Thesis

on a

Wrought Iron Lattice Bridge.

by

Christopher A Church.

1875.

Description of the Abutments and Details.

This bridge is on the line of the Boston and Maine R. R., over the Lamprey river, near New Market. N. H. and was built by the Leighton Bridge Co. in March 1875.

The Abutments are built of granite and have a batter of 1 in. in 12 ft.

The right abutment (as shown in the elevation) rests upon a solid ledge. The wing wall on the up stream side slopes backward at an angle of 45° in order to prevent the water from washing away the earth from behind it.

The opposite abutment rests on 107 piles. These piles are 12" in diameter and their lengths vary from 35 ft. to 45 ft. They first passed through about 20 ft. of soft material, when they struck a layer of clay, afterwards passing into a soft earth. The amount a pile would sink from a given blow was measured in the case of a 38' pile, which moved an inch and a half from the effect of a 15' fall of a 1350 lb. hammer.

Both the wing walls of this abutment slope back at an angle of 45°; the one on the down stream side being built so, because the ground is much firmer at a little distance back, the slope of the river bank being very steep and the earth very soft and muddy.

There are 413 cu. yds of masonry in this abutment, which (considering the weight of masonry equal to 2000 lbs per cu. yd) weigh 816000 lbs.

The weight of the bridge being about 180000 lbs and the greatest travelling load 468000 lbs, the total weight on the piles will be 1145000 lbs, which will give about 10700 lbs on each pile if the load should be considered as uniformly distributed over the piles. But such is not the case as the greater portion of the load on them acts under the direct supports of the bridge. Hence the piles under the main part of the abutment are set much closer together than under the other portions.

On the top of each row of piles is spiked a piece of 6" × 12" timber, which forms a cap for the piles, and on which the floor is laid which also consists of 6" × 12" planks nailed close together, the space between the floor and the ground being closely packed with gravel. The abutment is built directly on this floor. The two bottom courses are laid in steps, each projecting about a foot.

Details.— The bridge has a clear span of 150', its total length being 156'. It's rise is 21', and its panel length is 11' 8", each girder consisting of four systems of triangulation.

In the detail sheet there is shown a side elevation of one half the bridge. The chords and end posts are built beams as shown in fig. 4, which is a section of the upper chord taken in the first panel. The lower chord, in the first panel has no plate riveted to the bottom, and in the second panel there is a 8"×½" plate riveted to the angle iron.

The diagonal bracing consists of pairs of angle irons which are shown in end elevation in fig. 5. The struts which are riveted to the inside of the vertical plates of the chords are braced with flat iron bars, as shown in the figure, to give them sufficient stiffness. The ties, which are riveted to the outside of the vertical plates of the chords, are also riveted to the struts, as shown in fig. 1, which aids in stiffening the struts. Fig. 2 shows the connection of the diagonals with the lower chord. The strap used in fastening the tie is not needed at the four middle apices.

The track stringers are 10½ rolled beams spaced 6' apart, and are shown in the side elevation of the bridge directly over the chord. They are in pieces of a panel length each, and are fastened to the cross-girders, which support them, by means of angle irons, as shown in fig. 3. In fig. 5 is seen the side elevation of the cross-girder and section of the stringers.

Fig. 5 also shows the manner in which the cross-girders are supported. The bottom of the cross-girder is cut away just before it reaches the chord, and in order to strengthen it at this part and to give it a broad enough base for a support, there are two pieces of angle iron, each about two feet long, riveted to the web of the girder, one on each side just above the space made by the cutting. These angle irons are riveted to angle irons which are shown in section on the inner side of the chord, at the top, and are shown in plan in fig. 7. The large plates which are shown in this last figure, outside of the chords are the plates to which the bottom sway-bracing is fastened, and are shown in section in fig. 5 directly over the top of the chord, the rivets which fasten the cross-girder to the chord

passing through them, thus holding them in place.
The part of the cross-girder shown in fig. 7 is the plan of the lower part, the upper flange being supposed to be cut away so that the fastening of the girder to the chord might be shown. Fig 6. is one of the cover plates of the vertical plate of the chord, showing the arrangement of rivets. Fig 8 shows the arrangement of plates & rivets in the upper corner of the girder. Fig. 9 shows the same in the lower corner; also the section of the rollers on which the bridge rests, the frame which holds them being taken away. Both above and below the rollers there is a 3" cast iron plate, and above the upper one, between it and

the chord is a ½" plate, a groove being made in the 3" plate to receive the heads of the rivets which fasten the ½" plate to the angle iron of the lower chord.

