Thesis

"The Design of a Suspension Bridge."

Span 520 Feet.

April, 6, 1918.

Munson J. Dowd.

Design of Suspension Bridge.

Design of Truss.

The length of span is 520 ft.
The truss will contain 20 spans each 26 ft. in length.
The depth of truss is to be 14 ft.
The loading assumed is a line of 20 ton trucks with a wheel base 16 ft. by 10 ft. over which the load will be considered as uniformly distributed.

In the design of a truss for a suspension bridge the maximum moment is taken as $\frac{1}{54} wl^2$ and the maximum shear as $\frac{1}{8} wl$.

When there is no load on the bridge, there are no stresses in the members of the truss. It is supported at each panel point by a suspender from the main cable, the functions of the truss being to distribute any load, that may come on the bridge, to all of the suspenders equally and to stiffen the bridge as regards lateral movement.

Thus it is seen that the truss does not have to be designed for dead load but for live load.

It has been the custom to find the maximum moment and shear and to design all of the chords for the maximum moment and all of the diagonal for the maximum shear. The diagonals and chords to take either tension or compression.

Design of Suspension Bridge.

Design of Truss.

Unit stress for shear assumed as 12000 #/in.^{2}
" " " moment " " 16000 #/in.^{2}.

Equivalent uniform load = $\frac{40,000}{16}$ = 2,500 # per linear ft. of Bridge.

Maximum moment = $\frac{1}{54} w l^2$.
= $\frac{1}{54} \times 2500 \times (520)^2 \times 12$
= 150,000,000 in. lbs.

Maximum shear = $\frac{1}{8} w l$
= $\frac{1}{8} \times 2500 \times 520$
= 162,500 #

Design of Chords of Truss.

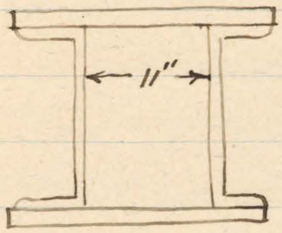
Stress = $\frac{\text{Moment}}{\text{Depth of Truss}} = \frac{150,000,000}{14 \times 12}$ = 893,000 # for 2 trusses.

For one truss stress = $\frac{893,000}{2}$ = 496,500 #

The chords must be designed to take both tension and compression and ~~as~~ since compression is the limiting condition the chords will be designed for it. If they can take the compression they can take the tension as both stresses are 496,500 #.

Design of Suspension Bridge.
Design of Chords in Truss.

Assume a section composed of 2 channell and 2 cover plates as shown.



Channels 15" x 7/16" – 33#/ft. 3 3/8" Flanges.
Cover Plates 17 3/4" x 5/8".
Total Area 42.3 sq. in.
Radius of Gyration 5.68

$\frac{P}{A} = 16000 - 70\frac{l}{r}$ l = unsupported length = 26 ft.
P = load = 496,500#

So $\frac{496{,}500}{A} = 16000 - 70\frac{26 \times 12}{5.68}$

$A = \frac{496{,}500}{16{,}000 - 3850}$

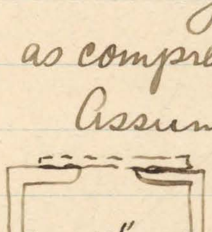
$A = 40.7$ in.² area needed

As area assumed was 42.3 in.² the section is alright.

Design of Diagonals.

The diagonals must be designed to take the load either as compression or as tension.

Assume section as shown. Channels to be latticed



Channels 10" x 1/4" – 15#/ft. 2 5/8" Flanges.
Total Area = 8.92 in.²
Radius of Gyration = 3.87"

$l = 19.5$ ft. $P = \frac{162{,}500}{2} = 81{,}300$#

$\frac{P}{A} = 16000 - 70\frac{l}{r}$ or ~~162,~~ $\frac{81{,}300}{A} = 16{,}000 - 70\frac{19.5 \times 12}{3.87}$

$A = \frac{81300}{9580}$

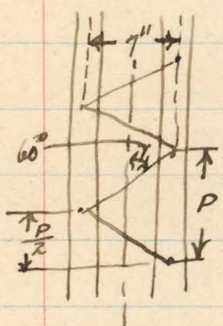
$A = 8.5$ in.²

As area assumed was 8.92 in.² section assumed in all right.

Design of Suspension Bridge.

Design of Lattice Bars For Diagonals of Truss.

Since the channel flanges are $2\frac{5}{8}$", $\frac{3}{4}$" rivets must be used
The width of the bars cannot be less than 2".



The bars cannot be inclined at at angle of less than 60° with the axis of the member.

Let P = pitch of bars.

Then $\frac{\frac{P}{2}}{7} = \tan 30°$

or $P = 14 \times \tan 30°$ So P = 8 inches.

