6208

Thesis

Plan for Widening a Stone Arch (at Pawtucket R.I

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May 1891

Thesis

It is with the same degree of interest with which the citizens of Massachusetts recall the founding of Plymouth, that the citizens of Rhode Island recall the days of Roger Williams and Samuel Slater. It is with the latter however that we are at present concerned. One hundred years ago last October, Samuel Slater founded the first cotton mill in America.
The spot which he selected as the site for what has since become the greatest manufacturing industry in America, is situated at

the Pawtucket Falls on the Blackstone River.

A century ago manufacturing was comparatively lacking in this country and the increasing population was entirely dependant on foreign nations for manufactured products. Great Britian was the chief manufacturing nation of the old world and she determined to keep our country, in, at least industrial vassalage.
One of her statutes interdicted the exportation of "any machine, engine, tool or press which now is or hereafter may be used in

the woolen, cotton or silk manufacture"

But thanks to the daring skill and energy of Samuel Slater, the gauntlet was safely run, and the Arkwright patent transported to our land, not on paper, not in wood, not in iron but in the retentive memory of Samuel Slater.

Providentially, he was led to Pawtucket, Rhode Island. Here he built his machinery, constructed his dam, erected his mill and soon there began on the banks of the Blackstone the whirr of seventy two spindles.

The business increased rapidily and new problems arose.
The water at that portion of the stream was rapid and he found it difficult to pass to the other shore. A bridge must be had. With his indomitable pluck he erected a very peculiar wooden structure, which would be classed in the words of modern times, as "statically undetermined"
No one knows how Sam Slater managed to transfer the products of his cotton mill across this bridge.

But for many years it stood as an honor to its owners engineering ability.
Sketches which remain bear the same stamp of peculiarity and excite fully as much curiosity, as the portrait of Samuel Slater with his knickerbockers, his bullet head, and the single lock of hair hanging over his forehead.

As the prosperity of Pawtucket increased the old frame bridge began to claim the attention of the more progressive citizens.
Attempts were made to repair it, but these efforts

only made it still more statically undetermined. The skill of its originator was lacking and a new bridge must be had.

The flourishing condition of the town seemed to warrant a stone arch and this was soon erected.

It was thought that the width of twenty four feet would be ample for generations to come. Time advances another pace and our bridge is again found inadequate to the demand. Relief is suggested by removing the foot passages from the roadway

Accordingly a side-walk is suspended on each side of the bridge making its total width forty feet with a high stone coping five feet high and two feet thick between each side and walk and the roadway. Five years ago the stone copings were removed and a small iron railing substituted. Bridges have been built both above and below the original bridge of Samuel Slater, but they only afford partial relief to the crowded business portions of the city. The recent introduction of the street

railway did not in the least alleviate matters. Various plans, accordingly, have been suggested during the past few years, for the widening of the Main Street bridge.
No definite action was taken however, until about a year ago, when a board of commissioners were appointed by the City Council to prepare plans for widening the bridge.
Accordingly an able engineer in Providence was consulted and with the assistance of the Pencoyd Bridge Works, he submitted plans

widening the bridge on the up stream side. It was to be accomplished by extending the center pier of the arch up stream upon which a double Warren Truss was rested.

There is little doubt but that the plans would have been accepted had not the mill owners on the East objected.

It was found that the truss on the East shore abutment, interfered with their gates and sluice ways.

The opposition was headed by Darius Goff perhaps the most influential man in the city and by far the most concerned in the improvement financially. (See Sheet No 1) He desired that the bridge should be widened on the down stream side.

The advantages claimed were:-

1st Little or no interference with water priveleges.

2d Foundations on either side easily arranged upon the ledge which extends under the river and is the cause of the water fall.

3d Property damaged would be limited to various frame structures.

more in number but of less value than the buildings cut upon the other side.

4th Improve and straighten the line of Main St. to better advantage.

The chief objection was the greater expense of extending the center pier down stream. This difficulty was caused by the greater height to the water surface and by the immense pot holes formed by the turbidity of the water.

Upon investigation, indeed, it was found that this disadvantage was most serious. Soundings were taken and the feasibility of extending the pier down stream was consequently abandoned.

One span must suffice and its length must be limited by high water. From the level of the dam to the top of the roadway there are but nineteen and a half feet. Record shows that in the recent flood eleven feet of water have stood upon the crest. This leaves but eight feet for the height of the truss. The span is one hundred and twelve feet.

The question of raising

the road bed was then discussed, but when it was found that the level of the bridge already exceeded that on either side relief from that quarter was acknowledged to be impracticable.

A straight chord bridge is thus practically out of the question, and as any structure except a deck bridge, is out of consideration, we are compelled to adopt the cantilever or the arch. The latter has been adopted With a span of one hundred feet rise twelve feet a three hinged arch has been designed. Said arch is placed eighteen feet from the present stone structure. The floor beams are allowed to extend six feet further making in all twenty four feet, and giving for the total width fifty six feet.

The advantages claimed were as a rule well taken. It was found that no water privelege would be seriously damaged. The sluice way on the west side would be partially filled by the abutment but there is no reason why the distance appropriated on one side could not be made up on the other. The bed is solid rock on both sides and on the east no difficulty is encountered. The arch could easily rest upon the ledge with little or perhaps no additional foundation

How much better the line of Main Street may be improved by widening on the south side is fully shown by the accompanying plan Sheet No 1
Two red lines are shown upon the east side they coincide. The old wooden

mill must be cut and a very disagreeable jag at the corner of River Street will be removed.

The abutments do not in the least affect the water privileges and sluice ways. The only extra damage to this property will possibly be the removal of the turbines a few inches further down the river. The difficulty of the western abutment has already been mentioned.

The longer line extending to the Post Office is the one recommend by reason;

1st Of the greater relief

afforded to the crowded portion.

2d. Straightening and improving the thorough fare generally

3d Because it would necessitate the removal of many old frame buildings which from a sanitary point of view should have been removed long ago.

Everyone of these buildings, with one minor exception, are wood. Widening on the north side would involve the cutting of three valuable brick block.

In view of these considerations, the south side was approved and the dimensions of a three hinged arch next claimed our attention.

Span;- The span of one hundred and twelve feet was about right and was accordingly adopted,

Rise; - From the road bed to the dam there are only nineteen and a half feet. The arch has been placed in the sidewalk in order to secure greater height. The center line of the upper chord being eight inches below the surface of the walk. Placing the center of the abutment three feet ten inches about the level of the dam leaves but fifteen feet for the end vertical. From these two points, one on each bank and one hundred and twelve feet apart, circles parabolas and ellipses have been drawn with a view to fitting the present stone arch. Both for the sake of appearance and to avoid danger of flood water. To do this it was necessary to know the exact shape of the stone arch. Measurements were made with this end in view and the results are as shown on Sheet No. 2 which shows the structure to be a five centered arch of radii nine twenty and forty one feet

It was thought that with a radius of one hundred and thirty six and two thirds feet a new arch could be designed which would best conform to the

the requirements mentioned. This gave a height of three feet at the center hinge and a rise of twelve feet.

Panels; — An excessive panel length brought the inclination of the diagonals nearly in line with the chords. For this reason a panel length of eight feet seemed to conform best to the requirements. Thus making a total of fourteen panels

Floor Beams;-
An effective widening of twenty four feet necessitated a floor beam of about twenty six and a half feet; the excess being in the sidewalk strut and the support on the stone arch. From the stone arch to the center of the iron arch there are eighteen feet, the remainder of the floorbeam being a cantilever. Being limited in height the floor beams cannot be placed on the upper chord nor can they

be suspended to the lower. Connection with the upper chord is the only available way. This connection has been made by passing the floor beams between the two channels of the verticals and resting them upon brackets riveted to the back of the channels which compose the verticals. The upper chord is ten inches deep the lower sixteen inches deep while the center vertical is but three feet. This limits the height of the floor beams to about fifteen inches consequently they are made of steel plates and angles.

Stringers:—

The stringers are made of plates and angles in the shape of steel flooring. This is supported upon the tops of the floor beams and is also limited in height Like the floor beam it is made of steel. Pencoyd iron flooring was not used owing to the greater efficiency of the above section.

The filling is to be concrete and tar capped with block paving.

Loading; — The structure has been designed to carry a live load of one hundred pounds to the square foot or the steam road roller used in the city.

Specification; —
The specifications are those recommended for highway bridges by the Massachusetts Institute of Technology

Calculations;—
The following calculations are submitted as a supplement to the plans and details shown on Sheet No 3

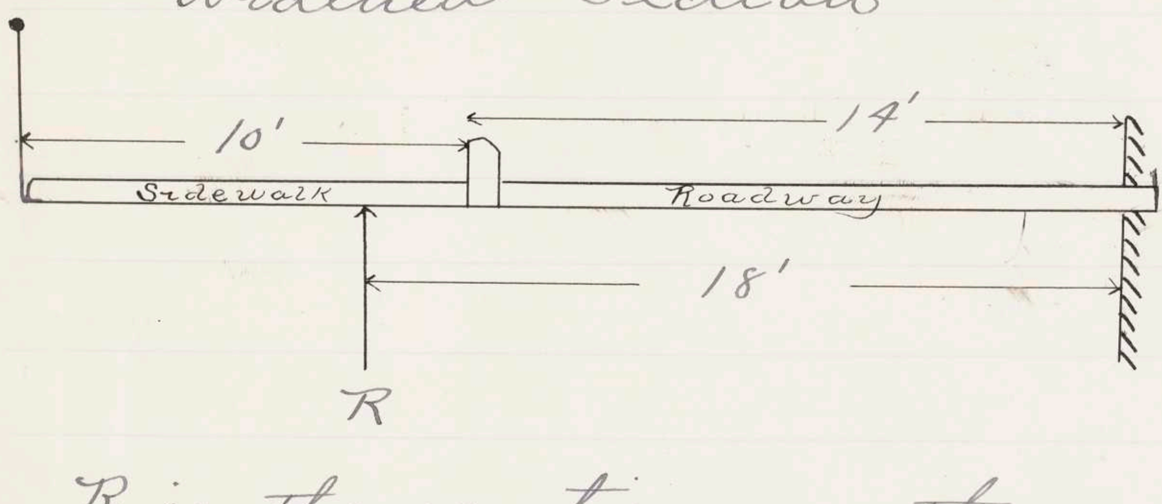
Conclusion:—
The seventy two spindles of Samuel Slater have been increased to over fourteen million.
The "Old Slater Mill" on the banks of the Blackstone has begotten thousands of cotton mills These, indeed, remain to recall the work of Samuel Slater.

But the old wooden bridge across which were carried many pounds of yarn, many pounds of cotton cloth, has been worn away by the hurrying steps of countless thousands.

In presenting our Design for Widening a Stone Arch to span this historic spot, we trust we have done no violence to the renown of him whose zeal, industry, courage, and skill won him the title of "Father of American Manufactures"

Live Loading
100 lbs per square foot or
Steam Road Roller
Used in Pawtucket R I

Widened Section

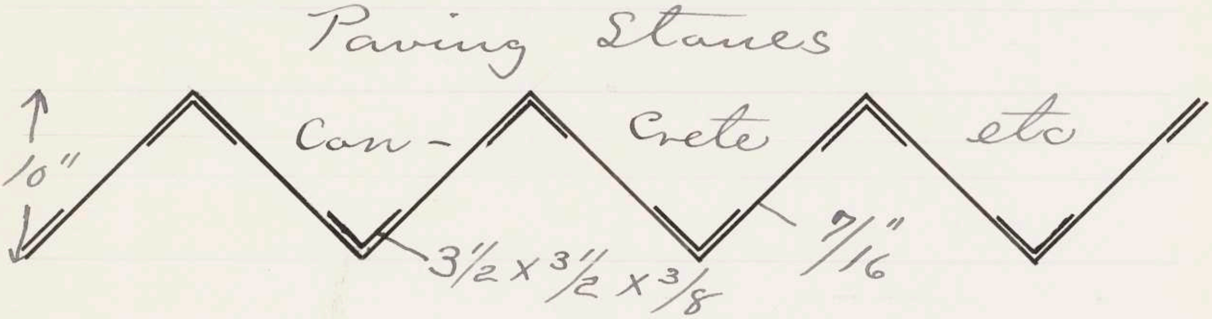


R is the reaction on the Iron arch which is placed 18 feet from the present stone arch

M.I.T. Specifications

Iron Flooring

Iron Flooring is used in the roadway some 14 feet



Loading ;— Section 20" wide

150 □" sand @ 100 lbs cu ft = 95
Paving stones @ 160 " " " = 140
Dead weight of flooring = 65
Total Dead Load = 300
per linear foot 20" wide

Live Rear wheel on Roller
6 tons placed in the center
of the span

$$M = \frac{300 \times 8 \times 8 \times 12}{8} + 6000 \times 4 \times 12$$

Iron Flooring

Max moment on section 20" wide

= 318600

Use Steel plates & L's ∴ $f = 10000$

Hence $I = \frac{316800 \times 5}{10000} = 15840$

Moment of Inertia of

2 Plates 7/16" thick

$\frac{2 \times .4375 \sqrt{2} \times 10 \times 10 \times 10}{12} = 103.2$

2 L's $3\frac{1}{2} \times 3\frac{1}{2} \times \frac{3}{8}$" A = 2.4

$2.48 (5 - 1.55)^2 \times 2 = 59.1$

164.7

OK

Required value of $I = 158.40$

Weight of Flooring 20" wide

2 Plates $10\sqrt{2} \times \frac{7}{16}$" = 35.35

2 L's $3\frac{1}{2} \times 3\frac{1}{2} \times \frac{3}{8}$ = 16.6

51.95

Assumed at 65 lbs ∴ OK

Iron Flooring

Pitch of Rivets :— $s = \frac{SQ}{I}$

S = Reaction = for 20"

Dead = 300 × 4 = 1200

Live = 6 tons = 12000

20" wide Total S = 13200

Shear on \ = 6600

$Q = 1.24 \times 3.45 = 3.87\ 4.28$

$s = \frac{6600 \times 4.28}{164.7} = 172$

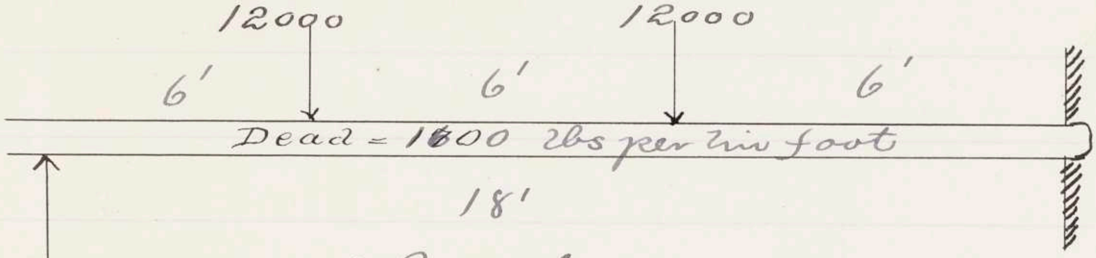
Shearing = 4500

Bearing = $\frac{7}{8} \times \frac{3}{8} \times 16000 = 5400$

$\frac{4500}{172} = 26.2"$ Pitch Rivets

Use about 4" or 5" pitch

Floor Beam



Dead load :— lin ft

Flooring 300 lbs 20" wide

$= 8 \frac{300}{20} 12 = 1440$ say 1500

Assume Floor Beam 100

Total Dead say 1600

Live Load Road Roller as shown

Moment :— $12000 \times 6 \times 12 = 864000$

$\frac{1600}{8} \times 18 \times 18 \times 12 = 777600$

Total moment inch lbs 1641600

Upper Flange

Assume depth 15" $R = \frac{1641600}{10000}$

$= 164.20$

$\frac{164.2}{15} = 10.92$ □"

Web $= \frac{1}{6} \times 3/8 \times 10 = .62$

10.30

2 L's $3\frac{1}{2} \times 3\frac{1}{2} \times 3/8 = 4.98$

Floor Beam

Upper Flange Continued

5.32

2 Plates $8 \times 3/8$ = 6.00

Lower Flange :— $\frac{1641600}{10500 \times 15}$

Required Area = 10.42 □"