Fig. 10 shows the opposite side of the end post from that shown in (9).

Fig 11 is the top of the end elevation, fig 12, the bottom of the end post and rollers shown in elevation, and fig. 13 a plan of the rollers.

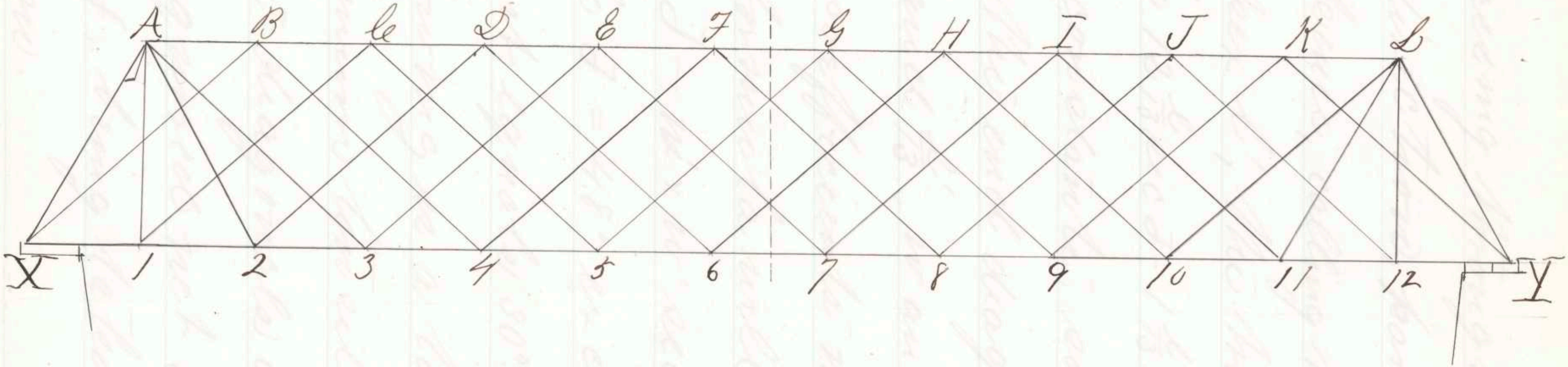
Calculation of Stresses & Sizes of Pieces Required.

The stresses in the diagonals and chords are calculated by a method given in Vose's Manual of Engineering.

1° Diagonals.

(a) Ties. These are generally considered to resist the shearing force while the bending moment is resisted by the chords. In order to get the greatest shearing force at any section, we must consider the longer segment loaded. The rolling load is assumed to be 3000 lbs per foot of track, and the dead load 1000 lbs per ft., giving 1 ton per ft. ~~for~~ each girder. The load acts on the girders at the apices and as the panel length is 11⅔ ft. we shall have a load of $11\frac{2}{3}$ tons acting at each apex.

To illustrate the method of procedure, take any diagonal, for instance B 4, (see next page) The apices of the system to which B 4 belongs are 4, 8, and 12. From apex 4 there are 9/13 of total load on that apex which pass to abutment X, from 8, 5/13 of total load and from 12, 1/13, making in all $\frac{15}{13}$ of $11\frac{2}{3}$ tons, which pass through B 4. Calling the total live and dead load at each apex $\underline{l}$, and the angle made by the diagonal with the vertical ∂, the maximum stress on B 4 will be $15\frac{l}{13}$ sec ∂. On C 5 the stress, arising from the loads on the apices of the angles of the system to which it belongs, is $(\frac{8}{13}+\frac{4}{13}) l$ sec $\partial = 12\frac{l}{13}$ sec. ∂, but there is also 1/13 of the dead load on


A B C D E F G H I J K L
X 1 2 3 4 5 6 7 8 9 10 11 12 Y

apex 1 passing through C5 in the opposite direction, partially neutralizing it. Hence, calling the dead load at each apex l', the true stress on C5 will be $12\frac{l}{13}\sec\theta - 1\frac{l'}{13}\sec\theta$. Now $\frac{l}{13}$ and $\frac{l'}{13}$ are constants; so also is $\sec\theta$ except for the end diagonals. Therefore calling $\frac{l}{13}$ and $\frac{l'}{13}$, w and w' respectively, and their coefficients n and n', the general formula will become

$n \times w \sec\theta - n' \times w' \sec\theta$.