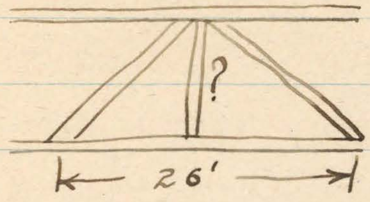
The bars shall be 2" x $\frac{3}{8}$".

Design of Batten Plates.

The specifications state that batten plates must have a length of not less than the greatest width or $1\frac{1}{2}$ times the least width of the member.

∴ Make them 15" x $\frac{3}{8}$" and use $\frac{3}{4}$" rivets with a pitch of $2\frac{1}{2}$".

Design of Suspension Bridge.
Investigation of Mid-suspender for Truss.



The lower chord acts as a beam and must carry 3700# dead weight.

Consider it as a beam with fixed ends.

$$M = \frac{1}{12} w l^2$$

$$= \frac{1}{12} \times \frac{3700}{26 \times 12} \times (20 \times 12)^2$$

$$= 74{,}700 \text{ in. lb. maximum moment.}$$

$$f = \frac{Mc}{I} = \frac{74{,}700 \times 8}{1430}$$

$$= 420 \#/\text{in.}^2$$

As steel is allowed 16,000#/in.² no mid-suspender will be needed.

Design of Suspension Bridge.

Design of Concrete Floor Slab.

The slab will rest on stringers placed 6.8' apart.

Loading:- 20 ton truck, load uniformly distributed of its wheel base.

Assume a 7" slab and a 3" wood block wearing surface

Wt. of 1 ft. strip of slab = $150 \times 7/12 = 87.5$ #/ft.

" " wood block paving = $4\frac{1}{2}$# $\times 3$" = 13.5 #/ft.

Equivalent uniform load = $\frac{40,000}{72}$ = 555.0 #/ft.

Total Load = 656.0 #/ft.

$$M = \tfrac{1}{12} w l^2$$

$$= \tfrac{1}{12} \times 656 \times (6.8)^2 \times 12$$

$$= 30,300 \text{ in lbs.}$$

Assume unit stress of concrete to be 650 #/in² = f_c

" " " " steel " " 18,000 #/in² = f_s

$$M_c = \tfrac{1}{2} f_c k j b d^2 \qquad k = 3/8 \quad j = 7/8$$

$$30,300 = \tfrac{1}{2} \times 650 \times 3/8 \times 7/8 \times 12 \times d^2$$

$$\text{or } d^2 = \frac{30,300 \times 32}{650 \times 63} = 23.7$$

so $d = 4.75$" effective depth.

So total depth of slab will be 6.75" thick.

Design of Steel Reinforcement.

$$M_s = f_s A j d$$

$$\text{or } 30,3000 = 18,000 \times A \times 7/8 \times 4.75$$

$$\text{or } A = \frac{30,300 \times 8}{18,000 \times 7 \times 4.75}$$

$A = .405$ in² amount of steel per ft. required.

So use 3/8" twisted steel spaced 4 inches.

For longitudinal tie rods, use 1/4" twisted steel spaced 8".

Design of Suspension Bridge.

Design of Stringers.

Length of stringers 26 ft.

Stringers placed 6.8' apart.

Loading 20 ton truck.

Wt. of floor slab per ft. of stringer $= 150 \times 7/12 \times 6.8 = 595$ #

" " truck " " " " $= \frac{40\,000}{26} = 1540$ #

Total Uniform Load $= 2135$ #

So $\frac{2135 \times 26}{2000} = 27.8$ tons, total load on stringer.

So use a 20"-80#/ft. I-beam.

Connection Plate to Floor Beam.

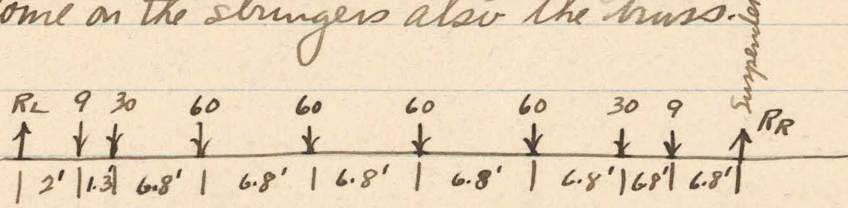
From the table of connections it is found that for connection, there must be used 2∠s 4"×4"×7/16"×0'-11½".

There will be 4-⅞" rivets, in each angle leg, with a pitch of 3 inches.

Design of Suspension Bridge.

Design of Floor Beams.

The floor beams will carry all of the load which may come on the stringers also the truss.



A girder was assumed to weigh 160#/ft. Uniform load.
The weight of two trusses was 18,000#
As the I-beam stringers were capable of carrying 30 tons, they are assumed to be loaded to that amount.

$R_L = R_R = 9 + 30 + 60 + 60 + .16 \times 20 = 162.2$ thous. lbs.

