1897

Design of a 240' through span railroad bridge: Including analysis of stresses due to concentrated wheel loads, design of individual members, and drawings showing stresses, and details

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DESIGN
of
A 240' THROUGH SPAN
RAILROAD BRIDGE.

by
L. C. Torrence.

May 1897.
THESIS
For the Degree
of
Bachelor of Science
in
Civil Engineering
Design of a 240' Rail Road Bridge;
including analysis of stresses due to concentrated
wheel loads, design of individual members, and
drawings showing stresses and details.

By
L C Torrence

May 1897
The span length will be 340' center to center of end pins. Truss to be square ended, Track straight. Live load to consist of two engines, concentrating 280 tons over a length of 104' followed by a uniform train of 2.1 tons per linear foot.

Style and dimension of truss. The truss will be of the Baltimore type, and consist of eight full panels, each 30' center to center of pins and sixteen semi-panels each 15' center to center.

The inclined end posts will be 50' center to center of end pins. The seven main verticals will be 40' center to center of pins, and the eight semiverticals will be 20' center to center. The length of the upper chord will be increased 1/8" for each 10' for camber.

The main diagonals will be 50' long, and consist of two sets of eye bars 35' center to center of pins, plus allowance for camber. The semi-diagonals will be 25' center to center of pins, corrected for camber.

The true length of the main diagonals will be determined by adding 1/16" to top chord for each 10' solving.
for the hypotenuse of the right triangle formed by the main vertical and length of top chord thus increased, true length of main diagonals will be 50' \frac{11}{32} " . The lower chord will be made of eyebars 15' center to center.

DEAD LOAD.

The weight of floor will be determined by allowing 165 \# per linear foot for rails, guard rails, bolts, spokes, &c. and 270 \# per linear foot for cross ties. The cross ties will be 8" x 10" x 12' spaced 16" apart center to center; Total weight of floor equals 435 \#es. The weight per linear foot of the steel in the bridge will be given by the formula

\[ W = 5L + 350 \] \#es., when \( W \) equals weight per linear foot, \( L \) equals span in feet.

\[ W = 5 \times 240 + 350 = 1550 \] \#es.

Total weight per linear foot per truss equals

\[ \frac{1550 + 435}{2} = 932.5 \] \#es.

Panel load per truss equals 932 \times 15 = 14930 \#es.

Total weight per truss equals 14930 \times 16 = 238080 \#es.
DESIGN OF THE STEEL FLOOR SYSTEM.

The permissible working stress in flanges of stringers and floor beams to be determined by the following formula:

\[ a = \frac{u(1 + r)}{(J.B.J. 318)} \]

\[ a \text{ equals permissible stress per sq.in either tension or compression.} \]

\[ r \text{ equals } \frac{\text{min. stress}}{\text{max. stress}} \]

\[ u \text{ equals } \begin{cases} 7800 & \text{permissible stress compression.} \\ 3400 & \text{tension} \end{cases} \]

Correction for stress in top flange by column formula:

\[ b = \frac{a}{1 + \frac{u}{5000}} \]

\[ b \text{ equals allowed stress, (corrected).} \]

The stringers are plate girders of a span length equal to panel length. The dead load on a pair of stringers consist of the weight of the stringers plus the weight of the floor.

The weight of the steel may be approximated by the formula:

\[ w = \frac{9L + 55}{625} \]

Total dead load per linear foot equals

\[ w \text{ equals } 9L + 55 \text{ plus } 435 \text{ equals } 625 \text{ lbs.} \]
Maximum dead load bending moment equals

\[
\frac{625 \times 15 \times 15}{2 \times 3} \text{ equals } 3800 \text{ ft. lbs.}
\]

The maximum live load bending moment will occur when wheel (3) or (4) is at the center of the stringer.

Max. L.L. M. equals \(64500 \times 7.5 \times 7.5 - 107500 \) equals \( \frac{15}{15} \)

134400 ft. lbs.

Total bending M. equals 143200

Assume depth of web to be 26" o.a., 24" effective.