The angle $\theta = 48°$ except for A2 and L11 where it equals 30°.

The following is a table showing the maximum tensile stresses to which the diagonals are subjected, also the required net cross section ~~required~~, f, being taken as 10000 lbs on the sq. in.

Tensile Stresses.

Diag.	n × w sec θ	n' × w' sec θ	Stresses in tons	Cross-sections
A 1	$24 \times \frac{l}{13} = 24 \times .897$		21.53	4.306
A 2	21 × 1.035		21.74	4.348
A 3	18 × 1.3416		24.149	4.829
B 4	15 × "		20.124	4.024
C 5	12 × "	−1 × .323	15.775	3.155
D 6	10 × "	−2 × .335	12.746	2.549
E 7	8 × "	−3 × "	9.727	1.945
F 8	6 × "	−4 × "	6.710	1.342
G 9	4 × "	−6 × "	3.366	.673
H 10	3 × "	−8 × "	1.35	.27

If these calculations were to be carried beyond this point we would get minus results, showing that those diagonals could never be subjected to a tensile stress.

(b) Struts. In getting these stresses we have only to follow this rule: The compression on any diagonal is the same as the tension on the diagonal which it meets at its upper or unloaded end.

The compression on the end post is due to the forces acting on A1, A2, and A3, therefore to get this compression we have only to get the components of these three forces acting in a direction of the end posts, and sum them, as follows:

$$\left\{\frac{24.148}{\sec 48^\circ} + \frac{21.74}{\sec 30^\circ} + 21.50\right\} \div \cos 31^\circ 45''$$

$$= \left\{16.15 + 18.83 + 21.50\right\} \div .85 = 66.48 \text{ tons}.$$

The following table gives the maximum stresses of compression in the diagonals, and the cross sections required.

In calculating the area of the cross-sections f is taken as 8000 lbs, Gordon's formula not being used on account of the bracing in the struts; they being prevented from bending in a transverse direction by the bracing shown in detail plan, fig 5; and from bending longitudinally by their connection with the ties, as seen in fig 1.

Diag.	n × w sec θ	n' × w' sec θ	Comp. in tons	Cross-section
A X̄			66.48	16.62
B X̄	15 × 1.3416		20.124	5.031
C 1	12 × "	−1 × .328	15.775	3.943
D 2	10 × "	−2 × .335	12.746	3.186
E 3			9.727	2.43
F 4			6.710	1.67
G 5			3.366	.841
H 6			1.35	.34

None of the diagonals beyond H6, which slope in the same direction, can ever be under a compressive stress.

Some of the diagonals in the middle part of the girder are subjected alternately to tension and compression, the area of the cross section being fixed [accordingly.

The following table shows what diagonals are subjected to these stresses, the compression and tension in each case, and the required sectional area.

Diagonal	Compression	Tension	Cross section.
E 3	9.727	1.35	2.43
F 4	6.710	3.366	1.678
G 5	3.366	6.710	1.342
H 6	1.35	9.724	1.945

The diagonals similarly situated on the other side from the middle of the girder are in the same state as the above [four.

Chord Stresses.

(a.) The upper chord. The compression in AB is the sum of the horizontal components of AX, A2, and A3, and the increments added at each apex to get the compression in the middle of the chord are simply the sum of the horizontal components of the stresses in the diagonals which intersect the chord at this point. As the chords resist the bending moment, in considering the stresses in them, the girder must be loaded over its entire length. In getting these increments the stresses on the diagonals will not be the same as in the preceding tables, for as the bridge is loaded over its whole length the factors w & w' used in the formula become equal to each other and substituting tan θ for sec θ, the formula for the horizontal components of stress on each diagonal, becomes

$$(n - n') \times w \tan \theta.$$

and for the two meeting at each apex

$$(\Sigma n - \Sigma n') \times w \tan \theta.$$

The tables below give the stress in the chords, those in the lower chord being calculated in the same way as those in the upper.

Upper Chord.

Panel.	$(\Sigma n - \Sigma n') \times w \tan \theta$	Increments	Compression in tons	Section
A B	Hor. comp AX + [21 × .3178 + 18 × .996]		63.78	15.945
B C	30 × .996	29.880	93.660	23.415
C D	(24 − 2) × .996	21.912	115.572	28.893
D E	(20 − 4) × "	15.936	131.508	32.877
E F	(16 − 6) × "	9.961	141.469	35.367
F G	(12 − 8) × "	3.984	145.453	36.36

Lower Chord.

