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HURRICANE PROTECTION PROJECT

FOX POINT

HURRICANE BARRIER

PROVIDENCE RIVER, PROVIDENCE, RHODE ISLAND

DESIGN MEMORANDUM NO. 9

RIVER GATES

U.S. Army Engineer Division, New England
Corps of Engineers Waltham, Mass.

JANUARY 1960

Engr.

ERECW-E (29 Jan 60) 3rd Ind
SUBJECT: Fox Point Hurricane Barrier, Providence, Rhode Island, Design Memorandum No. 9, River Gates

Office, Chief of Engineers, Washington 25, D. C., 2 August 1960

TO: Division Engineer, U. S. Army Engineer Division, New England
Waltham, Massachusetts

The additional information and Division comments are approved except for the following:

Reference is made to Paragraph 3, Comment m. The loading condition referred to in the 1st indorsement is that of hurricane tide with still water to El. 20.5 on bay side. It is believed that an emergency condition could exist in which for some reason it may be impossible to close one gate. This would give an unbalanced load on the thrust girders and should be investigated, particularly since there is no provision for stop logs for this structure. Since this would be an emergency condition, allowable stresses could be increased.

FOR THE CHIEF OF ENGINEERS:

F. B. Slichter

F. B. SLICHTER
Chief, Engineering Division
Civil Works

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.

ADDRESS REPLY TO:
DIVISION ENGINEER

REFER TO FILE NO.
NEDGW

COPY

2 June 1960

SUBJECT: Fox Point Hurricane Barrier, Providence, Rhode Island, Design Memorandum No. 9, River Gates

TO: Chief of Engineers
Department of the Army
Washington 25, D. C.
ATTENTION: ENGCW-E

1. Submitted herewith for review and approval is Appendix A, Foundation Pile and Base Slab Design, for the Fox Point Hurricane Barrier River Gates.

2. The base slab has been redesigned as a slab on elastic foundations in accordance with the 1st Indorsement dated 1 March 1960 to letter of this office dated 29 January 1960, subject as above.

FOR THE DIVISION ENGINEER:

John Wm Leslie R
JOHN WM. LESLIE
Chief, Engineering Division

Incl:
Appendix A, Des Memo
No. 9, River Gates,
Fox Pt. Barrier
(10 cys)

DESIGN MEMORANDUM NO. 9

RIVER GATES

APPENDIX A

FOUNDATION PILE AND BASE SLAB DESIGN

Computation pages 102 to 105 inclusive are added at the end of the structural computations. Computation pages 85 - 94 inclusive are void and new sheets 85A to 95A inclusive are substituted.

Sub-paragraph 13b is amended deleting the first two sentences and the following sentence substituted in lieu thereof . . .

The base slab was designed as a continuous slab on a rigid foundation.

The following sub-paragraph d is added at the end of paragraph 13:

d. Pile Foundation. - Pile loading has been investigated using an Elastic Center Method for Cases I, II and III which are considered the critical loading conditions. Under Case III loading it was found that the piles at the riverside edge would have 248.6 kips compression while the piles at the bayside edge would be loaded to 55.6 kips tension. The pile selected is a 14" BP 89# with an allowable load of 294 kips using the full area at 7500 p.s.i. and permitting an overstress of 50% for construction and hurricane loadings. Allowable tension is assumed to be 59 kips.

SUBJECT: FOX POINT BARRIER - GATE STRUCTURE

COMPUTATION: DESIGN OF BASE SLAB

COMPUTED BY: BZW CHECKED BY: Cmt DATE: 5/16/60

ASSUMPTION: FLEXURE OCCURS ALONG LONGITUDINAL LENGTH OF 148'