Max. flange stress equals \((143200 \times 12)\) divided by 24" equals

71600 lbs.

Allowed stress in bottom flange equals

\[
3400(1 \text{ plus } 3300) \text{ equals } 3900 \text{ lbs. call it } 9000 \text{ lbs.}
\]
Allowed stress in top flange, equals

\[
id = \frac{7800(1 + \frac{8800}{143200})}{1 + \frac{8800}{5000}} \text{ equals } 7800 \text{ lbs. call it } 8000 \text{ lbs.}
\]

Correction of stress in top flange,

\[
b = \frac{8000}{8300} \text{ equals } 7800 \text{ lbs. call it } 8000 \text{ lbs.}
\]

Lower flange area, equals

\[
71800 \text{ divided by } 9000 = \text{ equals } 7.9 \text{ sq.in. net.}
\]

The flange shall consist of \(2 \frac{1}{2} \times 6" \times 2" \times 1" \) net area \(35 \text{ sq.in. } 15.3 \text{ lbs.}

Will use same \(\frac{1}{2} \) for top flange. The max. end shear will occur when three wheels are on the stringer and one is just off the floor beam.

Max., shear equals \(21.500 + 2(21500) + \frac{1}{3}(21500) \)

\[
equals 42000 \text{ lbs.}
\]

Allowing a bearing and shearing value of \(4000 \text{ lbs. per } 2" \) rivet in single shear, 11 rivets will be required through the stringers web and end flanges; also the same number will be required to attach the stringer to the floor beam; but since the stringers must be riveted to the floor beams in the field it will probably be advisable to use 16 rivets \(3 \text{ in. each} \)/.

The rivets in the flange shall be pitched \(3" \) at the ends and \(6" \) in the middle \(3" \) of the stringers. Each stringer will consist of:-

1 web plate \(20" \times 24" \times 15'\), area\(90 \text{ sq.in. equals } 422 \text{ lbs.}
\]

2 top \(\frac{1}{2} \times 6" \times 21" \times 1" \) gross area \(35 \text{ sq.in. at } 15.3 \text{ equals } 459 \text{ lbs.}
\]

2 bottom \(\frac{1}{2} \text{ net } 8" \) \(16" \) \(16" \) \(16" \) \(16" \) \(16" \) \(16" \) \(16" \) \(16" \) \(16" \) \(16" \) \(16" \) \(16" \) \(16" \) \(16" \) \(16" \)

4 end fillers \(18" \times 6" \times \frac{1}{2}"
\]

4 \(\frac{1}{2} \times 6" \times 4" \) \(2" \) at \(12.3 \) \(108 \text{ lbs.} \)
There will be 32 stringers:
Total amount equals 1640 x 32 equals 52,480 lbs

Intermediate floor beams to be 17' center to center and 43" deep o.a., stringers to be riveted to floor beam and spaced 7' center to center:

Maximum floor beam load will occur when wheel 4 is over the floor beam

Max. load equals \( \frac{1333 \times 28 \times 2 - 332.5}{2} \times 2 = \frac{58.3}{15} \times 2 \)
or \( 2(39-332.5-332.5) \) equals \( 58.24 \times 2 \) call \( 116 \) x 2.

Max. end shear equals 60 plus \( 4.7(\frac{d}{1}) \) equals 64.7
Beam 43" o.a., 46" effective.

Flange stress equals \( 60000 \times 1.2 \times 5 \) equals 73000 \( \text{lbs} \)
allowed bottom flange stress equals 9000 \( \text{lbs} \)

Therefore 73000 divided by 9000 equals 8.7 sq.in., net.
Each intermediate floor beam will consist of:-

1 web plate 48" x 2", 18 sq. in. equals 336 \( \text{lbs} \)
4 \( \frac{3}{4} \times 4" \times 5" \) or \( \frac{5}{8} \) equals 18.4 sq. in.
956 "
4 end \( \frac{3}{4} \times 4" \times 6" \times \frac{1}{2} \) equals 265 "
4 fillers 6" x 5" equals 185 "
160, 7" rivets 70 "

Total mat, equals 2380 "

Details of end floor beams will be shown in drawing.