Panel	(Σu - Σu') Tan θ	Increment	Stress in tons	Section
X̄ 1	Hor. Comp AX̄ + 15. × 996		49.92	9.98
1 2	(12-1) × .996	10.956	60.876	12.175
2 3	[21 × .3178 + 10 × .996] - 2 × .996	18.842	79.718	15.943
3 4	(26 - 3) × .996	22.908	102.626	20.525
4 5	(21 - 4) × "	16.932	119.558	23.91
5 6	(16 - 7) × "	8.965	128.523	25.704
6 7	(13 - 10) × "	2.988	131.511	26.30

Diagram of Stresses.

Compression written in black

Tensions " " red.

Calculations for the number of rivets required to attach the diagonals to the chords.

The limit for bearing and shearing stress[22] is taken as 5 tons per sq. in. The rivets used are 7/8" in diameter having a sectional area of .6□". The bearing area of a 7/8" rivet hole in a ½" plate is .437" and in a 3/8" plate .328," hence in all cases where we have these plates the number of rivets required to give sufficient bearing area will be greater than that required to give the rivet area.

In diagonal A1 we have two 3"×3"×½" <s riveted, on each side of the chord to a ½" plate. No. rivets $= \frac{21.306}{5 \times .437} = 10$ (nearly) or five for each angle iron. The bottom chord not being large enough to have more than 5 rivet holes in one line in the direction of the

diagonal, whenever there are more rivets required. The diagonal is fastened to the chord by means of straps.

In A2 we have also two 3" × 3" × 1/2" ∠s fastened to 1/2" plate. no. rivets = $\frac{21.74}{5 \times .437}$ = 10 or 5 for each

In A3 there are two 3" × 3" × 1/2" ∠s fastened to the same plate as A1 & A2 are fastened.

no. rivets = $\frac{24.148}{5 \times .437}$ = 11 or 6 for each.

In B4 there are two 3" × 3" × 7/16" angle irons riveted to a 3/8" plate. no. rivets required to give sufficient bearing in the chord = $\frac{20.124}{5 \times .328}$ = 11 or 6 for each. no. required to give bearing area in the diag. = $\frac{20.124}{5 \times .383}$ = 10 or 5 for each.

C5 The angle irons from here to the middle are all 3" × 3" × 3/8". no. rivets in C5 = $\frac{13.773}{5 \times .328}$ = 10. or 5 for each ∠

D6. no. = $\frac{12.746}{5 \times .328}$ = 8 or 4 for each ∠

E7. no. $\frac{9.27}{5 \times 328}$ = 6. F8 = $\frac{6.71}{5 \times 328}$ = 5 (nearly)

Struts — At diagonal BX there are two $3\frac{1}{2}'' \times 3\frac{1}{2}'' \times \frac{1}{2}''$ <s riveted to the chord.

no. rivets to give sufficient bearing area in the chord $= \frac{20.124}{8 \times .328} = 11$ or 6 for each.

no. to give bearing area in the strut $=$ $\frac{20.124}{5 \times .437} = 10$ or 5 for each. ⋕

D2. Here there are two $3'' \times 3'' \times \frac{7}{16}''$ <s. no. of rivets required to give bearing area in chord $= \frac{12.746}{5 \times .328} = 8$ or 4 for each. About the same number is required to give bearing area enough in the angle iron.

⋕ C1. Two <s $3'' \times 3'' \times \frac{1}{2}''$ no. required to give bearing area in chord $= \frac{15.775}{5 \times .328} = 10$ or 5 for each

no. required for the diagonal $= \frac{15.775}{5 \times .437} = 7$ or 4 for each

E3. The angle irons in this and from this to the centre are $3'' \times 3'' \times \frac{3}{8}''$. In E3, the same number of rivets is required as in E7, and in F4, the same number as in F8.

In G5 and H6 the tensile stresses

are greater than ~~the~~ the compressions and the number of rivets will conse-quently be, for G5, $\frac{6.71}{5\times.328} = 5$ or 3 for each, and for H6 $\frac{9.727}{5\times.328} = 6$ or 3 for each.

