AN ANALYSIS OF AN I-BEAM GIRDER BRIDGE

Thesis for the Degree of B. S.

MICHIGAN STATE COLLEGE

C. A. Peterson

1949

An Analysis of an I-Beam Girder Bridge

A Thesis Submitted to

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of

AGRICULTURE AND APPLIED SCIENCE

by

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Candidate for the Degree of

Bachelor of Science

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OUTLINE OF ANALYSIS

I. Railings.
  A. Railings.
  B. Railing posts.

II. Curbs.

III. Slab.

IV. Rolled Beams.

V. Abutments.
  A. Case I.
  B. Case II.
  C. Case III.
  D. Case IV.

VI. Wingwalls.

Allowable Stresses

f'_c = 3000 psi (28 day strength concrete)

f_c = 1350 psi (Extreme fiber stress in compression)

n = 10 (Modular ratio)

v = 40 psi (Shear)

u = 150 psi (Bond)

f_s = 18,000 psi (Steel stress tension)

Data

j = 0.857

K or R = 248

k = 0.429

$\delta = 25^{\circ}$

$\phi = 33^{\circ} - 40'$

p = 28.7h

A_s = (Area of steel)

V = (Shear)

M = (Moment)

I = (Moment of inertia)

d = (Effective depth)

Σ_o = (Perimeter of steel)

b = (Width)

Design of Railings:

AASHO 3.1.10. Substantial railings along each side of the bridge shall be provided for the protection of traffic. Consideration shall be given to the architectural features of the railing to obtain proper proportioning of its various members and harmony with the structure as a whole. Consideration shall also be given to avoiding, as far as consistent with safety and appearance, obstruction of the view from passing vehicles. . .

Roadway railings shall have a minimum height of 2 feet 6 inches above the roadway adjacent to the curb. . .

Provision shall be made for the expansion and contraction of railings consistent with the design.

Loading of Roadway Railings:

AASHO 3.2.11.1.1. Top members of roadway railings shall be designed to resist a lateral horizontal force of 150 pounds per linear foot together with a simultaneous vertical force of 100 pounds per linear foot applied at the top of the railing. When curbs are 10 inches or less in height, lower rails shall be designed to resist a lateral horizontal force of 300 pounds per linear foot; or if there is no lower rail, the web members shall be designed to resist a horizontal force of 300 pounds per linear foot applied not less than 21 inches above the roadway. For each inch of height of curb above 10 inches, this lateral horizontal force may be reduced 15 pounds per linear foot, but this force shall not be less than 150 pounds per linear foot. The horizontal forces shall be applied simultaneously. Railings without webs and with single rails shall be designed for the forces specified above for lower rails.

In our railing top and bottom are identical, so I will design for the bottom railing as its loading will be maximum. The curb is 10 inches in height therefore a lateral force of 300 pounds will be used on the bottom rail.

Bolt:

Capacity of 3/4" bolt in single shear

$$= (3/4)^2 \, \pi/4 \, (11,200) = 4925^{\#}$$

$$\text{Load on bolt} = \frac{300(9.5)}{2} = 1425^{\#}$$

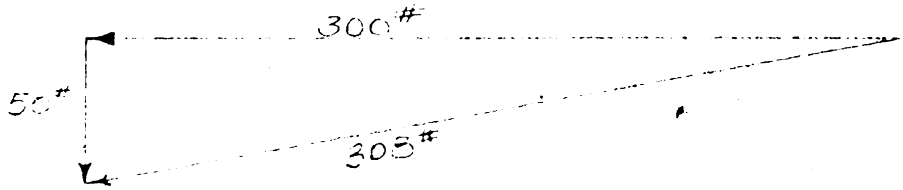
Safety factor is 3.45

Strap:

$$\text{Capacity in shear} = \left(1\tfrac{3}{4} - \tfrac{13}{16}\right)\left(\tfrac{5}{8}\right)(11,000) = 6450^{\#}$$

Approximate dead weight of railing $= 2860^{\#}$ (sh. 6)

$$\text{Approximate dead wt. per foot} = \frac{2850}{6 \times 9.5} = 50^{\#}$$



$$\text{Load} = \frac{308(9.5)}{2} = 1460^{\#}$$

Bending Moment in Strap:

$$f = \frac{Mc}{I} = \frac{M}{Z} \qquad Z = \frac{bh^2}{6}$$

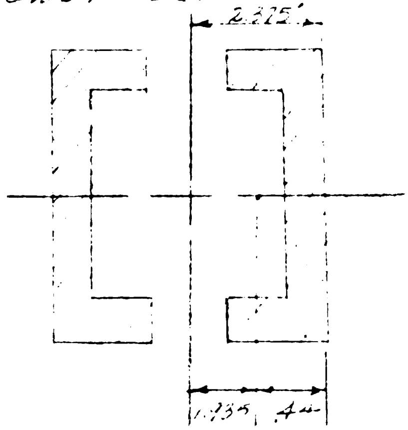
$$f_{act.} = \frac{1460(2)(6)}{(.625)(1.75)^2} = 9160 \text{ psi}$$

$$f_{vert} = \frac{50(9.5)(2.[illegible])}{2(1.75)(.625)^2} = 4,[illegible] \text{ psi}$$

$$13,320 \text{ psi}$$

Bending moment is the controlling factor in the design, therefore the strap is safe as allowable $f_s = 18,000$ psi

Lower Rail:



To simplify calculations only 2 channels will be used. If these prove adequate it will therefore be additionally safe when the other channel is added.

Length of Rail = 9.5'

$$M = \frac{wL^2}{8} = \frac{[illegible](9.5)^2(12)}{8} = 40,000 \text{ in-lbs}$$

Area = $2 \times 1.46 = 2.92$ sq. in.; $d = 1.935''$

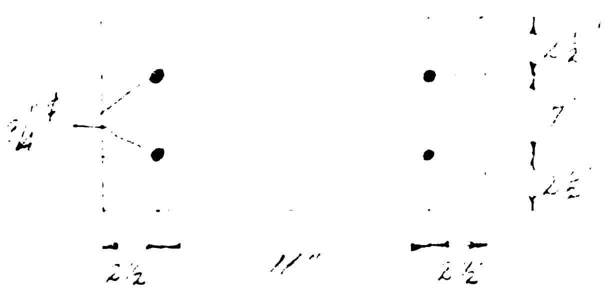
$$I_1 = 2(.25) = 0.50 \text{ in}^4$$

$$I = I_1 + Ad^2 = 0.50 + 2.92(1.935)^2 = 11.42 \text{ in}^4$$

$$f = \frac{Mc}{I} = \frac{40,000 \times 2.375}{11.42} = 8450 \text{ psi}$$

All right – allowable = 18,000 psi. This stress would even be lower as 3 channels are used in the standard railing section.

Railing Posts:



$b = 16"$, $d' = 1\frac{1}{2}$, $n = 10$

$A_s = 2 - \frac{3}{4}\text{"}\ \phi$ bars $= 0.88\ \square"$

$$k = \frac{1}{\frac{f_s}{n f_c} + 1} = 0.43$$

$$j = \left(1 - \frac{k}{3}\right) = 1 - \frac{.43}{3} = 0.860$$

Bending Moment

$.50\,(9.5 + 1.333)(\ldots) \qquad = 51,500$ in-lbs

$300\,(10.833)(4.25) \qquad = \underline{13,800}$ in-lbs

Total = 65,300 in-lbs

$$d = \sqrt{\frac{65,300}{243 \times 16}} = 4.1" \quad (\text{ok. have } d = 9\tfrac{1}{2}")$$

$$f_s = \frac{65,300}{.88 \times .860 \times 9.5} = 9100 \text{ psi} \quad \left(\text{ok - allowable } f_s = 18,000 \text{ psi}\right)$$

Curb:

AASHO 3.2.11.B. Curbs shall be designed to resist a lateral force of not less than 500 pounds per lineal foot of curb, applied at the top of the curb, or at a point not over 10 inches above the floor.

The curb is 10 inches thick and 15" wide every lineal foot, therefore it is made that [illegible] to withstand a lateral force of 500#

Sol:

Data:

$f_c = $ [illegible] psi

$f_s = $ [illegible] psi

$f_s = $ [illegible]

K or $n = 24$ [illegible]

[illegible]

$u = $ [illegible] psi

$s = 40$ [illegible]

$d = $ [illegible]

[illegible] spacing.

AASHO [illegible]

[illegible] $S = $ [illegible]

[illegible]

[illegible]

AASHO [illegible] $I = $ [illegible]

$I = 0.6(4\ldots) + 25 = 2\ldots + 2\ldots = 53'$

[illegible] AASHO [illegible] $M = $ [illegible]

$M = $ [illegible] $=$ [illegible]

Impact: AASHO 3.2.12

$I = \dfrac{50}{4\ldots + 125} = $ [illegible]

[illegible] $= 1070$ [illegible]

Dead load:

$10'$ [illegible] 37 [illegible]

[illegible] $= 272$ lb-ft.   272 lb-ft

Wearing surface   = 25 lb-ft

Total   = 4307 lb-ft

[illegible]

[illegible] $= 5$ [illegible]

[illegible]

$f_c = \frac{6M}{bd^2} = \frac{6 \times 42 \ldots \times 12}{12 \times \ldots}$ [illegible]

[illegible]

[illegible] $= 17{,}3\ldots$ [illegible]

(All [illegible])

[illegible]

AASHO 3.7.2. [illegible] not [illegible]

[illegible]

[illegible] $\frac{1}{2}$ [illegible] $\frac{1}{4}$ [illegible]

[illegible]

AASHO [illegible] Not less than $\frac{1}{5}$ [illegible]

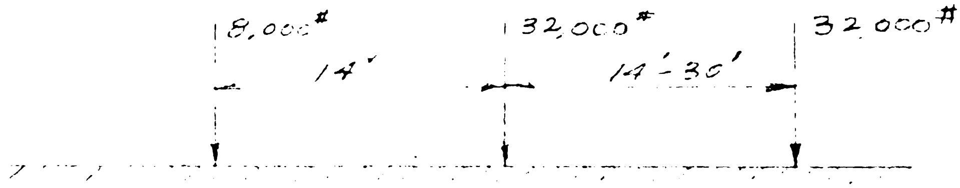
[illegible]

[illegible] $\frac{1}{2}$ [illegible] $= 0.13$ [illegible]

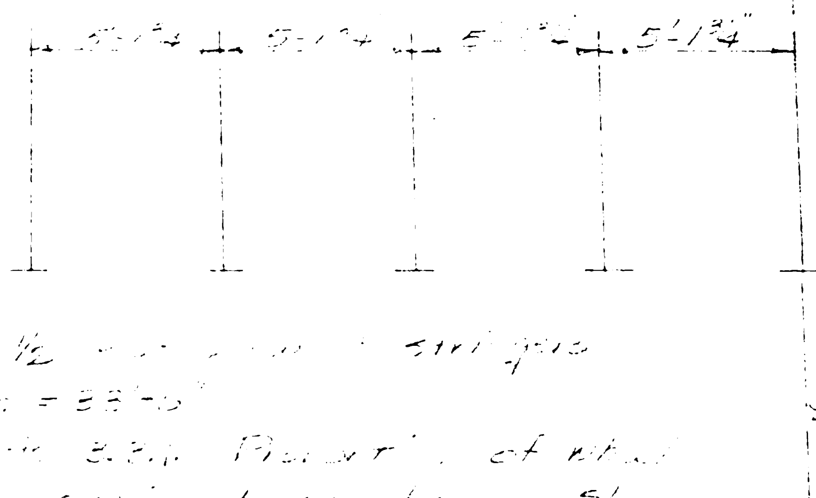
AASHO 3.7.2. [illegible] Slabs designed for bending moment in accordance with [illegible] shall be [illegible] in [illegible]

Rail Beams:

We have AASHO H20-S16 truck loading.