So maximum shear $= 162,200$#

Area needed in web $= A = \frac{4}{3} \times \frac{V}{v} = \frac{4}{3} \times \frac{162,200}{10,000}$

$A = 21.63$ sq. ins.

The maximum moment will be at the center and will equal:-

$(162.2 \times 20.3) - (9 \times 18.3) - (30 \times 17) - 60(10.2) - 60(3.4) - .16 \times 20 \times \frac{20}{2} = M.$

$M = 3,290 - 164.5 - 510 - 612 - 204 = 1767$ thous. ft. lbs.

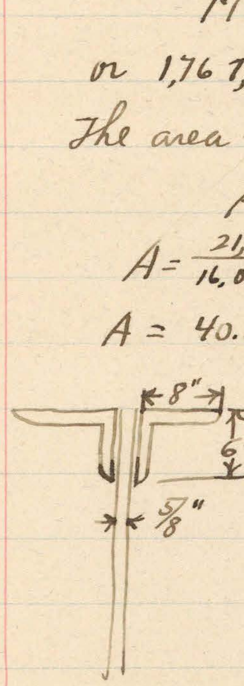
or $1,767,000 \times 12 = 21,204,000$ in lbs.

The area needed in the flanges for this, will be

$A = \frac{M}{2h} - \frac{1}{12} t\,h,$ Assume 36" web. and ∠s 8"×6"×3/4"

$A = \frac{21,204,000}{16,000(36 - 3.12} - \frac{1}{12} \times \frac{1}{2} \times 36.$

$A = 40.5 - 1.5 = 39$ in.² needed so angles are O.K.



So use 4 ∠s 8"×6"×3/4"
and a web plate 36"×5/8"

Design of Suspension Bridge

Design of Rivet Pitch in Floor Beam.

$$p = \frac{Rh}{V}$$

In bearing, unit rivet stress $= \frac{5}{8} \times \frac{7}{8} \times 24{,}000 = 14{,}375$ #/in.²

" shear, " " " $= .6 \times 12{,}000 \times 2 = 14{,}400$ #/in.²

By which it appears that the rivet will be limited by bearing.

So $p = \frac{14{,}375(36 - 3.12)}{162{,}200} = 2.9''$

So make 1 row of 7/8" rivets in flange with pitch of 2.9".

Investigation of Web Stiffners.

$$V = 16{,}000 - 12\frac{d}{t}$$

or $\frac{162{,}000}{\frac{3}{4} \times 36 \times \frac{5}{8}} = 16{,}000 - 120\frac{d}{\frac{5}{8}}$

or $9800 = 16000 - 192d$

$d = 32.5''$

As the unsupported web = 36 - 12 = 24" no web stiffners will be needed.

Suspenders.

Total load on each suspender = 9+30+60+60+(16×20) = 162,200#

This load will be carried by 2 steel suspenders each one carrying $\frac{162{,}200}{2} = 82{,}000$#. Taking the working stress of steel wire rope as 40,000#/in.² each suspender must have $\frac{82{,}000}{40{,}000} = 2.05$ sq. in.

So diameter of suspender will be 1½" weighing 4.25#/ft.

Design of Suspension Bridge.

Suspender Lengths.

It was assumed that the middle suspender should be 4 ft. above the floor beam thus making the sag 56 ft.

Let y = length of suspender.

and x = distance of said suspender from center of bridge.

and let h = sag and l = length of span.

~~Suspender No.~~ 1. $y = \frac{4h}{l^2}(x^2)$ or $y = \frac{4 \times 56}{(520)^2} \times x^2 = .000828\,x^2$

Suspender No. 1. $y = .000828 \times 0 = 0$

" " 2 $y = .000828 \times (26)^2 = 4.56$

" " 3 $y = 6.26$ ft.

" " 4 $y = 9.04$ ft.

" " 5 $y = 12.95$ ft.

" " 6 $y = 18.00$ ft.

" " 7 $y = 24.15$ ft.

" " 8 $y = 31.4$ ft.

" " 9 $y = 39.85$ ft.

" " 10 $y = 49.4$ ft.

" " 11 $y = 60.0$ ft.

Design of Suspension Bridge.

Design of Cable.

Load on one cable per ft.

Live Load	$\frac{2500}{2}$ =	1250 #
Wt. of Trusses	$\frac{9000}{26}$ =	346 #
Wt. of Floor Beam	$\frac{200 \times 20.3}{26}$ =	156 #
Wt. of Stringers	80 x 3 =	240 #
" " Floor Slab	(150 x 7/12 + 13.5) 20.3 =	2050 #
Assume cable to weigh/ft.		250 #

Total Load per ft. = 4292 #

$H = \frac{wl}{8s}$ $T = \frac{wl}{8s}\sqrt{1+16s^2}$

$H = \frac{4290 \times 520}{8 \times .115} = 2,430,000$ #

$T = 2,430,000 \times 1.1 = 2,870,000$ #

The working stress of the cable steel may saftley be assumed at 40,000 #/in².