The areas given on page 14 are, as stated there, the net areas, and, as these areas are supplied in each case by two angle irons, each of which is weakened by one rivet hole, to get the total area add 2× area lost by 7/8" rivet hole, to the areas in the table

	Total area		Total area		Total area
A1	4.74 sq. in	B4	4.40 sq. in	E7	2.27 sq. in
A2	4.79 "	C5	3.48 "	F8	1.67 " "
A3	3.16 "	D6	2.88 "		

In considering the diagonals acting as struts no area is supposed to be lost by rivet holes.

Calculation of the number of rivets in the joints of the girder.

1° Lower chord – The first joint is in the second panel. The total cross section is 17.5□" and the tension is 60.876 tons. Each vertical plate bears a tension of $\frac{4.5}{17.5}$ 60.876 T = 15.645 tons. The vertical plate being 3/8" thick, the number of rivets required on each side of the joint = $\frac{15.645}{5 \times .328}$ = 10, 5 tons being the limit for f. Each angle iron bears .157 × 60.876 tons = 9.557 tons. no. rivets = $\frac{9.557}{5 \times .328}$ = 4 on each side of joint. Each 8" × ½" plate resists 5.235 tons. no. rivets = 3 for each side.

In the third panel the 18" × 3/8" breaks. The total cross section is 19.47□" and the tension 79.718 tons, of which the 18" × 3/8" plate bears 27.246 tons. no. rivets = $\frac{27.246}{5 \times .328}$ = 13 on each side of the joint.

In the fourth panel the sectional area

is 25.6$^{\square}$" and the tension is 102.626 tons. of which each vertical plate bears $\frac{4.5}{25.6} \times 102.626$T $= 18.04$ tons, and ~~the~~ each angle iron $\frac{2.11}{25.6} \times 102.626 = 8.46$. No. rivets required for vertical plate $= \frac{18.04}{5 \times .328} = 11$ on each side, and for the angle irons $\frac{8.46}{5 \times .328} = 6$.

The 18" × 5/16" plate ends at this joint and the 19" × 1/2" begins. The 5/16" plate bears $\frac{5.62}{25.6} \times 102.626$ tons $= 22.53$ tons. No. rivets required on this side of joint $= \frac{22.53}{5 \times .273} = 16$, while on the side of the 1/2" plate the no. $= \frac{22.53}{5 \times .437} = 10$.

Fifth panel. — Section $= 29.47^{\square}$" Tension $= 119.558$T

The 18" × 3/8" plate ends and the 18" × 1/2" begins

The 3/8" plate bears $\frac{6.75}{29.47}$ 119.558T $= 28.40$ tons

no. rivets required on the 3/8" side of joint $= \frac{28.40}{5 \times .328} = 17$ while on the side of the 1/2" plate the no. $= \frac{28.40}{5 \times .437} = 13$

Sixth panel — Section $= 33^{\square}$" Tension $= 128.532$ tons

Each vertical plate bears $\frac{4.5}{33} \times 128.532 = 17.979$T.

and will require $\frac{17.979}{3 \times .328}$ = 11 rivets on each side of the joint.

Each angle now bears 11.667 tons and requires $\frac{11.667}{3 \times .328}$ = 7 rivets on each side

The 19" × 1/2" plate has a joint in this panel and requires $\frac{36.996}{3 \times .437}$ = 17 rivets

The 18" × 1/2" ends in this panel and the 20" × 1/2" plate commences.

no. rivets required on each side of joint = $\frac{35.958}{3 \times .437}$ = 16

2° The Upper Chord — Section = 17.72 □"

Compression = 63.78 tons.

Near the end of the first panel the vertical plates break. Each one bears $\frac{4.5}{17.72} \times 63.78$ T = 16.31 T. no. rivets used on each side of the joint = $\frac{16.31}{3 \times .328}$ = 10

At the other end of the panel there is an other joint where the vertical plates and the angle irons break, and where the 18" × 1/4" plate ends and the 19" × 9/16" plate begins. The number of rivets required in the vertical plates is the same as before. No. rivets required for angle iron $= \frac{7.58}{3 \times .328} = 4$ for each side of joint. No. rivets required in the horizontal plate, on the 1/4" side of joint $= \frac{16.31}{3 \times .219} = 15$; while on the other $\frac{16.31}{3 \times .491} = 7$ are required.

