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Sir Adolphe

With Mr Tomlinson's
Compliments

EXPLANATORY NOTES

OF THE

CANADIAN LONG-SPAN RAILWAY BRIDGE

BY

JOSEPH TOMLINSON, Bridge Engineer.

OTTAWA, CANADA,

MAY 1ST., 1886.

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CANADIAN LONG-SPAN RAILWAY BRIDGE

DESIGNED BY

JOSEPH TOMLINSON, Bridge Engineer.

EXPLANATORY NOTES.

The design has been conceived in connection with the growing necessity of bridging large streams, or other navigable waters, where from the depth, rapidity of the current, or other cause, it would be impracticable to cross otherwise than by long spans, self supporting during erection.

The length of span has hitherto been limited, in bridges constructed with eye-bars, by the fast increasing width of the chords. This difficulty is overcome in the present design by placing a number of eye-bar chords one over the other until the required section or strength is attained, thus forming what may be called a compound chord of chords.

Not only, however, does the design set forth the great lengths to which bridges with eye-bar and pin connections can be carried, but it also illustrates that in large bridge structures the details can be simplified so that only ordinary sizes and shapes of steel need be used; such sizes and shapes as are usually made at first class rolling mills. The great number, similarity and simplicity of the several parts, admit of their being fitted and finished with great accuracy and economy in the shops, and erected with facility, without more labor than is required in ordinary first class bridge work.

The principles of the design are specially adapted to the great range of temperature of the Canadian climate.

The upper and lower members of the cantilever trusses, in this design, are both curved, but either might be straight or horizontal.

The most important feature of the whole design is the facility with which any desired number of medium sized eye-bars can be brought into effective action in the tension members of the structure, and still have every bar take its due proportion of the stresses.

The whole of the steel eye-bars, with the exception of those forming the saddles, are eight inches deep, and generally one and a half inches thick. There are a few that vary in thickness, from seven eighths of an inch to one and three quarter inches. As the stresses in the members increase the number of eye-bars is increased, thus, only a few eye-bars have to deviate from the standard thickness. They are connected together with steel pins, proportioned to resist the calculated bending moments.

GENERAL DIMENSIONS.

The total length of the cantilever trusses and the connecting span is 2640 feet; the distance between the centres of main piers 1510 feet; and the length of each of the shore arms of the cantilevers 565 feet. Over the main piers the cantilever trusses are 212 feet high, and 100 feet in width from centre to centre of trusses. They converge to 32 feet wide at each end of the cantilevers.

The span connecting the cantilevers is 384 feet long, 50 feet deep at the centre and 160 feet above high water.

MASONRY.

MAIN PIERS.

The main piers are 95 feet high above low water, the length at the base, including the ice breakers, is 240 feet; extreme thickness 75 feet, and the thickness of the ice breakers 31 feet. The length of the pier on top is 123 feet, and each bridge seat 21 feet by 66 feet.

The main piers are designed for a rock foundation about 30 feet below low water, and 50 feet below extreme high tides. Each pier, being of large dimensions, is divided into two equal parts below water, and united at the surface by an arch of masonry.

The plan of the piers at bottom consists of two octagons, each 75 feet in diameter, with inclined ice-breakers the same thickness as the length of the side of the octagon; this arrangement presents inclined surfaces of masonry to ice moving either down or up stream. Above the water each pier gradually assumes the shape of the letter **H**, forming the longitudinal bridge-seats, 21 feet wide, and 66 feet long on the top. On each bridge-seat are two sets of masonry bases, upon which stand cast pedestals, placed in line with the converging members of the superstructure.

ANCHORAGE PIERS.

The anchorage piers are about 125 feet high, 66 feet square at the base, and 50 feet square on the top. They have their foundations on rock, above the level of low water. At suitable distances from their upper surfaces, grillages of heavy I beams are built into the masonry for the anchor plates and washers to bear against. Eight well-holes are formed in each pier for the anchorage eye-bars and eye-bolts to pass through. Passages and chambers are formed in the interior of the masonry, to admit of the adjustment and inspection of the anchorages and eye-bar pins. On each pier there are eight masonry bases, placed parallel with the trusses, and mortised through for the eye-bars of the anchorages.

