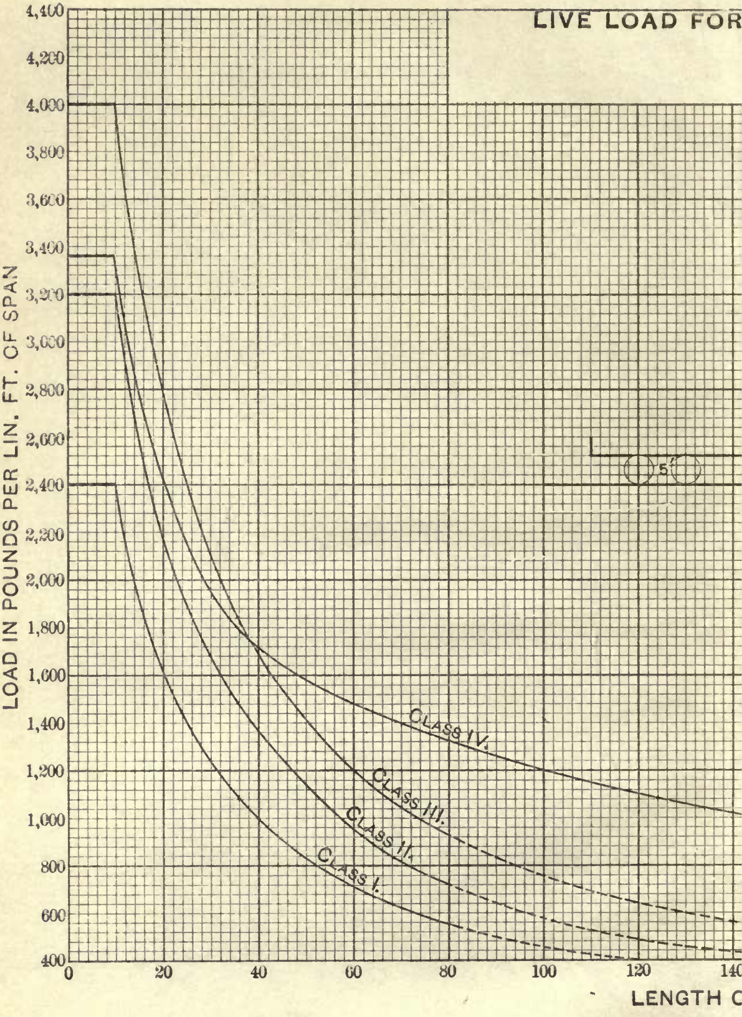

LIVE LOAD FOR
LOAD IN POUNDS PER LIN. FT. OF SPAN
4,400
4,200
4,000
3,800
3,600
3,400
3,200
3,000
2,800
2,600
2,400
2,200
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
0
20
40
60
80
100
120
140
5'
CLASS IV.
CLASS III.
CLASS II.
CLASS I.
LENGTH C

PLATE VI

CTRIC CARS FOR HIGHWAY BRIDGES.

J.A.L. WADDELL,
CONSULTING ENGINEER,
KANSAS CITY, MO.