Third Panel — Section $= 29.90^{\square''}$. Compression 115.572 T. No. rivets for each vertical plate $= \frac{17.39}{3 \times .328} = 11$, on each side of the joint. Each angle iron requires $\frac{8.16}{3 \times .328} = 5$ on each side. In the horizontal plates the 19" × 9/16" ends and the 20" × 10/16" begins, also, the 19" × 5/16" ends and the 19" × 7/16" begins. In the first case, the no. rivets required on the side of the 9/16" plate is $\frac{40.972}{3 \times .491} = 17$ and on the other $\frac{40.972}{3 \times .546} = 15$ is required. In the second case, $\frac{23.19}{3 \times .273} = 17$ rivets are required on the 5/16" plate side while the number on the other $= \frac{23.19}{3 \times .383} = 12$.

Fourth Panel. — Section $= 34.03^{\square''}$ — Compression $= 131.508$. In this panel the 19" × 7/16" plate ends and the 19" × 9/16" plate begins. No. rivets required on the 7/16" side of joint $= \frac{32.12}{3 \times .383} = 16$ while on the other only $\frac{32.12}{3 \times .491} = 14$ are needed.

Fifth Panel – Section = 36.32□" —

Compression = 141.469 T.

Each vertical plate requires $\frac{17.53}{5 \times .328} = 11$ rivets on each side of the joint.

The 20" × 5/8" plate has a joint which requires $\frac{47.03}{5 \times .346} = 17$ rivets on each side.

The 19" × 9/16" plate ends and the 19" × 5/8" commences. No. rivets required on one side of the joint is $\frac{41.28}{5 \times .491} = 17$, and on the other $\frac{41.28}{5 \times .346} = 15$

3°. The End Posts – Section = 17.72□" —

Compression = 66.48.

Near the top the vertical plates are attached to the corner plates. Each vertical plate bears $\frac{4.5}{17.72} \times 66.48\text{T} = 17.56\text{T}$

No. rivets required on each side of the joint is $= \frac{17.56}{5 \times .328} = 11$. The same number is required in the joint at the bottom.

Strength of the Floor.

The track stringers and cross girders which constitute the iron portion of the floor have already been described. The ties are of oak, the dimensions being 13'×6"×8", spaced 6" apart and notched onto the stringers.

Stringers.— These being in pieces of a panel length, the greatest load which would be apt to come upon any one of them would be an engine such as are used for "making up trains," in which the whole weight of 30 tons rests on its four drivers, which are 8' from centre to centre.

The stringer will be subjected to its greatest bending moment when one of the drivers is in the middle, the other being on the next panel.

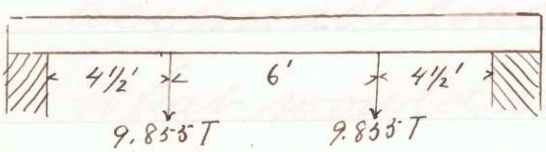
$M_o = \frac{W}{2} \times \frac{l}{2} = 3\frac{3}{4} \text{ tons} \times 5\frac{5}{6}' = 21.875 \text{ ft. tons}$

The uniformly distributed load required to produce the above bending moment $= \frac{8 \times 21.875}{l} = \frac{175.000}{11\frac{2}{3}''} = 14.9$ tons, and by reference to a table giving strength of Iron ton rolled beams, (which are the kind used in this bridge) we see that a $10\frac{1}{2}$ heavy beam is required.

The beam will be subjected to the greatest shearing force when one of the drivers has just passed over the point of support, the shearing force being the weight resting on one driver plus the portion of the weight, which comes to this support from the other driver.

$F_0 = 7\frac{1}{2}$ tons $+ \frac{11\frac{2}{3} - 8}{11\frac{2}{3}}\, 7\frac{1}{2}$ tons $= 9.855$ tons, which will require the web to have a cross section of 1.97 sq. in. It will require nearly 4 rivets to fasten the end of the stringer to the cross-girder.

The Cross Girders — These will be subjected to greatest stress when the engine is directly over them, the wheels (on one side of the engine) each being 4' to one side. The load coming on to the girder from each stringer being $2 \times \frac{11\frac{2}{3}' - 4}{11\frac{2}{3}} \cdot 11\frac{1}{3}$ tons $= 9.855$ tons. Hence they are in the condition shown in the diagram



$M_0 = 4\frac{1}{2}' \times 9.855\,T = 44.3475$ ft tons $= 532.170$ inch tons.

In resisting the bending moment 1/6 of the web may be considered as helping each flange. In these girders the area of a section of the flange plus 1/6 the web $= 7.375^{\square''}$

The distance between the centres of gravity of the flanges is 15".