Load concentration on main panel joints:

Try wheel (3) at joint /2

The length of uniform load from right end equals 310' = 91 equals 119';

\( g \) equals \( 269 \) plus \( 112 \times 2.1 \) equals 67.5

\( \text{N} \)
\( G \) equals 53 or 75 \( \frac{1}{1} \) 1

Try wheel (4) at \( L_1 \)

\( G \) equals 289 plus \( 210 - 85 \) 21 equals 38.67

\( N \) 3

\( G \) equals 53 or 75 \( \frac{1}{1} \) 1

Hence the moment will be a max. where wheel (4) is at \( L_1 \).

Moment about 19 equals 169 81

The right abutment is 124' to the right of 19:

Hence the total moment about right end equals

16981 plus 239 x 124 plus \( \frac{124}{3} x 2.1 \) equals 57872 ft. (1000)

Left abutment reaction equals \( \frac{57872}{3} x 30 \)

Moment of left abutment reaction about \( L_1 \) equals

\( \frac{57872 \times 30 - 511}{30} \) equals 7973

Wheel (2) gives a max. at \( L_4 \)

Max. moment about \( L_4 \) equals 13650.

Wheel (15) gives a max. at \( L_4 \)

Max. moment about \( L_4 \) equals 16497.

Wheel (16) gives the Max. at \( L_4 \)

Max. moment about \( L_4 \) equals 17139.

The moment at \( U_x, U_y, U_1, U_4 \) equals

the moment at \( L_4, L_4, L_4 \) plus

the moment of the load at panel points \( L_5, L_5, \&c. \) about \( L_4 \)

\( L_4, \&c. \)

The max. panel load equals \( 30 \), and assuming it possible for the max. load and max. moment to come together we have moment about:

\( U_4 \) equals 13650 plus \( 30 \times 15 \) equals 13950.

\( U_4 \) equals 16497 " " " 17297

\( U_4 \) equals 7973 " " " 8373.
LIVE LOAD SHEARS.

Wheel (5) at $L_3$ gives a max. shear in $L_3 - L_1$.
Shear equals 290.

The loading for max. shear in $L_3$ will be the same as for max shear at $L_0$, i.e., wheel (4) at $L_2$.

$s$ equals \[\frac{15391 + 239 \times 124 + 2 \times 240}{240} = \frac{5111}{240} \text{ Equals 2157.}\]

Wheel (4) gives max. at $L_2$.
$s$ equals 201.

Wheel (3) gives a max. at $L_0$.
$s$ equals 1444.

Wheel (5) gives a max. at $L_4$.
$s$ equals 267.

Negative shears.

Wheel (3) at $L_4$ gives max. negative shear in $L_6 - L_7$.
$s$ equals 57.9.

Wheel (2) at $L_4$ gives a max. in $L_4 - L_5$.
$s$ equals 261.

WEB STRESS.

The max. stresses in the web members $L_4 - O_1 - L_6 - O_2$ $L_4 - O_2$ occur when max. shear is in $L_3$. $L_3 - L_5 - L_7 - L_4$ max. stress in $L_4, O_2, O_3, O_2, U_2$ equals max. stress in $L_4, O_2, L_4, O_2$ plus one half stress due to load on the corresponding sub-vertical at time of max shear in the panels as given above.

Wheel (5) gives max. shear in $L_3, L_5$ load an $O_1, L_3$ equals 50.
Shear in $L_3, L_5$ equals 260.

Therefore, vertical component in $O_3, U_0$ equals 260 plus 15 equals 275.
Wheel (3) gives max. shear in \( L_3 \) the corresponding increment to be added for stress in upper half of diagonals equals 96.

While wheel (3) gives max. shears in panels last named, the Max. shear is only slightly in excess of shear for wheel(4) at the corresponding points, while the load on the sub-vertical is much greater. The Max. stress in the upper half of the diagonal will be when wheel (4) is at the corresponding panel points. We will use 15 as the increment to be added for vertical components.