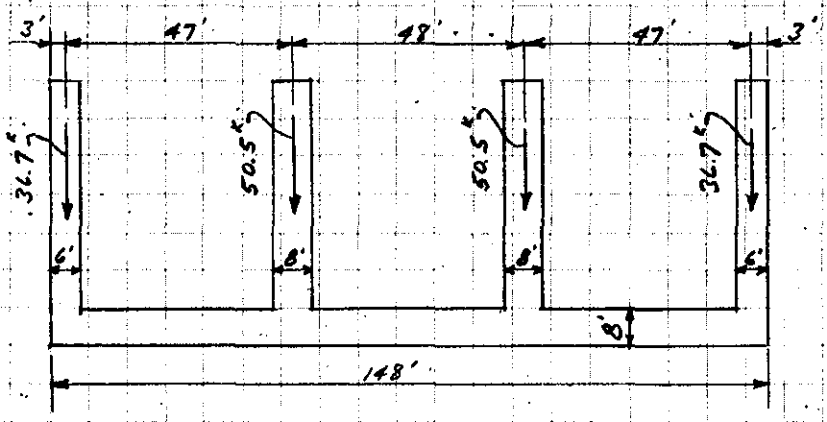
LOADS DUE TO CONST. COND (NO GATES) B.P. = 1.18 KSF

EXTERIOR PIER (6')	INTERIOR PIER (8')
WT. OF BRIDGE = 450 + 324 + 86 = 860^K	
EXT. REACT. = $860 \times \frac{20}{120}$ = 143^K ↓	INT. REACT. = $860 \times \frac{40}{120}$ = 287^K ↓
WT. OF EXT. PIER = 353^K ↓	
6090 ↓	
830 ↓	
1490 ↓	
662 ↓	
24 ↑	
28 ↑	
9873^K ↓ $\times \frac{6}{28}$ = 2116^K ↓	9873^K ↓ $\times \frac{8}{28}$ = 2820^K ↓
ΣP EXT. PIER = 2259^K ↓	ΣP INT. PIER = 3107^K ↓
" /LF = $\frac{2259}{61.5}$ = 36.7 KLF	" " /LF = $\frac{3107}{61.5}$ = 50.5 KLF

$\Sigma P_T = (2259 + 3107)2 = 10{,}732^K$ ↓

B.P. = 1.18 × 148 × 61.5 = 10,740^K ↑

ΣV = 0 O.K.



B.P. RIGID = 1.18 KSF

SUBJECT FOX POINT BARRIER - GATE STRUCTURE
COMPUTATION DESIGN OF BASE SLAB
COMPUTED BY BFW CHECKED BY Cmt DATE 5/16/60

Moment Diagram:- M due to Up Loads (+), M due to Down Loads (-)

Mom. @ 10' In.
36.7 x 7 = -257
1.18 x $\overline{10}^2/2$ = + 59
-198 'K

Mom @ 20'
36.7 x 17 = -624
1.18 x $\overline{20}^2/2$ = + 236
-388 'K

Mom. @ 30'
36.7 x 27 = -991
1.18 x $\overline{30}^2/2$ = + 531
-460 'K

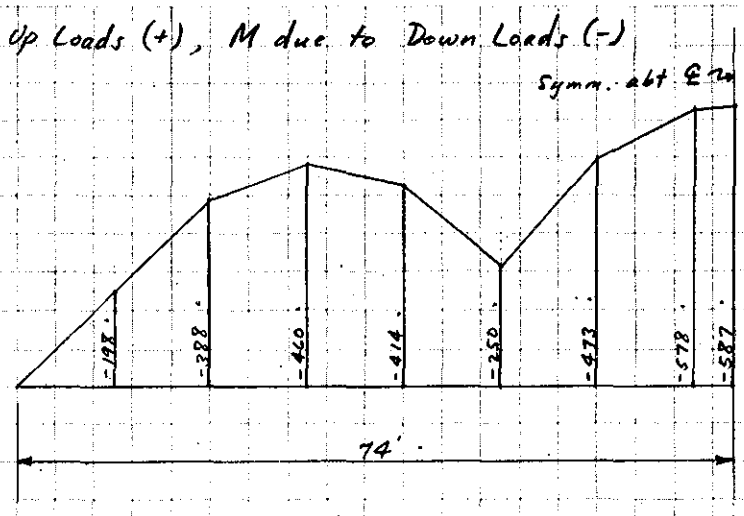
Mom. @ 40'
36.7 x 37 = -1358
1.18 x $\overline{40}^2/2$ = + 944
-414 'K