So $\frac{2,870,000}{40,000} = 71.75$ net area needed in cable

The gross area is generally taken 1/3 more than net area.

So 71.75 x 1.33 = 93.25 gross area needed in cable.

$\frac{93.25}{\pi} = r^2$ $r = 5.45''$ radius.

So diameter of cable must be 10.9".

Assume the cable to be made up of No 6 A.S. Co. wire which is .192" in diameter and weighs .0975 #/ft.

$D = d\sqrt{1.3n}$ so $10.9 = .192\sqrt{1.3n}$

n = 2500 wires needed in cable.

2500 x .0975 = 244 # weight of cable per ft.

So assumption of 250 #/ft. was O.K.

Design of Suspension Bridge.

Deflection of Cable.

$H = \frac{244 \times 520}{8 \times .115} = 138,000^{\#}$

$T = 138,000 \times 1.1 = 152,000^{\#}$

The stress in cable per sq. in. under its own weight would be equal to

$\frac{152,000}{71.25} = 2,100^{\#}/in.^2$

Let δc = elongation of cable under uniform load exclusive of the weight of the cable itself.

$$\delta c = \frac{Hl}{AE}\left(1 + \frac{16}{3} s^2\right)$$

$$\delta c = \frac{2,292,000 \times 520}{71.75 \times 30,000,000}\left(1 + \frac{16}{3} .0132\right)$$

$$= .554 \times 1.0702$$

$$= .594 ft.$$

Now let c = length of cable when $h = 60$ ft.

and " c_1 = " " " without uniform dead and live load.

The $c_1 = c - \delta c$ $\qquad c = l(1 + \frac{8}{3} s^2)$

$c_1 = 538.040 - .594$ $\qquad = 520 (1 + \frac{8}{3} \times .0132$

$c_1 = 537.45$ ft. $\qquad = 538.04$ ft. length of cable.

Now $c_1 = l(1 + \frac{8}{3} s_1^2)$

so $s_1^2 = \frac{c_1 - l}{\frac{8}{3} l}$

or $s_1^2 = \frac{537.45 ft - 520}{\frac{8}{3} \times 520} = .01258$

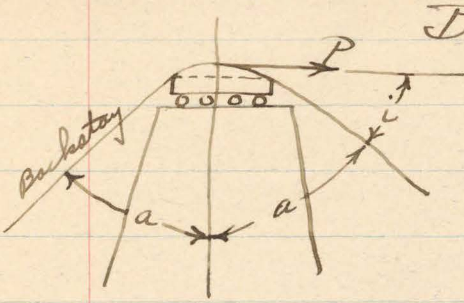
and $s_1 = .112 \therefore h_1 = s_1 l_1 = .112 \times 520 = 58.24$ ft.

$\delta h = 60 - 58.24 = 1.76$ ft. cable will deflect.

So under construction cable must have sag of 58.24 ft.

Design of Suspension Bridge.

Backstay



Let a = angle of inclination of cable at top of tower to vertical.
Let i = ∠ made by cables with horizontal.

$$\tan i = \frac{4h}{l} = \frac{4 \times 60}{520} = .46154$$

$$i = 24° 46' 42''$$

$$\text{So } a = 90° - 24° 46' 42''$$

$$a = 65° 13' 18''$$

In order that there shall be ~~not~~ no horizontal component, outside of that caused by friction, the ∠ of the backstay must be the same as the ∠ of the main span cable.

There will be a horizontal component of stress at the tops of the towers due to the pull needed to overcome the friction of the rollers.

Assume the coefficient of friction to be .01 and let W = total load on saddle.

$$W = \frac{wl}{2} = \frac{4292 \times 520}{2} = 1,120,000\#$$

H has already been found to be = 2,430,000#

So $P = .01 \times 1,120,000 = 11,200\#$ required to move saddle.

So H. for the backstay will be = 2,418,800# and this is the horizontal tension transmitted to the anchorage.