The above loads are axle loads.



½ [illegible] stringers

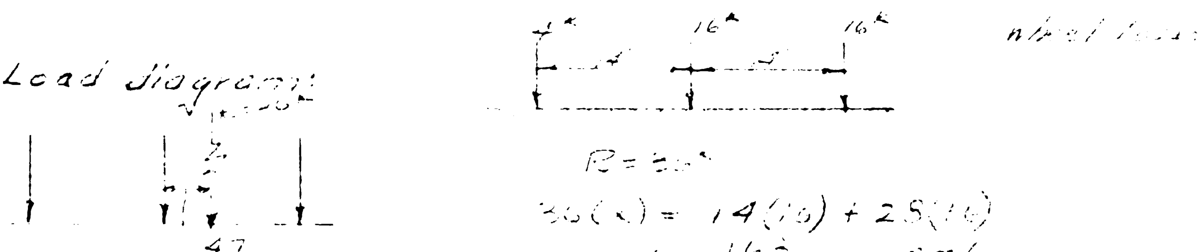
Span = 33'-6"

AASHO 3.23 Fraction of wheel load carried by one beam = S/5

$\frac{5.17}{5} = 1.03$

Live load moments & shear : Truck

Load diagram:

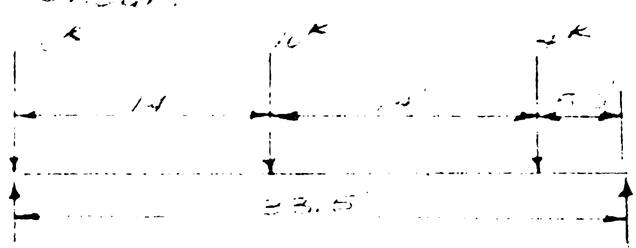


$R = 36^k$

$36(x) = 14(16) + 28(16)$

$x = \frac{168}{9} = 18.7'$

Shear:

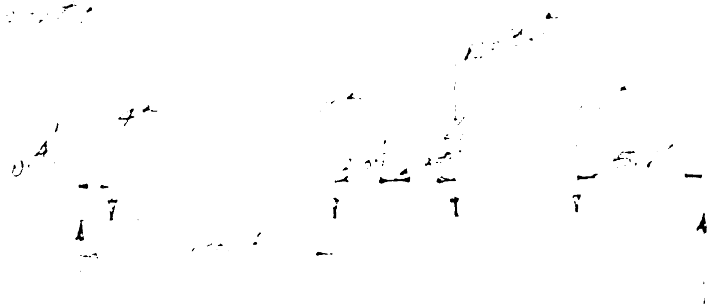


$V = 16 + \frac{19.5}{33.5}(16) + \frac{5.5}{33.5}(4) = 16 + 9.3 + 0.65 = 25.95^k$

$V = 25.95 \times 1.03 = 26.7^k$

[illegible]
Live Load [illegible]

Moment:



$\frac{14.4}{33.5} \times 36 = 15.5^k$

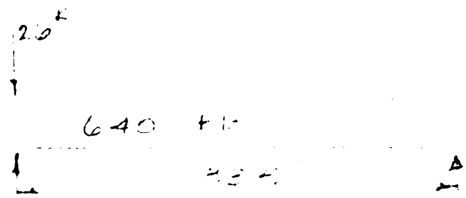
$M = 15.5 \times 14.4 = 223$

$-2.8(20) = -56$

$M: \quad 167 \times 1.03 = 172 \text{ k-ft}$

Live load moments & shears: Lane loads.

From AASHO – Shear

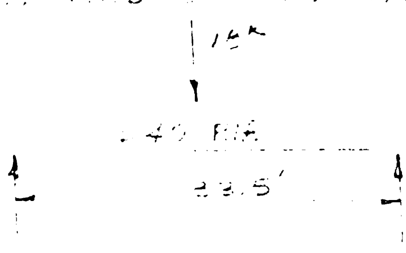


$26 + \frac{33.5}{2}(.640)$

$26 + 10.7 = 36.7^k$

$V = 36.7 \times \frac{5.167}{10} = 19^k$

From AASHO – Moment



$\frac{0.64(33.5)^2}{8} = 90^{k\text{-}ft}$

$\frac{18 \times 33.5}{4} = 151^{k\text{-}ft}$

241

$M = 241 \times \frac{5.167}{10} = 124 \text{ k-ft}$

Rolled beams (Cont)

Dead load moment & shear

Average slab thickness $8\frac{1}{2}'' = 106 \times 5.167 = 547$ plf

Beam $= 110$

657 plf

Shear

$V = \frac{1}{2} \times 657 \times 33.5 = 11,000$ lbs.

Moment

$M = \frac{657 \times (33.5)^2}{8} = 92,000$ pf

	Shear	Moment
Live load	26,700#	172,000 pf
Impact $\frac{50}{33.5+125} = 0.315$ max. $= 30\%$	8,000#	51,600 pf
Dead	11,000#	92,000 pf
Total	45,700#	315,600 pf

Req'd section modulus $= \frac{315,600 \times 12}{18,000} = 210.0$

24 WF 110 has a section modulus $= 274.4$

$f_b = \frac{M}{S_{req'd}} = 13,800$ psi

Shear: $\frac{45,700}{32.30} = 14,100$ psi

Allowable stress $= 13,000$ psi

For moment not overstressed too much, but for shear by AASHO it is overstressed, however the M.S.H.D. specs might bring it in within the allowable 13,500 psi.

[illegible]

The [illegible] following four cases:

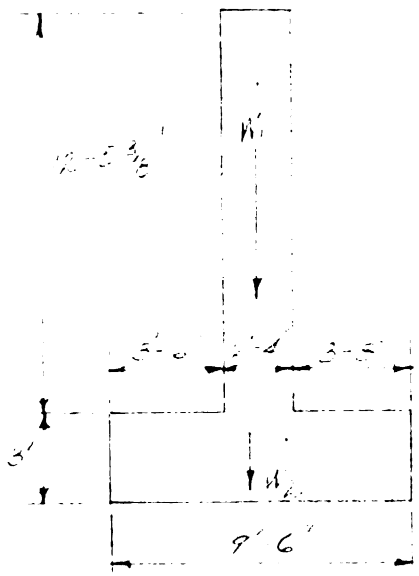
Case I – No superstructure load or surcharge.

Case II – Superstructure dead load & live load surcharge.

Case III – Superstructure dead load & live load; no surcharge.

Case IV – Superstructure dead load, no live load or surcharge; and no backwall pressure.

Abutment: Case I - No superstructure load or surcharge.



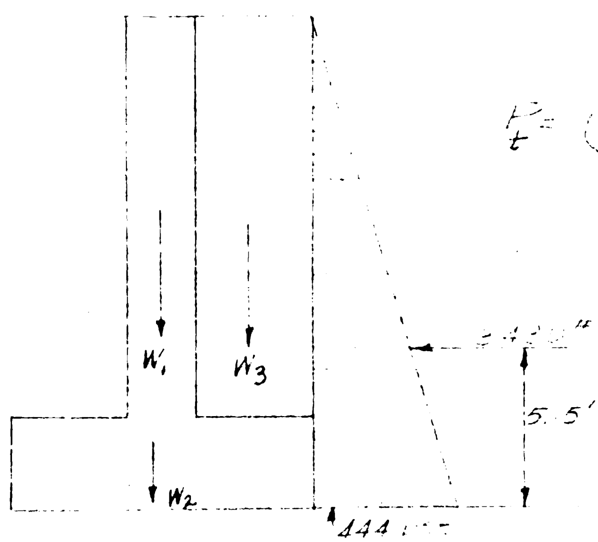
$\phi = 33°40'$

$p = 28.7h$

$W_1 = 12.45 \times 2.33 \times 150 = 4350^{\#}$

$W_2 = 9.5 \times 3 \times 150 = 4270^{\#}$

$W_3 = 3.67 \times 12.45 \times 100 = 4570^{\#}$



$p = 28.7h = 28.7 \times 15.45 = 444$ psf

$P_t = \left(\frac{444}{2}\right)(15.45) = 3430^{\#}$

[illegible] Case I

Base pressures: Moments about toe.

$W_1 = 4350^{\#} \quad ; \times 4.67 \quad = 20{,}300$ lb-ft

$W_2 = 4270^{\#} \quad ; \times 4.75 \quad = 20{,}300$ lb-ft

$W_3 = \underline{4570^{\#}} \quad ; \times 7.67 \quad = \underline{35{,}000}$ lb-ft

$13{,}190^{\#} \qquad\qquad 75{,}600 = M_R$

$3430 \times 5.15 = \underline{-17{,}650} = M_{OT}$

$13{,}190 \,|\, \underline{57{,}950}$

4.4 ft. from toe.

$e = 4.75 - 4.4 = 0.35'$

Heel & Toe pressures.

$$p = \frac{P}{A}\left(1 \pm \frac{6e}{d}\right) = \frac{13{,}190}{9.5}\left(1 \pm \frac{6 \times 0.35}{9.5}\right)$$

$$= \begin{cases} 1700 \text{ psf - toe} \\ 1050 \text{ psf - heel} \end{cases}$$

Safety factor overturning.

$$S.F. = \frac{M_R}{M_{OT}} = \frac{75{,}600}{17{,}650} = 4.28$$

(ok – 1940-J.C. says 50% greater than sliding factor of safety)

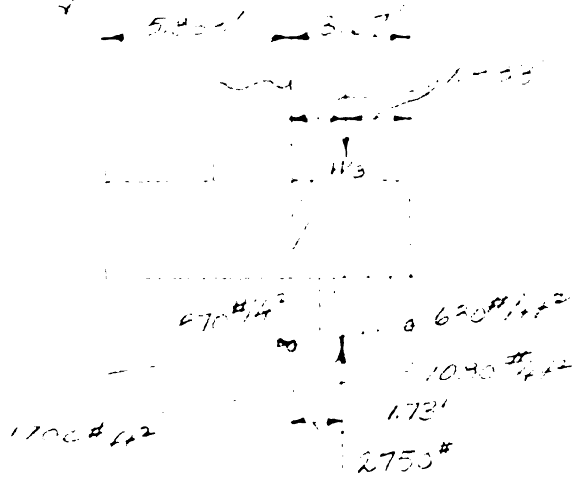
Abutment No. 1

Safety factor – sliding

$$F.S. = \frac{\mu \times \text{[illegible]}}{P_t} = \frac{13{,}110 \times 0.40}{3430} = 1.54$$

All other abutments [illegible] safe against sliding.