Between the trusses are blocks of masonry, in which are built heavy box beams, to resist the stresses acting through the wind struts.

SUPERSTRUCTURE.

PEDESTALS.

Four cast pedestals under each of the four cantilever trusses sustain the superstructure and all loads that may be supported by it. Each pedestal must have a bearing surface of about 170 square feet on the masonry. Their upper surfaces are to be planed perfectly true and level to receive the steel bed plates under the lower members and the pier posts.

ANCHOR PEDESTALS.

There are also four cast pedestals under each lower chord of the shore arms of the cantilevers, to form bearings for the fixed pins which connect the rocker links to the anchorage eye-bars; their bases have openings to allow the eye-bars to pass through them.

The ribs are arranged to support the pins, and hold the rocker links and eye-bars in juxtaposition.

ANCHORAGES.

There are four separate anchorages at the end of each lower chord of the shore arms of the cantilevers: each anchorage is connected, by the rocker links, with one of the four systems of suspenders, thus allowing the anchorages to spread under a great area of masonry.

The upper eye-bars of the anchorages are connected by the fixed pins to the rocker links, and by similar pins to the loops on the upper ends of the anchor bolts.

Each pair of bolts is slightly inclined in opposite directions, in order that the nuts on their lower ends may be sufficiently far apart to screw up with facility. Large steel plate washers, perforated with holes to suit the anchor-bolts, are to be bedded against the I beam grillages; and to increase the bearing surfaces of the nuts, large cast-steel washers are placed between them and the plates.

LOWER CHORDS.

The lower or compression chords of the cantilever trusses have rectangular sections, formed of four vertical webs with steel angles at top and bottom, top covering plates, and stay plates and channel bar lacing on the under side.

The chords, in each direction from the main piers, are curved upwards, but the curves are composed of straight parts, extending on the under side between points midway between the pairs of vertical posts; and, on the upper side the straight parts extend nearly to the vertical posts nearest the piers in each direction. This arrangement forms plane surfaces for the pairs of posts to rest upon, and cuts off tapering pieces from the upper edges of the webs, thus gradually diminishing the depth of the chords from the panel adjoining the piers to their ends in each direction. The chords are also gradually diminished in width, partly by reducing the thickness of the webs, and partly by extending the re enforcing plates at the pin holes on the inside surfaces of the webs; thereby keeping the details of the work straight and parallel, notwithstanding the general curvature and tapering of the chords in both depth and width.

The chords are spliced between each pair of posts, the plates and angles breaking joints, the whole being stiffened with the re-enforcing plates required at the pin holes.

The ends over the anchorages are horizontal, so that the rocker-links and pedestals may be of the same dimensions.

The covering plates are perforated for the suspension eye-bars to pass through to make their pin connections with the webs.

The convergence of the lower chords commences about eight feet from the middle of the piers, under the inside pier posts. The enormous pressure at these points would cause the chords to spread farther apart, were they not united together from side to side; this connection is effected by two sets of eye-bar ties united to the plates against which the chords abut.

LOWER LATERALS.

The chords are retained firmly in position, and enabled to resist lateral and wind pressures, in either direction, by two diagonal lateral braces in each panel of their length.

These braces are of great strength, and are proportioned to act either in compression or tension, they are united to the inside chord webs between each pair of vertical posts, and are stiffened and supported by rods and struts, which connect them to the lower flanges of the transverse girders.

The shore ends of the lower lateral system are united by wind struts, with pin connections, to heavy box beams built into the masonry; thus resisting lateral pressures without interfering with the free expansion and contraction, (in extent, about 5 inches,) of the shore arms of the cantilevers.

UPPER CHORDS.