**SHOE PIN**

The pressure on the shoe is vertical and equals the vertical component of stress in the portal post.

Pressure on shoe equals 532 x 3 equals 425.6

Bearing an area required for pin equals 425.6 divided by 13.5 equals 31.52 sq.in.

Assume a 6" (pin for first trial), 31.52 divided by 6 equals 5.25" bearing thickness required, or 3.32" on each side of shoe. Each side of shoe will consist of 1 \( \frac{1}{2} \text{" hinge plate} \)

\( 3 \frac{1}{2} \text{" plates and} \ 1 \frac{3}{4} \text{" plate.} \)

Each side of \( L_0 \) will consist of \( \frac{1}{2} \text{"web plate reinforced with} \ 4 \ 1 \text{"plates and} \ 1 \frac{1}{2} \text{" hinge plate.} \)

Horizontal forces are

\( L_0 \) equal 355.8 and \( L_0 \) equals 351.8

**VERTICAL FORCES ARE**

\( U_0 \) equals 425.6

\( L_0 \) to \( L_5 \) will consist of 4 knee bars \( \frac{11}{16} \text{" x 7"} \)
Moment of $\ell_6 \ell_1$ on $\ell_6 U_0$ equals

155.9 x 2 1\[4\] equals 350

Momentum of $\ell_6 U_0$ on Shoe equals

312.3 x 3 equals 159.6

$M(t) \ (350 \ plus \ 159.6) \ equals \ 335.$

A 6" pin will be larger than needed for bending, will use

$\frac{61}{3}$" pin to be uniform.

**PIN FOR AXLE.**

Assume $U_0$, 0, have its Max. stress, also that $\ell_6 U_0$

$\notin U_0 U_1$. To meet in a planned joint and have sufficient

thickness to take up all bearing force, so that the pin will

have to resist only the bearing and bending moment of

$U_0 \ell_1 = U_0 \ell_0$

two

$U_0 \ell_6$ will consist of a 1" web reinforced with $\frac{1}{2}$" pin plate

and one $\frac{1}{2}$" hinge plate.

$U_0 \ell_1$ will consist of $\frac{3}{2}$" web, one $\frac{3}{8}$" pin plate and one

$\frac{1}{2}$" hinge plate, and one $\frac{1}{4}$" pin plate.

$U_0 \ell_0$ will consist of 4 11" x 7" Eyebars.

$U_0 \ell_1 \ " \ " \ 2 \ 11" x 3" \ " \ " \ 16$

Vertical forces are

$U_0 \ell_0$ equals 372.7 x 3 equals 238.16

$U_0 \ell_1$ equals 433

Horizontal forces are

$U_0 \ell_0$ equals 372.7 x 6 equals 223.62 equals $U \ell_0$

Momentum equals

$\left(149 x 3 \ plus \ 23.4 x 3 \ \frac{3}{2}\right) plus \left(111.3 x 2 \ \frac{3}{4}\right) \ equals \ 445.$

a 6 $\frac{1}{2}$" pin will answer for bending;

Bearing diameter equals

$136.3 \ plus \ 13500 \ equals \ 6.11$

a 6 $\frac{1}{3}$" pin will answer.
PIN FOR L,

Assume same conditions for this point as for L,
we have the forces $U_i$, $L_i$, compression and $U_i$, $O_i$, tension for the vertical forces, and $U_i$, $O_i$ for the horizontal forces.

$U_i$, $O_i$ will consist of 17" $L_i$, reinforced to have a bearing thickness of 1 $L_i$.

$U_i$, $O_i$ will consist of two 1 $L_i$ x 7" eye bars.

Vertical forces are $U_i$, $O_i$ equals plus 105.7 equals $-U_i$, $O_i$.