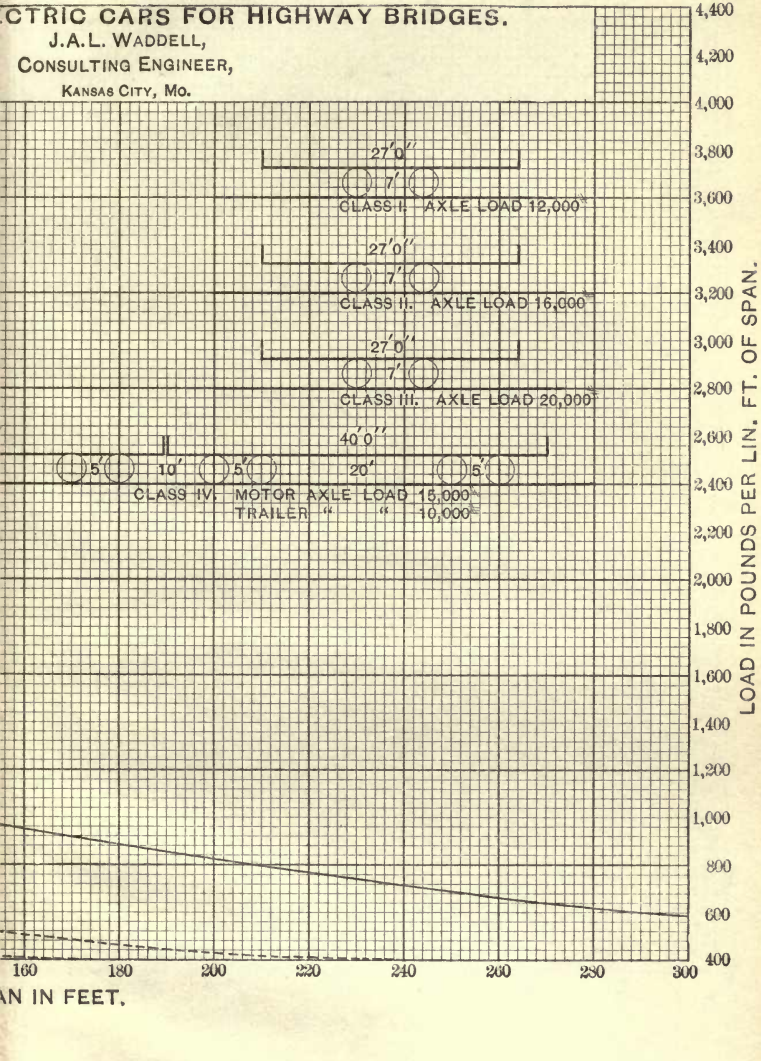


PLATE VII.

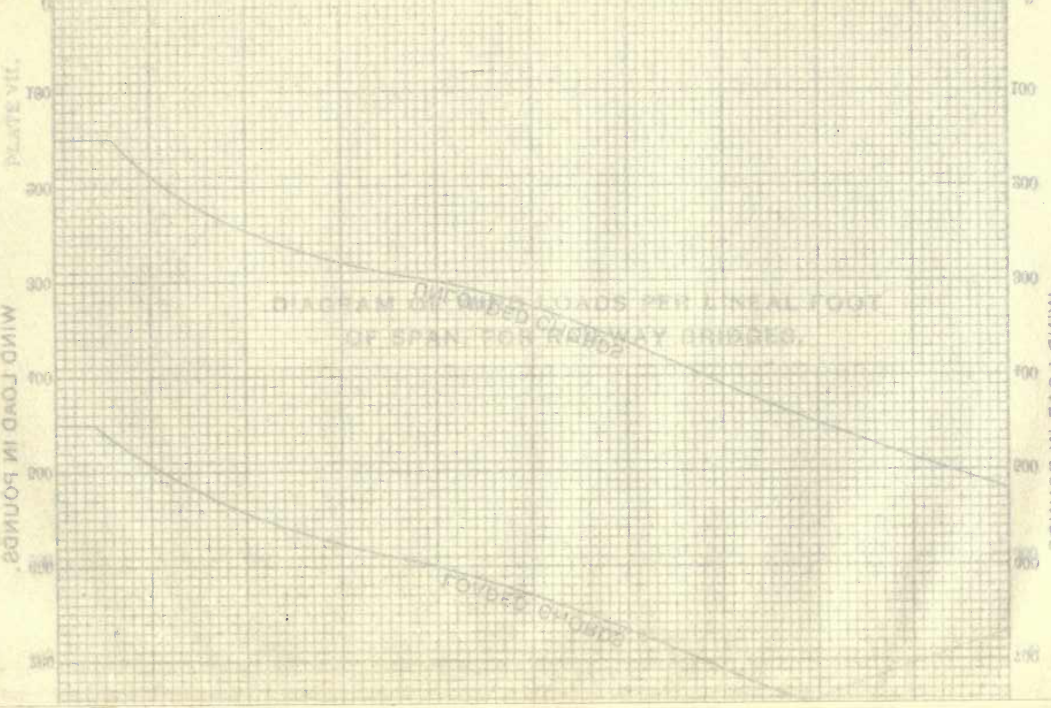


DIAGRAM OF WIND LOADS PER LINEAL FOOT
OF SPAN FOR RAILWAY BRIDGES.
UNLOADED CHORDS
LOADED CHORDS
WIND LOAD IN POUNDS.
WIND LOAD IN POUNDS
100
200
300
400
500
600
700