The upper or tension chords of the cantilevers are formed of tiers of eye-bar chords, placed over each other. In the design there are three tiers of chords near the pier saddles ; but it might be advisable to increase this number to four or five, in order to reduce the bending moment on the pins. The upper tier begins at the ends of the cantilevers, and when the point is reached at which the accumulated stresses, from the suspenders, require a sufficient number of eye-bars to make up the maximum width of the chord, a second tier is begun, the first being continued the full width to its connections with the top tier of the saddle eye-bars. The second is then continued, and the number of eye-bars increased, according to the accumulated stresses from the suspenders, until the required width is again reached, when it is continued up, and connected with the middle tier of saddle bars ; the third or lowest tier is arranged in a similar manner.

The eye-bars in the several tiers of chords are kept exactly parallel by the pins passing through the extension plates of the posts; so that all the bars, in any one panel, are precisely the same length.

Any desired number of tiers can be packed successivly one over the other. If, in the present design, the chords had been reduced in width, by using a less number of eye-bars in each tier, a fourth tier would have been required. By this arrangement of parallel tiers of chords, it is evident that each tier will transmit the tensile strain imparted to it, without inducing any additional stress in the adjoining tiers.

SADDLES.

The saddles over the pier posts are also formed of three or more tiers of eye-bars, to correspond with the chords, and are made in three such lengths, so that the pin connections are brought exactly over the pier posts. They not only transfer the stresses between the opposing chords, but their ends are formed to fit truly upon each other, in order that the vertical stresses may be transmitted through them to the pier posts.

The eye-bars of the middle set have to be curved horizontally, to allow for the convergence of the chords towards the ends of the cantilevers, the pin holes at their ends being so bored that they are at right angles to the directions of the chords. To enable the curved eye-bars properly to resist the action of the chords, they are furred apart with packing pieces, and each pair of saddles is kept in position by a stretcher, extending from side to side of the bridge, with ends fitted against the curved surfaces of each tier, and firmly connected to the whole of the curved bars.

The eye-bars of the saddles are 9 inches deep, their thickness corresponding to the 8-inch eye-bars of the chords; their ends are sufficiently wide to keep the bars the same vertical distance apart; or plates can be introduced between them to make up for any deficiency in their depth. The lowest tier has twelve less eye-bars than the two upper ones; there being that number of suspenders connected to each of the lower pins. The suspenders pass through the caps of the posts, and have their heads rounded; the stresses on them are transmitted by the pins to the adjoining saddle eye-bars.

The middle or curved sets of eye-bars will require great care in their construction, they will probably have to be packed together, exactly as they will be when placed in their permanent positions, and the holes in their ends bored out exactly at right angles to the general direction of the chords on each side. In consequence of the great weight of these parts, their manufacture with the requisite precision will probably be more difficult than that of any other portion of the structure.

UPPER LATERALS.

The upper lateral system of bracing, like the lower, consists of two diagonal braces in each panel, formed to resist either tensile or compressive stresses. They are connected to the vertical posts immediately below the chords, and above the upper wind struts. The stresses are not transmitted directly from panel to panel, but are carried through the braced pairs of struts. Those connected with the pier posts transmit their stresses to the horizontal plate bracing of the wind struts. Each pair of braces has light struts, uniting them half way between their intersections and ends.

PIER POSTS.

The four pier posts of each cantilever are placed in pairs; each pair being in line with the converging chords in each direction, and united together their whole height by a system of triangular bracing, and the inside posts united together by horizontal struts parallel to the general direction of the structure. This arrangement allows the upper ends of the posts to spring slightly as the deflections are varied by the passing of heavy loads from one arm of the cantilever to the other. If the four posts of each truss were rigidly braced together, and the saddles made fast to them, the equilibrium of the web system of the opposite arm would be destroyed.

The bases of the posts are attached to the horizontal covering plates of the chords, the webs of which are abundantly re-enforced under them to support the additional weights imposed.