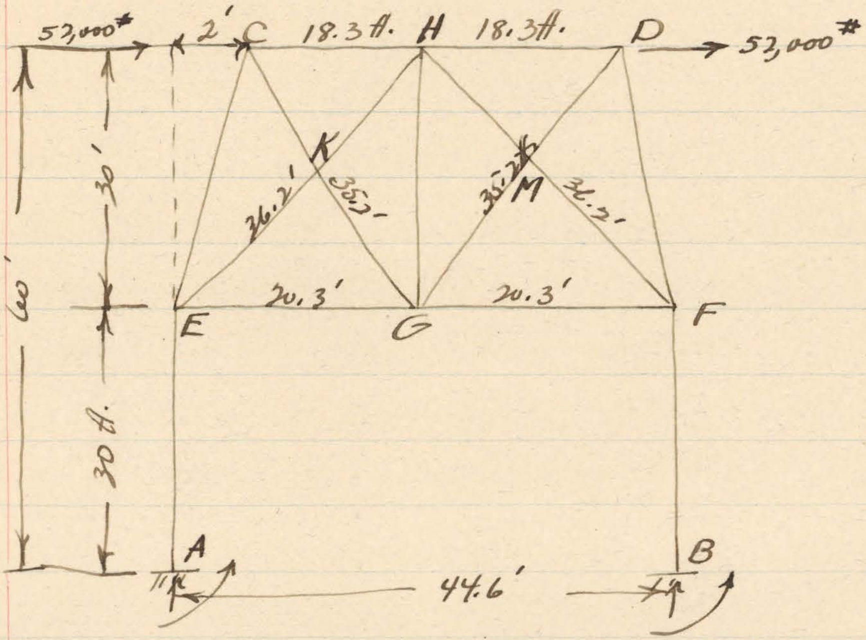
The length of the backstay will be

$$L_B = \frac{60}{\cos a} = \frac{60}{.4191} = 142.92 \text{ ft}.$$

The horizontal length will be

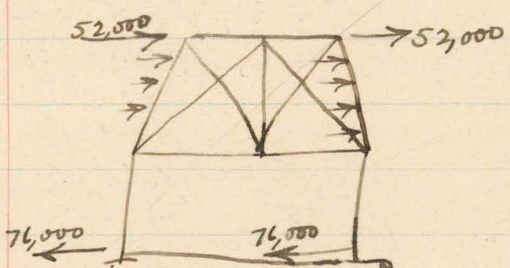
$$l_B = 60 \tan a = 60 \times 2.1663 = 129.98 \text{ ft}.$$

Design of Suspension Bridge
Design of Towers.



Assume wind Load of 400#/ft. of elev. of tower.

The wind bracing was investigated as any portal and so I will not go thru with the various steps but simply show the reactions found and the stresses found in the various members.



Design of Suspension Bridge.

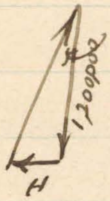
Design of Towers.

Member	Hor. Stress	Vert. stress	Stress.
AE		141,000	+141,000
		~~70,500~~	~~70,500~~
EC	~~-75,600~~	70,500	~~-75,600~~ 70,500
CH	- 75,600		- 75,600
GF	-75,600		-75,600
HD	75,600		75,600
EG	75,600		75,600
CG	-47,700	-70,500	$47,700 \times \frac{36.2}{20.3} = -85,000$
GD	47,700	70,500	85,000
EH	+47,700	70,500	85,000
HF	-47,700	-70 500	- 85,000
DF		- 70,500	-70,500
FB		-141,000	-141,000
HG		½ wt. of lower chd and diagonals.	

Design of Suspension Bridge.

Tower Bracing.

Due to the inclination of the upper part of the towers the vertical load will cause compression in the upper cross brace and tension in the lower cross brace.



$\frac{H}{1,200,000} = \tan 3°52' \quad H = 81,250^{\#}$

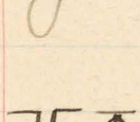
So to the stress in the cross braces, found on the preceding page, must be added 81,500#

So the top cross brace will be designed for a compression of $75,600 + 81,500 = 156,800^{\#}$

and the lower cross brace for a tension of 156,800#

The diagonals will all be designed for a compression of 85,000 #

Design of Diagonal Bracing.



Assume 4∠s $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}''$ $D = 9''$ $A = 6.92 \text{ in}^2$

$I = 101$

$l = 15.1 \text{ ft.}$

$\frac{P}{A} = 16000 - 70\frac{l}{r}$

So $\frac{85,000}{A} = 16000 - 70 \frac{15.1 \times 12}{\sqrt{\frac{101}{6.92}}}$

$A = 6.71$ sq. in. needed

As section assumed contained 6.92 in^2 it is all right.

Make lattice bars $1\frac{1}{2}'' \times \frac{3}{8}$ spaced 7.5"

Wt. of diagonals per ft.

Wt. of 4∠s = 5.9 × 4 = 23.6#/ft.

" of latt. Bars = 2.55 × 4 = 10.2#/ft.

Total 33.8#/ft.

Design of Suspension Bridge.

Tower Bracing.

Design of Lower Cross Brace.

$S = \frac{P}{A} + \frac{Mc}{I}$ as the span is short $\frac{Mc}{I}$ may be left out.

so $\frac{156,800}{A} = 16,000$

$A = 9.85$ in² needed of net area.

Gross area = 10.85 in²

So use 4 ∠s 3"x3"x½" D=10"

Make lattice bars 2"x⅜" with a pitch of 8".