Design of heel



Heel press. = 150 x 3 = 450 #/ft²

$$3.67\left(\frac{630+870}{2}\right) = 2750^{\#}$$

$$x = 3.67\left(\frac{870+1260}{870+630}\right) = 1.73'$$

Shear	Moment
-4570 x 1.833	= - 8350 ft-lbs.
2750 x 1.73	= + 4750 ft-lbs.
V = 1320#	M = 3600 ft-lbs.

$$d = \frac{1820}{40 \times .857 \times 12} = 4.4'' \qquad d = \sqrt{\frac{3600}{243}} = 3.8''$$

thickness ok (have d = 33")

$$v = \frac{1920}{12 \times .857 \times 33} = 5.45 \text{ psi} \quad (\text{allowable} = 40 \text{ psi})$$

Steel: min. 3/4" ϕ @ 12" c/c = 0.44 sq in./ft. (T.)

$$f_s = \frac{3600 \times 12}{0.44 \times .857 \times 33} = 3460 \text{ psi} \quad (\text{allowable} = 18{,}000 \text{ psi})$$

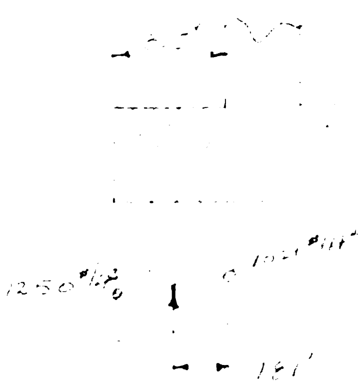
Alternate [illegible] 1
Design of [illegible] (cont)

Bond [illegible] $\frac{[illegible]45 \times 12[illegible]}{24}$ = [illegible] psi (allowable = 150 psi)

Concrete:

$$f_c = \frac{6M}{bj^2} = \frac{[illegible] \times 3000 \times 12}{12 \times 33^2} = 20 \text{ psi}$$
(allowable = 1[illegible])

Design at [illegible] Toe



R [illegible] = $\frac{1250 + 1021}{2} \times 3.5 = 4000^{\#}$

$$x = \frac{3.5}{3} = \left(\frac{1021 + 2500}{2271}\right) = 1.31 \text{ ft}$$

$M = 4000 \times 1.31 = 7200$ ft-lbs
$V = 4000^{\#}$

$$v = \frac{V}{bjd} = \frac{4000}{12 \times .857 \times 33} = 11.8 \text{ psi} \quad (\text{allowable} = 40 \text{ psi})$$

Steel: [illegible] $\frac{7}{8}$" ϕ @ 12" c/c = 0.60 [illegible]

$$f_s = \frac{M}{A_s jd} = \frac{7200 \times 12}{0.60 \times .857 \times 33} = 51[illegible] \text{ psi}$$
(allowable = 18,000 psi)

Bond:

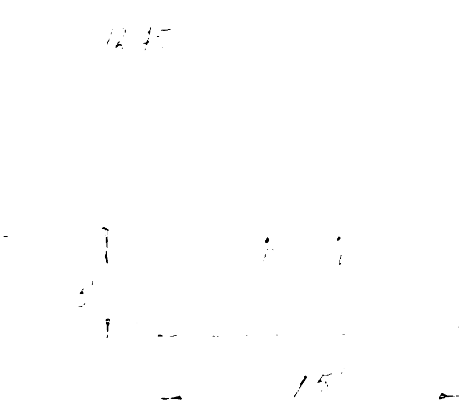
$$u = \frac{V}{\Sigma_o} = \frac{11.8 \times 12}{2.8} = 50.5 \text{ psi}$$
(allowable = 150 psi)

Concrete:

$$f_c = \frac{6M}{bj^2} = \frac{[illegible] \times 7200 \times 12}{12 \times 33^2} = [illegible] \text{ psi}$$
(allowable = 135[illegible])

[illegible]

$V = \frac{12.45}{2}$ [illegible] $= 22$ [illegible]



[illegible] $\frac{12.45}{2}$ (35) $\frac{12.45}{3}$ = 92 [illegible]

$d = \sqrt{92 \ldots} = 6.1''$

[illegible] 25)

St [illegible] 12" @ [illegible] = 0.38 sq in per ft

$\frac{92 \ldots \times 12}{0.38 \times \ldots \times .25}$ = [illegible]

[illegible] $\frac{V}{b\,d}$ = [illegible] psi

[illegible] 3.5 [illegible]

[illegible] of height.

Req'd = 0.125 sq in per ft

[illegible] $\frac{1}{2}$ ϕ @ 1'-7 [illegible] = 0.125 sq in [illegible]

[illegible]

$f_c = \frac{6M}{bd^2} = \frac{6 \times 12 \ldots}{12 \times 22^2}$ = [illegible]

([illegible] = 1350 psi)

[illegible] Case [illegible] — Superstructure dead load and live load surcharge.

Superstructure dead load

Railings: $\frac{2 \times 30}{[illegible]}$ = 1425 #

Slab = $\frac{54}{2} \times 4000$ = 10[illegible],[illegible] #

Curb = $\frac{7}{2} \times 4[illegible]$ = 14,200 #

Railing posts = $\frac{1.8}{2} \times 4[illegible]$ = 3,640 #

I-Beams = $\frac{4 \times 37.5 \times 110}{2}$ = 16,600 #

144,065 #

Width of abutment under load = 44'

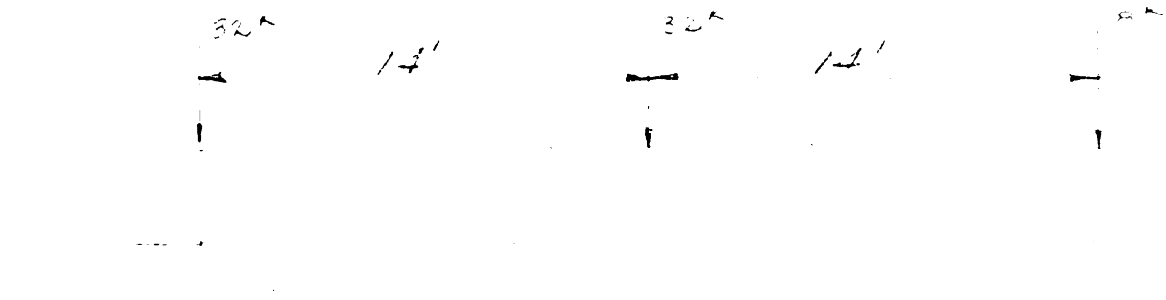
Load per foot of abutment = $\frac{144{,}[illegible]65}{44}$

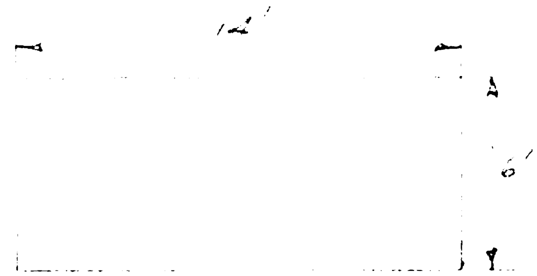
= 3,300 lb per ft

Use 4000 #/ft for diaphragm etc.

3'-1 1/3" from top of abutment to top of grade is fill at 100 #/cu ft

Abutment Sec. II
Surcharge:

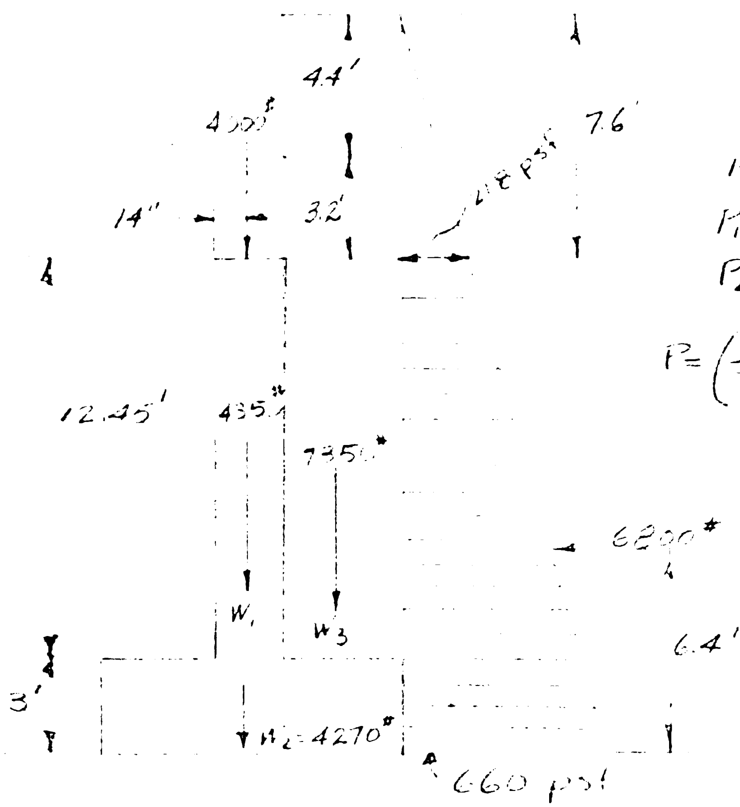




Equivalent surcharge:
15% Impact

$$= \frac{32{,}000}{14 \times 6 \times 100} + .15\left(\frac{32{,}000}{14 \times 6 \times 100}\right)$$

$$= 3.81 + .57 = 4.38'$$



$W_3 = 3.67 \times 20.05 \times 100 = 7350^{\#}$

$p = 28.7h$

$P_1 = 28.7 \times 7.6 = 218$ psf

$P_2 = 28.7 \times 23.05 = 660$ psf

$$P = \left(\frac{218 + 660}{2}\right)(15.45) = 6800^{\#}$$

$$x = \frac{15.45}{3}\left(\frac{660 + 436}{878}\right)$$

$x = 6.4'$

Abutment Case II
Footing pressure & Moments about toe

$W_1 = 4350^{\#}$; $\times 4.67$ = 20,[illegible] lb-ft
$W_2 = 4270^{\#}$; $\times 4.75$ = 20,300 lb-ft
$W_3 = 7350^{\#}$; $\times 7.67$ = 56,300 lb-ft
$W = 4[illegible]^{\#}$; $\times 4.67$ = 19,600 lb-ft

$19,170^{\#}$ $\qquad$ $115,550 = M_R$

$6800 \times 6.4 = 43,500 = M_{OT}$

$19,170 \,\overline{)\,72050}$

3.61' from toe

$e = 4.75 - 3.61 = 1.14'$

Heel and toe pressures.

$$p = \frac{P}{A}\left(1 \pm \frac{6e}{d}\right) = \frac{19,970}{9.5}\left(1 \pm \frac{6 \times 1.14}{9.5}\right)$$

$$= \begin{cases} 3620 \text{ psf toe} \\ 5[illegible] \text{ psf heel} \end{cases}$$

Safety factor overturning:

$$S.F. = \frac{M_R}{M_{OT}} = \frac{115,550}{43,500} = 2.66$$

(ok - must be 50% greater than sliding S.F. - J.C. 1940)

Safety factor sliding.

$$F.S. = \frac{W \tan\delta}{P_h} = \frac{19,170 \times 0.40}{6500} = 1.18$$

(ok - AASHO says S.F. sliding must be adequate)

[illegible]

$x = \frac{[illegible]}{3}\left(\frac{[illegible]}{[illegible]}\right) = 1.35'$

[illegible] 240#

Shear [illegible]	Moment [illegible]
$-[illegible] \times [illegible]$	$= -13{,}[illegible]$ ft-lb
$[illegible] \times [illegible]$	$= 3{,}[illegible]$ ft-lb
[illegible]	$M = 10{,}2[illegible]$ ft-lb

$d = \sqrt{\frac{[illegible]}{24[illegible]}} = 6.4''$

$(d - [illegible]\ d = 33)$

$v = \frac{4[illegible]}{12 \times .857 \times 33} = [illegible]$ psi (allowable $= 40$ psi)

[illegible] $9/16$ [illegible] @ $12''$ [illegible] $= 0.44$ sq.in/ft

$f_s = \frac{M}{A_s j d} = \frac{10{,}260 \times 12}{0.44 \times .857 \times 33} = 9{,}700$ psi

(allowable $= [illegible]$ psi)

Bond: $u = \frac{[illegible]}{[illegible]} = \frac{14.5 \times 12}{24} = 72.5$ psi

(allowable $= 150$ psi)

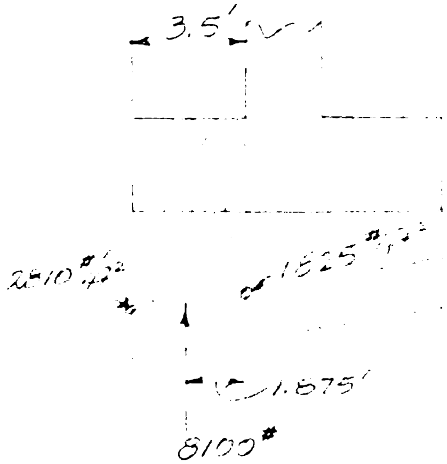
Concrete: $f_c = \frac{6M}{bd^2} = \frac{6 \times 10{,}2[illegible] \times 12}{12 \times 33^2} = 56.6$ psi

(allowable $= 1350$ [illegible])

Abutment: Case II
Design of Wall: Toe

P on soil $= \dfrac{2810 + 1825}{2} \times 3.5$

$= 8100^{\#}$



$x = \dfrac{3.5}{3}\left(\dfrac{1825 + 5620}{4635}\right) = 1.875'$

$M = 8100 \times 1.875 = 15{,}200$ lb-ft.
$V = 8100^{\#}$

$v = \dfrac{V}{bjd} = \dfrac{8100}{12 \times .857 \times 33} = 23.8$ psi (allowable = 40 psi)

steel: have 7/8"φ @ 12" c/c = 0.60 sq.in./ft.