Mom. @ 50'
36.7 x 47 = -1725
1.18 x $\overline{50}^2/2$ = + 1475
-250 'K

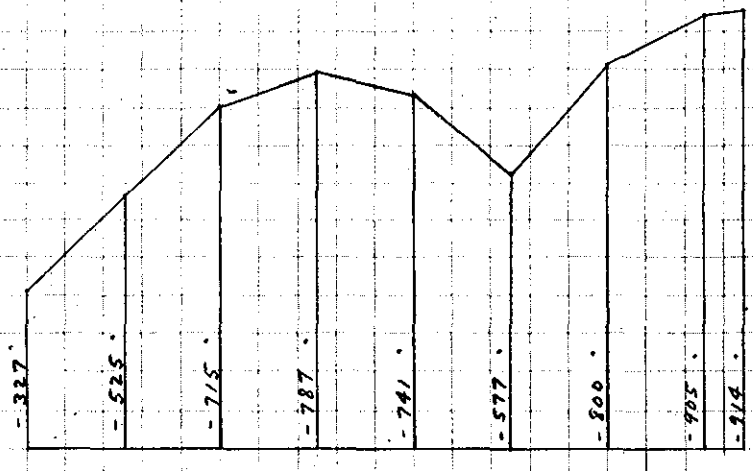
Mom. @ 60'
36.7 x 57 = -2092
50.5 x 10 = -505
1.18 x $\overline{60}^2/2$ = + 2124
-473 'K

Mom. @ 70'
36.7 x 67 = -2459
50.5 x 20 = -1010
1.18 x $\overline{70}^2/2$ = + 2891
-578 'K

Mom. @ 74'
36.7 x 71 = -2606
50.5 x 24 = -1212
1.18 x $\overline{74}^2/2$ = + 3231
-587 'K



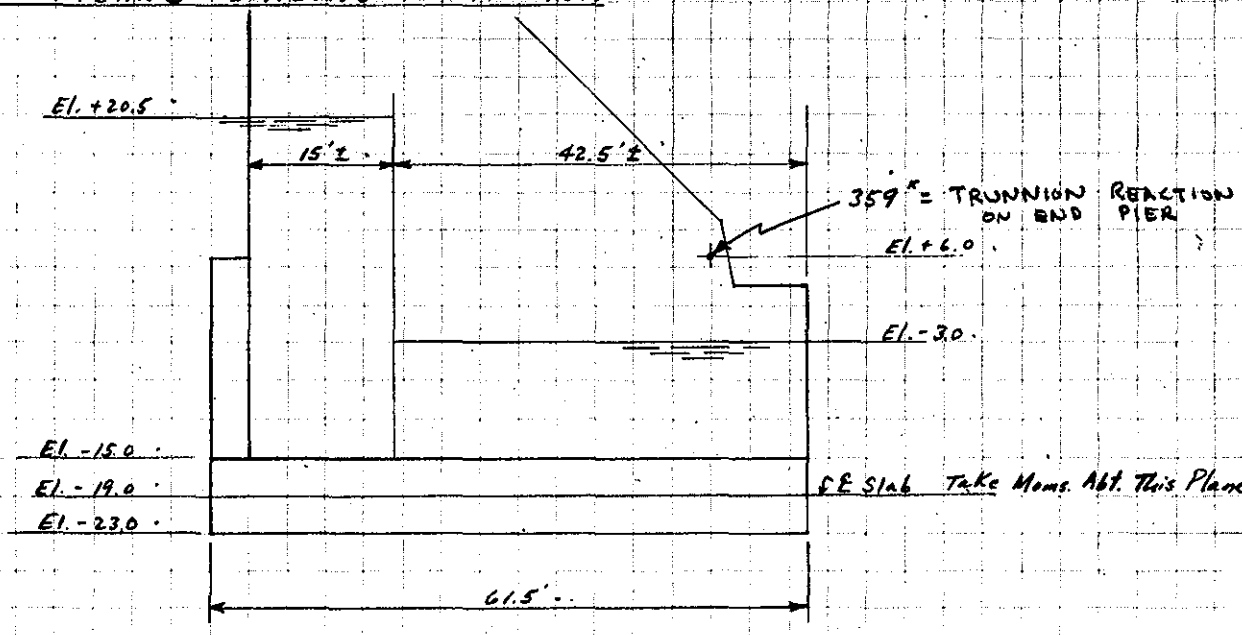
MOM. DIAG. - CONST. COND.