$\frac{532.170}{15} = 35.411$ tons = the stress to be born by a flange and 1/6 of the web. Taking the value of f, for the upper flange as 4 tons, an area of 8.85□" will be required which is larger than the area of upper flange of the girder plus 1/6 the web, in the beam used.

In assuming f a very large factor of safety has been used, and the assumed load is greater than what would ordinaryly come upon the girder so that ~~the~~ it is probably strong enough for the ordinary traffic.

Weight of the Bridge.

(a) Upper Chord. – The following is the weight of one half the top chord of one girder.

2 plates	62 2/3′ × 12″ × 3/8″	weigh	1880 lbs.
2 ∠s	64 1/6′ × 3″ × 3″ × 1/2″	"	900 "
1 plate	10′ × 18″ × 1/4″	"	540 "
" "	23 1/3′ × 19″ × 9/16″	"	830 "
" "	11 2/3′ × 19″ × 5/16″	"	230 "
" "	23 1/3′ × 20″ × 5/8″	"	972 "
" "	11 2/3′ × 19″ × 7/16″	"	323 "
" "	11 2/3′ × 19″ × 9/16″	"	415 "
" "	8 1/4′ × 20″ × 3/8″	"	343 "
" "	8 1/4 × ~~20~~ 19″ × 3/8″	"	326 "
	Total =		6759 lbs.

4 × 6759 lbs = 27036 lbs = weight of top chord in both girders, not including cover plates.

(b) Bottom Chord — In one half the bottom chord of one girder we have:

2 plates	76½' × 12" × 3/8"	weighing	2295 lbs.
2 <s	76½' × 3" × 3" × 3/8"	"	1076 "
1 plate	46 2/3' × 18" × 3/8"	"	772 "
" "	11 2/3' × 18" × 3/16"	"	219 "
" "	33' × 19" × 1/2"	"	1008 "
" "	11 2/3' × 18" × 1/2"	"	380 "
" "	11 2/3' × 20" × 12"	"	388 "
		Total weight =	6208 lbs.

4 × 6208 lbs = 24832 lbs. = weight of bottom chords in both girders.

(c) End Posts — In one end post there are:

2 plates	21' × 12" × 3/8"	weighing	630 lbs.
2 <s	24' × 3" × 3" × 3/8	"	338 "
1 plate	24' × 18" × 1/4	"	360 "
		Total weight	1328 lbs.

Weight of the 4 end posts = 5312 lbs.

(d) Diagonals – 1° Ties. In one half of one girder there are –

2<s	11⅔' × 3" × 3" × ½"	weighing	412 lbs.
"	23½' × 3" × 3" × ½"	"	430 "
{ 2<s	30¾' × 3" × 3" × ⅜"	"	431 "
{ 2 plates	30¾' × 3" × ⅜"	"	230 "
2<s	30¾' × 3" × 3" × 7/16"	"	498 "
4<s	30¾' × 3" × 3" × ⅜"	"	865 lbs.
2<s	23' × 3" × 3" × ⅜"	"	323 "
2<s	7½" × 3" × 3" × ⅜"	"	105 "
		Total =	3096 lbs

4 × 3096 = 12384 lbs. = wt. of ties in both girders.

2° Struts –

2<s	30¾' × 3½" × 3½" × 9/16"	weigh.	625 lbs.
"	30¾' × 3" × 3" × ½"	"	563 "
"	30¾' × 3" × 3" × 7/16"	"	498 "
4<s	30¾ × 3" × 3" × ⅜"	"	865 "
2<s	23' × 3" × 3" × ⅜"	"	323 "
"	7½ × 3" × 3" × ⅜"	"	105 "
		Total =	2979 lbs.

4 × 2979 lbs = 11916 lbs = wt. of struts in both girders

(e) Plates riveting the ties and struts together — In both girders there are 152 8" × 8" × 3/8 plate weighing 6 2/3 lbs making a total weight of 1013 lbs

(f) Diagonal bracing in struts. — There are 12 diagonals in each girder which require this bracing, which in each diagonal consists of 40 pieces of iron of dimensions 2 1/4" × 1/4" × 17" which weighs 106.25 lbs. 24 × 106.25 lbs. = 2550 lbs = total weight of bracing in both girders.

(g) Floor — 1° Cross-girders.