$f_s = \dfrac{15{,}200 \times 12}{0.60 \times .857 \times 33} = 10{,}750$ psi (allowable = 18,000 psi)

bond:

$u = \dfrac{v b}{\Sigma_0} = \dfrac{23.8 \times 12}{2.8} = 102$ psi (allowable = 150 psi)

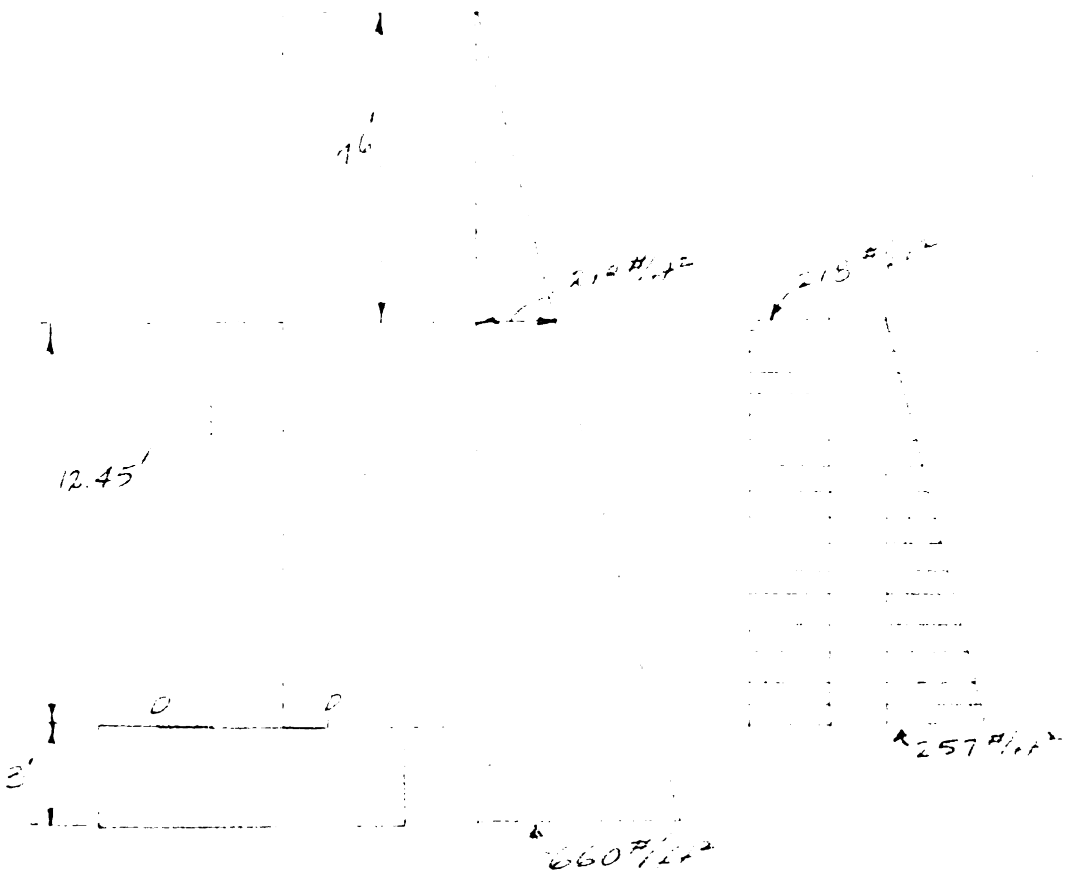
Concrete:

$f_c = \dfrac{6M}{bd^2} = \dfrac{6 \times 15{,}200 \times 12}{12 \times 33^2} = 83.7$ psi

(allowable = 1350 psi)

Automatic Dam II

Design of vertical stem



$p = whC = 23.1h$

$P_{0\cdot0} = 575\ \#/ft^2$

$V = \frac{12.45}{2}(218 + 575) = 4940\#$

$M = (218 \times 12.45)\left(\frac{12.45}{2}\right) + \left(\frac{257}{2}\right)\left(\frac{12.45}{3}\right)(12.45)$

$M = 16,900 + 6,650$

$M = 23,550$ ft-lbs.

$K = \frac{M}{bd^2} = 248$

$d = \sqrt{\frac{23,550}{248}} = 9.75''$

(ok - stem 2'-4" top & bottom)(d = 25")

[illegible]

([illegible])

Steel: have 3/4"φ @ 8" c.c. = 0.66 sq.in. per ft

$$f_s = \frac{M}{A_s j d} = \frac{23,[illegible] \times 12}{0.66 \times .857 \times 25} = 20,000 \text{ psi}$$

(allowable = [illegible] psi) therefore the steel is overstressed. The [illegible] the [illegible] might have used a different method. Our method conforms with the AASHO, with AASHO allowable stresses.

$$\text{Bond: } u = \frac{V}{\Sigma_o j d} = \frac{4140}{[illegible].5 \times .857 \times 25} = [illegible]6 \text{ psi}$$

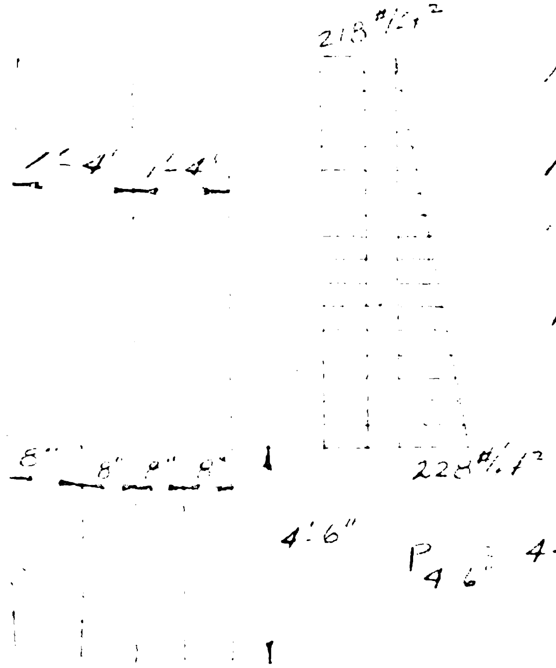
(allowable = 1[illegible]0 psi)

Temperature steel: AASHO [illegible]. Not less than 1/8 sq. in. per foot of height.

Req'd = 0.12[illegible] sq.in./ft.

we have 1/2"φ @ 1'-7" c.c. = 0.125 sq.in./ft

Cut-off of steel.



$P_{4'6"}$ 446#/ft²

$$M = (219 \times 7.95)\left(\frac{7.95}{2}\right) + \left(\frac{229}{2}\right)\left(\frac{7.95}{3}\right)7.95$$

$M = [illegible] + 2400$

$M = 9300$ ft-lbs.

We have 3/4"φ @ 16" c.c. = 0.33 sq.in/ft

$$f_s = \frac{M}{A_s j d}$$

$$f_s = \frac{9300 \times 12}{0.33 \times .857 \times 25}$$

$f_s = 1,575$ psi

(allowable = 18,000 psi)

[illegible]
[illegible] (cont)

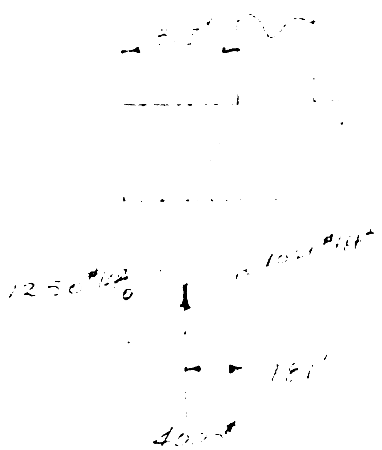
Bond: $u = \frac{[illegible]}{2.4} = [illegible]$ psi (allowable = 150 psi)

Concrete:

$$f_c = \frac{6M}{bd^2} = \frac{[illegible] \times 3000 \times 12}{12 \times 33^2} = 20 \text{ psi}$$

(allowable = [illegible])

[illegible]



$$P = \frac{1250 + 1021}{2} \times 3.5 = 4000^{\#}$$

$$x = \frac{3.5}{3}\left(\frac{1021 + 2500}{2271}\right) = 1.31 \text{ ft}$$

$$M = 4000 \times 1.31 = 7200 \text{ ft-lb}$$

$$V = 4000^{\#}$$

$$v = \frac{V}{bjd} = \frac{4000}{12 \times .857 \times 33} = 11.8 \text{ psi} \quad (\text{allowable} = 40 \text{ psi})$$

Steel: [illegible] 7/8" ⌀ @ 12" c/c = 0.60 [illegible]

$$f_s = \frac{M}{A_s jd} = \frac{7200 \times 12}{0.60 \times .857 \times 33} = [illegible] \text{ psi}$$

(allowable = 18,000 psi)

Bond:

$$u = \frac{V}{\Sigma_o} = \frac{11.8 \times 12}{2.8} = 50.5 \text{ psi}$$

(allowable = 150 psi)

Concrete:

$$f_c = \frac{6M}{bd^2} = \frac{[illegible] \times 7200 \times 12}{12 \times 33^2} = [illegible]$$

(allowable = 13[illegible])

[illegible]

[illegible]

[illegible] 22.0 [illegible]

[illegible] = 2'-11

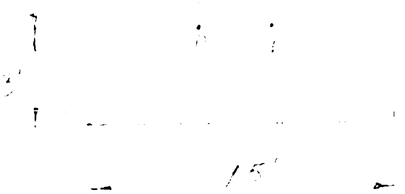
[illegible] = 25 [illegible]

$V = \frac{[illegible] 4.5}{2}$ [illegible] = 2220#

12.45 [illegible]

[illegible] = [illegible] 12 [illegible]

([illegible] = 25)



$M = \frac{12.45}{2}(355)\frac{12.45}{3} = 92[illegible]$ [illegible]

$= \frac{M}{[illegible]}$ [illegible]

$d = \sqrt{92[illegible]}$ [illegible] 6.1"

([illegible] 25)

Steel [illegible] @ [illegible] = 0.33 sq in per ft

$= \frac{M}{[illegible]} = \frac{9200 \times 12}{0.33 \times [illegible] \times 25} =$ [illegible]

[illegible] 18 [illegible] psi

[illegible] $= \frac{V}{[illegible]} = \frac{2220}{12 \times [illegible]} =$ [illegible] psi

([illegible] = 150 psi)

[illegible] 3.5 [illegible]

[illegible] of height.