MOM. DIAG. - HURRICANE COND.
(see next page)

SUBJECT FOX POINT BARRIER - GATE STRUCTURE
COMPUTATION DESIGN OF BASE SLAB
COMPUTED BY BPW CHECKED BY Cmt DATE 5/16/60

HURRICANE LOADING CONDITION



M abt. El -19.0

$$= \frac{15 \times .0642 \times \overline{35.5}^2/2 \left(\frac{35.5}{3} + 4\right) + 359 \times 25 + 42.5 \times .0642 \times \overline{12.0}^2/2 \left(\frac{12}{3} + 4\right)}{61.5}$$

$$= \frac{9600 + 8970 + 1575}{61.5} = \frac{20{,}145}{61.5} = 327.4 \text{ ^K/Ft.}$$

The hydrostatic loads & trunnion side thrusts on the exterior piers influence the base slab by introducing a constant moment of 327^K across the entire length of 148'.

SUBJECT: FOX POINT BARRIER - GATE STRUCTURE
COMPUTATION: DESIGN OF BASE SLAB
COMPUTED BY: BJW CHECKED BY: Cmt DATE: 5/16/60

$$N = \frac{15 \times .0642 \times \frac{35.5^2}{2} + 35.9 + 42.5 \times .0642 \times \frac{12.0^2}{2}}{61.5}$$

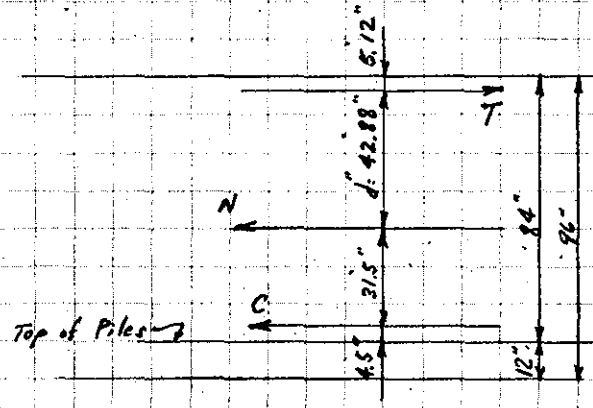
$$= \frac{206 + 359 + 197}{61.5} = \frac{1162}{61.5} = 18.9^{k\text{-}f} \ (T)$$

Design Moments

			Shears
℄ At End Piers	$-327 - 36.7 \times 3 + 1.18 \times 6^2/2$	$= -416^{ik}$	$29.6 \downarrow$
℄ Max End Spans	$-787 + 0$	$= -787^{ik}$	$1.3 \downarrow$
℄ At Int. Piers	$-327 - 36.7 \times 5.4 + 1.18 \times 5.4^2/2$	$= -589^{ik}$	$23.5^{k} \downarrow$
℄ Max Ctr. Span	$-914 + 0$	$= -914^{ik}$	0

End Pier

$M = 416^{ik}$
$N = 18.9^{k}$ (T)



$$M_s = M - N\frac{d}{12}$$
$$= 416 - 18.9 \times \frac{42.88}{12}$$
$$= 416 - 67.5 = 348.5^{ik}$$

$$d = \sqrt{\frac{12 M_s}{Kb}} = \sqrt{\frac{12 \times 348{,}500}{160 \times 12}} =$$

$$= \sqrt{2179} = 46.7'' \text{ O.K.} \qquad d_{min.} = 90.88''$$

$$A_s = \frac{12 M_s}{f_s j d} + \frac{N}{f_s} = \frac{12 \times 348.5}{20 \times .885 \times 90.88} + \frac{18.9}{20} = 2.60 + 0.95 = 3.55^{\square''}$$

SUBJECT FOX POINT BARRIER - GATE STRUCTURE
COMPUTATION DESIGN OF BASE SLAB
COMPUTED BY BJW CHECKED BY Cmb DATE 5/16/60

Max. End Span

$M = 787^{'k}$
$N = 18.9^{k}\ (T)$

$M_s = 787 - 18.9 \times \frac{42.88}{12} = 787 - 67.5 = 719.5^{'k}$

$A_s = \frac{12 \times 719.5}{20 \times .885 \times 90.88} + \frac{18.9}{20} = 5.37 + 0.95 = 6.32^{\square''}$

At Int. Pier

$M = 589^{'k}$
$N = 18.9^{k}\ (T)$

$M_s = 589 - 18.9 \times \frac{42.88}{12} = 589 - 67.5 = 521.5^{'k}$

$A_s = \frac{12 \times 521.5}{20 \times .885 \times 90.88} + \frac{18.9}{20} = 3.89 + 0.95 = 4.84^{\square''}$