Horizontal forces are $U_i$, $O_i$ equals $-146.5$ equals plus $U_i$, $O_i$ bearing diameter required equals

$132.1 + 13.5 \times 1 \frac{7}{16}$ equals 6" 

Moments equals $(33 \times 1 \frac{1}{2} \text{ plus } 74 \times 5^{1/2})$ equals 230 $L_i$

there the diameter of the pin will be determined by the bearing, will use 6 $\frac{1}{2}$" pin.

Pin $L_i$.

Assume Max. chord stress, and so far load on $O_i$, $L_i$.

Then horizontal forces are $L_i$, $O_i$ equals $324.9$

$L_i$, $O_i$ equals 430.2

$L_i$, $O_i$ equals 117.7

$L_i$, $O_i$ equals 18.7

Vertical forces are $U_i$, $O_i$ equals 130

$O_i$, $L_i$ equals 30

$L_i$, $O_i$ equals 160

$L_i$, $L_i$, will consist of 6 eye bars 1 $\frac{3}{15}$ x 8"
\[ L_4 - L_6 \] will consist of 4 eyebars 1 \( \frac{5}{3} '' \times 3'' \).

\[ L_6 \] will consist of 2 eyebars 1 \( \frac{5}{16} '' \times 7'' \).

\[ L_6 \] will consist of 2 channels 12'' x 9c'' reinforced to 1'' thick for bearing.

\[ L_6 \] will consist of \( \frac{5}{2} 7'' \times 45\# \) with \( \frac{1}{2} '' \) eye plates.

The bearing area at 15000' equals 41.6

" " " 13500" " 46. sq. in.

If we use six eyebars 1 \( \frac{3}{16} '' \) thick the bearing depth will be 7 \( \frac{1}{8} '' \) and the diameter of pin required for the above cases will be 6'4" & 5.8".

**PIN** \( L_6 \)

---

Plan of horizontal forces at joint \( L_6 \) showing method of packing half the joint. all joints to be packed as shown above. The lower chord eyebars to be placed within the post.
Horizontal bending moments on joint $L_6$

<table>
<thead>
<tr>
<th>Member</th>
<th>Stress</th>
<th>Shear</th>
<th>M. (t)</th>
<th>Inc.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_1$</td>
<td>$+104.15$</td>
<td>$15\over 16$</td>
<td></td>
<td>$+136.7$</td>
<td></td>
</tr>
<tr>
<td>$L_1$</td>
<td>$-122.3$</td>
<td></td>
<td></td>
<td>$+136.7$</td>
<td></td>
</tr>
<tr>
<td>$R_2$</td>
<td>$104.15$</td>
<td>$33.15\over 16$</td>
<td></td>
<td>$+112.9$</td>
<td></td>
</tr>
<tr>
<td>$L_2$</td>
<td>$-122.3$</td>
<td>$-36.3\over 16$</td>
<td></td>
<td>$+229.9$</td>
<td></td>
</tr>
<tr>
<td>$R_3$</td>
<td>$104.15$</td>
<td>$67.35\over 12$</td>
<td></td>
<td>$+178.3$</td>
<td></td>
</tr>
<tr>
<td>$L_3$</td>
<td>$-3$</td>
<td></td>
<td></td>
<td>$+279.1$</td>
<td></td>
</tr>
<tr>
<td>$L_4$</td>
<td>$-53.3$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Vertical M. equals $15 \times 1 + 65 \times 1 \frac{1}{4}$ equals 95,

M. (t) equals $(95 + 230)\frac{1}{2}$ equals 296.

The bearing stress will determine the size of pin.