Req'd = 0.125 sq in per ft.

[illegible] ½ ∅ @ 1'-7 [illegible] = 0.125 sq in per [illegible]

Concrete:

$f_c = \frac{6M}{bd^2} = \frac{[illegible] 1200 [illegible]}{12 \times 25^2} =$ [illegible]

(allowable = 1350 psi)

[illegible] - Superstructure dead load and live load reactions.

Superstructure dead load

Railings = $\frac{2850}{2}$ = 1425 #

Slab = $\frac{54}{2} \times 4000$ = 108,000 #

Curb = $\frac{7}{2} \times 4050$ = 14,200 #

Railing posts = $\frac{1.82}{2} \times 4000$ = 3,640 #

I-Beams = $\frac{2 \times 75.5 \times 110}{2}$ = 16,600 #

144,065 #

Width of abutment under load = 44'

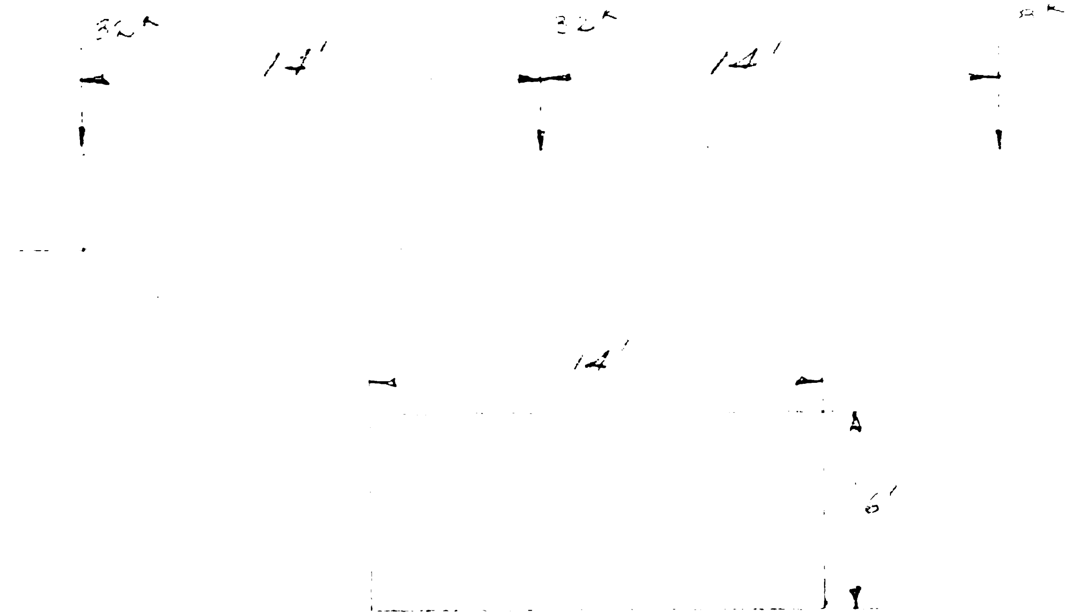
Load per foot of abutment = $\frac{144,065}{44}$

= 3,300 lbs per ft

add 4000 lbs for diaphragms etc.

5'-1 1/3" from top of abutment to top of grade is fill at 100 #/cu ft

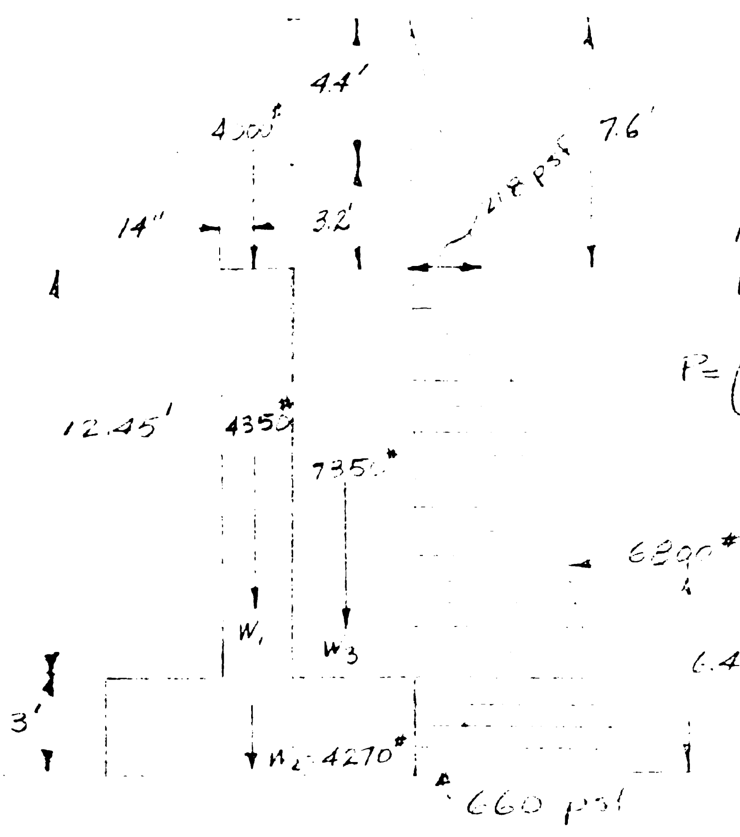
Abutment Live Load
Surcharge:



Equivalent surcharge:
15% Impact

$$= \frac{32{,}000}{14 \times 6 \times 100} + .15\left(\frac{32{,}000}{14 \times 6 \times 100}\right)$$

$$= 3.81 + .57 = 4.38'$$



$W_3 = 3.67 \times 20.05 \times 100 = 7350^{\#}$

$p = 28.7h$

$P_1 = 28.7 \times 7.6 = 218$ psf

$P_2 = 28.7 \times 23.05 = 660$ psf

$$P = \left(\frac{218 + 660}{2}\right)(15.45) = 6800^{\#}$$

$$x = \frac{15.45}{3}\left(\frac{660 + 436}{878}\right)$$

$x = 6.4'$

Abutment Case II
Foundation pressure Moments about toe

$W_1 = 4350^{\#}$; $\times 4.67$ = [illegible] lb-ft
$W_2 = 4270^{\#}$; $\times 4.75$ = 20,300 lb-ft
$W_3 = 7350^{\#}$; $\times 7.67$ = 56,300 lb-ft
$W = 4[illegible]^{\#}$; $\times 4.67$ = 19,650 lb-ft

$19,970^{\#}$ — $115,550 = M_R$

$6800 \times 6.4 = 43,500 = M_{OT}$

$19,970 \overline{)72,050}$
3.61' from toe

$e = 4.75 - 3.61 = 1.14'$

Heel and toe pressures.

$$= \frac{P}{A}\left(1 \pm \frac{6e}{d}\right) = \frac{19,970}{9.5}\left(1 \pm \frac{6 \times 1.14}{9.5}\right)$$

$$= \begin{cases} 3620 \text{ psf toe} \\ 510 \text{ psf heel} \end{cases}$$

Safety factor overturning.

$$S.F. = \frac{M_R}{M_{OT}} = \frac{115,550}{43,500} = 2.66$$

(ok - must be 50% greater than sliding S.F. - J.C. 7/4/40)

Safety factor sliding.

$$F.S. = \frac{W \tan\theta}{P_h} = \frac{19,970 \times 0.40}{6800} = 1.18$$

(ok - AASHO says S.F. sliding must be [illegible] required)

[illegible]

[illegible] 450 #/ft

$P = 267 \left(\frac{440 + [illegible]}{2} \right) = [illegible]$

$x = \frac{[illegible]}{3} \left(\frac{[illegible]}{1310} \right) = 1.35'$

[illegible] 240 #

Shear	Moment
[illegible]	= −13,5?? ft-lb
[illegible]	= 3,240 ft lb
[illegible]	M = 10,2?? ft lb

$d = \frac{V}{v_c j} = \frac{4??}{[illegible] \times 12} = 12''$ $\quad d = \sqrt{\frac{10???}{24?}} = 6.4$

(d - use d = 33)

$v = \frac{4??}{12 \times .?? \times 33} = [illegible]$ (allowable = 40 psi)

[illegible] bars 3/4" @ 12" c/c = 0.44 sq.in/ft

$f_s = \frac{M}{A_s j d} = \frac{16,260 \times 12}{0.44 \times .857 \times 33} = 7,900$ psi

(allowable = [illegible] psi)

Bond: $u = \frac{V}{[illegible]} = \frac{14.5 \times 12}{24} = 72.5$ psi

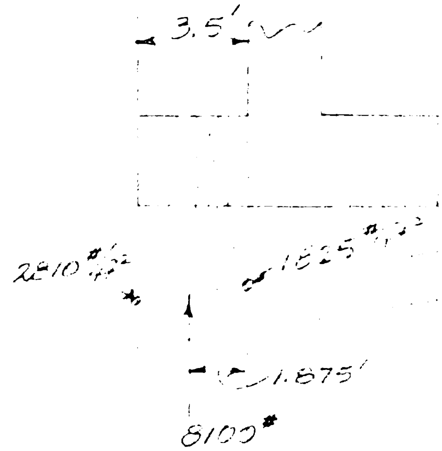
(allowable = 150 psi)

Concrete: $f_c = \frac{6M}{bd^2} = \frac{6 \times [illegible]}{12 \times 33^2} = 56.5$ psi

(allowable = 1350 psi)

Abutment: Case I
Design of [illegible]

P on soil $= \frac{2810 + 1825}{2} \times 3.5$
$= 8100^{\#}$



$x = \frac{3.5}{3}\left(\frac{1825 + 5620}{4635}\right) = 1.875'$

$M = 8100 \times 1.875 = 15{,}200$ lb-ft.
$V = 8100^{\#}$

$v = \frac{V}{bjd} = \frac{8100}{12 \times .857 \times 33} = 23.8$ psi (allowable = 40 psi)

steel: have $7/8''\phi$ @ $12''$ c/c $= 0.60$ sq. in./ft.

$f_s = \frac{15{,}200 \times 12}{0.60 \times .857 \times 33} = 10{,}750$ psi (allowable = [illegible] psi)

bond:

$u = \frac{vb}{\Sigma_0} = \frac{23.9 \times 12}{2.8} = 102$ psi (allowable = 150 psi)

Concrete:

$f_c = \frac{6M}{bd^2} = \frac{6 \times 15{,}200 \times 12}{12 \times 33^2} = 83.7$ psi

(allowable = 1350 psi)

Alternative Case II
Design of Vertical Stem

$p = whC = 23.1h$

$P_{b\text{-}b} = 575\#/ft^2$

$V = \dfrac{12.45}{2}\left(218 + 575\right) = 494\_\#$

$M = \left(218 \times 12.45\right)\left(\dfrac{12.45}{2}\right) + \left(\dfrac{257}{2}\right)\left(\dfrac{12.45}{3}\right)\left(12.45\right)$

$M = 16,900 + 6650$

$M = 23,550$ ft-lbs.