The caps have level bearing plates, formed to give firm supports to the saddle eye-bars, and have suitable openings in them for the suspenders to pass through. The posts on opposite sides are firmly united by wind struts, girders, gussets and very strong lattice bracing. The transverse bracing is also stiffened, by longitudinal triangular bracing and struts, the whole height, corresponding with those between the posts.

The vertical compressive members of the cantilevers are columns, formed of plates, channel-bars, and angles ; they are arranged in pairs, and each pair is complete in itself.

Each pair of vertical posts is united together, and retained in a straight and parallel position, by a system of triangular strut bracing, near the middle of their lengths by connections with the suspender pins, and in a transverse direction, by the extension of the web plates; they are united by wind struts, gussets, sway-bracing and the latticed framed girders, supporting the floor girders, to the posts in the opposite truss. Notwithstanding these rigid connections, each single post will transmit its due portion of the stresses with the same certainty that it would were the pair of posts not united by the bracing.

The plates on the upper ends of the posts are extended to pass between the eye-bars of each tier of chords, and have the requisite number of pin holes to unite them by the chord pins to each. The bases of each pair are formed at angles to suit the inclined parts of the chords upon which they are to stand; and they are united to the covering plates by angle-iron bases. The post stresses are transmitted by the chord webs to the pins connecting the chords and suspenders.

SUSPENDERS.

The eye-bar suspenders are connected, at their upper ends, by the chord pins, to the lowest tier of eye-bar chords and the extensions of the vertical posts, or to the saddles.

From each of the pier posts there are twelve suspenders, six in each set; as the stresses diminish four in each set are sufficient, which number is continued to the ends of the cantilevers.

The lower ends of the suspenders pass through the covering plates of the lower chords, and are connected with pins to the webs directly under the vertical posts.

Near the middle of their length they are connected, by eye-bar pins, to the vertical posts, which not only support them, but allow them to act as stays to the posts about midway between the upper and lower chords.

Whatever change of position may take place in the arms of the cantilevers from deflection, or other causes, the stresses are duly transmitted through the pins to the suspenders without producing any other effect than a direct tensile strain in the direction of their length.

Owing to the stresses of the web members of the cantilevers being trasmitted by two double or four single systems of suspenders and posts, the number of eye-bars in each set is reduced, so that they can be conveniently connected with the other members of the trusses; at the shore end each system is attached to a separate anchorage.

EXPANSION.

At both ends of the connecting span, provision is made for variation in the length of the longitudinal members of the main span, caused by changes of temperature and deflection. The two end posts at each extremity of the connecting trusses stand on pin bases, attached to the lower chords of the cantilevers; their upper ends are in like manner united to the top chords of the connecting trusses; therefore when the longitudinal members expand or contract, the lower ends move freely with the ends of the cantilivers; their upper ends moving in the opposite direction with the ends of the top chords of the connecting trusses.

The struts uniting both the upper and lower chords of the cantilivers and connecting trusses have each a slotted pin hole at one end, sufficiently long, (about 9 inches), and a simple pin connection at the other, to allow for vertical deflections.

These movements will not appreciably alter the distance between the upper and lower chord members, therefore the suspenders are not affected.

The slotted struts are united together laterally by extra wind struts, thus leaving the continuity of the upper and lower lateral systems of bracing unbroken by the expansion and contraction of the longitudinal members.

The anchorage ends of the cantilivers are attached to rocker links by the lower chord pins, and are free to move, (with a play of about 5 inches), as the shore arms expand or contract; the lower ends of the rocker-links are connected with the anchorages by the fixed anchor pins.

TRANSVERSE GIRDERS.

The transverse lattice girders vary in depth to suit the heights of the posts they connect. They transmit the lateral and wind stresses acting on the floor system, and those caused by passing trains, to the lower chords. The upper flanges of each pair of girders are united and kept accurately in line, by horizontal triangular bracing.

They also give additional stiffness to the posts.