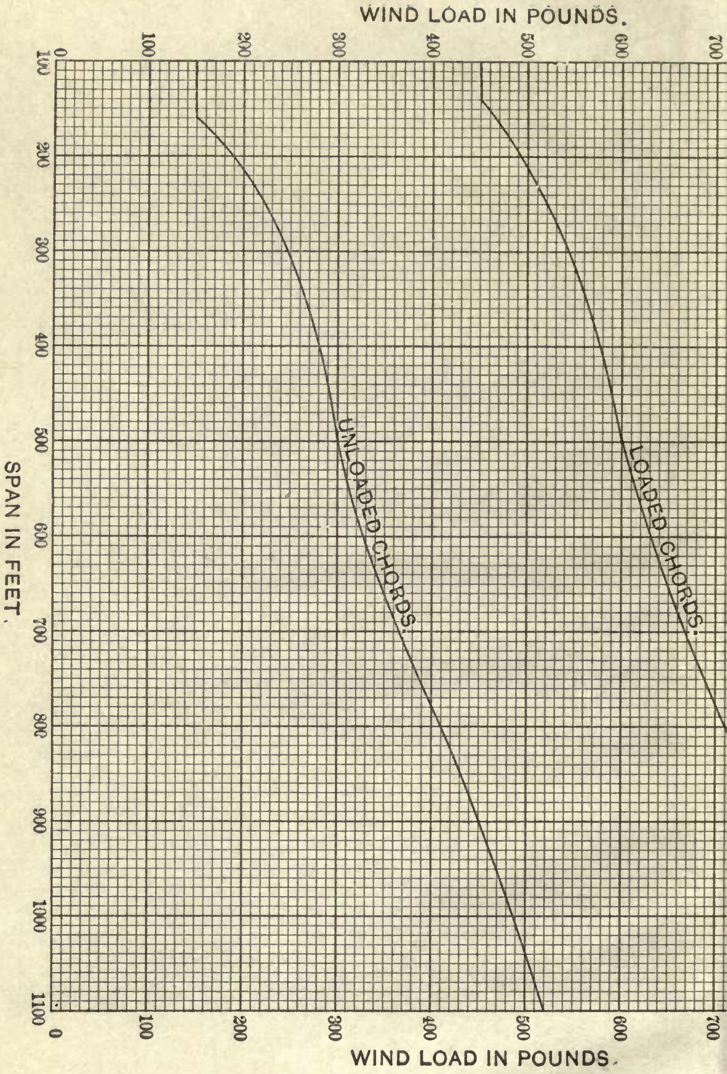

WIND LOAD IN POUNDS.
0
100
200
300
400
500
600
700
SPAN IN FEET.
100
200
300
400
500
600
700
800
900
1000
1100
UNLOADED CHORDS.
LOADED CHORDS.
WIND LOAD IN POUNDS.

PLATE VII.