$R = \dfrac{M}{bd^2} = 248$

$d = \sqrt{\dfrac{23,550}{248}} = 9.75'$

(ck - thick 2'-4" top & bottom)(d = 25")

Abutment Check
(Design of abutment wall contd)

Steel: have 3/4" φ @ 8" c/c = 0.66 sq. in per ft.

$$f_s = \frac{M}{A_s j d} = \frac{23{,}750 \times 12}{0.66 \times .857 \times 25} = 20{,}000 \text{ psi}$$

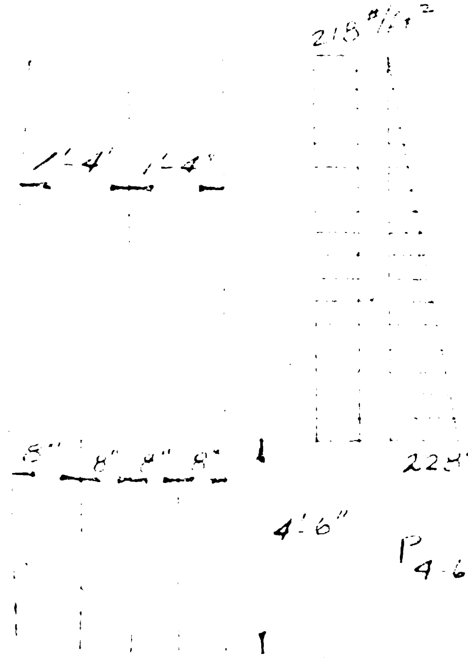
(allowable = 18,000 psi) therefore the steel is overstressed. In designing the abutment they might have used a different method. Our method conforms with the AASHO, with AASHO allowable stresses.

$$\text{Bond: } u = \frac{V}{\Sigma_o j d} = \frac{4140}{7.5 \times .857 \times 25} = 26 \text{ psi}$$

(allowable = 180 psi)

Temperature steel: AASHO 3.7.11 Not less than 1/8 sq. in. per foot of height.
Req'd = 0.125 sq. in./ft.
we have $\frac{1}{2}$" φ @ 1'-7" c/c = 0.125 sq. in./ft

Cut-off of steel.



$$M = 218 \times 7.95\left(\frac{7.95}{2}\right) + \left(\frac{228}{2}\right)7.95\left(\frac{7.95}{3}\right)$$

$M = 6900 + 2400$

$M = 9300$ ft-lbs.

We have 3/4" φ @ 16" c/c
= 0.33 sq. in/ft

$$f_s = \frac{M}{A_s j d}$$

$$f_s = \frac{9300 \times 12}{0.33 \times .857 \times 25}$$

$f_s = 15{,}785$ psi

(allowable = 18,000 psi)

[illegible] 20' – superstructure dead load [illegible]
[illegible]

Superimposed dead load
[illegible] = [illegible] #/ft of abutment

Live load
Max live load per stringer (truck loading)
= 26,7[illegible]#
26,7[illegible]# x 9 (stringers) = 24[illegible]#

live load = $\dfrac{24[illegible]}{44 \text{ [illegible]}}$ = 547[illegible] #/ft
allow 15% for impact

3'-1¾' [illegible] abutment to top of grade
[illegible] 10 #/[illegible]

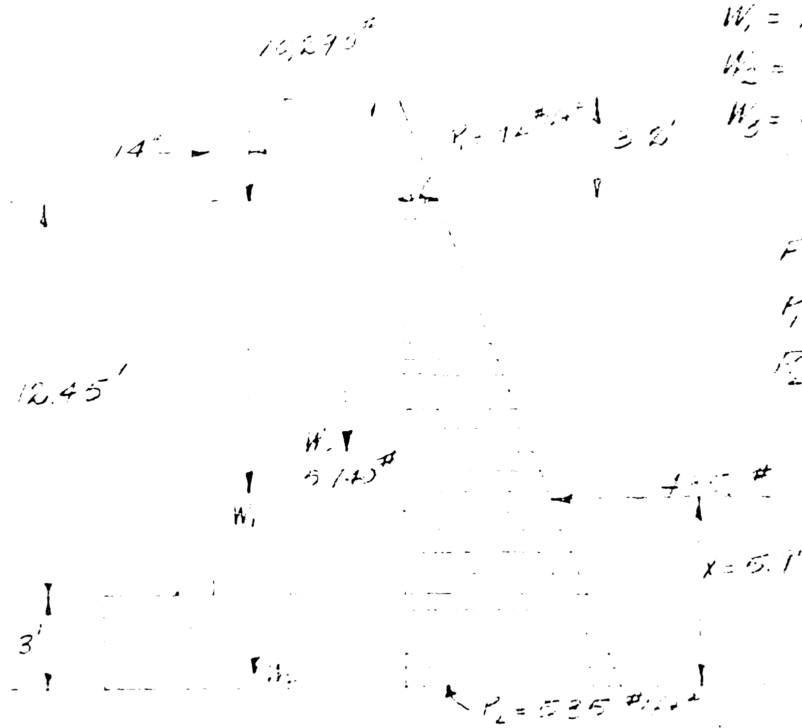
Dead load = 4000 #/ft
Live load = 5470 #/ft
Impact = 820 #/ft
D.L. + L.L. 10,290 #/ft

$\phi = 33°40'$
$\delta = 25°$

$C = \dfrac{1 - \sin\phi}{1 + \sin\phi}$

$p = Cwh = 100h \dfrac{1 - 0.554}{1 + 0.554} = 28.7h$

Abutment: Case 3.5



$W_1 = 12.45 \times 2.33 \times 150 = 4350^{\#}$

$W_2 = 7.5 \times 3 \times 150 = 4270^{\#}$

$W_3 = 3.67 \times 15.65 \times 100 = 5740^{\#}$

$P = 28.7h$

$P_1 = 28.7 \times 3.2 = 92\ ^{\#}/ft^2$

$P_2 = 28.7 \times 18.65 = 535\ ^{\#}/ft^2$

$$P_h = \left(\frac{92 + 535}{2}\right)(15.45) = 4850^{\#}$$

$$x = \frac{15.45}{3}\left(\frac{535 + 184}{627}\right) = 5.9'$$

Base pressure:

Moments about toe.

$W_1 = 4350^{\#}$	;	$\times$ 4.67	=	20,300 ft-lbs
$W_2 = 4270^{\#}$	;	$\times$ 4.75	=	20,300 ft-lbs
$W_3 = 5740^{\#}$	;	$\times$ 7.67	=	44,000 ft-lbs
$W = 10,210^{\#}$	;	$\times$ 4.67	=	48,000 ft-lbs
24,650 #				132,600 = M_R

$4850 \times 5.9 = 28,600 = M_{OT}$

$24,650 \overline{)104\,000}$

4.22' from toe

$e = 4.75 - 4.22 = 0.53'$

Alternate No. III

Heel & Toe pressure.

$$p = \frac{P}{A}\left(1 \pm \frac{6e}{d}\right) = \frac{24{,}850}{9.5}\left(1 \pm \frac{6 \times 0.53}{9.5}\right)$$

$$= \begin{cases} 3460\ \#/ft^2 - \text{Toe} \\ 1730\ \#/ft^2 - \text{Heel} \end{cases}$$

Safety factor overturning

$$S.F. \quad \frac{M_R}{M_{O}} = \frac{132{,}[illegible]}{28{,}600} = 4.63$$

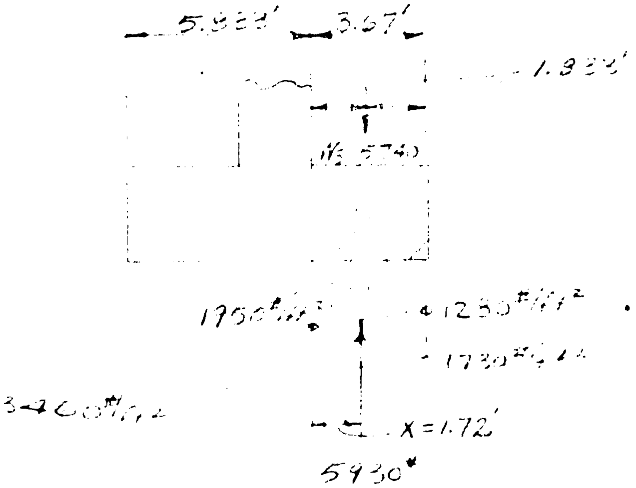
(ok - 50% greater than S.F. sliding)

Safety factor sliding.

$$F.S. = \frac{W \tan\alpha}{P_h} = \frac{24{,}850 \times 0.40}{4950} = 2.00$$

(J.C. 1941 - method 2)

Design of Heel



Heel pressure = 150 × 3 = 450 #/ft²

$$R = 3.67\left(\frac{1230 + 1950}{2}\right) = 5930\#$$

$$x = \frac{3.67}{3}\left(\frac{1950 + 2560}{3230}\right) = 1.72'$$

Abutment [illegible]
Design of [illegible] (Cont.)

Shear	Moment
-5740×1.85	$= -10,500$ ft-lbs
$+5930 \times 1.72$	$= 10,200$ ft-lbs
$V = 190^{\#}$	$M = 300$ ft-lbs

$$d = \frac{V}{v j b} = \frac{190}{40 \times .857 \times 12} = 0.46'' \qquad d = \sqrt{\frac{300}{273}} = 1.1''$$

(act. min. d. 33")

$$v = \frac{V}{bjd} = \frac{190}{12 \times .857 \times 33} = 0.56 \text{ psi} \quad (\text{allowable} = 40 \text{ psi})$$

steel: use bars $3/4''\phi$ @ $12''$ c-c $= 0.44$ sq. in/ft.

$$f_s = \frac{M}{A_s j d} = \frac{300 \times 12}{0.44 \times .857 \times 33} = 290 \text{ psi}$$

(allowable = [illegible] psi)

$$\text{bond} \quad u = \frac{v b}{\Sigma_o} = \frac{0.56 \times 12}{2.4} = 2.8 \text{ psi}$$

(allowable [illegible] 150 psi)

Concrete

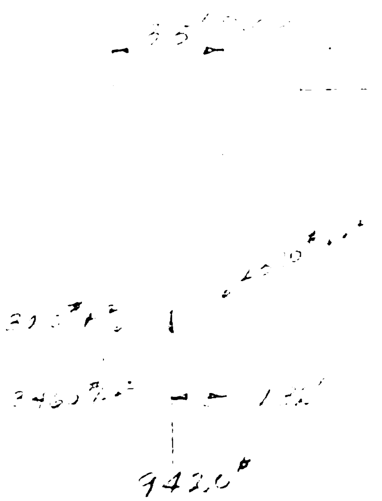
$$f_c = \frac{6M}{bd^2}$$

$$f_c = \frac{6 \times 300 \times 12}{12 \times 33^2}$$

$f_c = 1.65$ psi (allowable [illegible] psi)

Abutment [illegible] Check

Design of [illegible]



R_L or $50\% = \frac{[illegible]}{2}$

$= 9420^{\#}$

$x = \frac{5.5}{3}\left(\frac{2371+6620}{5350}\right) = 1.82'$

$M = 9420 \times 1.82 = 17{,}000$ ft lb.