The upper and intermediate wind struts have gussets at their ends to strengthen the posts, and to form firm connections for the sway bracing. The wind struts are also braced horizontally.

CONNECTING SPAN.

The connecting span is of the now generally used double intersection type.

The only novel feature, in this case, is the transmission of the stresses of each system directly, by two posts at each end of the trusses, to the compound system of the cantilevers, and not, as is usual, transfering all the stresses to the end posts of each truss. The object of this arrangement is to divide the weight of the connecting span and of its loads, as equally as possible, between each of the compound systems of the cantilever suspenders.

ROADWAY.

The roadway is formed of four longitudinal plate girders united together between the pairs of transverse girders, and extending the whole length of the cantilever trusses; the depth is varied with the distance between supports. They will be thoroughly braced laterally and vertically, and expansion joints will be provided at their connections with the stringers of the intermediate span.

The cross-ties are to be of creosoted timber, 8 inches wide by 5 inches deep, with $4\frac{1}{2}$-inch spaces between them. The third tie on each side is to project sufficiently to support plank walks and hand-railings.

Wooden guard rails are to be framed to the ties, outside the rails of each track, with their inner edges protected by $2\frac{1}{2}$-inch angles.

This kind of floor, with its open spaces, is very suitable for the Canadian climate, with its occasional heavy snow fall. The snow and ice cannot accumulate on such a floor to cause risk or inconvenience.

GENERAL OBSERVATIONS.

Notwithstanding the magnitude of the structure, the different members can be as easily constructed as ordinary first class bridge work.

The tension members of the trusses are all steel eye-bars of the same depth, with the exception of those in the saddles; the chief difficulty in making them will be in the immense number required; nearly ten thousand.

They are generally so long that, comparatively, a very small surplus of metal is required for their enlarged ends.

The compressive members are so thoroughly braced in each direction that the smallest allowable sections can be adopted.

All parts of the structure, except those permanently in contact, are accessible for painting.

The most important riveting to be executed during the erection, and which will require special machines, is at the splices of the lower chords and the plate bracing of the upper wind struts of the pier posts.

The above explanations show that the component parts of the structure sustain and stiffen each other in such a manner that few compressive members will need greater sections than are necessary to sustain with safety the greatest direct stresses to which they can be subjected.

STRESSES.

In preparing the diagrams of stresses, the stresses on the cantilever trusses, the connecting trusses and the upper and lower lateral systems of bracing only, are shown, it not being deemed necessary, for the illustration of the design, that the stresses on the transverse girders, the longitudinal plate girders and stringers should be given.

The stresses produced by the live or moving loads on the cantilever trusses, are calculated for loads of 2500 lbs., per lineal foot, on each track; on the connecting trusses the live loads are assumed to be 3000 lbs., per lineal foot, on each track. The maximum stresses produced in any member, by these moving loads, are in all cases taken, and assumed to be sufficient to meet the local engine excesses.

The dead loads are obtained, for each panel of the structure, by estimating the weight of the materials in the members, the flooring and rails of the different sized panels, and adding successively the portion of weight supported at each panel point of the upper and lower chords; a liberal allowance being made for the additional weight imposed by snow and ice storms. These estimates are founded on preliminary strain sheets, and are sufficiently correct for the illustration of the design.

The wind stresses are obtained by multiplying the superficial area of the members in each panel of both cantilever trusses, the plate girders and deck, by the assumed pressure of 35 lbs. per square foot, and considering the pressures on all surfaces above the centre line as concentrated at the upper panel points, and all below, at the lower panel points.

The wind pressure upon the train surface is assumed at 300 lbs per lineal foot, and is considered as a moving load, and only affecting the lower lateral system.

The maximum stresses, resulting from the above several causes acting simultaneously, in any member are in all cases adopted.

It will be seen by the diagrams that the chords have their sections materially increased to meet the enormous stresses produced by wind pressure. It is not at all probable that the greatest assumed live load and the greatest assumed wind pressure will come simultaneously into action. The increased sections allowed to meet the wind stresses, however, add very materially to the stiffness and stability of the structure as designed.