Wt. of lower brace per ft.

Wt. of 4∠s = 9.4x4 = 37.6#/ft.

" " bars = 2.55x4 = 10.7#/ft.

Total 50#/ft.

Make the middle vertical the same size as the lower chord.

The weight then suspended from the upper chord will be.

Wt. of lower chord = 50x20.3 = 1015#

" " diag. = 35x145 = 5080#

" " vertical = 50x30 = 1500#

Plates + rivets 500#

Total 8095#

Design of Suspension Bridge.

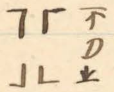
Tower Bracing.

Design of Upper Cross-braces

Compression of 156,850# Unsupported length 40.6 ft.

$$\frac{P}{A} + \frac{Mc}{I} = 16000 - 70\frac{l}{r}$$

$$A = \frac{P}{(16,000 - 70\frac{l}{r}) - \frac{Mc}{I}}$$



Assume 4 ∠s 6"×6"×½" D = 20½" I = 1769 A = 23"sq.
Wt. per ft. = 100# c = 10.25

$$M = \frac{8095}{4} \times 20.3 \times 12 + \frac{1}{8} \times 100 \times (40.6)^2 \times 12$$

$$= 492,500 + 248,000$$

$$= 740,500 \text{ in. lbs.}$$

So $$A = \frac{156,850}{\left(16,000 - 70\frac{40.6 \times 12}{\sqrt{\frac{1769}{23}}}\right) - \frac{740,500 \times 10.25}{1769}}$$

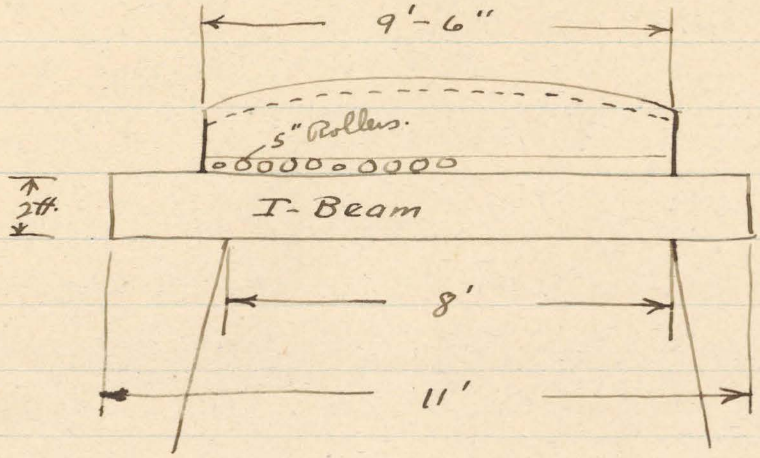
$$A = \frac{156,850}{16,000 - 3,880 - 4300} = \frac{156,850}{7,800}$$

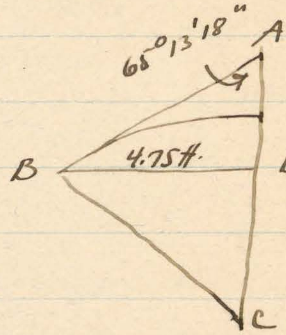
$A = 21$ in² needed so use 2 braces.

Make lattice bars 3"×⅜" with pitch of 15½"

Design of Suspension Bridge.

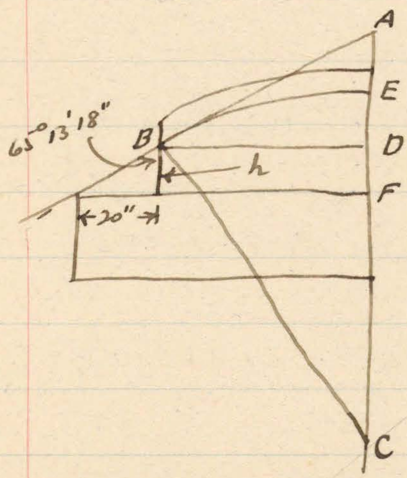
Cradle and I-Beam Supports.





$\frac{BD}{AB} = \sin 65°13'18"$ $AB = \frac{4.75}{.9079} = 5.33$ ft.

$\frac{CB}{AB} = \tan 65°13'18"$ $CB = 5.33 \times 2.1663$



$CB = 11.53$ ft. radius of cable.

To find height of cradle so that cable will clear edge of tower when cradle is at extreme position away from edge.

$\angle BCD = 24°46'42"$

$\frac{BD}{DC} = \tan 24°46'42"$

$DC = \frac{4.75}{.4616} = 10.3$ ft.

$\frac{20}{h} = \tan 65°13'18"$

$h = 9\frac{1}{4}$ ins.

So $11.53 - 10.3 = 1.23$ ft. $= ED$.