$V = 9420^{\#}$

$v = \frac{V}{bjd} = \frac{9420}{12 \times .897 \times 33} = 27.7$ psi (allowable = 40 psi)

Steel: we have $\frac{7}{8}"$ ⌀ @ 12" c-c = 0.60 sq in/ft

$f_s = \frac{M}{A_s jd} = \frac{17{,}000 \times 12}{0.60 \times .897 \times 33} = 12{,}450$ psi

(allowable = 19,000 psi)

Bond: $u = \frac{v b}{\Sigma o} = \frac{27.7 \times 12}{2.8} = 119$ psi

(allowable = 150 psi)

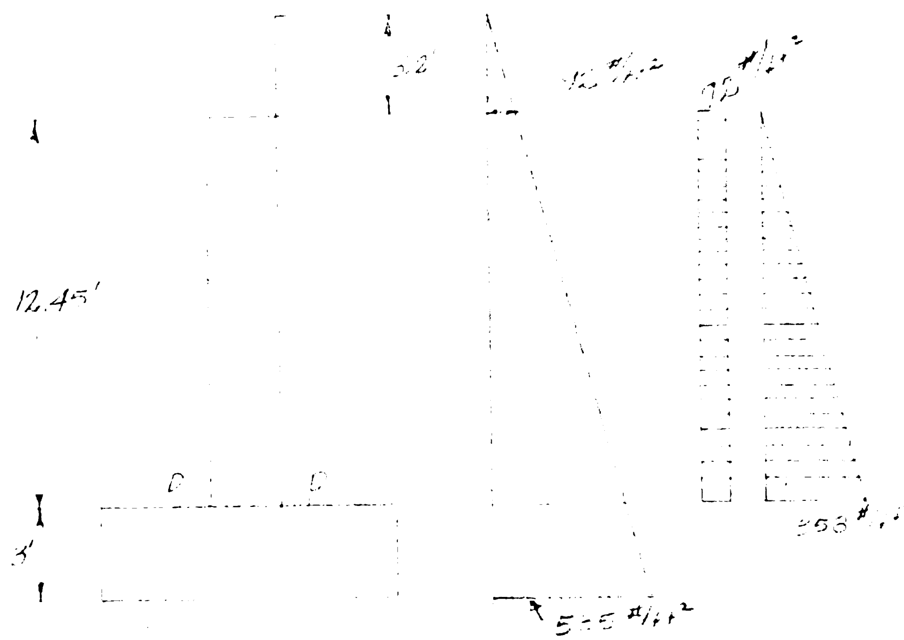
Concrete:

$f_c = \frac{[illegible]\,M}{b d^2} = \frac{[illegible] \times 17{,}000 \times 12}{12 \times 33^2}$

$f_c = 97$ psi

(allowable = 1350 psi)

Abutment: Case III
Design of vertical stem



$P_{base} = 28.1h = 450\ \#/ft^2$

$V = \frac{12.45}{2}(92 + 450) = 3380\#$

$d = \frac{V}{v\,b\,j} = \frac{3380}{40 \times 12 \times .857} = 8.2''$

$M = (92 + 12.45)\left(\frac{12.45}{2}\right) + \left(\frac{355}{2}\right)\left(\frac{12.45}{3}\right)(12.45)$

$M = 7140 + 9250$

$M = 16,390$ ft-lb.

$R = \frac{M}{b\,d^2} = 248$

$d = \sqrt{\frac{16390}{248}} = 8.1''$

(ok - our d = 25")

Abutment Case IV

Design of vertical stem (cont.)

steel at base 3/4"φ @ 8" c/c = 0.66 sq.in./ft.

$$f_s = \frac{M}{A_s j d} = \frac{16{,}330 \times 12}{0.66 \times .857 \times 25} = 13{,}900 \text{ psi}$$

(allowable = 18,000 psi)

bond

$$u = \frac{V}{\Sigma_o j d} = \frac{3320}{3.5 \times .857 \times 25} = 45 \text{ psi}$$

(allowable = 150 psi)

Concrete:

$$f_c = \frac{6M}{bd^2} = \frac{6 \times 16{,}330 \times 12}{12 \times 25^2} = 157 \text{ psi}$$

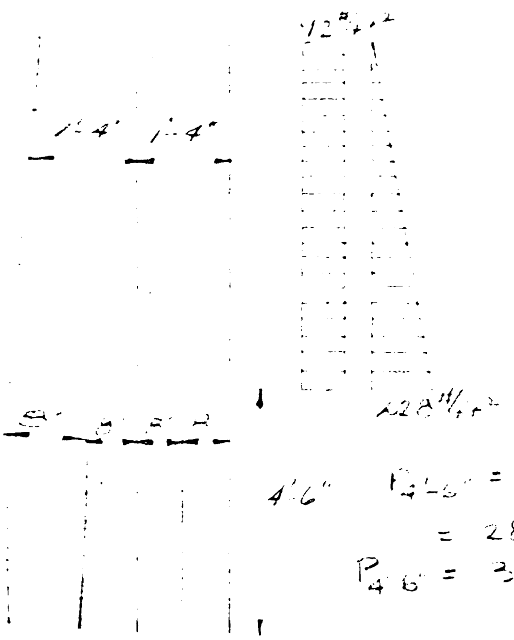
(allowable = 1350 psi)

Temperature steel: AASHO 3.5.3.b. Not less than $\frac{1}{8}$ sq in per foot of height.

Req'd = 0.125 sq.in./ft

use $\frac{1}{2}$"φ @ 1'-7" c/c = 0.124 sq.in./ft.

Cut-off of steel



$$M = (72 \times 8.99)\left(\frac{8.99}{2}\right) + \left(\frac{225}{2}\right)\left(\frac{8.99}{3}\right)(8.99)$$

$$M = 2910 + 2400$$

$$M = 5310 \text{ ft-lbs}$$

steel: have 3/4"φ @ 1'-4" c/c

$$f_s = \frac{M}{A_s j d} = \frac{5310 \times 12}{0.33 \times .857 \times 25}$$

$$f_s = 9050 \text{ psi}$$

(allowable = 18,000 psi)

$$P_{4'6"} = 28.7 h$$

$$= 28.7 \times 11.15$$

$$P_{4'6"} = 320 \text{#/ft}^2$$

Abutment Case IV – Superstructure dead load, no live load or surcharge; no backwall pressure

Superstructure dead load = 4000# (from Case II)

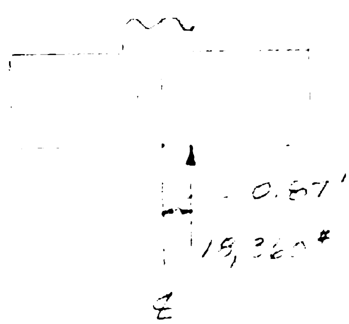
From Case III

$W_1 = 4350\#$
$W_2 = 4270\#$
$W_3 = 5740\#$

Base pressures: Moments about toe.

$W_1 = 4350\#$	; $\times$ 4.67'	= 20,300 ft-lbs
$W_2 = 4270\#$	; $\times$ 4.75'	= 20,300 ft-lbs
$W_3 = 5740\#$	; $\times$ 7.67'	= 44,000 ft-lbs
$W = 4000\#$	; $\times$ 4.67'	= 18,650 ft-lbs
18,360#		18,360 ⟌ 103,250 = 5.625'

$e = 4.75 - 5.62 = 0.87'$



[illegible]

$= 58.13$ [illegible]

[illegible]

[illegible] $= 1.95''$

[illegible]

$M = 4{,}800$ [illegible]

$d = \sqrt{\frac{4\ldots}{244}} = 4.4''$

[illegible]

[illegible] $= 0.44$ sq in/ft

[illegible] $= \frac{4\ldots}{.44 \times \ldots \times 33} =$ [illegible] psi

(allowable $= 18{,}000$ psi)

Abutment Case II
Design of [illegible]

Bond: $u = \frac{v\,b}{\Sigma_o} = \frac{6.[illegible]}{2.4} = 31$ psi (allowable = 150 psi)

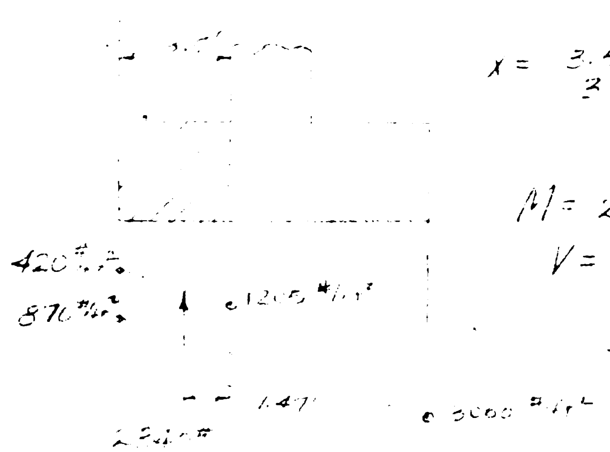
Concrete:

$$f_c = \frac{6M}{bd^2} = \frac{6 \times 4[illegible] \times 12}{12 \times 33^2} = 26.4 \text{ psi}$$

(allowable = 1350 psi)

Design of Toe

$$P \text{ on soil} = \frac{420 + 1205}{2} \times 3.5 = 2840^{\#}$$



$$x = \frac{3.5}{3}\left(\frac{1205 + 840}{1625}\right) = 1.47'$$

$$M = 2840 \times 1.47 = 4180 \text{ ft-lbs}$$

$$V = 2840^{\#}$$

$$v = \frac{V}{bjd} = \frac{2840}{12 \times .857 \times 33} = 8.4 \text{ psi}$$

(allowable = 40 psi)

steel we have $7/8''\phi$ @ $12''$ c/c = 0.60 sq in/ft.

$$f_s = \frac{M}{A_s j d} = \frac{4180 \times 12}{0.60 \times .857 \times 33} = 2,960 \text{ psi}$$

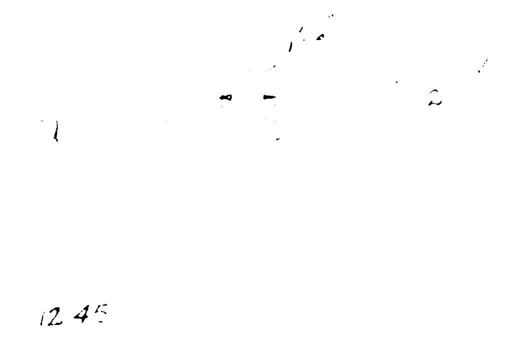
(allowable = 18,000 psi)

bond $u = \frac{v\,b}{\Sigma_o} = \frac{8.4 \times 12}{2.5} = 36$ psi (allowable = 150 psi)

Concrete: $f_c = \frac{6M}{bd^2} = \frac{6 \times 4180 \times 12}{12 \times 33^2} = 23$ psi

(allowable = 1350 psi)

Design of vertical stem: ok as there isn't any backwall pressure.