Web as before = .62

9.80

2 L's $3\frac{1}{2} \times 3\frac{1}{2} \times 3/8$ = 4.32 net

5.48

2 Plates $6\frac{1}{4} \times 7/16$ = 5.46

Weight of Floor Beam per ft

4 L's $3\frac{1}{2} \times 3\frac{1}{2} \times 3/8$ = 33.2

Web $15 \times 3/8$ = 18.75

2 Plates $8 \times 3/8$ = 20.00

2 Plates $8 \times 7/16$ = 23.34

95.30 + 2% = 97

Assumed as 100 ∴ OK

Dead load on the cantilever tends to diminishes M_v. so small it was neglected

Floor Beam

Max Panel Load = 29400

$s = \frac{SQ}{I}$ $\quad S = 29400$

$Q = 7.98 \times 7.5 = 59.8$

$I = 59.8 \times 2 \times 7.5 + I_{web}$

$$s = \frac{29400 \times 59.8}{896 + 106} = 1750$$

Value of a Rivets Steel Plates

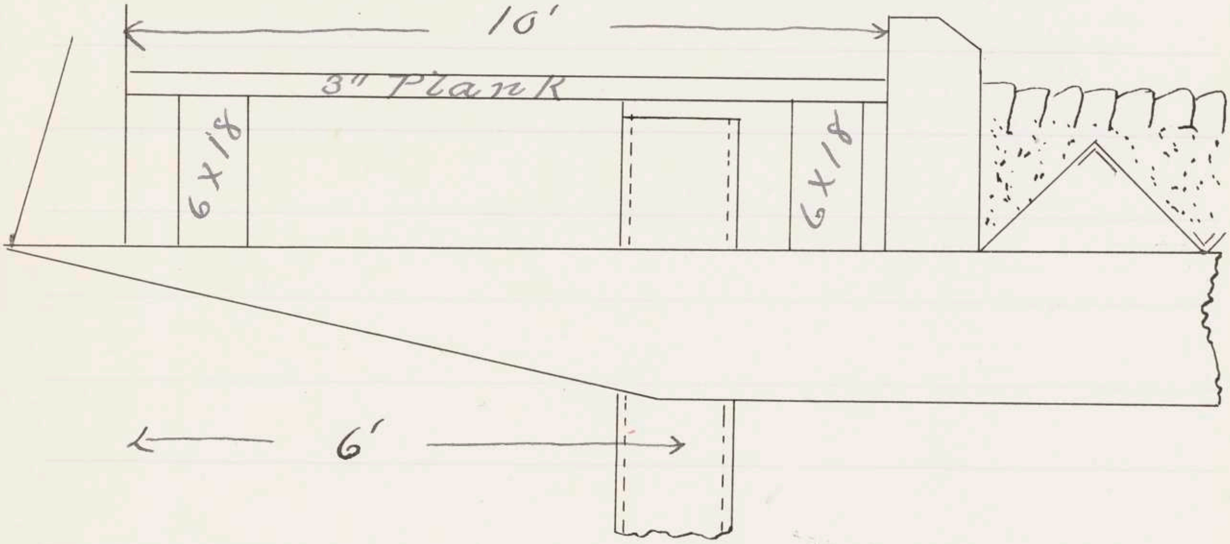
Bearing ;– $\frac{7}{8} \times \frac{3}{8} \times 18000 = 6000$

Shearing ;– $.6 \times 2 \times 7500 = 9000$

$$\text{Pitch} = \frac{6000}{1750} = 3.43''$$

3" Pitch is used

Floor Beam
Cantilever Portion :—



Sidewalk Live Load 100# □'
Yellow Pine Floor f = 1000

$$\frac{1000 \times 12 \times h^2}{6} = \frac{100 \times 9 \times 9 \times 12}{8}$$

$$h = 2.47''$$

∴ Call Floor 3" Planks

Stringers :— Must be 18" high on account of the truss
Use Cheap Timber f = 600
Loading Live = 5 × 100 = 500
Plank $40 \times \frac{1}{4} \times 5$ = 50; St = 25 say

Floor Beam

Cantilever Portion :- moment

200 x 6 x 12 = 14400

4600 x 5½ x 12 = 303600

Total moment 318000 inch lbs

Very much less than the other moment which this loading tends to diminish. Hence the entire area of the Floor Beam not quite as large as figured. Dead load of the wooden side so small that it was neglected in designing the first section.

Area of Cantilever portion diminished by cutting of plate. For other reasons the inner plates are carried throughout

Floor Beam

Stringer on Side walk

Load per ft = 500 + 50 + 25 = 575

$\frac{575}{8} \times 8 \times 8 \times 12 = \frac{1}{6} \times 600 \times b \times 18 \times 18$

$b = 1.75''$

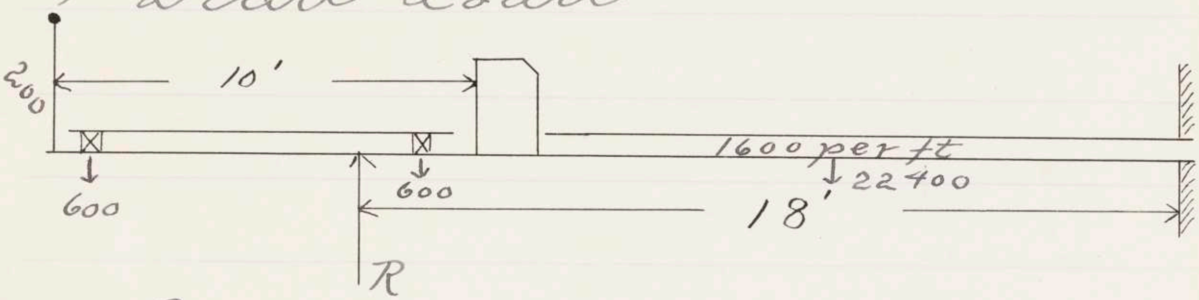
Here there must be some excess of material for the sake of getting the Arch as high from the water as possible Let us use 6" x 18"

Max Reaction on Stringer
= 575 x 8 = 4600 lbs
including both live & dead

Fence on Sidewalk weight
25 lbs per lin ft
25 x 8 = 200 lbs panel

Panel Loads

1° Dead Load



18 R = 22400 × 7 + 600 × 15 + 800 × 24

R = 9800 say 1300 per ft

2° Live Load 100 lbs □'

Stringer Reactions = 4000 each

8 × 100 × 14 = 11200 Roadway

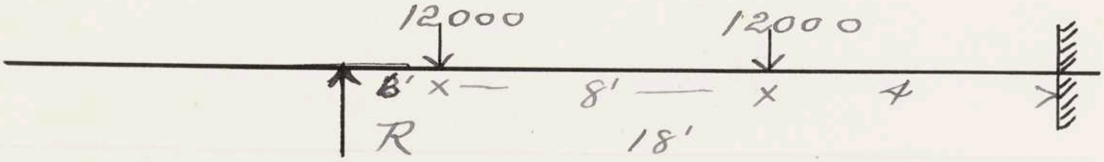
Hence 18 R = 11200 × 7 + 4000 (15 + 24)

R = 13000 say 1600 per ft

3° Road Roller Excess

Live on Roadbed

18 R = 11200 × 7 . R = 4355



18 R = 4 × 12000 + 12 × 12000 . R = 10555

Panel Loads

3° Continued

R. Live per panel = 4355

R. Road Roller = 10555

Excess ∴ = 6200 lbs. panel

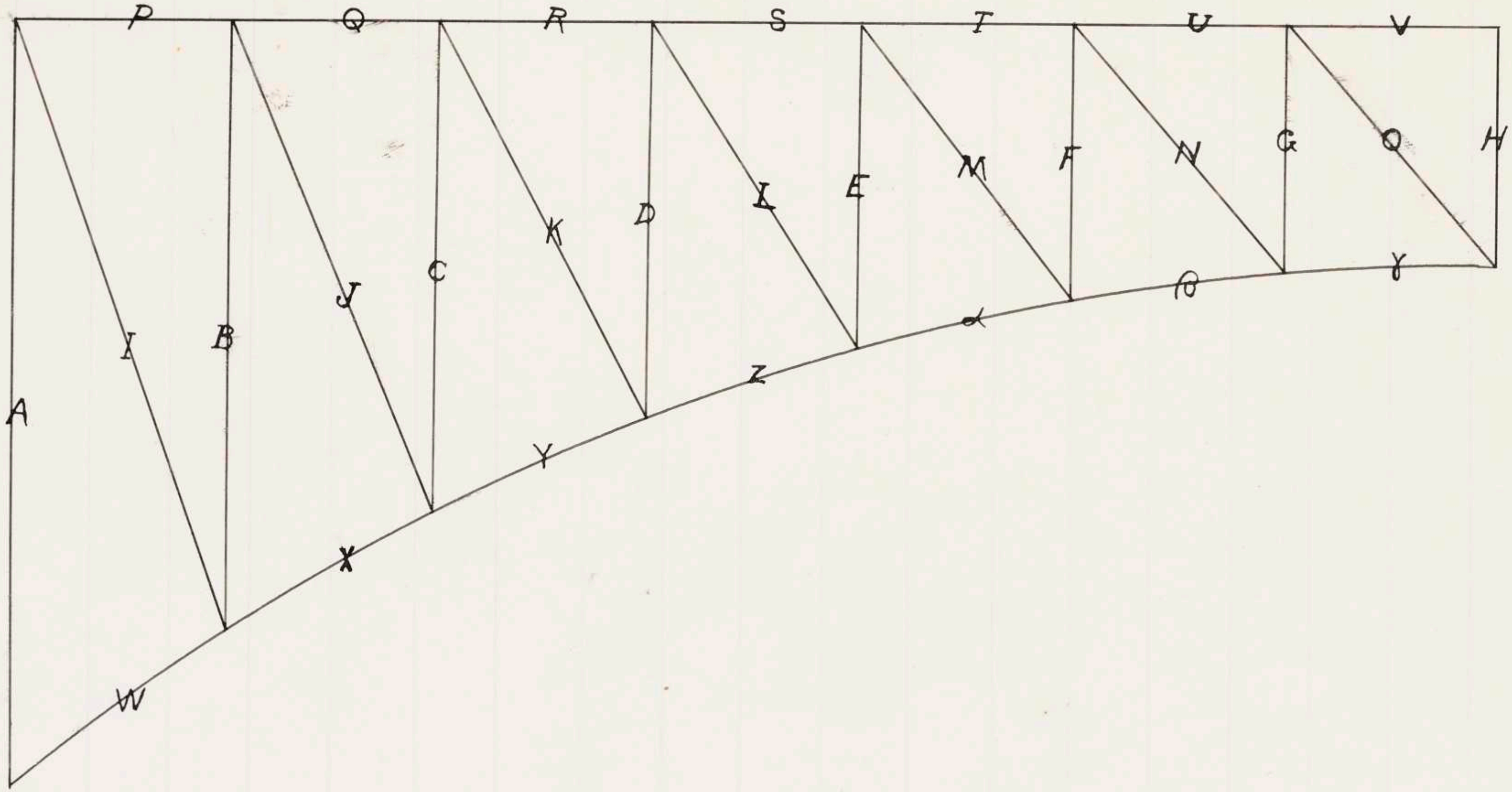
4° Dead Load Truss = 450 per ft

Summary for Influence Lines

Dead Load per ft = 1750

Live " " " = 1600

Road Roller Excess = 6200 per panel


P
Q
R
S
T
U
V
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
W
X
Y
Z

Span = 112   Rise = 12'
∴ Radius = 136.66'

Lengths of Bars

A = 15.00	I = 14.20	Q = 8.00	Y = 8.29
B = 11.71	J = 12.03	R = 8.00	Z = 8.17
C = 8.99	K = 10.50	S = 8.00	α = 8.08
D = 6.80	L = 9.50	T = 8.00	β = 8.03
E = 5.12	M = 8.92	U = 8.00	γ = 8.00
F = 3.94	N = 8.62	V = 8.00	
G = 3.24	O = 8.54	W = 8.65	
H = 3.00	P = 8.00	X = 8.45	

Reactions for Load Unity

Load at Joint

Panel	1 PQ	2 QR	3 RS	4 ST	5 TU	6 UV	7 V
V.C.	1/14	1/7	3/14	2/7	5/14	3/7	1/2
H.C.	1/3	2/3	1	4/3	5/3	2	7/3

Verticals — Bar A

Stress = V C of I + ½ Panel Load

Stress in I = ten 32000 Comp = 40000

V.C. : Stress = 11.71 : 14.2

V.C. = 26500 causing comp
10561 Road Roller
37061 = Total Comp.
16680
53741 Max Comp + 60%

V.C. = 33200 causing tension
5400 1350 × 4
27800 Max Tension
60
16680
44480 Max Tension + 60%

Assume 2-3.5 □" 8" [

$$\frac{9500}{1+\frac{1}{18000}\frac{15\times15\times144}{3\times3}} = 7920 \qquad \frac{53800}{7900} = 6.8$$

Hence 2 - 8" [3.5□" O.K.

Bar A Continued

Tension = 44480 " Comp = 53800

Pin = $3\frac{1}{8}$"

Bearing $= \dfrac{53800}{2 \times 3\frac{1}{8} \times 16000} = .54$ thick

∴ Use plate $\frac{9}{16}$"

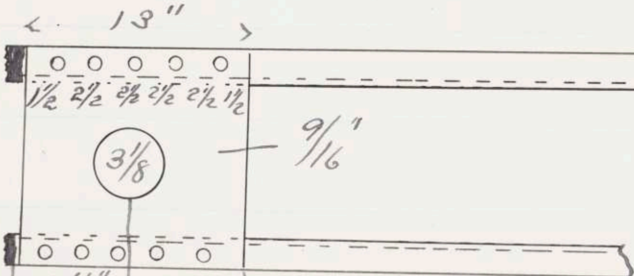
Rivets ; — $\frac{7}{8}$"

$.6 \times 7500 = 4500$ Shearing

$\frac{7}{8} \times 16000 \times .37 = 5150$ Bearing on 8" Ls

Shearing limits

$\dfrac{53800}{2 \times 4500} = 5.9$ Rivets on each side the vertical



8" Ls

6 Rivets necessary
10 used

This vertical carries tension 44480 Will the plate Shear?

Bar A Continued

Lanza gives $a = 100000$ in

$$a \frac{t l^2}{d} = 44480$$

solving $l = 1.15'' \pm$

Shearing :— $2\left(l + \frac{d}{2}\right) .56 \times 7500 = \frac{44480}{2}$

$l = 2.7''$

Hence $3\frac{1}{2}$ as used O K

Floor Beam Support

Live Load = 1600 per ft

Dead " = 1300 " "

2900

Reaction = 2800 × 8 = 23200

Road Roller Excess = 6200

Max Reaction 29400

Floor Beam at Panel A does not carry but 22000 Let us make detail same for all

Bar A Continued

Rivets ;– Shearing .6 x 7500 = 4500

8" ⊏ web = .21 + 3/8 Plate = .58

Bearing ;– 7/8 x 16000 x .58 = 8130

$\frac{29400}{4500}$ = 6.54 Rivets 4 on each

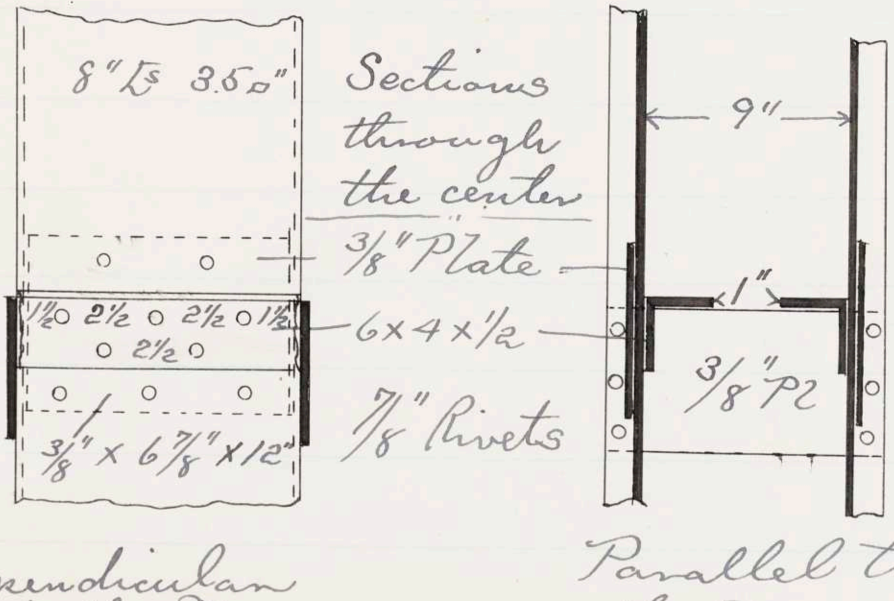
5 on each are used

Width ;– Floor Beam = 8" flange

Hence width in clear = 9"