For simplicity of execution and construction $6\frac{1}{2}$" pins will be used throughout the structure, except at 0 where 4" pins will be used.
The above is an analysis of U₀, U₁, the same "e" will be used for all members.

\[ w \text{ equals } 183.33 \text{ lbs per ft.} \]

\[ M \text{ (w) equals } 183.33 \times 30 \times 50 \times 12 \text{ equals } 247,800 \]

\[ S \text{ equals } 432,000 \]

therefore \( e' \) equals \( e \), \(-247,800 \text{ equals } e' - e''\)

\[ e'' \text{ equals } 2.89 \text{ at } 50' \text{ equals } 289. \]

Portal and upper chord members, using column formula:

\[ a \text{ equals } 10300 - 24 \left( \frac{l}{r} \right)^2; \quad r \text{ equals } 9.1 \]

\[ L \text{ equals } 50' \text{ for portal and } 30' \text{ for chord members.} \]

for portal \( a \) equals 9600 lbs.

portal area equals 532000 + 3300 equals 554"

chord members:

\[ a \text{ equals } 10300 lbs. \]

\[ U₀, U₁ \text{ equals } 401200 + 10300 \text{ equals } 452" \text{ area required,} \]

\[ U₁, U₂ \text{ equals } 596700 \text{ equals } 585" \]

\[ U₂ \text{ equals } 623300 \text{ equals } 61.7" \]

**POSTS.**

Using same formula as above.

\[ U₁ \text{ equals } 452\text{" area required, } 15\text{" } \sqrt{ } \text{ assume } r \text{ equals } 4.9 \]

\[ a \text{ equals } 10300 - 24 \left( \frac{l}{r} \right)^2. \]
equals 3200 or 3100 if \( \tau \) equals 4.8

this last \( \tau \) corresponds to 13" \( \sqrt{A} \) of about 45 lbs, area 13"

196000 \( \div \) 3100 equals 24.2

two of the above channels will be used

\( U_1 \) \( L_1 \) will use two 12" x 30" \( \sqrt{A} \),

\( U_2 \) \( L_2 \) " " 24" "

**Portal bracing**

\( R \) equals 150X 30 equals 13500"

\( P \) equals 15 \( \times \) 15 equals 2250", \( P \) equals 4500"

\( C \) equals 50', \( e \) equals 10'

stress in \( U_0 \) \( U_0 \) equals \( \frac{R + P}{2} \) \( \frac{R}{2} \)

\( (13500 \div 4500) \frac{50}{2} + \frac{13500}{2} \) equals 51700"

stress in \( D \) \( D \) equals \( \frac{R + P}{2} \) \( \frac{e}{2} \)

equals 45000"

stress in \( U_0 \) \( D' \) equals \( \frac{R + P}{2} \) \( \frac{e}{17} \)

\( \frac{13500 \times 50 \times 1}{17} \) equals 106000"

Bending M. at \( D \) equals \( \frac{R + P}{2} \) \( 50 - 10 \) equals 36000 ft. lbs.

stress \( \frac{L_1}{U_1} \) equals 36000 \( \div 17 \) equals 21200"

This stress will be included in the live load

stress on the portal chord. The above is the analysis of the stresses in a simple portal as shown in sketch, and will serve as a guide for the amount of metal needed in type of portal bracing shown in drawings, which will be used in the proposed bridge.

The Portal, Lateral and vibration bracing will consist of angles and adapted to resist compression as well as tension. The details, sizes, methods of attaching, will be shown in the drawings.
The stress in the various members of the lateral systems are shown in sketch. No attempt is made to adjust the material in the lateral systems precisely to the stress as the loss from using the greater variety of dimensions would be likely to exceed the gain by saving material.

**PIN PLATES.**

Portal bearing of \( L_0 \) will consist of \( \frac{5}{2} \) plates on each side plate of portal post making a total bearing of 6" including the side plates. The two inside plates are hinge plates. Since all plates have the same thickness they will require the same number of rivets. The second plate from web on each side will extend over the flanges and receive the flange rivets, number of rivets required for each plate using \( \frac{7}{3} \) rivets and allowing 4000" for single shear.

\[
U = 532000 \times \frac{1}{2} + 4000 \text{ equals 12.}
\]

\[
\frac{2}{6} \text{ total number of rivets required will be 36, method of placing them will be shown in drawing.}
\]

**PIN PLATES.**

Portal \( U_0 \)