NOTE—Patents have been applied for in the United States, Great Britain and Canada for the novel devices in the design herein described.

OTTAWA, 1st May, 1886.

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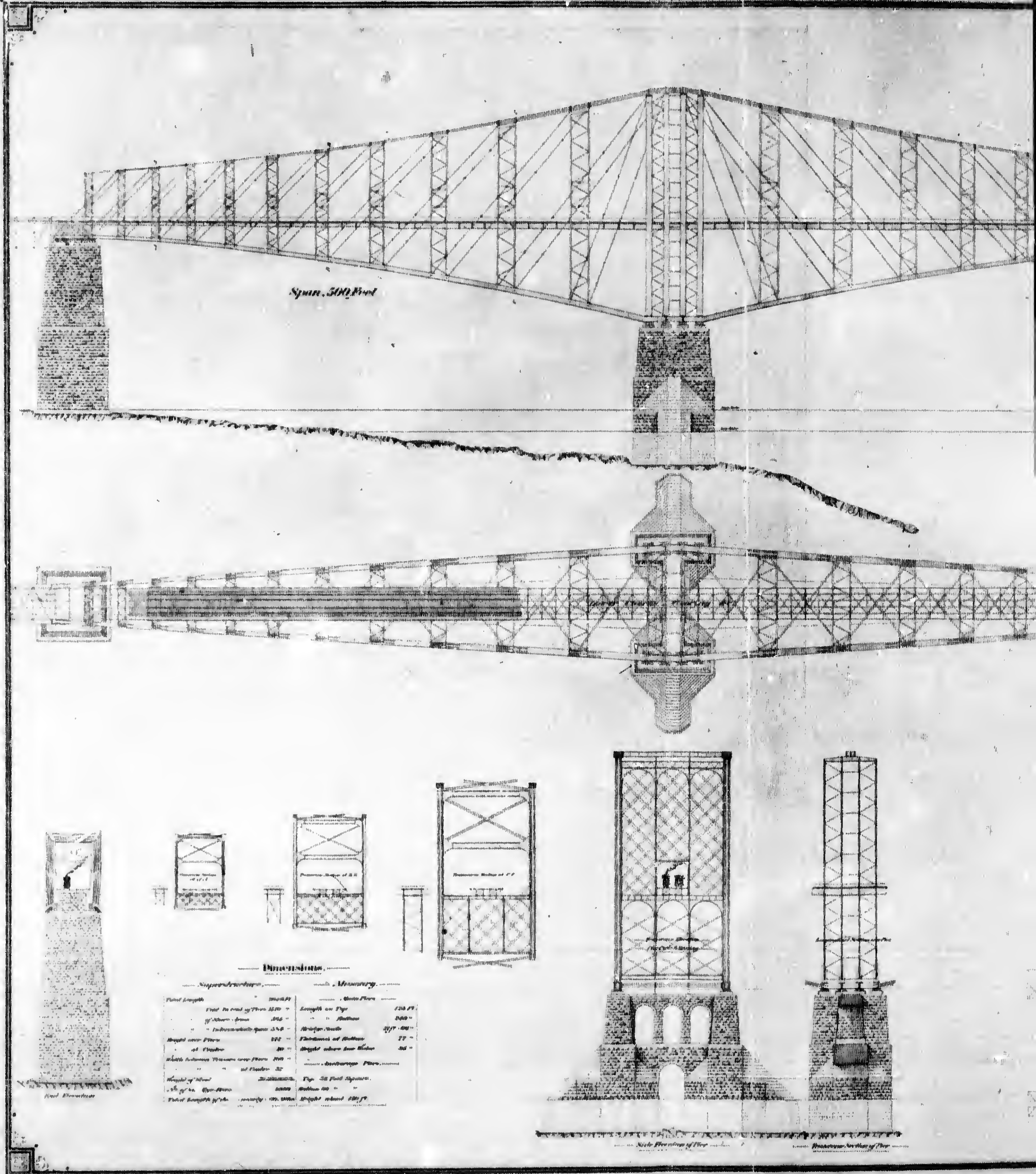
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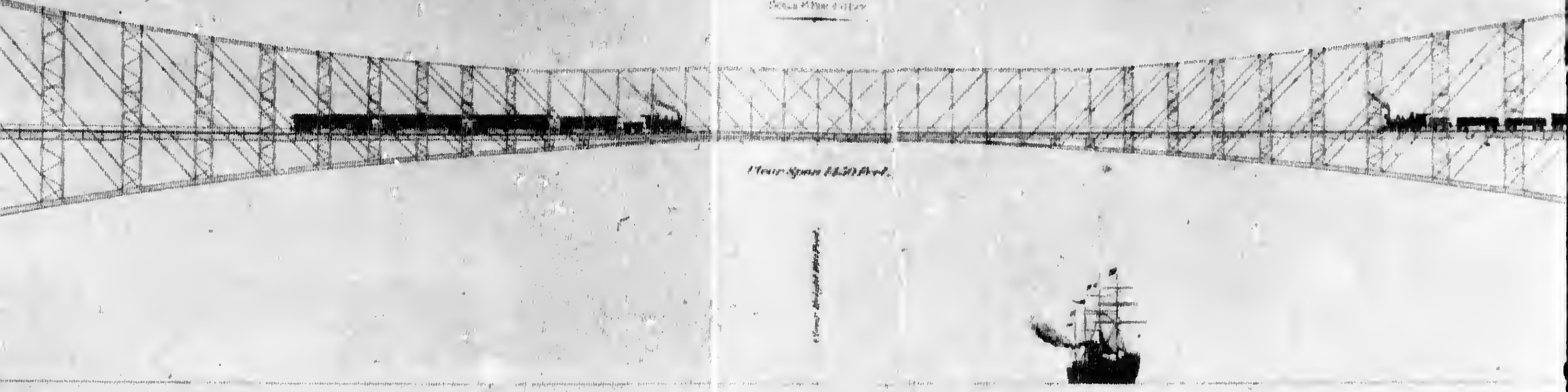
General Elevation.