Brackets ;– 6" x 4" x 1/2" ∠

4 Rivets (7/8) necessary use 5



Perpendicular to the Truss

Parallel to the Truss

Bar A Continued

Plate on lower end,—

Pin $5\frac{3}{4}''$

Assume plate as at the top $\frac{9}{16}$

$.56 \times 11 = 6.16$

$.56 \times 5.75 = 3.22$

3.94 net section

$\frac{22240}{394} = 7550$ Hence $\frac{9}{16}''$ Plate OK

Lanza,— $a = 100000$ in $a\frac{tl^2}{d}$

$$l^2 = \frac{5.75 \times 100000}{.56 \times 22240} = 46.21$$

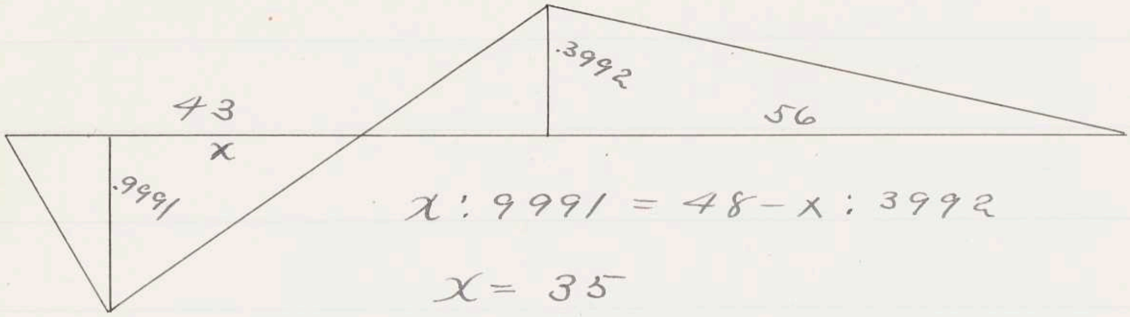
$l = 7'' \pm$

Shearing $2 \times 7500 \times (l + \frac{d}{2}) \times .56 = 22300$

$$l + \frac{5.75}{2} = 2.62$$

Hence Use same ($\frac{9}{16}''$) plate
Pin 7" from the edge

Bar B - Continued



$x : .9991 = 48 - x : .3992$

$x = 35$

Compression ;-

$\frac{43}{2} .9991 = 26.5$

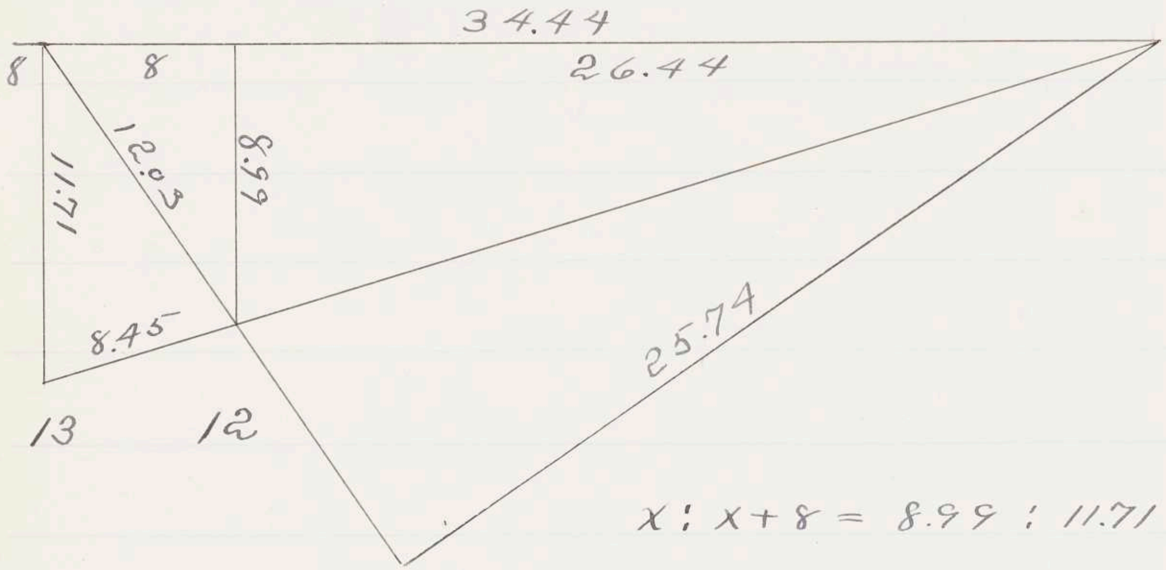
Tension ;- $\frac{79}{2}$ .3992 = 15.8

Difference = 10.7 Compression

Stresses ;-

Compression		Tension	
1750 x 10.7 =	18720	1600 x 15.8 =	25300
1600 x 26.5 =	42400	6200 x .3992 =	2480
			27780
6200 x .9991 =	6200		18720
	67320		9060
	5436 = 60 % 9060		5436
	72756		14496

Vertical Bar B



$x : x + 8 = 8.99 : 11.71$

$8 + x = 34.44$

$y : 34.44 = 8.99 : 12.03 \qquad y = 25.74$

Ordinates – Influence Lines

Load at 7;–

$-34.44\ S = -\frac{7}{3}\,15 + \frac{1}{2}\,42.44 \qquad S = +.3992$

Load at 13;–

$34.44\ S = \frac{1}{3}\,15 - \frac{13}{14}\,42.44 +$

$S = -.9991$

Load at 14 $\quad S = 0$

Bar B- Continued

Assume 2 - 8" [4.5 □"

$$\frac{9500}{1+\frac{1}{18000}\frac{11.7\times117\times144}{2.7\times2.7}} = 8260 \text{ Allow.}$$

$$\frac{72800}{2\times8200} = 4.44 □" \qquad 4.5 □" \text{ OK}$$

Bearing on Pin;-

$2\times3\frac{1}{8}"\times x\times16000 = 72800 \qquad x = .73$

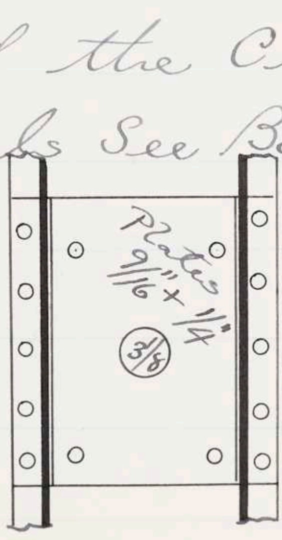
Hence 3/4" Plate this is the only place where 9/16" plate is not sufficient

Thus rivet on a 1/4" Plate inside and counter sink the rivets. This is done in order to maintain the width of the Chords

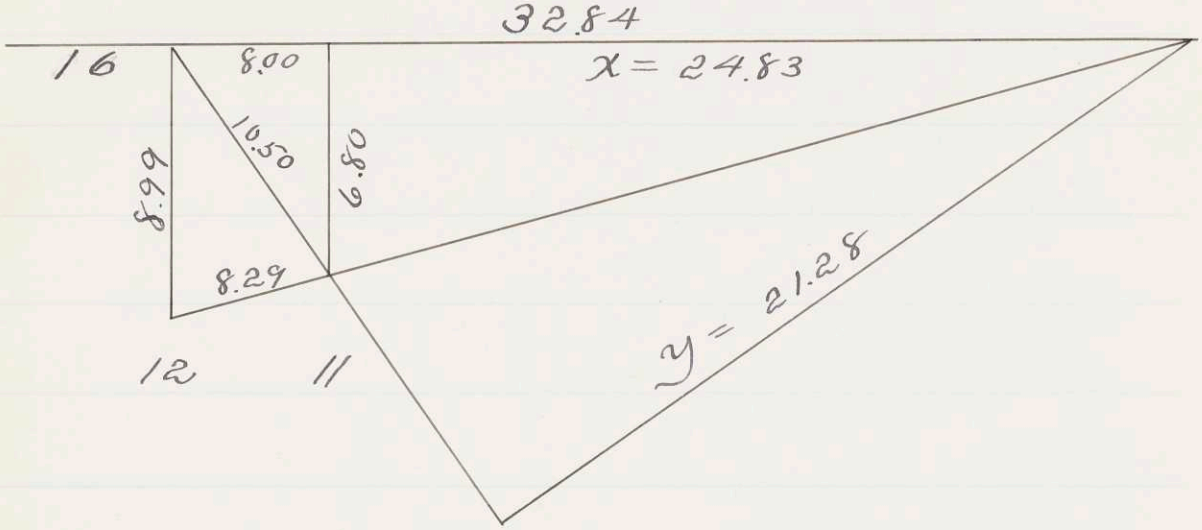
Rivets;- Other details See Bar A

$$\frac{72800}{2\times4500} = 8$$

10 rivets O.K.



Vertical – Bar C



$x : x + 8 = 6.80 : 8.99 \qquad x = 24.83$

$y : 32.84 = 6.80 : 10.5 \qquad y = 21.28$

Ordinates Influence Lines

Load at 7 $\qquad 32.84 + 16 = 48.84$

$+32.84\, S + \frac{1}{2}\, 48.84 - \frac{7}{3}\, 15 = 0 \qquad S = +.322$

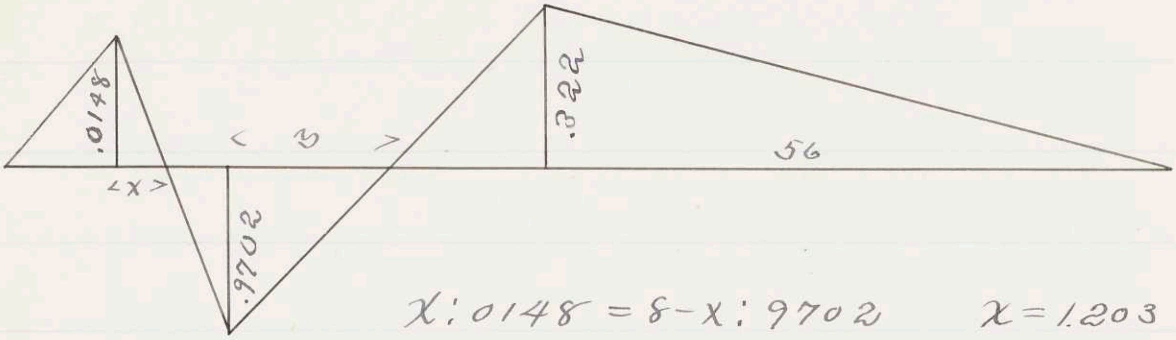
Load at 12

$+32.84\, S + \frac{6}{7}\, 48.84 - \frac{2}{3}\, 15 = 0 \qquad S = -.9702$

Load at 13

$32.84\, S + \frac{13}{14}\, 48.84 - \frac{1}{3}\, 15 - 40.84 \qquad S = +.0148$

Bar C-Continued



$x : .0148 = 8 - x : .9702 \qquad x = 1.203$

$y : .9702 = 40 - y : .322 \qquad y = 30.02$

Compression ;— $\frac{37.90}{2}$ .9702 = 18.40

Tension ;— $\frac{.0148}{2}$ 8.12 + $\frac{.322}{2}$ 65.98 = 10.67

Difference = 7.63 Compression

Compression	Tension
7.63 x 1750 = 13520	10.67 x 1600 = 17100
18.40 x 1600 = 29450	6200 x .322 = 1990
6200 x .9702 = 6020	19090
48990	Dead = 13520
3340	5570
52330	.6
	3342
Max Comp. + 60%	Ten. 8912

Bar C Continued

Assume 2-8" [3□"

$$\text{Allow Stress} = \frac{9500}{1 + \frac{1}{18000}\frac{9 \times 9 \times 144}{3 \times 3}}$$

$= 8860$

$$\frac{52400}{2 \times 8800} = 2.93□" \qquad 3□" \text{ O.K.}$$

Details of Connections with

(a) Floor Beam

(b) Pin

Same as bar A since

Bearing:— On Pin

$$\frac{52400}{2 \times 3\frac{1}{8} \times 16000} = .532 \quad \text{say } \tfrac{9}{16}" \text{ Plate}$$

Same as A

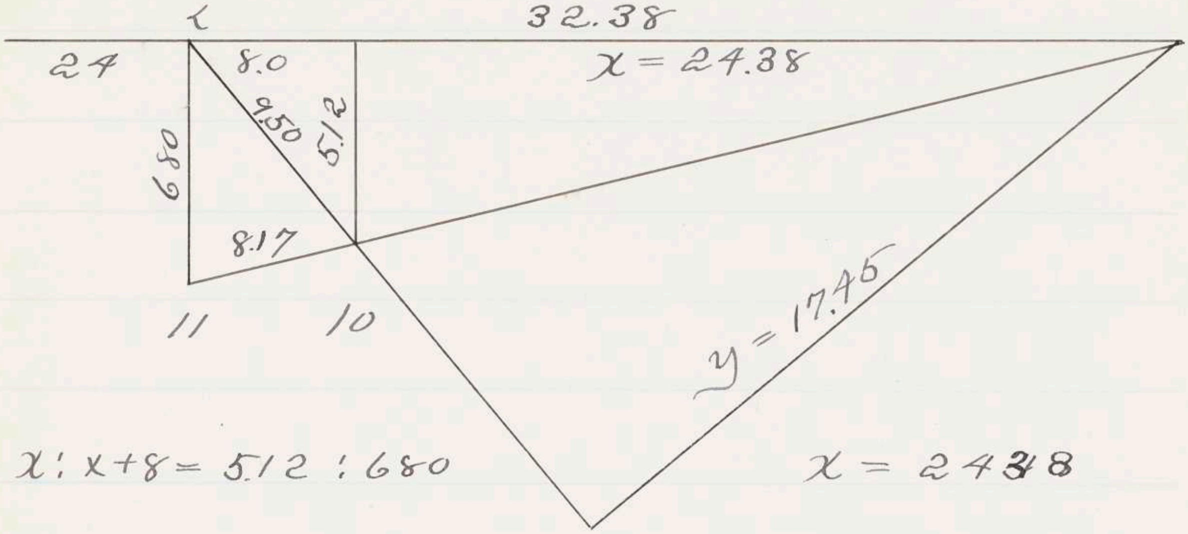
Rivets;— 7/8"

Shearing $4500 = .6 \times 7500$

Bearing $\frac{7}{8} \times 16000 \times .37 = .5180$

$$\frac{52400}{2 \times 4500} = 6 \text{ Rivets} \quad \text{Use 10 as in A}$$

Vertical - Bar D



$x : x+8 = 5.12 : 6.80$ $\quad x = 24.38$

$y : 32.38 = 5.12 : 9.50$ $\quad y = 17.45$

Ordinates - Influence Line

Load at 7 $\quad 8 + 24.38 + 24. = 56.38$

$32.38\,S - \frac{7}{3}\,15 + \frac{1}{2}\,56.38 = 0$

$S = +.210$

Load at 11

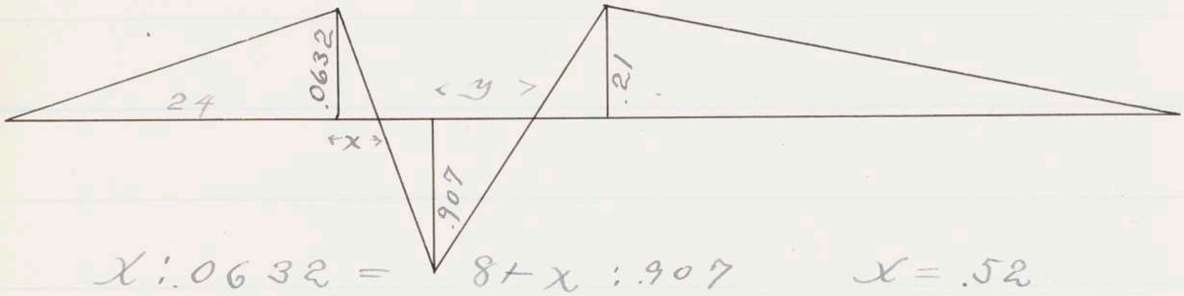
$32.38\,S + \frac{11}{14}\,56.38 - 15 = 0 \quad S = -.907$

Load at 12

$32.38\,S + \frac{6}{7}\,56.38 - \frac{2}{3}\,15 - 40.38 = 0$

$S = +.0632$

Bar D Continued



$x : .0632 = 8 + x : .907 \qquad x = .52$

$y : .907 = 32 - y : .21 \qquad y = 31.27$

Compression ;— $\frac{7.48 + 31.27}{2} .907 = 17.57$

Tension ;— $\frac{.0632}{2} 24.52 + 56.73 \frac{.21}{2} = 6.73$

Difference 10.84 Compression

Compression	Tension
10.84 x 1750 = 18990	1600 x 6.73 = 10780
17.57 x 1600 = 28110	6200 x .21 = 1310
6200 x .907 = 5630	12090
52730	18990
	Comp.