Portal \( U_0 \) will consist of a \( \frac{1}{2} \) web plates reinforce with two \( \frac{1}{2} \) plates, one \( \frac{1}{2} \) hinge plate. The web and reinforcing plates to be planned to make a neat bearing joint, so that the hinge plate will not bear a full \( \frac{1}{2} \) of the pressure. On this account we will take effective bearing thickness at \( \frac{3}{2} \) in stead of 4".
x equals $532 \times \frac{1}{4}$ equals 13

\[
n = \frac{3 \frac{1}{2}}{2}.
\]

The hinge plate will receive the same number,

Chord $U_e$ will consist of $\frac{5}{3}$ " web reinforced with a $\frac{5}{3}$ " plates and one $\frac{1}{2}$ " hinge plate. Hinge plate of chord $U_e$ to be on the outside. The bearing conditions to be the same as above and the effective bearing depth the same.

$U$ equals $461.3 \times \frac{1}{4}$ equals 13

all plates will receive the same number

all plates will receive the same number.

Upper chord splices will be made at a convenient distance from the column pins and towards the end of the truss from pin. The same plates will be used for the splices that are used for pin plates at the corresponding joints, the ends of the chord shall be neatly planned to make a close joint but enough rivets will be used through the splice plate to take all the stress so that no reliance will be placed upon the butt joint, see drawings.

The lower side of the top chord will be fitted with tie plates $\frac{3}{3}$ " x $\frac{3}{3}$ " x $\frac{3}{3}$ " placed on each side of the columns. The remainder of the chord will be latticed with $\frac{3}{3}$ " x $\frac{3}{3}$ " bars set at 45° Double laced.

SHOE

Each shoe will consist of one $\frac{1}{2}$ " bed plate, one $\frac{3}{3}$ " plate to be placed on top of bed plate and extend beyond bed plate, and inside, sufficiently far to attach the end members of the lower lateral system. The pin bearing members will be made of one $\frac{1}{2}$ " hinge plate, three $\frac{1}{2}$ " and one $\frac{3}{4}$ " plates, the members to be attached to bed plates by four $6" \times 6" \times \frac{3}{4}$ /5.
End reaction equals 425600".

Allow 250 " per sq. in. on the masonry

1700" required or 41" x 41"

Allowed pressure on rollers equals 500 \sqrt{d}

Let \(d\) equal 3

Then \(p\) equals 500\sqrt{3} equals 865"

Then 492" of 3" rollers will be required or 12.3 rollers each 46" long, will use 13 and, to allow for expansion and spacing of roller will use a bed plate 40" x 46").
Cross section and dimensions 7
U. U.
Estimated weight of materials used in the structure:

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor Beams</td>
<td>38000</td>
</tr>
<tr>
<td>Stringers</td>
<td>52500</td>
</tr>
<tr>
<td>End Posts (10)</td>
<td>18000</td>
</tr>
<tr>
<td>Upper Chords (10)</td>
<td>33800</td>
</tr>
<tr>
<td>Posts (10)</td>
<td>17000</td>
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<tr>
<td>Laminations (10)</td>
<td>6700</td>
</tr>
<tr>
<td>Hip vertices (20)</td>
<td>2000</td>
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<tr>
<td>Main Diagonals (20)</td>
<td>20800</td>
</tr>
<tr>
<td>Semi-diagonals (20)</td>
<td>6200</td>
</tr>
<tr>
<td>Lower Chords (20)</td>
<td>313600</td>
</tr>
<tr>
<td>Lower lateral bracing (20)</td>
<td>3180</td>
</tr>
<tr>
<td>Upper ‘’ ‘’ ‘’ ‘’ ‘’ ‘’ ‘’ ‘’ ‘’ (20)</td>
<td>1960</td>
</tr>
<tr>
<td>Portal (20)</td>
<td>12800</td>
</tr>
<tr>
<td>Pin Plates Stay Plates (60)</td>
<td>9000</td>
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<tr>
<td>Anchor Plates for lateral bracing (10)</td>
<td>400</td>
</tr>
<tr>
<td>Pine (400)</td>
<td>4000</td>
</tr>
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Total wt of metal in one truss = 290700 lbs