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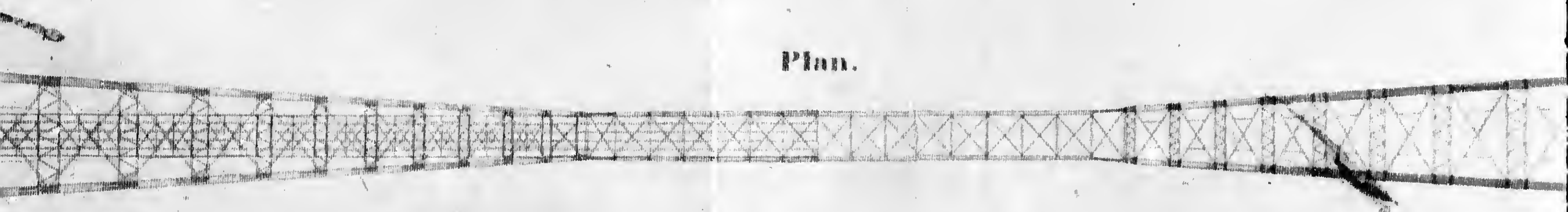


CANADIAN
LONG SPAN RAILWAY BRIDGE

DESIGNED BY

Joseph Tomlinson. Bridge Engineer.

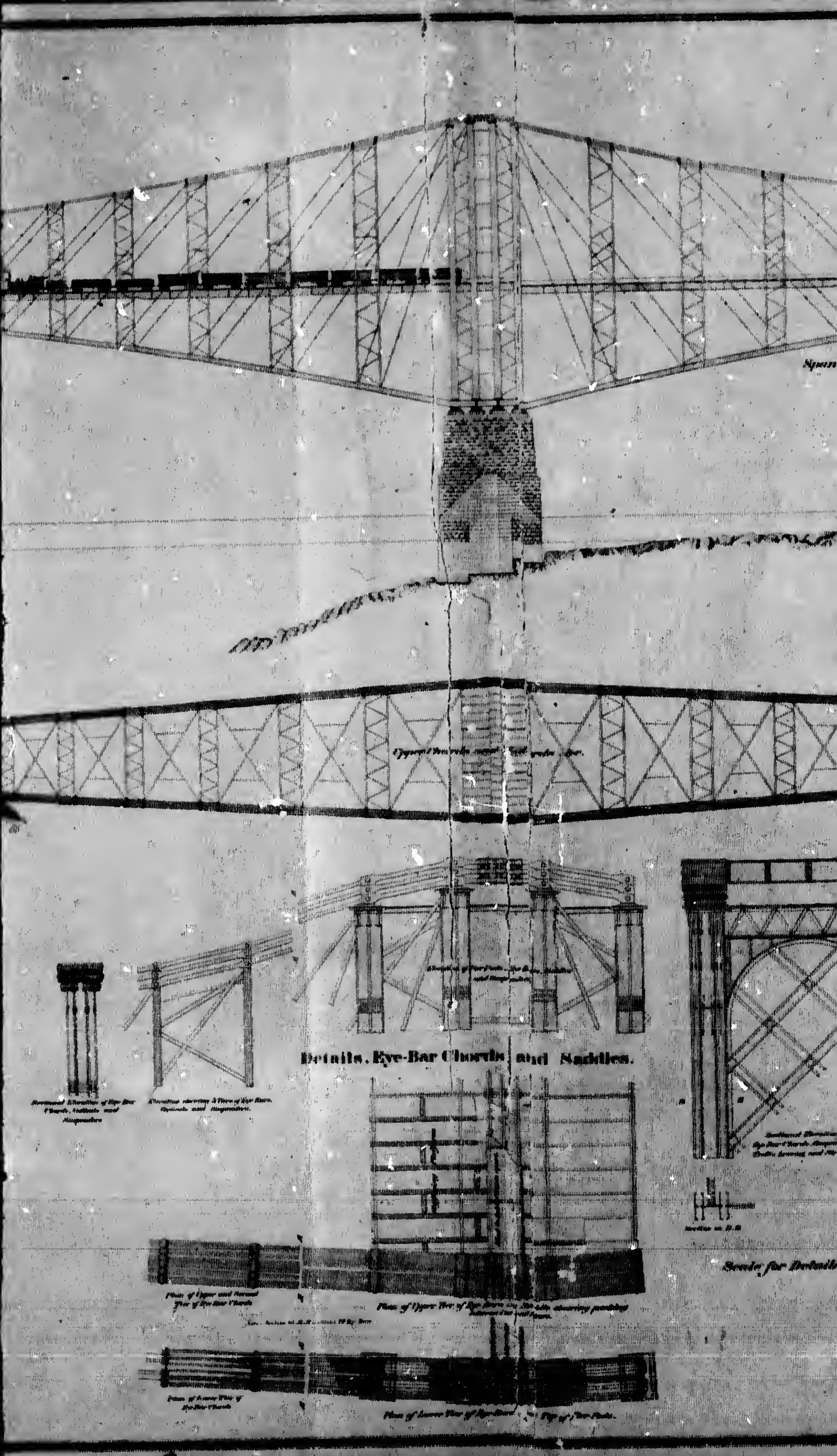
1886

Department of Railways and Canals. Canada.

Hon. John. H. Pope.
MINISTER OF RAILWAYS & CANALS.

Collingwood Schreiber.
CHIEF ENGINEER OF GOVERNMENT RAILWAYS.

Diagrams of Stresses.


Span
Details, Eye-Bar Chords and Saddles.
Scale for Details

Size of original Drawing
15 feet by 6