Assume 2 - 6" [30"

$$\frac{9500}{1 + \frac{1}{18000} \frac{6.8 \times 6.8 \times 144}{2.3 \times 2.3}} = 8930 \text{ allow}$$

Bar D Continued

$$\frac{53000}{2 \times 8900} = 2.98 \square''$$

∴ 2-6" [s 3□" O.K For sake of uniformity 2-8" [s same area

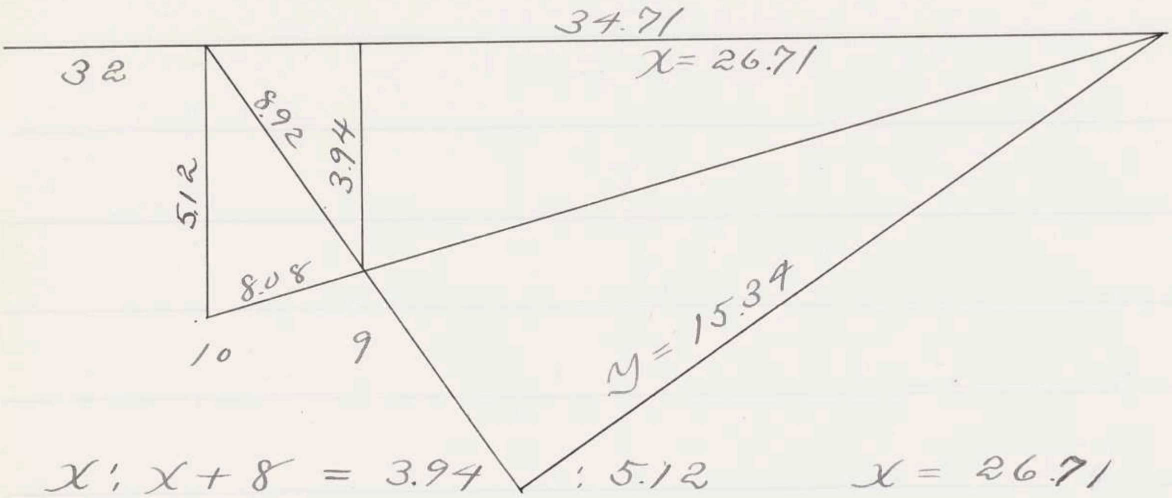
Bearing on Pin

$$\frac{53000}{2 \times 3\frac{1}{8} \times 16000} = .531$$ say 9/16" Plate and make it in this detail the same as Bar A

Floor Beam Connection

Same as Bar B, A etc.

Vertical Bar E.



$x : x + 8 = 3.94 : 5.12 \qquad x = 26.71$

$y : 34.71 = 3.94 : 8.92 \qquad y = 15.33$

Influence Lines

$S\ 34.71 + \frac{1}{2} 66.71 - \frac{7}{3} 15 = 0$

$S = +.0474$ Load at 7

Load at 10

$34.71\ S + \frac{5}{7} 66.71 - \frac{4}{3} \times 15 = 0$

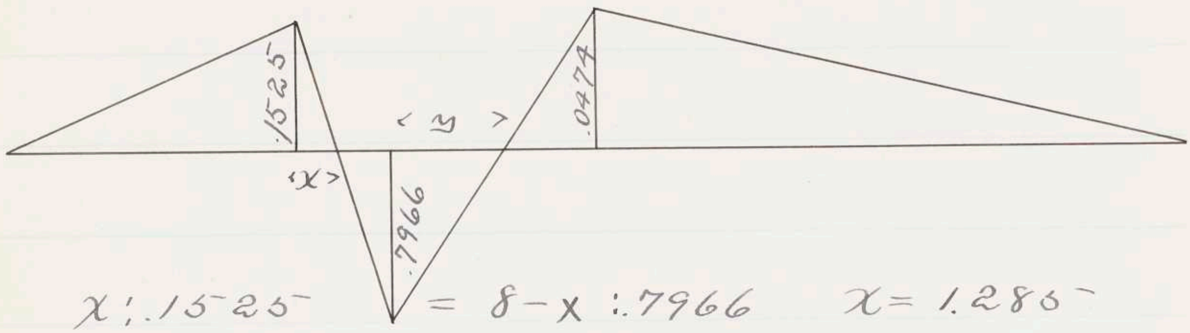
$S = -.7966$

Load at 11

$34.71\ S + \frac{11}{14} 66.71 - \frac{4}{4} 15 - 42.71 = 0$

$S = +.1525$

Bar E Continued



$x : .1525 = 8 - x : .7966 \qquad x = 1.285$

$y : 7966 = 24 - y : .0474 \qquad y - 2262$

Compression :– $\frac{29.34}{2}\ .7966 = 1170$

Tension :– $\frac{.1525}{2}\ 25.28 + \frac{0474}{2}\ 57.38 = 3.29$

Difference = 8.41 Compression

Compression	Tension
$8.41 \times 1750 = 14720$	Never
$11.70 \times 1600 = 18700$	
$6200 \times .7966 = 4940$	
38360	

Assume 2 – 6" [2.5 □"

$$\frac{9500}{1 + \frac{1}{18000}\ \frac{512 \times 512 \times 144}{2.3 \times 2.3}} = 9225 \quad \text{allow}$$

Bar E Continued

$$\frac{39000}{9200 \times 2} = 2.12 \square''$$

Call it 3□"

And make it like the others

2 - 8" [s 3□"

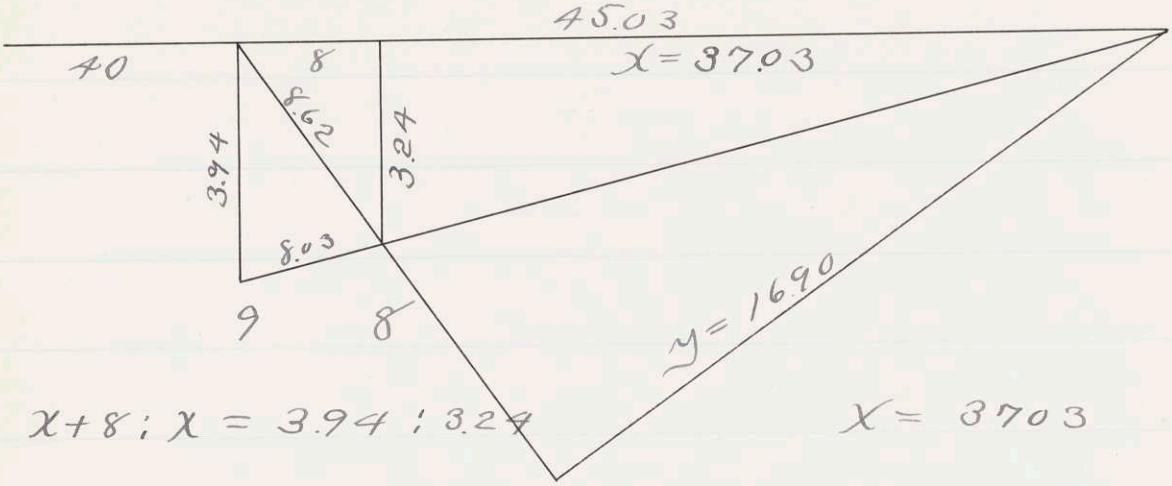
Bearing on Pin

$$\frac{39000}{2 \times 3\frac{1}{8} \times 16000} = .40$$

Call it 9/16 and make it like the others

Floor Beam Connections the same as stated Bar A

Vertical - Bar F



$x+8 : x = 3.94 : 3.24$ $\qquad x = 3703$

$y : 45.03 = 324 : 862$ $\qquad y = 16.90$

Influence Line

Load at 7

$45.03\ S + \frac{1}{2}\ 85.03 - \frac{7}{3}\ 15 = 0$

$S = -.1669$

Load at 9

$4503\ S + \frac{9}{14}\ 8503 - \frac{5}{3}\ 15 = 0$

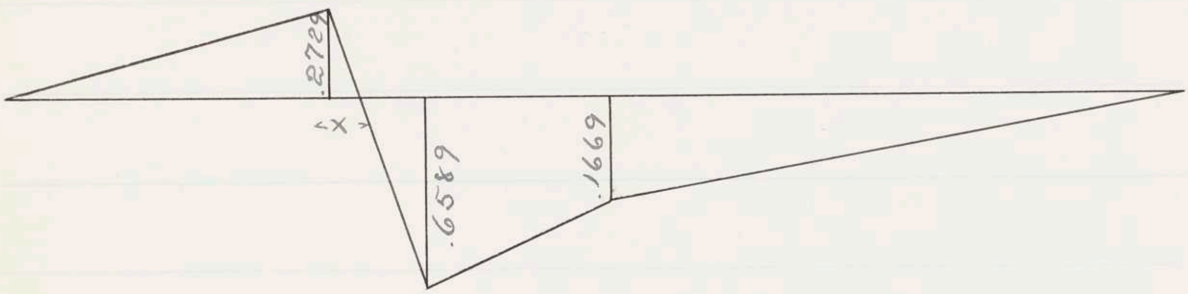
$S = -.6589$

Load at 10

$45.03\ S + \frac{5}{7}\ 85.03 - \frac{4}{3}\ 15 - 53.03 = 0$

$S = +.2729$

Bar F' Continued



$x : .2729 = 8 - x : .6589 \qquad x = 2.34$

Tension :— $\frac{.2729 \times 34.34}{2} = 4.68$

Compression :— $.1669 \times 28 + 8(.1669 + .6587)$

$+ \frac{5.66}{2} .6589 = 13.15$

Difference = 8.47 Compression

Compression

$8.47 \times 1750 = 14820$

$13.15 \times 1600 = 21200$

$6200 \times .6589 = 4080$

40100

Tension

$1600 \times 4.68 = 7500$

Never

Assume 2-6" [s 2.5 □"

Bar F Continued

$$\frac{9500}{1+\frac{1}{18000}\frac{3.94 \times 3.94 \times 144}{2.3 \times 2.3}} = 9290$$

$$\frac{40100}{2 \times 9200} = 2.18 \square''$$

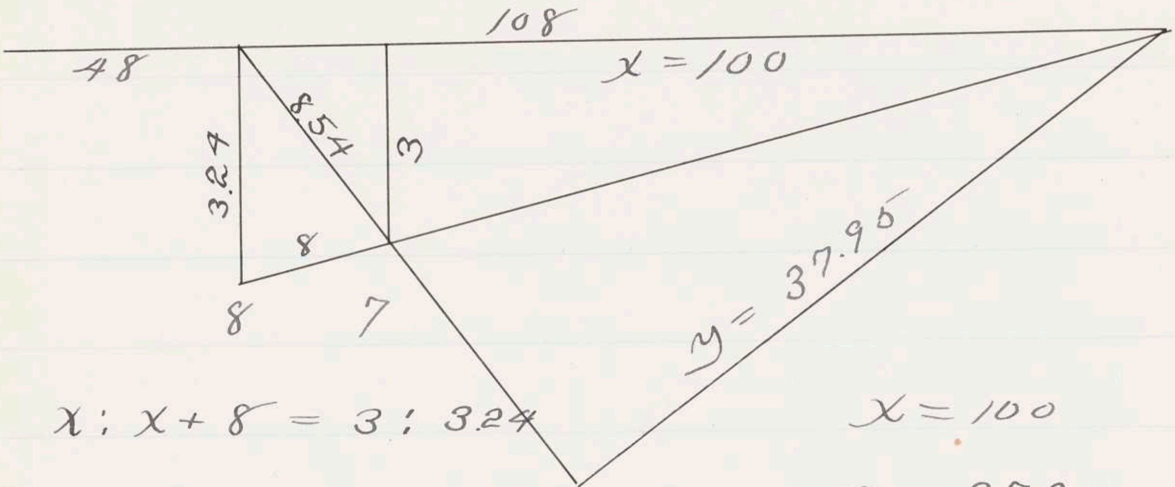
Use 2 - 8" [3□" same as before

Bearing on Pin

$$\frac{40100}{2 \times 3\frac{1}{8} \times 16000} = .41$$ say 9/16" Plate same as before

Floor Beam Connections same as Bar A

Vertical Bar Co



$x : x + 8 = 3 : 3.24$ $\qquad x = 100$

$y : 108 = 3 : 8.54$ $\qquad y = 37.95$

Influence Line :—

Load at 7 —

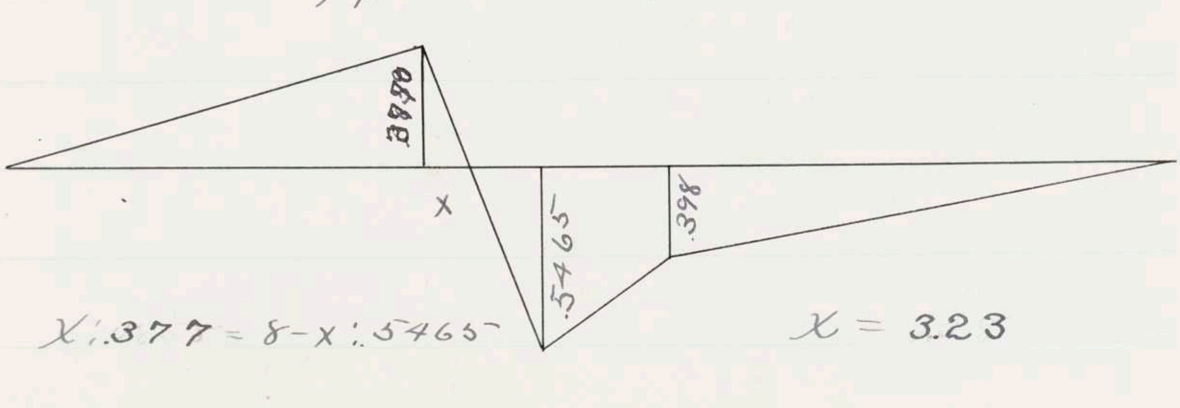
$108\,S + 156\,\frac{1}{2} - \frac{7}{3}\,15 = 0 \qquad S = -.398$

Load at 8 —

$108\,S + 156\,\frac{4}{7} - 2 \times 15 = 0 \qquad S = -.5465$

Load at 9 —

$-108\,S + \frac{5}{14} \times 44 + \frac{5}{3}\,15 = 0 \qquad S = +.3770$



$x : .377 = 8 - x : .5465 \qquad x = 3.23$

Bar G Continued

Compression :— $= 16.23$

$$\frac{.398}{2}\,56 + (.5465 + .398)\,4 + \frac{.5465}{2}\,4.77$$

Tension $= \frac{.377}{2}\,43.23 = 8.15$

Difference 8.08 Compression

Compression :— Tension

16.23 x 1600 =	26000	1600 x 8.15 =	13040
1750 x 8.08 =	14140	6200 x .377 =	2400
6200 x .5465 =	3380		15440
	43520	Dead	14140
+60% T	780		1300
	44300		

Assume 2-8" ⊏s 3□"

$$\frac{9500}{1+\frac{1}{18000}\,\frac{324 \times 324 \times 144}{3.07 \times 3.07}} = 9430 \text{ allow}$$

$$\frac{45000}{2 \times 9400} = 2.72\ \square''$$

Hence 2-8" ⊏s 3□" OK some excess but better to be uniform

Vertical Bar H

Max Tension = 0

Max Compression = max panel load = 29800 as deduced under Bar A

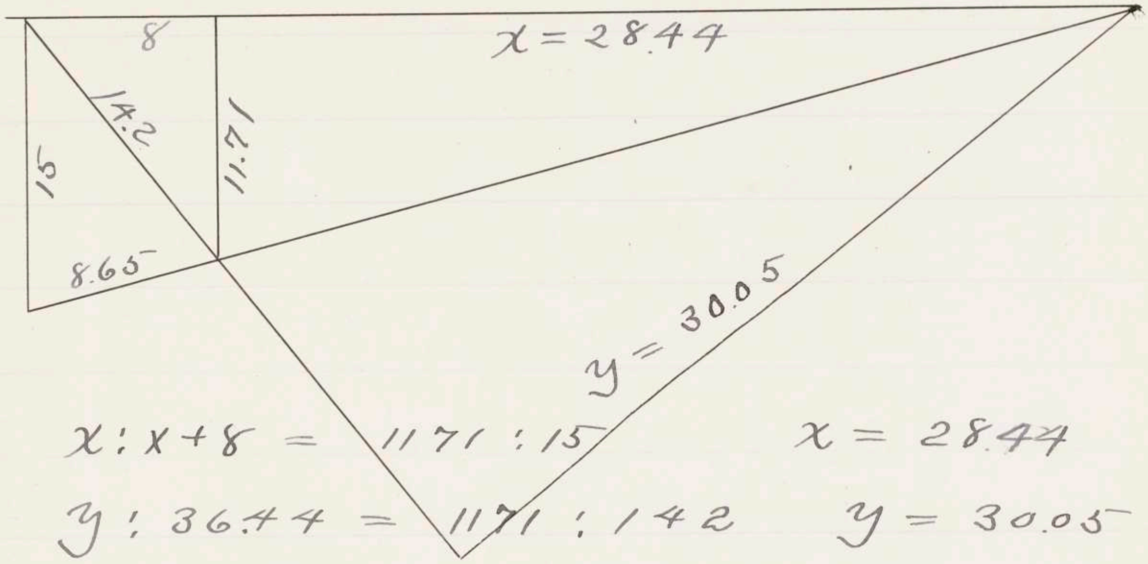
$\frac{29800}{6\square''} = 4970$ Allow. at least is 9300

For the sake of Floor Beam connection make it the same as the others

Hence 2 - 8" [3□" total 6□"

Shearing and Bearing on pin :- Much less than in any other case but for uniformity call it 9/16" plate 10 Rivets