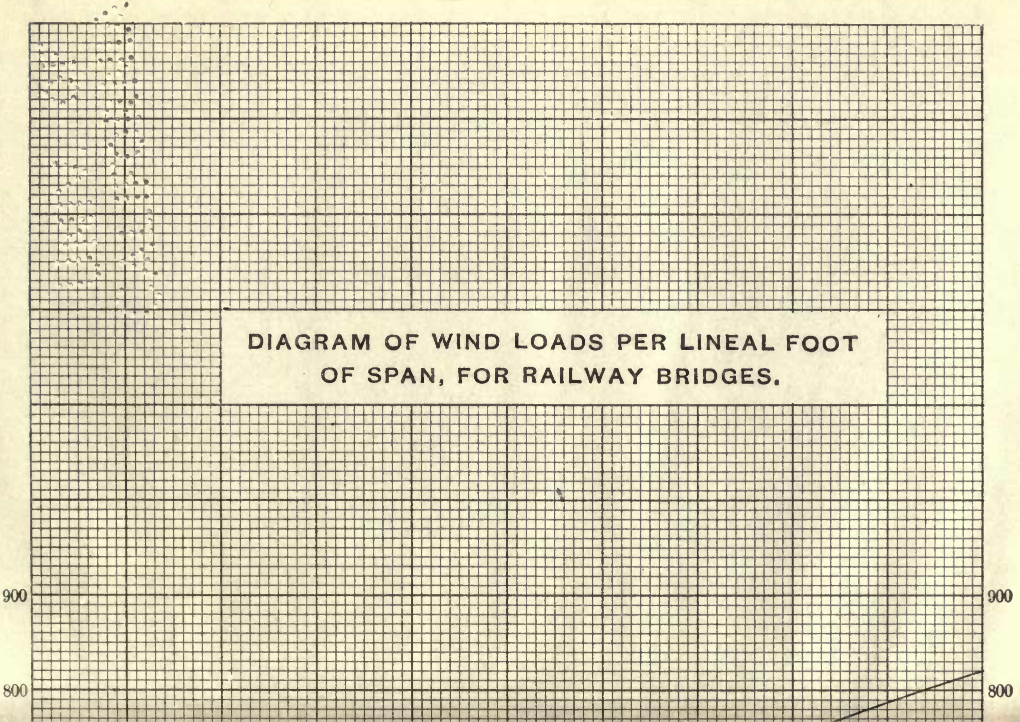


DIAGRAM OF WIND LOADS PER LINEAL FOOT OF SPAN, FOR RAILWAY BRIDGES.