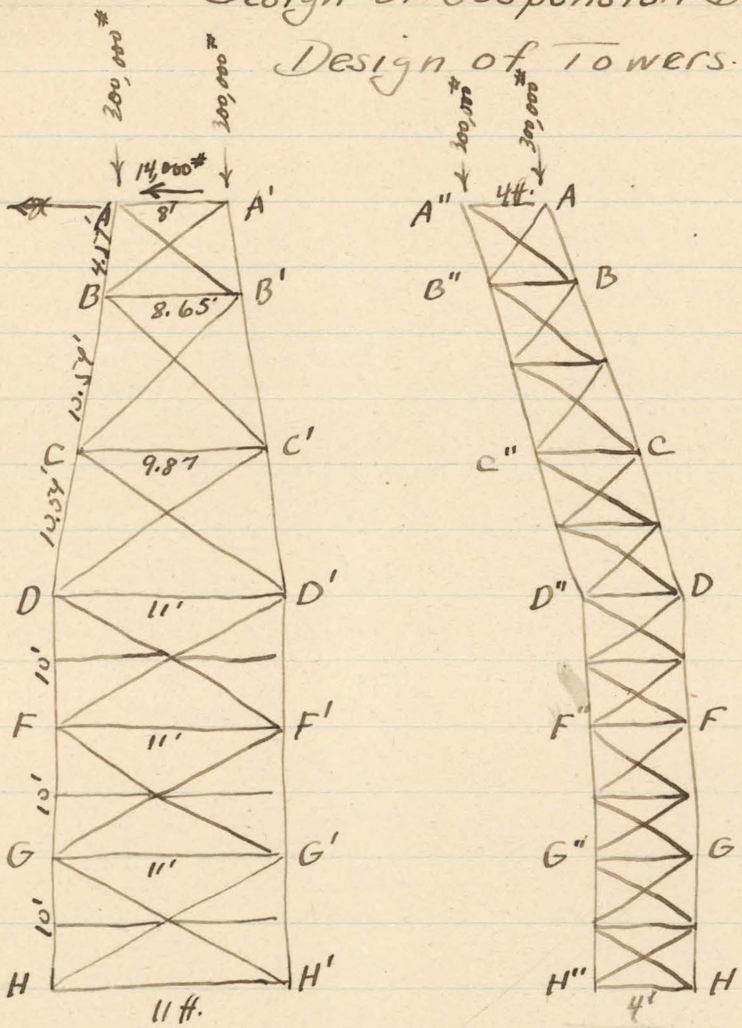
So $EF = 1.23 + .77 = 2$ ft.

From center of cable to $F = 2 + \frac{10.9}{2 \times 12}$

to $F = 2 + .45 = 2.45$ ft.

Design of Suspension Bridge.

Design of Towers.



Pull to overcome friction 11,200#

Wind load 2,800

Total Horizontal Load 14,000#

Total vertical Load on tower 1,200,000#

Load on each post $= \frac{1200,000}{4} = 300,000\#$

Assume weight of column as 400#/ft. of height.

Let ϕ = ∠ which column makes with vertical $= 5°45'$

" β = ∠ " horizontal project. makes with DD' $= 53°08'$

Let the friction force act 5 ft above the top of tower

M

Design of Suspension Bridge.

Design of Tower.

Member	Dead Load Stresses	Wind + Friction Load Stresses	Total Stress.
AB	$\frac{-300,000}{\cos\varphi} = \frac{-300,000}{.995} = -302,000$#	$-14,000 \times \frac{5+5.27}{8.65 \times \cos\varphi} = -14,000 \frac{10.27}{8.6} = -16,300$	-318,300#
BC	$-\frac{300,000+2,000}{\cos\varphi} = \frac{-302,000}{.995} = -304,000$	$-14,000 \times \frac{5+5.27+10.24}{9.87 \times \cos\varphi} = -14,000 \frac{20.81}{9.82} = -29,200$#	-333,200#
CD	$\frac{-300,000+2000+4000}{\cos\varphi} = \frac{-306,000}{.995} = -308,000$	$-14,000 \frac{20.81+10.54}{11 \times .995} = -14,000 \frac{31.35}{10.95} = -40,000$	-348,000#
AA'	$-300,000 \tan\varphi \cos\beta = -300,000 \times .1 \times .6 = -18,000$	$\frac{H}{2} = \frac{-14000}{2} = -7,000$	-25,000#
BB'	$-2000 \tan\varphi \cos\beta = 2000 \times .1 \times .6 = -120$#	$-14,000 + 2 \times 14,000 \frac{5+5.27}{8.65} \tan\varphi = -14,000 + 3,300 = -10,100$	-10,800
AA"	$-300,000 \tan\varphi \sin\beta = -300,000 \times .1 \times .8 = -24,000$	0	-24,000
BB"	$-2000 \tan\varphi \sin\beta = -2000 \times .1 \times .8 = -160$#	0	-160#
CC'	$-4000 \tan\varphi \cos\beta = -4000 \times .1 \times .6 = -240$#	$-14,000 + 2 \times 14,000 \frac{10.27+10.54}{9.82} \tan\varphi = -14,000 + 5,940 = -8,100$	-8340#
DD'	$-4000 \tan\varphi \sin\beta = -4000 \times .1 \times .8 = -320$#	$-14,000 + 2 \times 14,000 \frac{20.81+10.54}{11} \tan\varphi = -14,000 + 7,970 = -6,100$	-9,400#
A'B'	Same as AB = -302,000#	$-14,000 \times \frac{5}{8 \cos\varphi} = +14,000 \times \frac{5}{7.95} = +8,800$	-293,000#
B'C'	Same as BC. = -304,000#	$+14,000 \times \frac{5+5.27}{8.65 \times \cos\varphi} = +14,000 \times \frac{10.27}{8.6} = +16,300$	-287,700#
C'D'	Same as CD = -308,000#	$+14,000 \frac{10.27+10.54}{9.87 \cos\varphi} = 14,000 \frac{20.81}{9.82} = +29,200$	-278,800#