Diagonal Bar I



$x : x+8 = 11.71 : 15 \qquad x = 28.44$

$y : 36.44 = 11.71 : 14.2 \qquad y = 30.05$

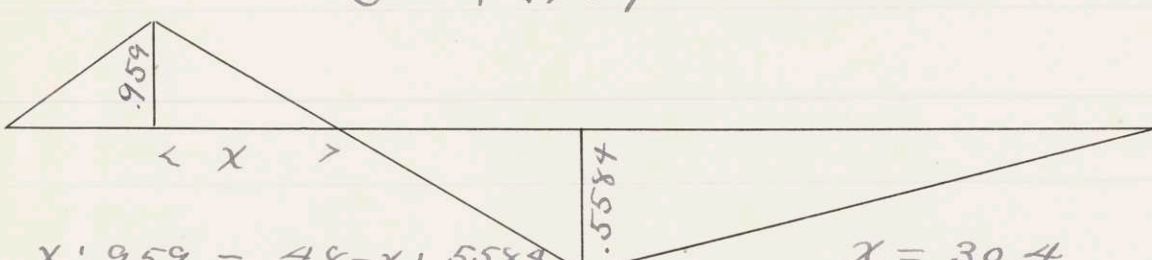
Influence Lines :—

Load at 7 $\quad -30.05\,S + 36.44\,\frac{1}{2} - \frac{7}{3}\,15 = 0$

$S = -.5584$

Load at 13 $\quad -30.05\,S + \frac{13}{14}\,36.44 - \frac{15}{3} = 0$

$S = +.959$



$x : .959 = 48 - x : .5584 \qquad x = 30.4$

Tension : $\frac{.959}{2}\,38.4 = 18.45$

Compression :— $\frac{.5584}{2}\,73.6 = 20.58$

Difference = 2.13 Compression

Bar I Continued

Compression		Tension	
1750 x 2.13 =	3730	1600 x 18.45 =	29500
1600 x 20.58 =	32900	6200 x .959 =	5950
6200 x 5584 =	3460		35450
	40090	Dead	3730
60% ten =	19032		31720
		+ 60%	19032
max =	59122		50752

Assume 2 - 8" ⊏ 4 □"

$$\frac{9500}{1+\frac{1}{18000}\,\frac{14.2 \times 14.2 \times 144}{2.89 \times 2.89}} = 8080 \text{ allow}$$

$$\frac{59122}{2 \times 8000} = 3.7 \text{ □"} \quad \text{Comp OK}$$

Tension; -

Bearing on Pin, -

$$\frac{59200}{2 \times 16000 \times 3\frac{1}{8}} = .60 \quad \text{Web} = 34$$

∴ say 3/8" Filler

Gross Section = 4 □"

Pin hole .34 x 3 1/8 = 1.06

2.94 Net

$$\frac{50800}{2 \times 2.94} = 8500 \quad \text{Tension O.K.}$$

Diagonal Bar J

Sketch and Lever Arms see Bar B

Influence Line:—

Load at 7 $-25.74\,S + \frac{1}{2}\,42.44 - 15\,\frac{7}{3} = 0$

$S = -.5353$

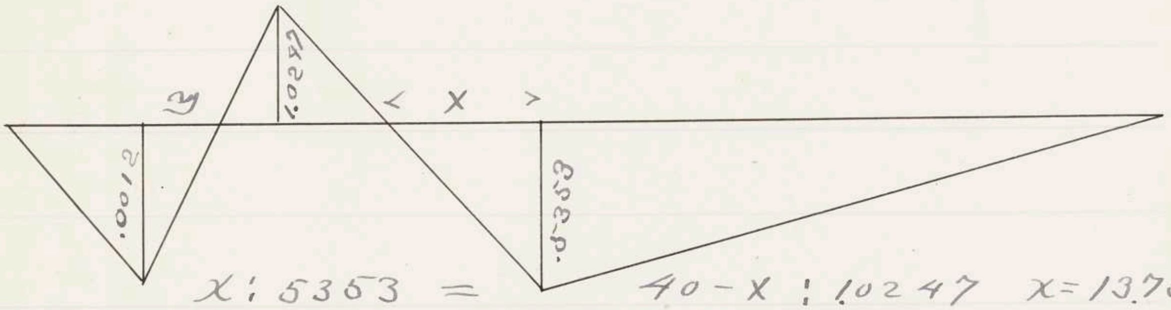
Load at 12 —

$-S\,25.74 + \frac{6}{7}\,42.44 - 15\,\frac{2}{3} = 0 \qquad S = +1.048$

Load at 13

$-S\,25.74 + \frac{13}{14}\,42.44 - 15\,\frac{1}{3} - 3444 = 0$

$S = -.0012$



$x : .5353 = 40 - x : 1.0247 \qquad x = 13.75$

$y : .0012 = 8 - y : 1.0247 \qquad y = 0.0094$

Tension:— $\frac{1.0247}{2}\,34.25 = 17.52$

Compression:— $\frac{.5353}{2}\,69.75 = 18.68$

Difference 1.16 Compression

Bar J Continued

Compression		Tension	
1.16 x 1750 =	2030	1600 x 17.52 =	28100
18.68 x 1600 =	29900	6200 x 1.0247 =	6350
6200 x .5353 =	3320		34450
	35250	Dead	2030
+ 60% ten	19450		32420
Max	54700	+ 60%	19450
		Total	51870

Compression:

Assume 2 - 8" [4□"

$$\frac{9500}{1 + \frac{1}{18000}\frac{12 \times 12 \times 144}{2.89 \times 289}} = 8280 \text{ allow}$$

$$\frac{54700}{2 \times 8200} = 3.34 □" \quad 4□" \text{ OK}$$

Bearing:—

$$\frac{54700}{2 \times 16000 \times 3/8} = .55$$

.34
.21 say 3/8" Plate

Tension:—

Gross Area = 4"

Pin Hole 1.06
2.94

$$\frac{52000}{2 \times 294} = 8850 \quad \text{O.K.}$$

Diagonal Bar K

Sketch and Lever Arms Bar C

Influence Line

Load at 7

$-21.28\,S + \frac{1}{2}\,48.84 - \frac{7}{3}\,15 = 0 \quad S = {}^{-}.4975$

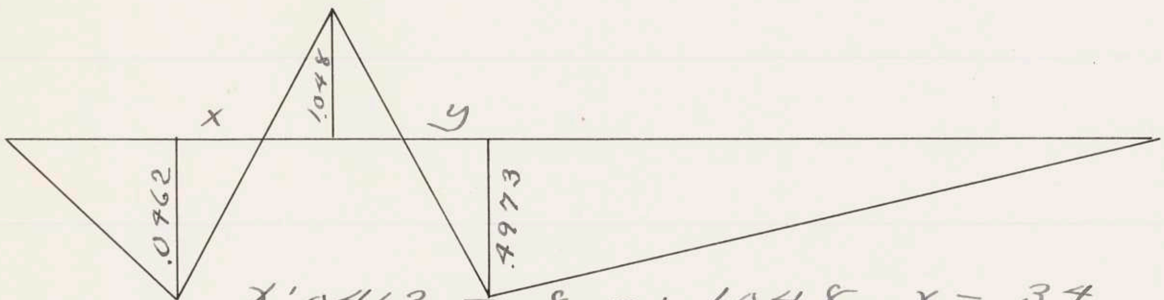
Load at 11

$-21.28\,S + \frac{11}{14}\,\sout{48.84} - \frac{7}{7}\,15 = 0 \quad S = {}^{+}1.048$

Load at 12

$-21.28\,S + \frac{6}{7}\,48.84 - \frac{2}{3}\,15 - 32.84 = 0$

$S = {}^{-}.0462$



$x : .0462 = 8 - x : 1.048 \quad x = .34$

$y : .4975 = 32 - x : 1.048 \quad y = 10.25$

Compression :—

$\frac{16.32}{2}\,.0462 + \frac{.4975}{2}\,66.25 = 16.84$

Tension :— $\frac{1.048}{2}\,29.41 = 15.38$

Difference = .46 Compression

Bar K Continued

Compression		Tension	
.46 x 1750 =	805	15.38 x 1600 =	24600
16.84 x 1600 =	26950	6200 x 1.048 =	6500
6200 x .4973 =	3080		31100
	30835	+ 60%	805
+60% ten.	18177		30295
	49012		18177
			48472

Compression :— 2-8" ⊏s 4 □"

$$\frac{9000}{1+\frac{1}{18000}\frac{10.5 \times 10.5 \times 144}{2.89 \times 2.89}} = 8580$$

$$\frac{49012}{2 \times 8500} = 2.9 \text{ □}''$$

Bearing :— $\frac{49012}{2 \times 3\frac{1}{8} \times 16000} = .492$

Web of 8" ⊏ 4 □" = .34

Say use a 3/8" Plate

Tension :— Gross Area 4 □"

Pin hole = 1.06

2.94

$$\frac{48472}{2 \times 2.94} = 8270$$

∴ Use 2-8" ⊏s 4 □"

Diagonal Bar L

Sketch and Lever arms Bar D

Influence Line:

Load at 7 $-17.45 S + 56.38 \frac{1}{2} - 15 \, 7/3 = 0$

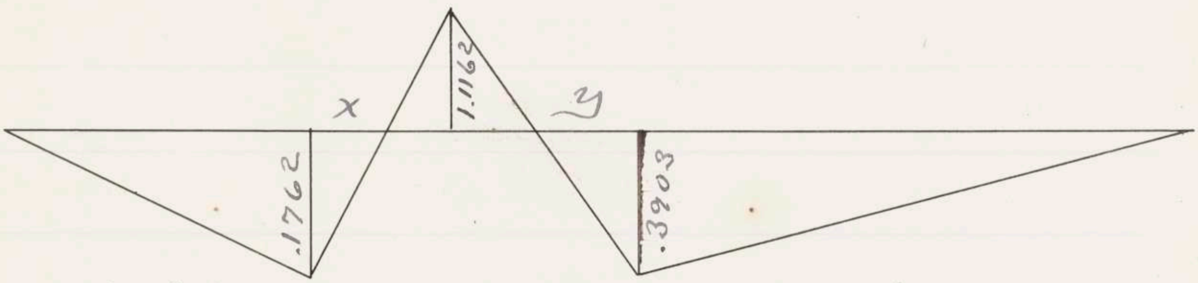
$S = -.3903$

Load at 10: $-17.45 S + \frac{5}{7} 56.38 - 15 \, 4/3 = 0$

$S = +1.162$

Load at 11; $-17.45 S - \frac{11}{14} 56.38 - 15 - 32.38 = 0$

$S = .1762$



$x : .1762 = 8 - x : 1.1162 \quad x = 1.09$

$y : .3903 = 24 - y : 1.162 \quad y = 6.20$

Tension: $\frac{24.71}{2} \, 1.1162 = 13.78$

Compression: $\frac{3.903}{2} \, .1762 + \frac{62.2}{2} \, .3903$

$= 14.36$

Difference .58 Compression

Bar L Continued

Compression		Tension	
$.58 \times 1750 =$	1014	$13.78 \times 1600 =$	22040
$14.36 \times 1600 =$	23000	$1.1162 \times 6200 =$	6920
$6200 \times .3903 =$	2440		28960
	26554	Dead	1014
+ 60 %	15932		27946
	42486	+ 60% Com	15932
			43878

Compression :— 2-8" Ls 4 □"

$$\frac{9500}{1+\frac{1}{18000}\ \frac{9.5 \times 9.5 \times 144}{2.89 \times 2.89}} = 8680 \text{ allow}$$

$$\frac{43500}{2 \times 8600} = 2.54\ □''$$

Tension :— Gross 4

Pin hole 1.06

2.94 Net

$$\frac{43900}{2 \times 2.94} = 7350$$

Some Excess but better to make the diagonals uniform when there is such a slight difference ∴ 2-8" Ls 4 □" with 3/8" Filler for Bearing

Bar M Diagonal

Sketch & Lever Arms Bar E

Influence Lines :—

Load at 7 $-15.34 S + \frac{1}{2} 66.71 - 15 \frac{7}{3} = 0$

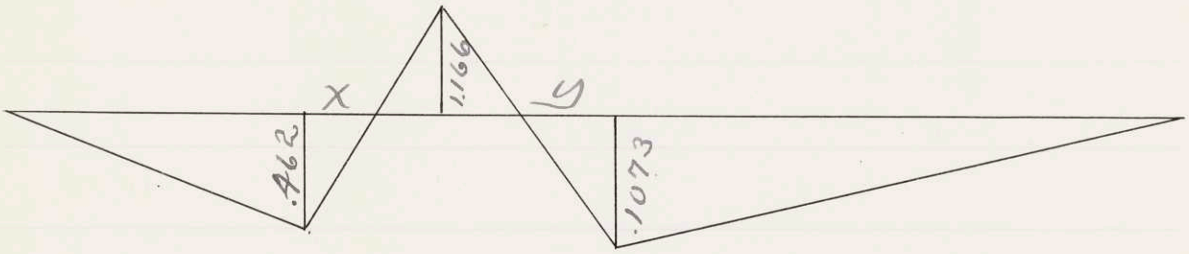
$S = .1073$

Load at 9 :— $S = +1.166$

$-15.34 S + \frac{9}{14} 66.71 - 15 \frac{5}{3} = 0$ $S =$

Load at 10 :— $S = -.462$

$-15.34 S + \frac{5}{7} 66.71 - 15 \frac{4}{3} - 34.71 = 0$



$x : .462 = 8 - x : 1.166$ $x = 2.27$

$y : .107 = 24 - y : 1.166$ $y = 2.018$

Tension :—

$\frac{1.166}{2} 27.72 = 16.16$

Compression :—

$\frac{.462}{2} 34.27 + \frac{.1073}{2} 58.018 = 9.20$

Difference 6.96 Tension

Bar M Continued

Tension | Compression

Tension		Compression	
6.96 x 1750 =	12180	9.2 x 1600 =	14710
16.16 x 1600 =	25800	6200 x .462 =	2860
6200 x 1.166 =	7240		17570
	45220	Dead	12180
+60% Comp	3234		5390
	48454	+60% =	3234
			8624

Assume 2-8" [4□"

Compression OK

Tension :- Gross 4□"

Pin Hole 1.06

2.94 Net

$\frac{48500}{2 \times 2.94} = 8320$

Hence 2-8" [4□" OK

Bearing on Pin

$\frac{48500}{3/8 \times 16000 \times 2} = .49$ Web 34

Use the same uniform plate 3/8"

Diagonal Bar N

Sketch and Lever Arms Bar F

Influence Lines

Load at 7 $S = +.4471$

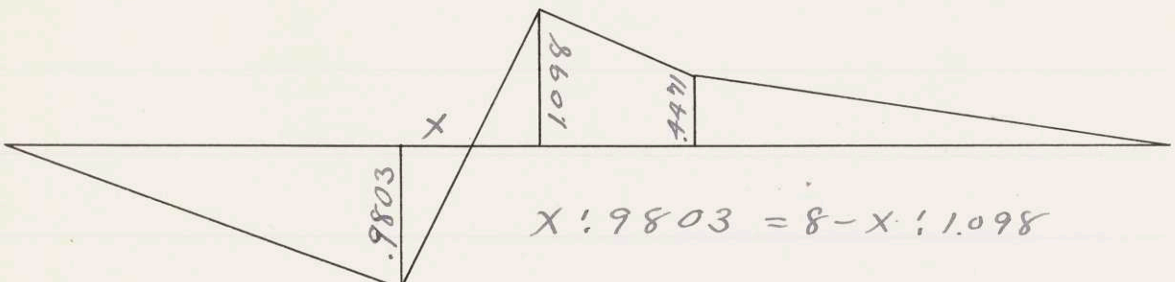
$-16.90\,S + 85.03\,\frac{1}{2} - 15\,\frac{7}{3} = 0$

Load at 8 $S = +1.098$

$-16.90\,S + 85.03\,\frac{4}{7} - 2 \times 15 = 0$

Load at 9 $S = -.9803$

$-16.90\,S + 85.03\,\frac{9}{14} - \frac{5}{3}\,15 - 45.03 = 0$



$X : .9803 = 8 - X : 1.098$

$X = 3.78$

Tension :—

$\frac{.4471}{2}\,56 + \frac{1.098 + .4471}{2}\,8 + \frac{1.098}{2}\,4.22 = 21.00$

Compression :—

$\frac{.9803}{2}\,43.78 = 21.5$

Difference .5 Compression

Bar N Continued

Will the plate shear out the $\perp$

Stress in N is greater than in any other diagonal in which $\perp$ is used

Hence Safer for N safer for all

Lanza gives $a = 100000$

$$\text{Stress} = a\frac{t l^2}{d}$$

$$42000 = 100000\frac{.7 l^2}{3\frac{1}{8}} \qquad l = 1.66''$$

Shearing:

$$2 \times 7500\left(l + \frac{d}{2}\right) \times .7 = 31000$$

$$l = 1.39''$$

Nothing less than 3" used on any diagonal generally much more Hence there is no danger from shearing on the diagonals

Bar N Continued

Compression		Tension	
1750 x .5 =	875	1600 x 21 =	33600
1600 x 21. =	34400	6200 x 1.098 =	6810
6200 x .98 =	6100		40410
		Dead	875
	41375		39535
+60% ten	22500	+60%	23500
Compression	63875		62000

$$\frac{9500}{1 + \frac{1}{18000} \frac{86 \times 86 \times 144}{2.89 \times 289}} = 8850 \text{ allow}$$

Assume 2-8" [4 □"

$$\frac{63875}{2 \times 8800} = 3.52 \ \square$$

∴ 2-8" [4 □" OK

Tension: Gross Area 4 □"

Pin hole 1.06

2.94

$$\frac{62000}{2 \times 2.94} = 10600$$

Plate must be used

Bearing: $\frac{64000}{2 \times 3/8 \times 16000} = .65$

web = .34

Say 3/8" Plate .31 Ten. O.K.