PLATE VIII.

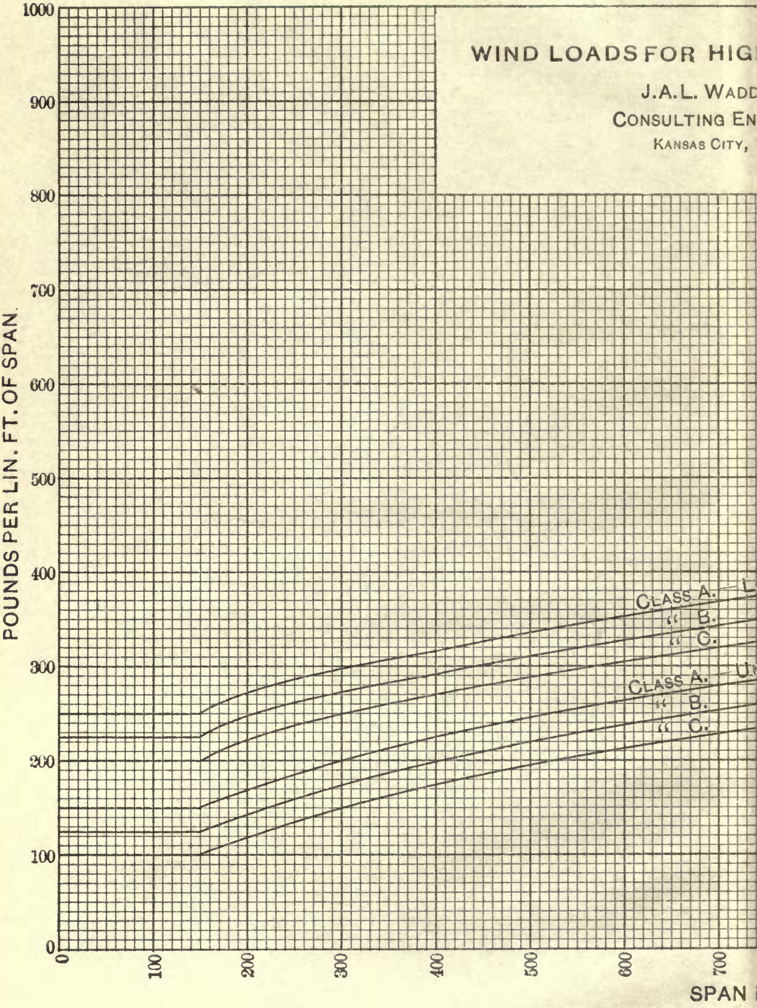
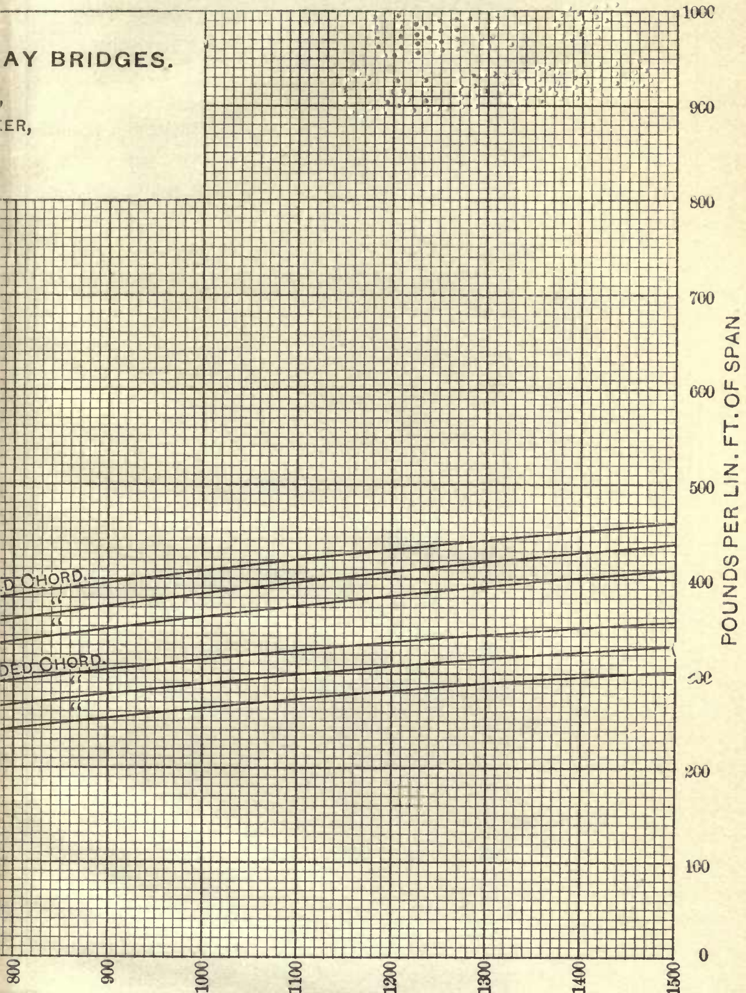