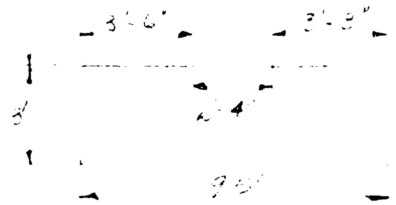
$P = 28.7 h$

$P_1 = 1.75 \times 28.7 = 50.3$ psf

$P_2 = 28.7 \times 17.2 = 413$ psf

$P = \left(\frac{50.3 + 413}{2}\right)(15.45) = 4190^{\#}$

$x = \left(\frac{15.45}{3}\right)\left(\frac{413 + 100.6}{543.3}\right) = 5.6'$

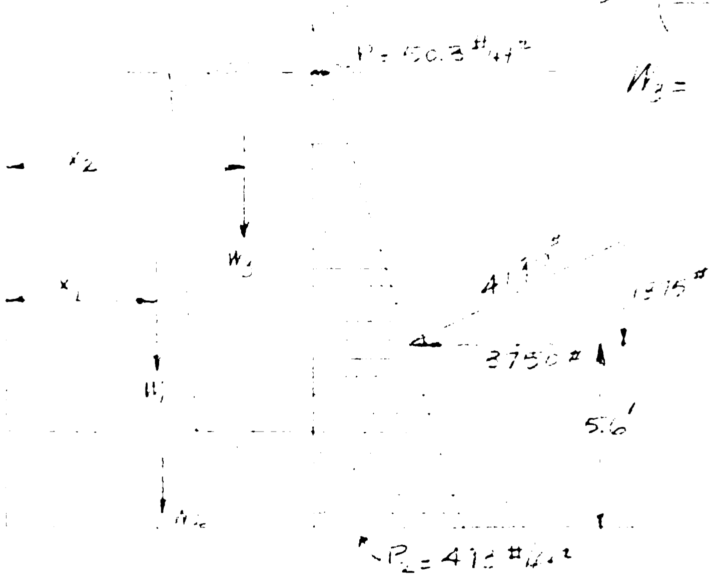


$W_1 = \left(\frac{1.5 + 2.33}{2}\right)(12.45)(150) = 3580^{\#}$

$W_2 = 9.5 \times 3 \times 150 = 4270^{\#}$

$W_3 = \left(\frac{3.67 + 4.5}{2}\right)(12)(100) + \left(\frac{4.5 \times 2.25}{2}\right)(100)$

$W_3 = 4900 + 506 = 5406^{\#}$



$x_1 = \frac{11,150 + 4,820}{3580}$

$x_1 = 4.475'$

$$x_2 = \frac{12(.833)\left(\frac{1}{2}\right)(.583)(100) + (3.67)(12)(100)(2.11) + (4.5)\left(\frac{2.25}{2}\right)(3)(100)}{5406}$$

$$x_2 = \frac{218 + 9300 + 1520}{5406}$$

$x_2 = 7.05'$

[illegible]

[illegible] Moments about Toe

W_1 = [illegible] #	;	×	4.475'	=	10,020 lb-ft
W_2 = 4275 #	;	×	4.75'	=	20,300 lb-ft
W_3 = 5490 #	;	×	7.05'	=	39,100 lb-ft
W_4 = 1575 #	;	×	[illegible]	=	17,500 lb-ft
[illegible] #					

$$92,220 = M_R$$

$$5.6 \times 3750 = \underline{21,000}\ M_o -$$

$$15131 \quad \underline{71,220}$$

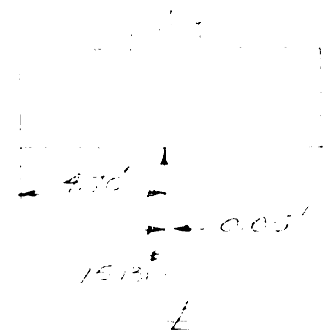
4.70' from toe

$$e = 4.75 - 4.70 = 0.05'$$

Heel & Toe pressure

$$\frac{W}{B}\left(1 \pm \frac{6e}{B}\right) = \frac{15131}{9.5}\left(1 \pm \frac{6 \times 0.05}{9.5}\right)$$

$$= \begin{cases} 1640 \text{ psf} - \text{Toe} \\ 1550 \text{ psf} - \text{Heel} \end{cases}$$



Safety factor overturning

$$S.F = \frac{M_R}{M_{o}} = \frac{92220}{21,000} = 4.4$$ (ok - T.C. 1940 say 50% greater than sliding S.F)

Safety factor sliding

$$F.S. = \frac{W \tan\delta}{P_h} = \frac{15,131 \times 0.40}{3750} = 1.61$$ (This is adequate - [illegible])

[illegible]

Here [illegible] = 450 psf [illegible]

$$P = \left(\frac{1135 + 1475}{2}\right) 3.67 = 41[illegible]^{\#}$$

$$x = \frac{3.67}{3}\left(\frac{1135 + 2[illegible]}{2235}\right) = 1.92'$$

5400# [illegible] = 1375#

1135# [illegible]

1475#

Shear		Moment
-5411×1.22	=	-6600 ft-lbs
-1375×3.67	=	-6700 ft-lbs
$+41[illegible] \times 1.92$	=	$7[illegible]$ ft-lbs
$V = 3191^{\#}$		$M = 6[illegible]$ ft-lbs

$$v = \frac{V}{F\,d\,b} = \frac{3191}{4 \times [illegible] \times 12} = 7.7 \qquad d = \sqrt{\frac{6[illegible]}{2[illegible]}} = 4.7''$$

([illegible] 33)

Steel [illegible] 3/4" ⌀ @ 12" [illegible] = [illegible] sq in/ft

$$f_s = \frac{M}{A_s j d} = \frac{6600 \times 12}{0.44 \times [illegible] \times 22} = [illegible] psi$$

(allowable = [illegible] psi)

Concrete: $f_c = \frac{6M}{b d^2} = \frac{6 \times 6[illegible] \times 12}{12 \times 52^2} = 23$ psi

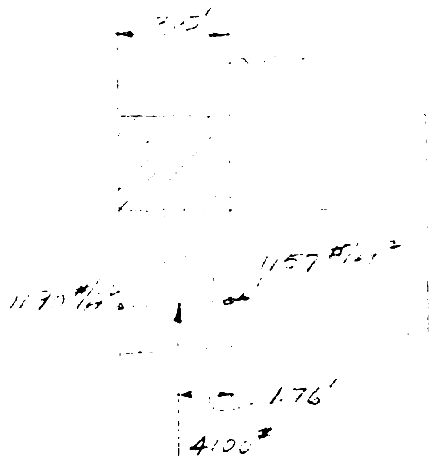
(allowable = [illegible] psi)

[illegible] $\frac{V}{b j d} = \frac{[illegible]}{12 \times .57 \times 22} = 7.4$ [illegible] (allowable = 40 psi)

Bond: $u = \frac{[illegible]}{[illegible]} = \frac{24 \times [illegible]}{2.4} = 470$ psi (allowable = 150 psi)

Appendix

Design of base: Toe



Heel pressure $150 \times 3 = 450$ psf

P_t on soil $= \frac{1190 + 1157}{2} \times 3.5 = 4100^{\#}$

$x = \frac{3.5}{3} \left(\frac{1157 + 2380}{2347} \right) = 1.76'$

$M = 1.76 \times 4100 = 7200$ ft-lbs.

$V = 4100^{\#}$

$v = \frac{V}{bjd} = \frac{4100}{12 \times .857 \times 33} = 12.1$ psi (allowable = 40 psi)

Bond: $u = \frac{v\,b}{\Sigma_0} = \frac{12.1 \times 12}{2.8} = 52.0$ psi (allowable = 150 psi)

Steel: we have $\frac{7}{8}$"ϕ @ 12" c/c = 0.60 sq. in/ft

$f_s = \frac{M}{A_s j d} = \frac{7200 \times 12}{0.60 \times .857 \times 33} = 5{,}100$ psi

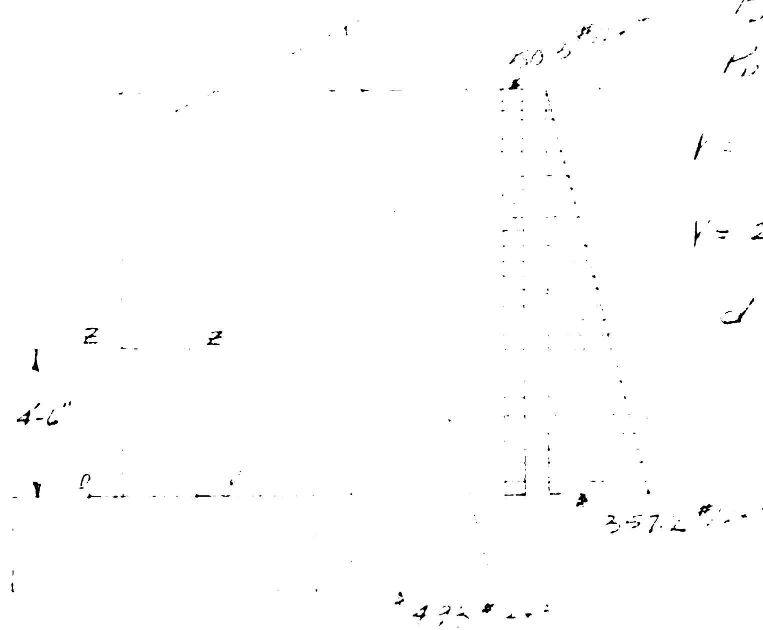
(allowable = 18 000 psi)

Concrete:

$f_c = \frac{6M}{bd^2} = \frac{6 \times 7200 \times 12}{12 \times 33^2} = 40$ psi

(allowable = 1800 psi)

Design of vertical stem



$P_{b.w} = 28.7k$

$M_{b.w} = (14.2)(28.7) = 407.5$

$V = \frac{12.45}{2}(503 + 407.5)$

$V = 2850^{\#}$

$d = \frac{V}{v b j} = \frac{2850}{40 \times 12 \times .857}$

$d = 7.0"$

At section D-D

$M = (503 \times 12.45)\left(\frac{12.45}{2}\right) + \frac{357}{2}\frac{(12.45)^2}{3}$

$M = 3900 + 9230$

$M = 13,130$ ft-lbs

$d = \sqrt{\frac{13,130}{248}} = 7.3"$

(ok - we have $d = 25"$)

Steel: we have $\frac{3}{4}"\phi$ @ 8" c/c = 0.66 sq in/ft

$f_s = \frac{M}{A_s j d} = \frac{13,130 \times 12}{0.66 \times .857 \times 25} = 11,150$ psi

(allowable = 18,000 psi)

Concrete:

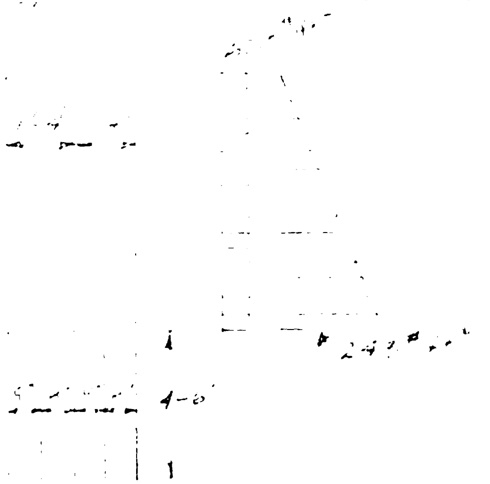
$f_c = \frac{6M}{b d^2} = \frac{6 \times 13,130 \times 12}{12 \times 25^2} = 126$ psi

(allowable = 1350 psi)

[illegible]

Design of [illegible] at [illegible] (Cont'd)

[illegible] section 2-2



$f_2 = (102)(23.1) = 245$ [illegible]

$M = \frac{(102)\,7.75^2}{2} + \frac{245}{6}(7.75^2)$

$M = [illegible] + 2560$

$= 4150$ [illegible]

[illegible] $\frac{1}{2}$" ϕ @ 15" = 0.33 sq in/ft

$$f_s = \frac{M}{A_s jd} = \frac{4150 \times 2}{0.33 \times .857 \times 21} = 8400 \text{ psi}$$

([illegible])

Concrete.

$$f_c = \frac{6M}{bd^2} = \frac{6 \times 4150 \times 2}{12 \times 21^2} = 56.5 \text{ psi}$$

(allowable = 1300 psi)

Temperature steel: AASHO 3.5.3.b. Not less than $\frac{1}{8}$ sq. in. per ft. of height.

(ck - use [illegible] $\frac{1}{2}$" ϕ @ 19" = 0.125 sq in/ft)

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