Hence 2-8" [4 □" OK

Diagonal Bar O

Sketch and Lever Arms Bar Co

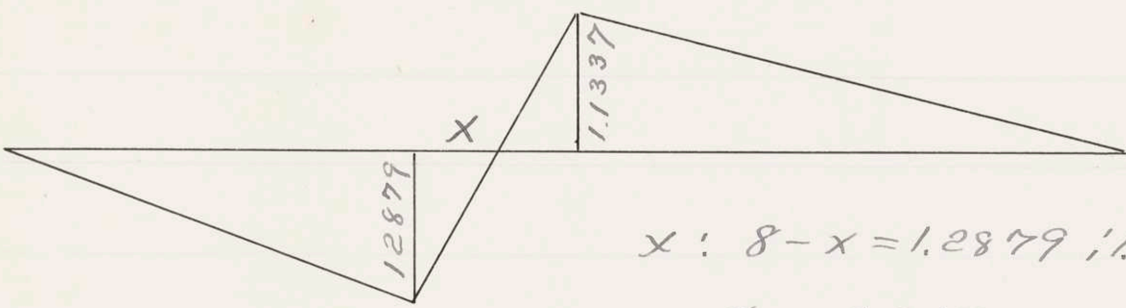
Influence Lines

Load at 7 $S = 1.1337$

$-37.95 S + \frac{1}{2} 156 - 15 \frac{7}{3} = 0$

Load at 8 $S = 1.2879$

$-3795 S + \frac{4}{7} 156 - 2 \times 15 - 108 = 0$



$x : 8 - x = 1.2879 : 1.1337$

$x = 4.25$

Tension :– $\frac{11337}{2}$ $5975 = 33.95$

Compression :– $\frac{12879}{2}$ $5225 = 33.62$

Difference = .33 Tension

Compression		Tension	
33.62 x 1600 =	53800	.33 x 1750 =	578
6200 x 1.2879 =	7990	1600 x 33.95 =	54300
	61790	6200 x 1.1337 =	7050
Dead	578		61928
	61212	+ 60% C	36727
+ 60%	36727	Total	98655
	97939		

Bar O Continued

Tension :—

$$\frac{98700}{2 \times 9500} = 5.2 \,\square''$$

$$5.25 = 7 \times 3/4$$

$7 \times 3/4$ + Rivet hole = $8 \times 3/4$ OK

Compression ;

$$I = \frac{3 \times 8 \times 8 \times 8}{4 \times 12} = 32 \qquad C^2 = 5.33$$

$$\frac{9500}{1 + \frac{1}{18000} \frac{854 \times 854 \times 144}{5.33}} = 8575 \text{ allow}$$

$$\frac{98000}{2 \times 8500} = 5.8 \,\square''$$

$\therefore$ 2 — Eye Bars $8 \times 3/4$

Lattice or spacers

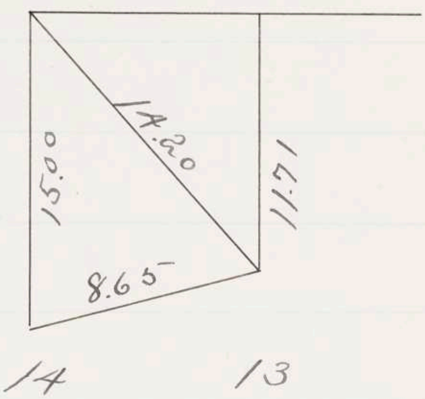
$$I = \frac{8 \times 3 \times 3 \times 3}{12 \times 4 \times 4 \times 4} = \frac{9}{32} \qquad C^2 = \frac{54}{32}$$

$$\frac{9500}{1 + \frac{1}{18000} \frac{l^2 \times 144}{1.688}} = \frac{98000}{12} = 8300$$

$l = 5.4$ ft $\therefore$ Use 2

Eye Beam spacers 3' apart

Upper Chord Bar P



Influence Lines

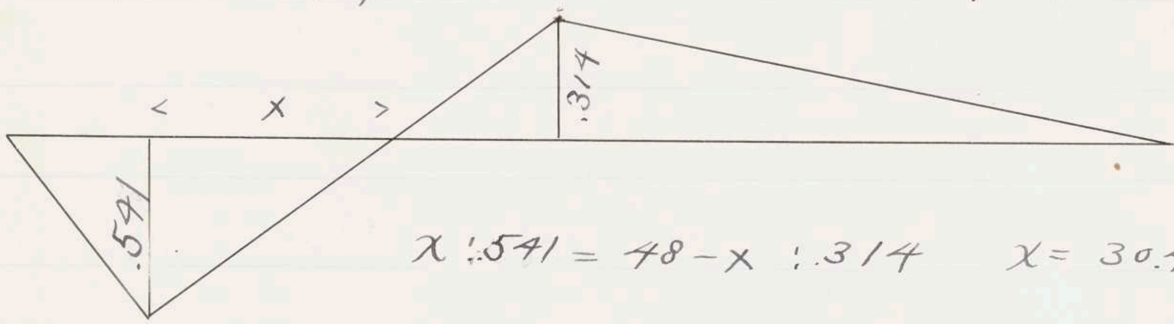
Load at 7

$11.71 S + \frac{1}{2} 8 - \frac{7}{3} 3.29 = 0$

$S = +.314$

Load at 13

$11.71 S + \frac{13}{14} 8 - \frac{1}{3} 3.29 \qquad S = -.541$



$x : .541 = 48 - x : .314 \qquad x = 30.4$

Tension :— $\frac{.314}{2}$ 73.6 = 11.55

Compression :— $\frac{.541}{2}$ 38.4 = 10.38

Difference 1.17 Tension

Tension	Compression
1.17 x 1750 = 2015	10.38 x 1600 = 16650
11.55 x 1600 = 18500	.541 x 6200 = 3350
6200 x .3141 = 1950	20000
22465	Dead 2015
	17985

Bar P Continued

Tension = 22465

60% Comp = 10791

33256 Total Tension

Compression = 17985

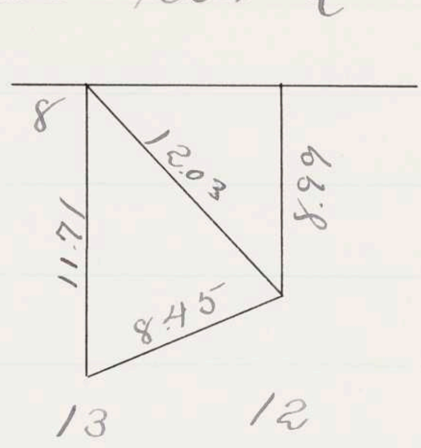
+60% = 10791

28776 Total Comp.

Such wide variations of stress between this and the adjoining panel necessitates an excess of material in this bar

Details see Bar Q

Upper Chord Bar Q



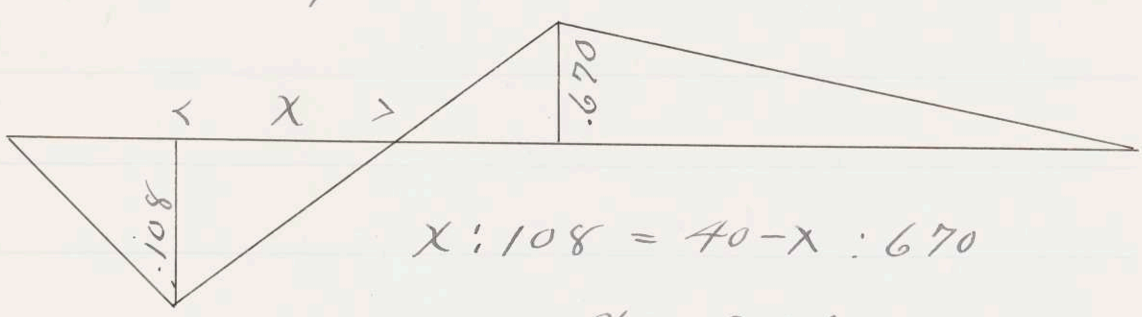
Influence Line
Load at 7

S 8.99 + $\frac{1}{2}$ 16 − $\frac{7}{3}$ 7.01

S = +.670

Load at 12

8.99 S + $\frac{6}{7}$ 16 − $\frac{2}{3}$ 7.01   S = −.108



X : .108 = 40 − X : .670

x = 24.7

Compression :− $\frac{40.7}{2}$ × .108 = 2.2.
Tension :− $\frac{71.3}{2}$ × .67 = 23.9

Difference = 1.92 Tension

Tension		Compression	
1.92 × 1750 =	3320	1600 × 22 =	35200
23.9 × 1600 =	38200	6200 × .108 =	670
6200 × .670 =	4160		35870
	45680		3320
		Total	32550

Bar Q Continued

Compression 32550 + .60% = 52080

Tension 45680 + 19530 = 65210

Compression:—

Use smallest 10" ⊏ 4.8 □"

$$\frac{9500}{1 + \frac{1}{18000}\frac{8 \times 8 \times 144}{3.62 \times 3.62}} = 9220$$

$$\frac{52080}{2 \times 9200} = 2.83 \ \square'' \text{ necessary}$$

Tension:— 4.8 □"

Pin hole 3 1/8 × 32 .99

Net section 3.81

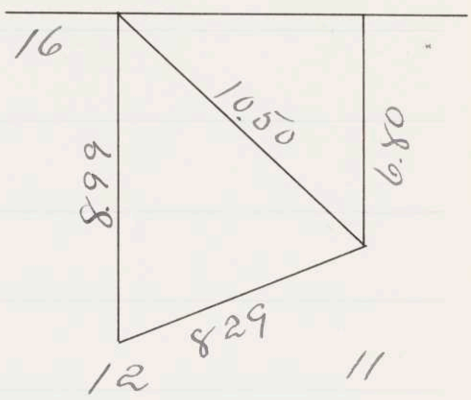
$$\frac{65210}{2 \times 3.81} = 8600$$

Hence use a 10" ⊏ 4.8 □" for the first two panel

Splice in the second panel

Details See Bar R

Upper Chord Bar R



Influence Lines

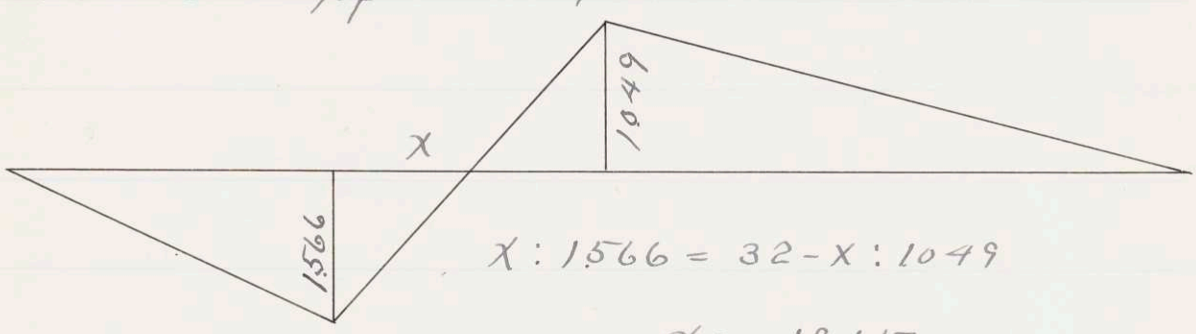
Load at 7

$6.80 S + \frac{1}{2} 24 - \frac{7}{3} 8.2$

$S = 1.049$

Load at 11

$6.80 S + \frac{11}{14} 24 - \frac{7}{3}$ $S = 1.566$



$x : 1.566 = 32 - x : 1049$

$x = 19.15$

Compression $\frac{1566}{2}$ 43.15 = 33.8

Tension $\frac{1049}{2}$ 6885 = 36.15

Difference 2.35 Tension

Tension	Compression
2.35 x 17.50 = 4125	33.8 x 1600 = 54100
36.15 x 1600 = 57800	6200 x 1.566 = 9700
6200 x 1.049 = 6500	63800
68425	Dead 4125
	59675

Bar R Continued

Compression 59675 + 60% = 95470

Tension 68425 + 35795 = 104220

Bars R, S, T, U are made in one piece of 10" ⊏ for section see Bar T

Connection with Bar Q Splice

10" ⊏ 4.8 □" & 10" ⊏ 9 □"

web .32 web .66 Filler .34

Make the splice in Bar Q

Rivets — Shearing = 4500

Bearing: = .66 × $\frac{7}{8}$ × 1600 = 9200

.34" Filler tight used on Q

Stress in Q = 65210

$\frac{65210}{2 \times 4500}$ = 7.2 Rivets

Put a plate on the inside 10 × 3/8

Bar R Continued

Then Rivets in Double Shear

$$\frac{65210}{2 \times 9000} = 3.6 \text{ Rivets}$$

6 Rivets are used

Area 10 ⊏ in Q = 4.8"□

$$\frac{4.8}{10" + 7"} = .283 \quad \text{say } 3/8"$$

Hence Splice consists

10 x 3/8" plate on outside

7 x .34" Filler on inside

7 x 3/8 plate on inside

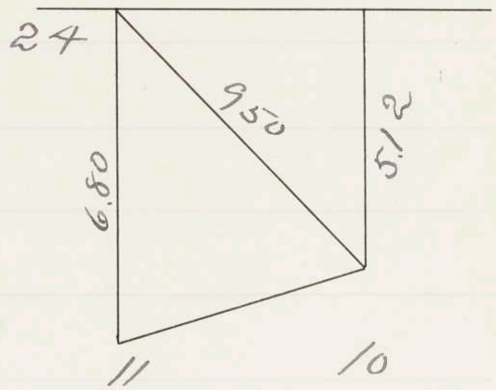
4 Rivets on each side necessary

6 being used with the

same number in the

7 x .34" tight filler

Upper Chord Bar S



Influence Line

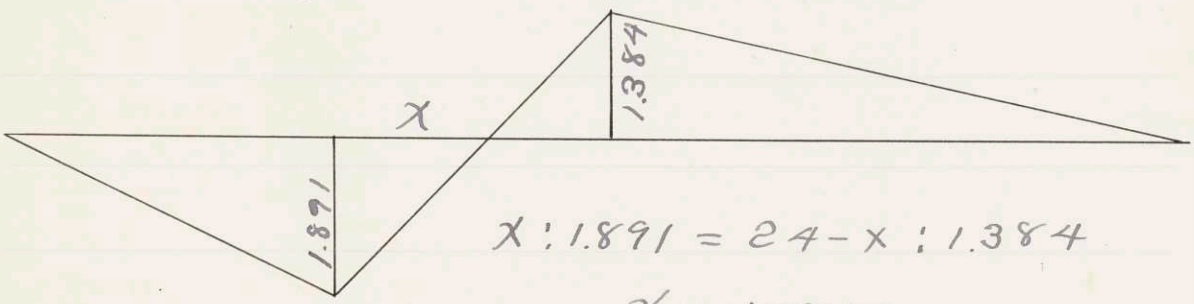
Load at 7

$5.12 S + \frac{1}{2} 32 - \frac{7}{3} 9.88 = 0$

$S = +1.384$

Load at 10

$5.12 S + \frac{5}{7} 32 - \frac{4}{3} 9.88 = 0 \qquad S = 1.891$



$X : 1.891 = 24 - X : 1.384$

$X = 13.85$

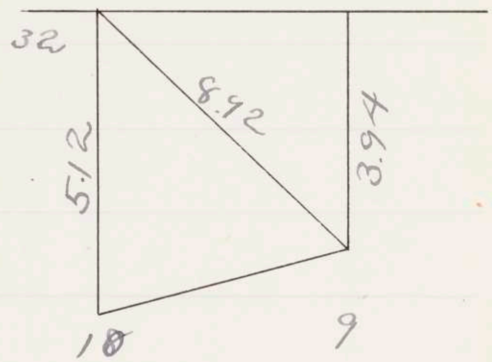
Compression $\frac{1.891}{2} 45.85 = 43.4$

Tension $\frac{1.384}{2} 66.15 = 45.7$

Difference = 2.3 Tension

Tension	Compression
2.3 x 1750 = 4020	1600 x 43.4 = 69500
45.7 x 1600 = 73300	6200 x 1.891 = 11710
1.384 x 6200 = 8580	81210
85900	Dead 4020
	77190
+60% C = 132214	+60% = 123504