WIND LOADS FOR HIG
J.A.L. WADD
CONSULTING EN
KANSAS CITY,
POUNDS PER LIN. FT. OF SPAN.
1000
900
800
700
600
500
400
300
200
100
0
0
100
200
300
400
500
600
700
SPAN
CLASS A. L
" B.
" C.
CLASS A. UN
" B.
" C.

PLATE VIII.

AY BRIDGES.

,

ER,



EET.

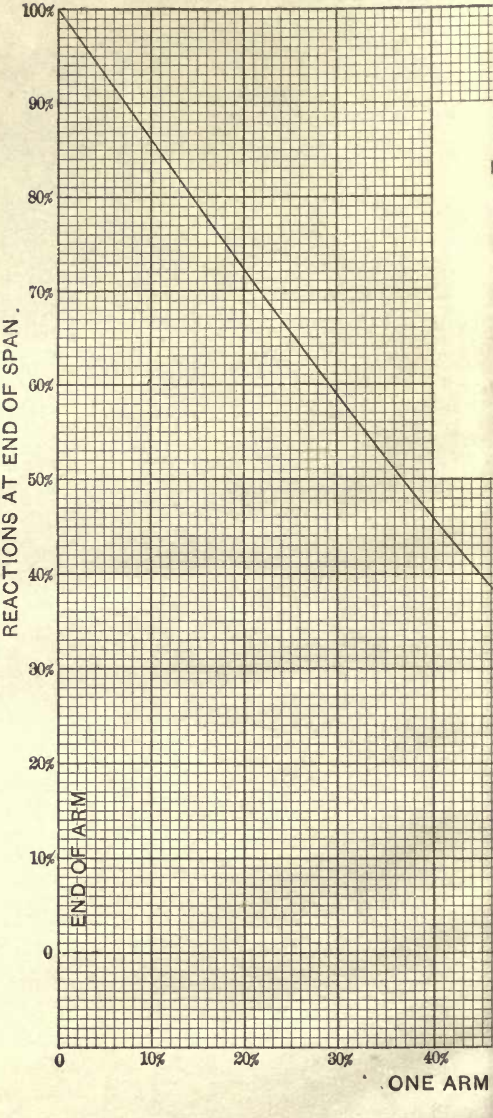
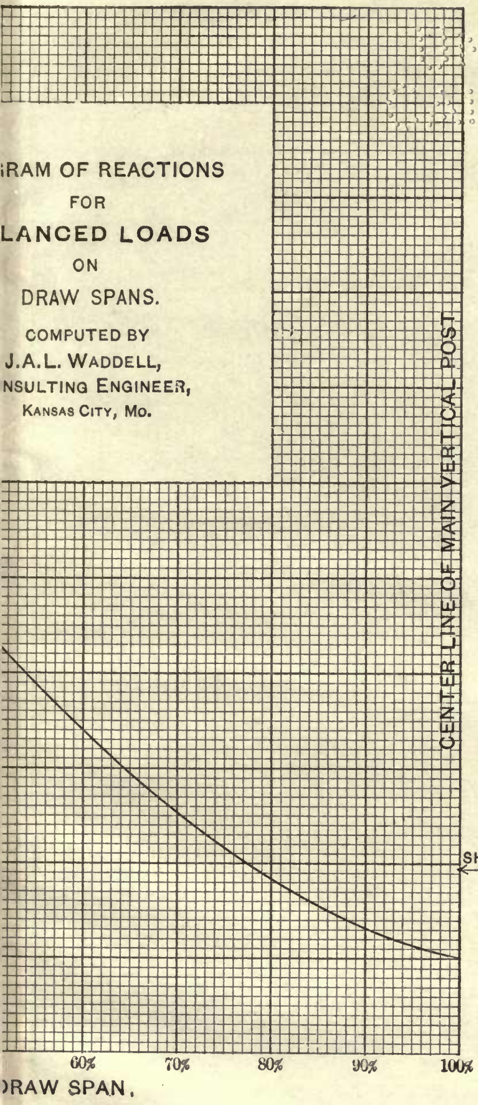