1 plate 17 1/2' × 18" × 3/8" weighing 393.64 lbs. Allowing 36 cu. in. for cutting, which weighs 10 lbs there will be left 383.64 lbs. The ∠s weigh 411 lbs. Weight of the girder 795 lbs. There are 12 in number giving total weight of 9541 lbs.

2° Track Stringers :- In these there are 312 ft. of 10½" rolled beams weighing 135 lbs per yard, giving a total weight of 14040 lbs.

(h) Ties – There are 135 oak ties of dimensions 13' × 6" × 8". Taking the wt. of oak as 36.75 per cu ft. the wt. of 1 tie will be 239.616 lbs, and 135 will weigh 32348 lbs.

(i) Track – There are 312 ft. of track weighing 60 lbs per ft., giving total weight of 18720 lbs.

(j) Sway Bracing – 1° at the bottom –.

13 pieces of ∠ 3" × 3" × ½" each 19.4' long. wt =

13 × (19.4 × 12) × 2.75 × 3/18 = 2311.84 lbs.

2 ∠s 15½' × 3" × 3" × ½". wt = 284.16 lbs

Total weight = 2596 lbs.

2° Sway bracing at top.

13 ∠s 21.4' × 3" × 3" × ½" weigh 2580.16 lbs.

Bracing at the top, at each end of the bridge.

32' of 8" x 3" x 1/2" ∠	weighing	293.33 lbs.
21' of plate 6" x 1/4"	"	105.00 "
Middle plate	"	30.00 "
18' of 2" x 3/8" "	"	45.00 "
	Total for one end	473.33 lbs

Weight for both ends = 946.66 lbs.
Total weight of bracing in the bridge = 2596 lbs + 2550.16 lbs. + 946.66 lbs = 6092 lbs.

(k) Cover Plates - 1°. For one half of one of the upper chords—

8 plates	weighing	35	lbs	each =	280 lbs.
6 "	"	30	"	" =	180 "
2 corner plates	"	78	"	"	156 "
3 horizontal plates 3 1/2' x 1 1/2" x 1/2"	"	105	"	"	315 "
2 plates	"	75	"	"	150 "
6 ∠s	"	18	"	"	128 "
				Total =	1209 lbs.

Total in both the top chords = 4 x 1209 lbs = 4836 lbs.

2°- In one half of the bottom chord there are—

6 plates	weighing	35 lbs	each	210 lbs.
"	"	30 "	"	180 "
3 "	"	105 "	"	315 "
2 "	"	75 "	"	150 "
6 ∠s	"	18 "	"	128 "
		Total =		983 lbs

Total for both the lower chords = 4 × 983 lbs = 3932 lbs.

3°- The End Posts— In one end post there are—

2 plates at bottom weighing	40 =	80 lbs
" " " top	"	= 80 lbs
	Total =	160 lbs

Total for the four end posts = 4 × 160 lbs = 640 lbs.

Total weight of cover plates in the bridge = 6459 lbs.

(e). Angle irons at the foot of the end posts.— At the foot of each there are—. 34" of 3" × 3" × ½" ∠ weighing 41 lbs

Total for the four posts = 4 × 41 = 164 lbs.

(m) The plates used to attach the sway braces to the chords weigh about 255 lbs.

(n) Weight of Rivets.—

No. rivets in the top chords	=	4560
" " " " bottom "	=	5220
" " " " end posts	=	2800
" " " " diagonals	=	3408
" " " " cross girders	=	1380
" " " " swaybraces	=	430
Total number rivets in the bridge	=	17798

As nothing has been deducted for rivet holes in the weight of the plates, in getting the additional weight given by the rivets, the weight of the heads only has to be added. The amount of iron in one head is equal to that in a piece of a rivet of a length equal to once and a half the diameter. The weight of one rivet head is .218 lbs. and the weight of the heads of 17798 rivets will be,

$2 \times 17798 \times .218$ lbs. $= 7760$ lbs.

Summary of Weights.

Weight of the top chords	=	27036 lbs.
" " " bottom "	=	24832 "
" " " end posts	=	3312 "
" " " diagonals {including plates + braces}		27863 "
" " " cross girders	=	9541 "
" " " track stringers	=	14040 "
" " " ties	=	32348 "
" " " track	=	18720 "
" " " swaybracing	=	6092 "
" " " cover plates		6459 "
" " " ∠s at bottom of posts		164 "
" " " straps {for attaching diag. to chords}		415 "
" " " plates for swaybraces		255 "
" " " rivets		7760 "

Total weight of the bridge = 180837 lbs.