Upper Chord Bar T

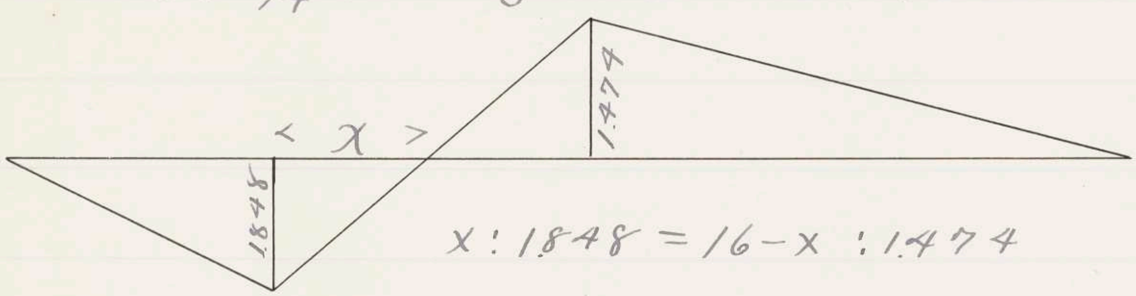


Influence Lines
Load at 7

394 S + $\frac{1}{2}$ 40 − $\frac{7}{3}$ 11.06

S = 1.474

394 S + $\frac{9}{14}$ 40 − $\frac{5}{3}$ 11.06 S = 1.848



x : 1.848 = 16 − x : 1.474

x = 8.90

Compression ;— $\frac{48.9}{2}$ 1.848 = 45.2

Tension ;— $\frac{1.474}{2}$ 63.1 = 46.5

Difference = 1.3 Tension

Compression	Tension
45.2 x 1600 = 72400	1.3 x 1750 = 2190
6200 x 1.848 = 11480	46.5 x 1600 = 74400
83880	
Dead 2190	6200 x 1.474 = 9150
81690	85740
+60% 49020	+60% C = 49020
130710	134760

Bar T Continued

Stress	Tension	Compression
Bar R	104220	95470
" S	132214	123504
" T	134760	130710

These bars made of one section say 2-10"⊏s 9□"

Compression:—

$$\frac{9500}{1+\frac{1}{18000}\frac{8\times 8\times 144}{3.46\times 3.46}} = 9080 \text{ allow}$$

$$\frac{130710}{2\times 9\square''} = 7300$$ ∴ Comp OK

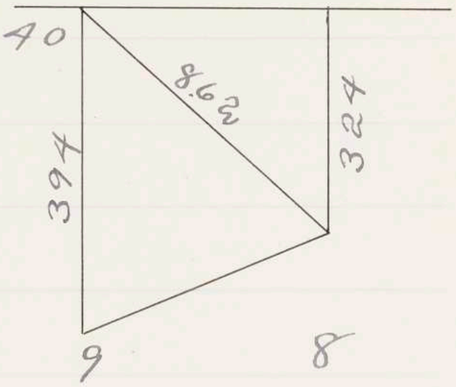
Tension:— Area 9□"

Pin hole .66 × 3⅛ = 2.06
6.94 net

$$\frac{134760}{2\times 694} = 9725$$ Call it OK

Hence Bars R S & T are one alias 2-10⊏s 9□" each

Upper Chord Bar U



Influence Lines

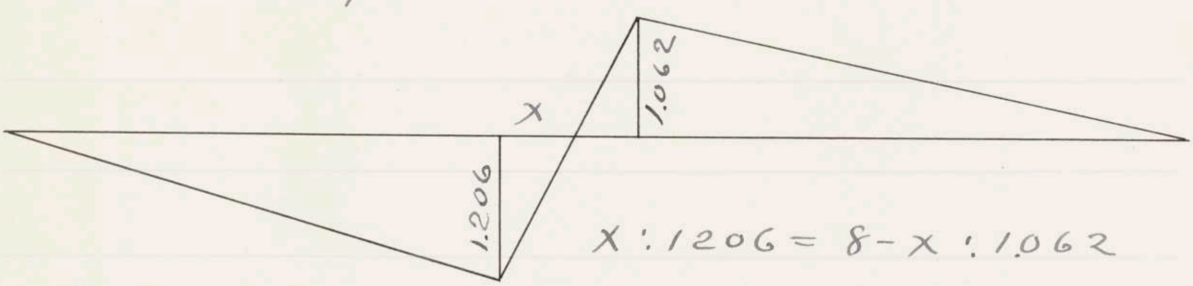
Load at 7

$3.24S + 40\frac{1}{2} - \frac{7}{3}11.76 = 0$

$S = 1.062$

Load at 8

$3.24S + \frac{4}{7}48 - 2 \times 11.76 \qquad S = 1.206$



$x : 1206 = 8 - x : 1.062$

Compression :— $\qquad x = 4.25$

$\frac{5225}{2}\ 1.206 = 31.5$

Tension $\frac{5975}{2}\ 1.062 = 31.7$

Difference = .2 Tension

$1750 \times .2 = 350 \qquad 1600 \times 31.5 = 50400$

$31.7 \times 1600 = 51000 \qquad 6200 \times 1.206 = 7480$

6200 × 1.062 =	6580		57880
	57930	Dead	350
			57530
+60 Comp	34524	+60%	34524
Tension =	92454	Comp =	92054

Bar U Continued

Assume 2-10" [s 6 □"

$$\frac{9500}{1+\frac{1}{18000}\frac{8\times8\times144}{3.85\times3.85}} = 9200 \text{ allow}$$

$$\frac{92054}{12} = 7700 \quad \therefore \text{Comp O.K.}$$

Tension Area = 6 □"

Pin hole 3/8 .30 = .936

5.06 Net

$$\frac{92460}{10.12} = 9100 \quad \text{Tension OK}$$

Splice or Connection with Bar T

$$\frac{6 □"}{10"+7"} = .353 \quad \text{say } 3/8" \text{ Plates}$$

Rivets Double Shear = 9000

$$\frac{92500}{2\times9000} = 5.15 \text{ Rivets} \quad 6 \text{ are used}$$

Splice Thus 10"×3/8" plate inside
Tight Filler 7"×3/8" plate on U
6 Rivets each side 7×3/8 plate outside

Upper Chord Bar V

Stress = zero

Cheaper to run the 10" [$6\square$" used in the adjoining panel U than to change

Connection at Hinge Joint

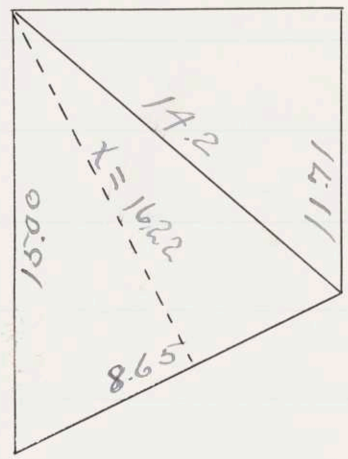
Rivet on a 3/8" plate with a slotted hole for the pin steadying the vertical

$7" \times 3/8" = 4.38$ @ $9500 \square"$

$$\frac{4.38 \times 9500}{4500} = 9.2 \text{ Rivets}$$

8 Rivets are used to hold this projecting plate $7" \times 3/8"$

Lower Chord Bar W

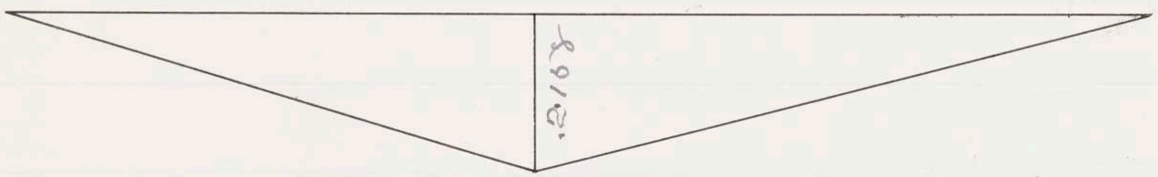


$x : 15 = 8.65 : 8 \qquad x = 16.22$

Influence Line

Load at 7

$-15\,\frac{7}{3} - S\,16.22 = 0 \qquad S = -2.158$



Compression; $- \frac{.2158}{2}\,112 = 120.9$

$120.9 \times 1750 = 211600$

$120.9 \times 1600 = 193300$

$6200 \times 2.158 = 133800$

Total 418280 Compres.

$\frac{418300}{9300} = 45\,\square''$ Each 22.5

2 Ls $6'' \times 4'' \times \frac{3}{4}'' = 14.44$

$16'' \times \frac{1}{2} = 8.00$

22.44

Bar W Continued

Value of ρ

$2 - 6 \times 4 \times 3/4$ ⊢ $= 11.00$

$(8 - 1.1)^2 \times 2 \times 7.22 = 686.00$

$\frac{16 \times 16 \times 16}{12 \times 2} = 170.5$

$$\frac{867.5}{22.44} = 38.6$$

$$\frac{9500}{1 + \frac{1}{18000} \cdot \frac{8.7 \times 8.7 \times 144}{38.6}} = 9350 \text{ allow.}$$

$$\frac{418280}{2 \times 2244} = 9330 \quad \text{Hence OK}$$

Connection with next panel
see Bar Y

Bed Plate Connection
See next page

Bar W Continued

Connection with Abutment

Pin $5\frac{3}{4}''$

Compression 418250

Bearing width:—

$$\frac{210000}{16000 \times 5.75} = 2.28'' \text{ thick}$$

.50 web
1.78 Filler $7\frac{3}{4} \times \frac{3}{4}$
.75
1.03
1.00 Plate 1" thick

Projecting Plate say 14"×1"

Rivets Shearing = 4500

Bearing $\frac{7}{8} \times \frac{1}{2} \times 16000 = 7000$

Filler $\frac{3}{4}'' \times 7\frac{3}{4}$; 16 Rivets used

$$\frac{.75}{2.28} \cdot \frac{210000}{4500} = 15.4 \text{ Rivets}$$

16 "

Projecting Plate 14"×1" 22 R. used

$$\frac{1}{2.28} \cdot \frac{210000}{4500} = 20.5 \text{ Rivets}$$

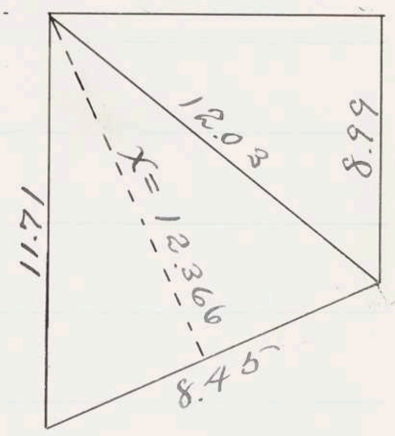
22 "

Use $\frac{7}{8}''$ Rivets Pitch 3"

Lower Chord Bar. X

$X : 11.71 = 8.45 : 8.00$

$X = 12.366$



Influence Line

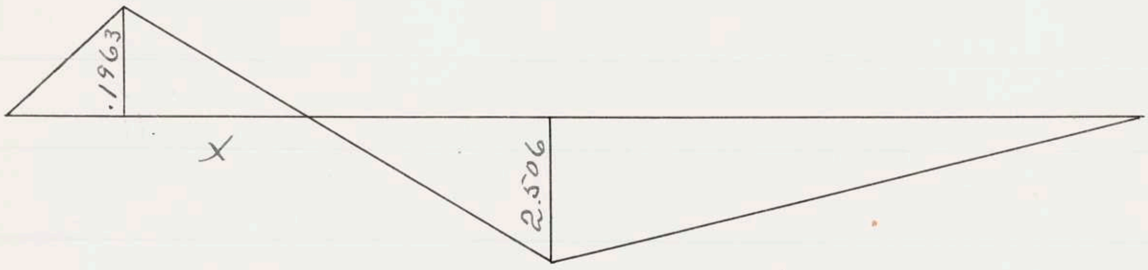
Load at 7

$12.366S - 8\frac{1}{2} + \frac{7}{3}15$

$S = -2.506$

Load at 13

$12.37\ S - 104\ \frac{1}{14} + \frac{1}{3}5 \qquad S = .1963$



$X : .1963 = 48 - X : 2.506 \qquad X = 3.48$

Compression :— $\frac{2.506}{2}\ 100.52 = 125.4$

Tension :— $\frac{.1963}{2}\ 11.48 = 1.13$

Difference 125.7 Compression

Compression = 125.7 + 1750

+ 126.4 × 1600 + 6200 × 2.506 = 437950

Section and Details Bar Y

Bar X Continued

Connection with Bar W

$$\frac{220000}{9500} = 23.18 \ \square''$$

$7\tfrac{3}{4} \times \tfrac{1}{2} = 3.88$ Filler

19.30

$16 \times \tfrac{3}{4} = 12.00$ Inside Plate

7.30

$14 \times \tfrac{9}{16}$ 7.88 Outside Plate

Rivets: —

Bearing - $\tfrac{1}{4}''$ tight filler on W

$$\frac{3}{4} \times \frac{7}{8} \times 16000 = 10500$$

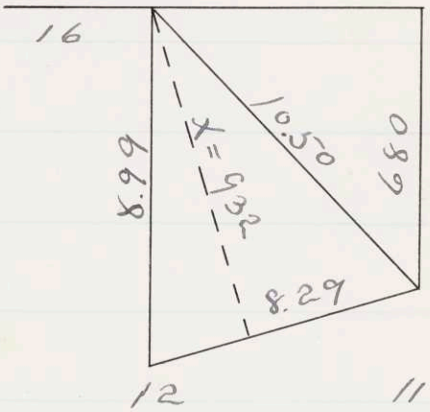
Shearing - Double

$$.6 \times 7500 \times 2 = 9000$$

$$\frac{220000}{9000} = 24.4 \text{ Rivets}$$

We must use the same plates on bar W ∴ let us use the same number of rivets, which is on the safe side

Lower Chord Bar Y



$x : 8.99 = 8.29 : 8$

$x = 9.32$

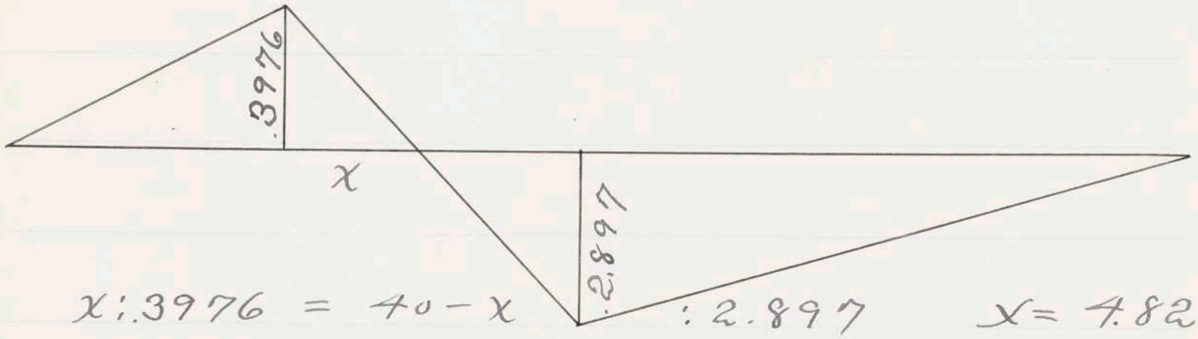
Influence Line

Load at 7

$9.32\,S + \frac{7}{3}\,15 - \frac{1}{2}\,16$ $\qquad S = -2.897$

Load at 12

$9.32\,S - 96\tfrac{1}{7} + \frac{2}{3}\,15$ $\qquad S = +.3976$



$x : .3976 = 40 - x : 2.897$ $\qquad x = 4.82$

Compression :— $\frac{10.41}{2}\,.3976 = 4.14$

Tension :— $\frac{91.18}{2}\,2.897 = 132$

Difference 127.86 Compression

Total Compression :—

$127.86 \times 3350 = 434900$

$6200 \times 2.897 = \underline{17950}$

452850

Bar V Continued

Total Compression = 452850

Increase the section by inserting a plate between the L's

I;- 2 - 6 x 4 x 3/4 + 16 x 1/2 = 867.5

I;- 7 3/4 x 1/4 = 9.7

877.2

Area = 22.44 + 1.94 = 24.38 □"

$$\rho^2 = \frac{877.2}{24.38} = 36.1$$

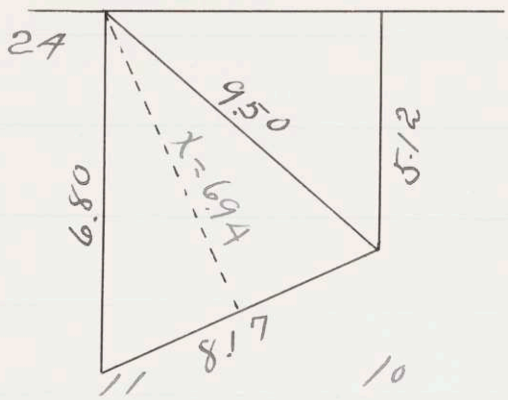
$$\frac{9500}{1 + \frac{1}{18000}\frac{8.3 \times 8.3 \times 144}{36.1}} = 9340$$