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0
REACTIONS AT END OF SPAN.
END OF ARM
0
10%
20%
30%
40%
ONE ARM

PLATE IX.



RAM OF REACTIONS
FOR
LANCED LOADS
ON
DRAW SPANS.
COMPUTED BY
J.A.L. WADDELL,
NSULTING ENGINEER,
KANSAS CITY, MO.

PLATE X

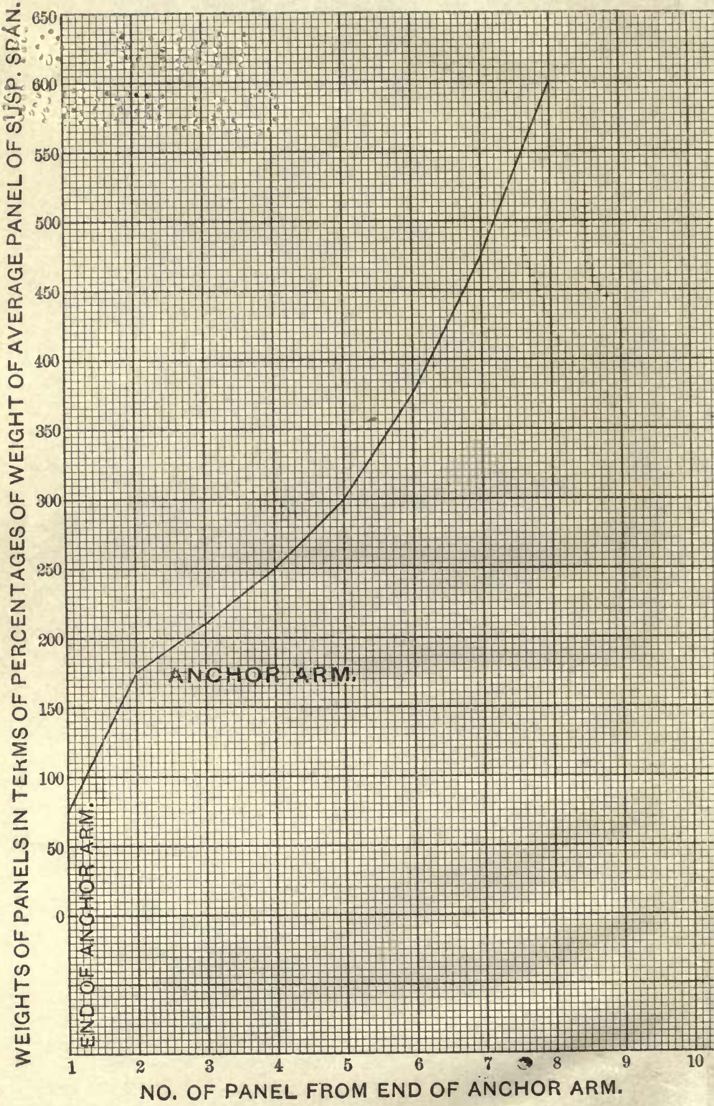
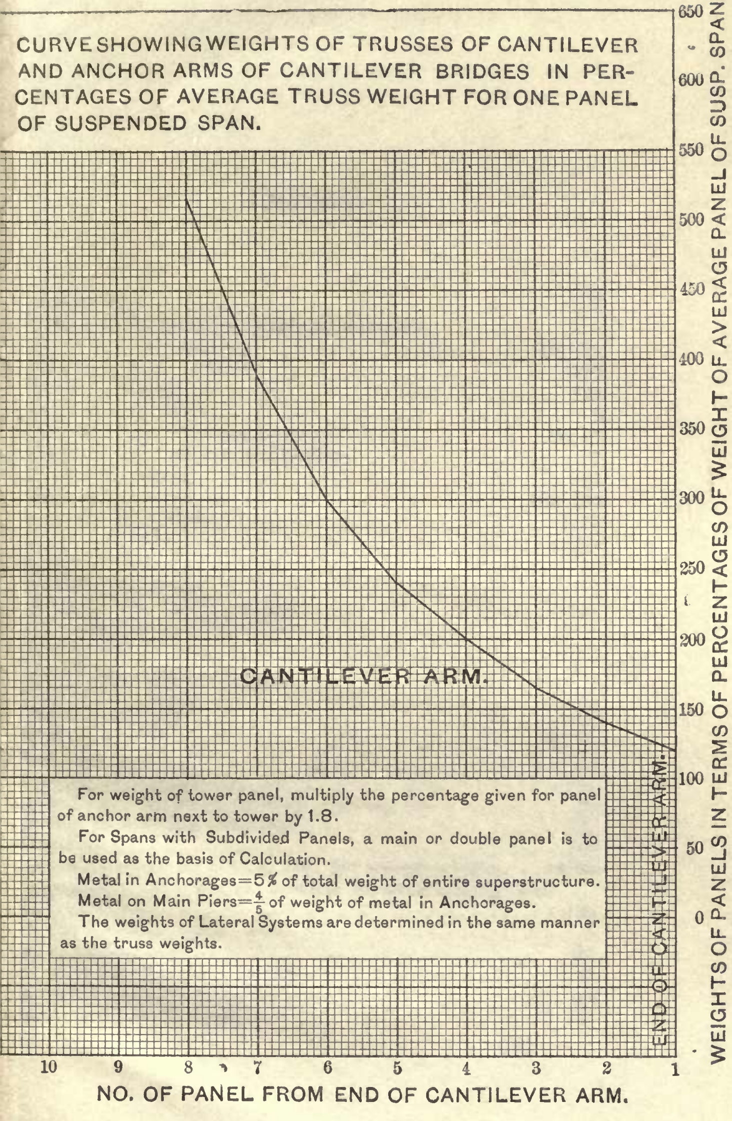

WEIGHTS OF PANELS IN TERMS OF PERCENTAGES OF WEIGHT OF AVERAGE PANEL OF SUSP. SPAN.
650
600
550
500
450
400
350
300
250
200
150
100
50
0
ANCHOR ARM.
END OF ANCHOR ARM.
1
2
3
4
5
6
7
8
9
10
NO. OF PANEL FROM END OF ANCHOR ARM.

PLATE X.



CURVE SHOWING WEIGHTS OF TRUSSES OF CANTILEVER AND ANCHOR ARMS OF CANTILEVER BRIDGES IN PERCENTAGES OF AVERAGE TRUSS WEIGHT FOR ONE PANEL OF SUSPENDED SPAN.

For weight of tower panel, multiply the percentage given for panel of anchor arm next to tower by 1.8.

For Spans with Subdivided Panels, a main or double panel is to be used as the basis of Calculation.

Metal in Anchorages = 5 % of total weight of entire superstructure.

Metal on Main Piers = $\frac{4}{5}$ of weight of metal in Anchorages.

The weights of Lateral Systems are determined in the same manner as the truss weights.

INDEX.