Thesis.
M.J. Dowd.

Design of Suspension Bridge.

Design of Tower.

Consider only one set of diagonals acting at the same time and they to take tension only.

Member.	Hor. Component.	Ratio	Stress.
AB′	+7500#	$\frac{9.55}{8.33}$	8,600#
BC′	7500 + 10,700 = 18,200#	$\frac{14.02}{9.26}$	29,200#
CD′	7500 + 10,700 + 8,100 = 26,300	$\frac{14.82}{10.43}$	37,400

Member.	Hor. Component	Vert. Component	Ratio	Stress.
D′F′		$-278{,}000 + 37{,}400 \times \frac{10.24}{14.82}$	1	−252,200#
DF′	26,300	23,900	$\frac{14.85}{11}$	35,000#
DF		$-348{,}000 - 26{,}300 \times \frac{10}{11}$	1	−371,900#
F′G		Stress in EF−(+4000)	1	−375,900#
FG′		23,900	$\frac{14.85}{11}$	35,500
FG		−375,900 − 23,900	1	−399,800#
G′H′		Stress in −(+4000)		−403,800#
GH′		23,900	$\frac{14.85}{11}$	35,500#
GH		−403,800 − 23,900		−427,700#

Design of Suspension Bridge.

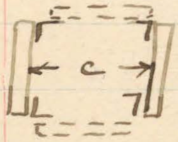
Design of Tower.

The lower columns up to 30 ft will be designed for a stress of 427,700# compression.
The upper column for a stress of 350,000# compression.
The diagonals for a stress of 40,000# tension
" cross braces for a stress of 26,500# compression.

Design of Columns.

Lower Columns.

$\frac{P}{A} = 16,000 - 70 \frac{l}{r}$ $l = 10$ ft. $P = 428,000\#$



Assume 4 ∠s $3\frac{1}{2}'' \times 3\frac{1}{2}'' \times \frac{1}{2}''$ and 2 plates $14'' \times \frac{5}{8}''$

$c = 10.6''$ $r = 5.12$ $I = 799$ $A = 30.50$ in².

So $\frac{428,000}{A} = 16,000 - 70 \frac{10 \times 12}{5.12}$

$A = \frac{428,000}{14,000} = 30.5$ in².

So section is all right.
Make lattice bars $2'' \times \frac{3}{8}''$ with pitch of 7.6".

Upper Columns.

Assume 4 ∠s $3 \times 3 \times \frac{1}{2}$ $l = 10.54$ ft. $P = 350,000\#$

$c = 10.8''$ $r = 5.20$ $I = 677$ $A = 25$ in². 2 plates $14'' \times \frac{1}{2}''$

$\frac{350,000}{A} = 16,000 - 70 \frac{10.54 \times 12}{5.20}$

$A = \frac{350,000}{14,000} = 25$ in².

So section is all right.
Use lattice bars $2'' \times \frac{3}{8}''$ with a pitch of 7.6".

Design of Suspension Bridge.

Design of Tower.

Design of Diagonals.

As they are in tension and are stressed to only 40,000# the smallest allowable angles will do but for general appearance use

2∠s 3½" x 3½" x 3/8" riveted together every 12".

Cross Braces.

Assume 2∠s 3½" x 3½" x 3/8"

$l = 11$ ft. $r = 1.25$ net area $= 4.76$ $P = 27,000$#

$$\text{So } \frac{27,000}{A} = 16,000 - 70\,\frac{11 \times 12}{1.25}$$

$$A = \frac{27,000}{7,600}$$

$$A = 3.6 \text{ in}^2.$$

So use these angles and rivet them together every 12 inches.