$$\frac{453000}{2 \times 24.38} = 9300$$ Section OK

Bar X Stress = 437950 Comp

A 1/4" plate reinforce, small enough. Hence make it the same as Bar V

Lower Chord - Bar Z



x : 6.8 = 8.17 : 8.0

x = 6.94

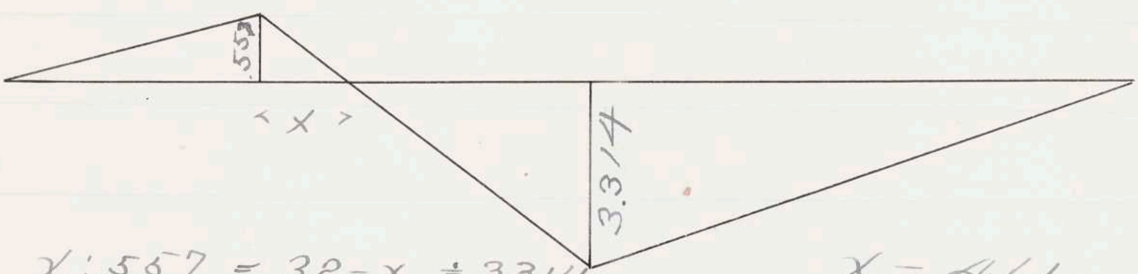
Influence Line

Load at 7

−5.17 S − 7/3 15 + ½ 32 S = −3.314

Load at 11

5.17 S − 2/7 80 + 4/3 15 S = + .557



x : .557 = 32 − x : 3.314 x = 4.61

Tension :— $\frac{28.61}{2}$ .557 = 7.96

Compression :— $\frac{83.39}{2}$ 3.314 = 138

Difference 130.04 Compression

Compression :—

3350 × 130.04 = 449200

6200 × 3.314 = 20520

469720 Total

Details Bar L

Bar Z Continued
Connection with Bar Y
Sections

Bar Y constant section + $7\frac{3}{4} \times \frac{1}{4}$
Bar Z " " + $7\frac{3}{4} \times \frac{7}{16}$
Stress Bar Z 469720

$$\frac{235000}{9500} = 24.72$$

$7\frac{3}{4} \times \frac{5}{16}$	=	2.42	Filler
		22.30	
$16 \times \frac{3}{4}$	=	12.00	Inside Plate
		10.30	
$14 \times \frac{3}{4}$	=	10.50	Outside "

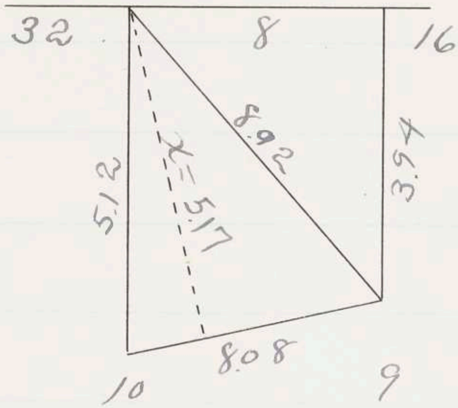
Rivets Double Shear

$$\frac{235000}{9500} = 26.1 \text{ Rivets}$$

Used

Same Plates over Bar Y + 3/16" loose filler Let us use the same no of rivets as on Bar Z

Lower Chord Bar L



$x : 5.12 = 8.08 : 8$

$x = 5.17$

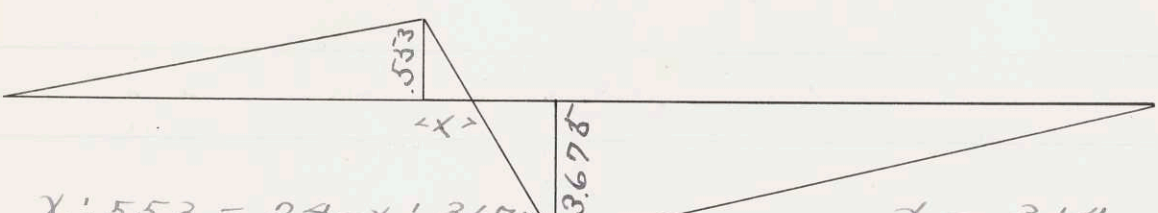
Influence Line

Line / Load at 7

$-5.17\,S - 15\,\frac{7}{3} + \frac{1}{2}\,.32 \qquad S = 3.675$

Load at 10

$5.17\,S + \frac{4}{3}\,15 - \frac{2}{7}\,80 \qquad S = +.553$



$x : .553 = 24 - x : 3.675 \qquad x = 3.14$

Compression :—

$\frac{3.675}{2}\,76.86 = 141$

Tension :— $\frac{35.14}{2}\,.553 = 9.70$

Difference = 131.3 Compression

$131.3 \times 3350 = 455800$

$6200 \times 3.675 = \underline{22800}$

Total Comp = 478600

Bar L Continued

Bar L and Z are one piece

Compression in Z = 470000

" " L = 478600

I Constant Section = 867.5

$\frac{7}{16} \times \frac{1}{12} \times 7.75 \times 7.75 \times 7.75 = 16.95$

884.45

$$\rho^2 = \frac{884.45}{22.44 + 3.39} = 34.3$$

$$\frac{9500}{1 + \frac{1}{18000} \frac{8.2 \times 8.2 \times 144}{34.3}} = 93.60 \text{ allow}$$

$$\frac{478600}{2 \times 25.83} = 9275 \quad OK$$

Connection with B

$$\frac{478600}{2 \times 9500} = 25.1 \square''$$

2.42 = $7\frac{3}{4} \times \frac{5}{16}$ filler

22.68

11.38 = $14 \times \frac{13}{16}$ outside

11.30

12.00 = $16 \times \frac{3}{4}$ inside

Bar L Continued

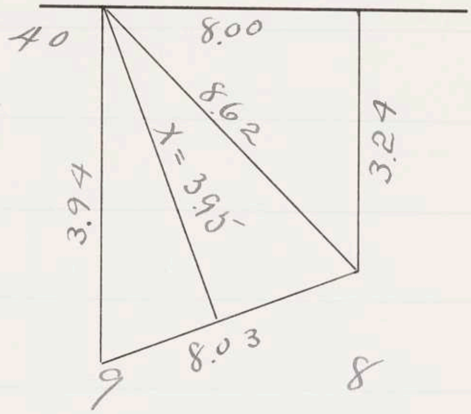
Rivets in double Shear

$$\frac{478600}{2 \times 9000} = 26.6 \text{ Rivets}$$

Same Plates extend on to Bar B let us use the same number of rivets

Section = Constant section alias Bar W + 7¾ x 7/16" reinforcement plate

Lower Chord Bar B



$x : 3.94 = 8.03 : 8.00$

$x = 3.95$

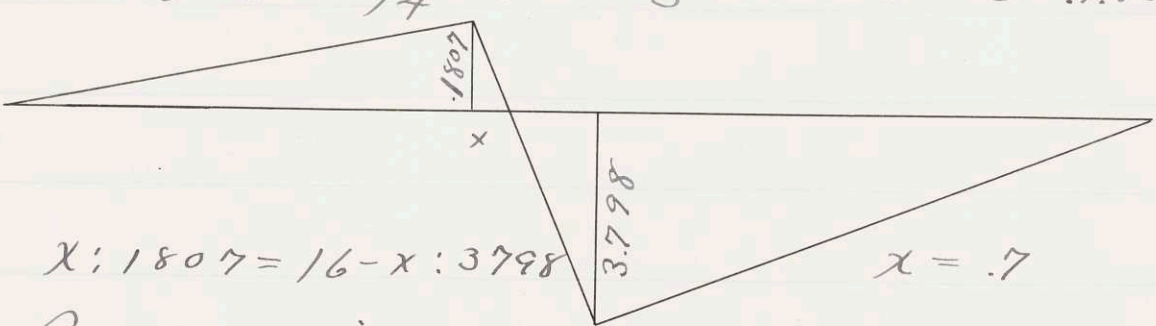
Influence Line

Load at 7

$-3.95\,S + 40 \times \frac{1}{2} - \frac{7}{3}\,15 = 0 \qquad S = -3.798$

Load at 9

$3.95\,S - \frac{5}{14} \times 72 + \frac{5}{3} \times 15 = 0 \qquad S = +1.807$



$x : .1807 = 16 - x : 3.798 \qquad x = .7$

Compression

$\frac{3.798}{2}\ 71.3 = 135.2$

$\frac{.1807}{2}\ 40.7 = 3.68$

131.52

$131.52 \times 3350 = 446900$

$6200 \times 3.798 = 23520$

470420

Bar B Continued

Bar B and P are in one piece

Compression in B = 470420

" " P = 458520

I Constant section = 867.5

$\frac{3}{8} \times \frac{1}{12} \times 7.75 \times 7.75 \times 7.75 = 14.6$

882.1

Area = 2244 + 291 = 25.35

$\rho^2 = \frac{882.1}{25.35} = 34.95$

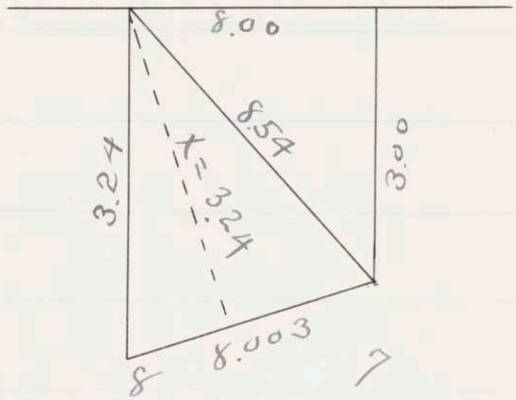
$$\frac{9500}{1 + \frac{1}{18000} \frac{8 \times 8 \times 144}{34.95}} = 9370 \text{ allow}$$

$$\frac{470500}{2 \times 25.35} = 9300$$

Hence 3/8" Reinforcement plate OK

Connection with L see Bar L

Lower Chord Bar V



$x : 3.24 = 8.003 : 8$

$x = 3.24$

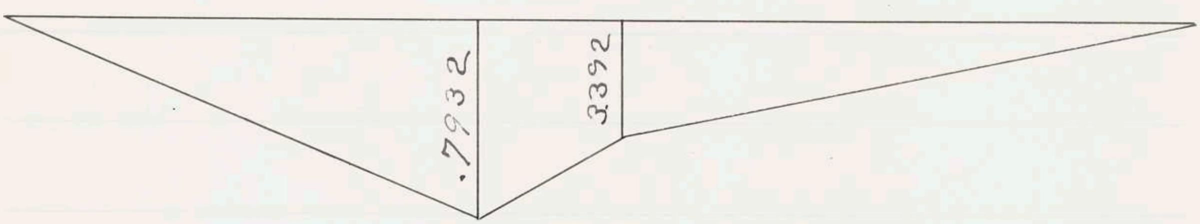
Influence Lines

Load at 7

$-3.24S - 15\,\frac{7}{3} + 48\,\frac{1}{2} = 0 \qquad S = -3.392$

Load at 8

$0 = 3.24\,S + 15 \times 2 - 64\,\frac{3}{7} \qquad S = -.7932$



Compression :—

$.7932 \times 24 = 19.03$
$3.392 \times 28 = 94.8$
$4.1852 \times 4 = 16.74$ total 130.57

$130.57 \times 3350 = 437500$

$6200 \times 3.392 = \underline{21020}$

Comp. 458520 total

Section and details see Bar B

Bar P Continued

Connection with Center hinge

Hinge = 5 3/4" Pin

Stress each side = 229300

$\frac{229300}{5.75 \times 16000}$ = 2.55" thick

.875 web

1.675

7 3/4 x 3/8   375 Filler

1.300

16 x 1/2   50 Projecting plate

Say 14 x 7/8" = .80 on the inside

Projecting plate on outside = 14 x 1/2

Rivets :— Shearing = 4500

$\frac{229300}{4500}$ $\frac{.375}{263}$ = Filler 7 3/4 x 3/8

= 8.6 Rivets

Plate 14 x 7/8   20 Rivets used

$\frac{875}{263}$ $\frac{229300}{4500}$ = 16.9 Rivets

Projecting Plate   12 Rivets used

$\frac{50}{263}$ $\frac{229300}{4500}$ = 9.7 Rivets

Abutment

Max Stress in Lower Chord = 420000

Caused by full loading

$$H.C. = \frac{420000 \times 8}{8.65} = 388000$$

V.C. = ½ The full load

$$= 3350 \times 56 + 3100 = 190600$$

$$\text{Resultant} = \sqrt{\overline{H.C.}^2 + \overline{V.C.}^2} = 432500$$

Direction of Max Resultant very near the line of the lower Chord

Thus the bed plate may be advantageously made perpendicular to the lower chord

Bearing:

$$\frac{532500}{2 \times 5\tfrac{3}{4} \times 16000} = 2.35''$$

Use Two Plates 1¼" Each

Abutment

Rivets :—

Bearing $1\frac{1}{4} \times \frac{7}{8} \times 16000 = 17500$

Double Shear $7500 \times .6 \times 2 = 9000$

$$\frac{432500}{2 \times 9000} = 24.04 \text{ Rivets}$$

25 are Used

Use 6 X 6 and 6 x 4 ∠'s

Thickness :—

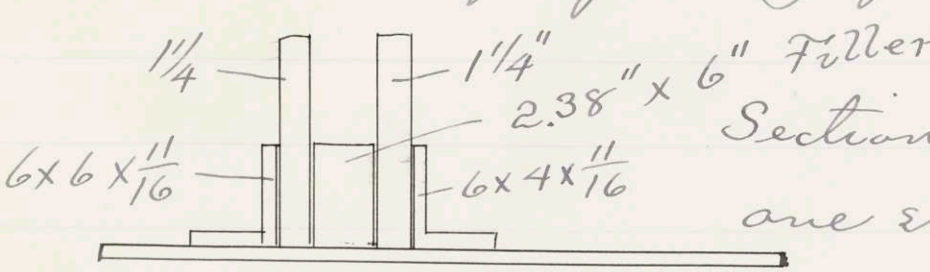
$9000 = t \times \frac{7}{8} \times 16000$

$t = .642$

∴ ∠s must be $\frac{11}{16}$" thick

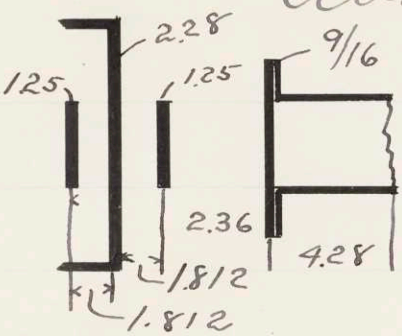
Thickness Lower Chord = 2.28

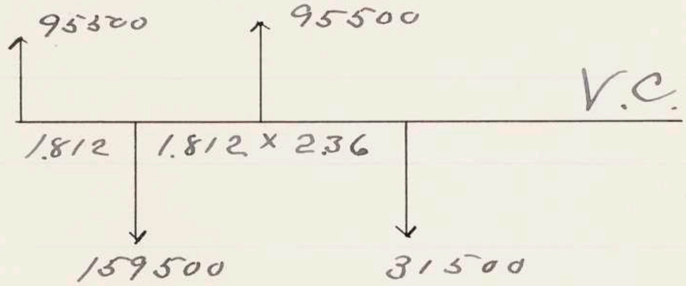
with 1-1" projecting plate



Section on one side

Abutment





$95500 \times 1.812 = +173000$ Chord

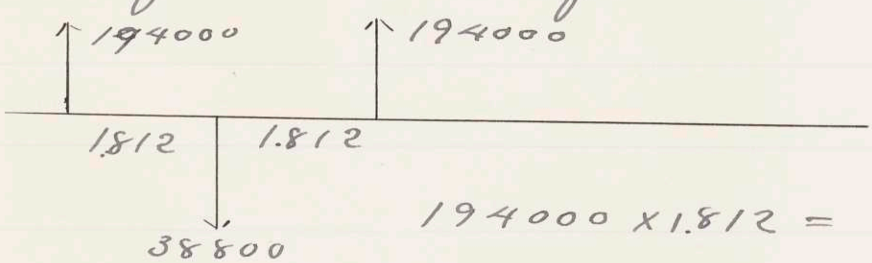
$64000 \times 1.812 = -116000$ Bed Pl

57000

$31500 \times 2.36 = +74400$ Vertical

131400

Horizontal Component



$194000 \times 1.812 = 352000$ C

$194000 \times 1.812 = -352000$ B

0

$M_r = \sqrt{173000^2 + 352000^2} = 392200$

Hence $5\frac{3}{4}$" Pin

Lower Chord = $14\frac{5}{8}$" clear

Upper Chord = $13\frac{1}{8}$" clear