At Ctr. Int. Span

$M = 914^{'k}$
$N = 18.9^{k}\ (T)$

$M_s = 914 - 18.9 \times \frac{42.88}{12} = 914 - 67.5 = 846.5^{'k}$

$A_s = \frac{12 \times 846.5}{20 \times .885 \times 90.88} + \frac{18.9}{20} = 6.32 + 0.95 = 7.27^{\square''}$

Max. Positive Mom. due to an Elastic Foundation

$M = 133^{'k}$
$N = 18.9^{k}\ (T)$

$M_s = 133 - 18.9 \times \frac{31.5}{12} = 133 - 49.6 = 83.4^{'k}$

$A_s = \frac{12 \times 83.4}{20 \times .885 \times 79.5} + \frac{18.9}{20} = 0.71 + 0.95 = 1.66^{\square''}$

NED FORM 223
27 Sept 49

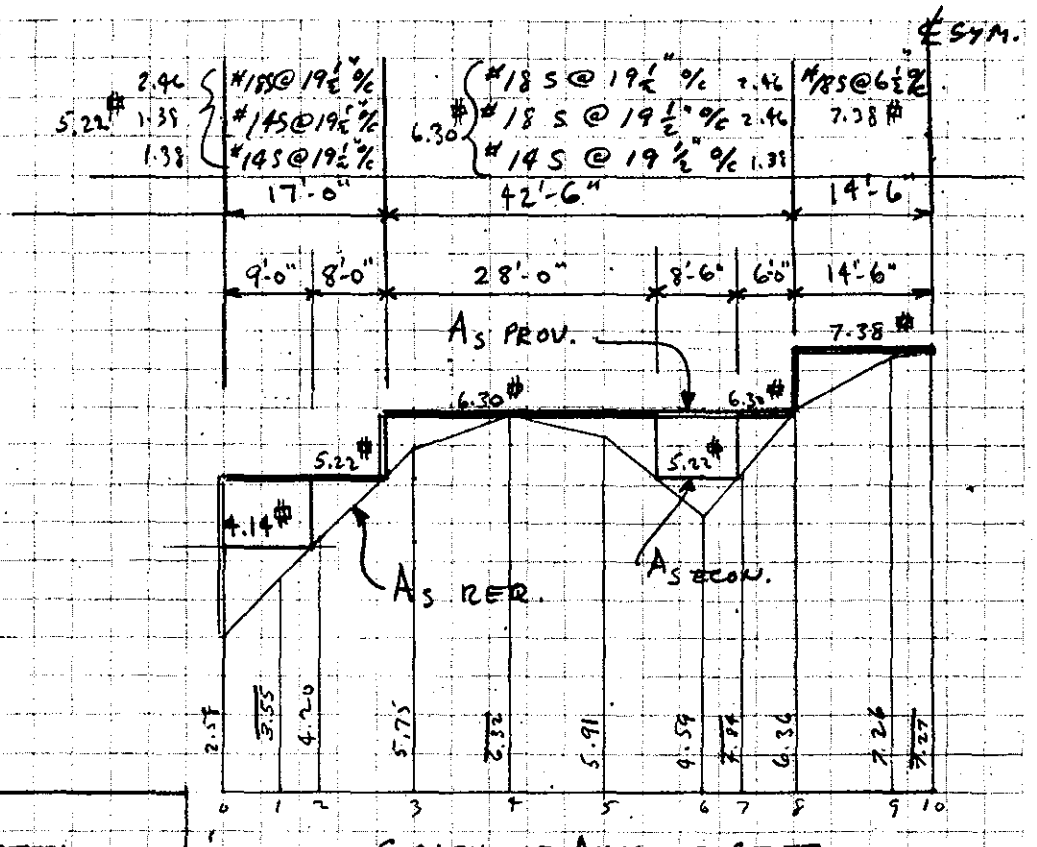
NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT Fox Point - Hurricane Barrier
COMPUTATION Gate Structure - Design of Base Slab
COMPUTED BY Gnt CHECKED BY BFM DATE 5/21/60
PAGE 904

1" = 3.23#

	INCHES		#
0)	0.80	=	2.58
1)	1.10	=	3.55
2)	1.30	=	4.20
3)	1.78	=	5.75
4)	1.95	=	6.32
5)	1.83	=	5.91
6)	1.42	=	4.59
7)	1.65	=	4.84
8)	1.97	=	6.36
9)	2.25	=	7.26
10)	2.26	=	7.27

NOTE: See Next Sheet for Reinf. Steel Actually Used



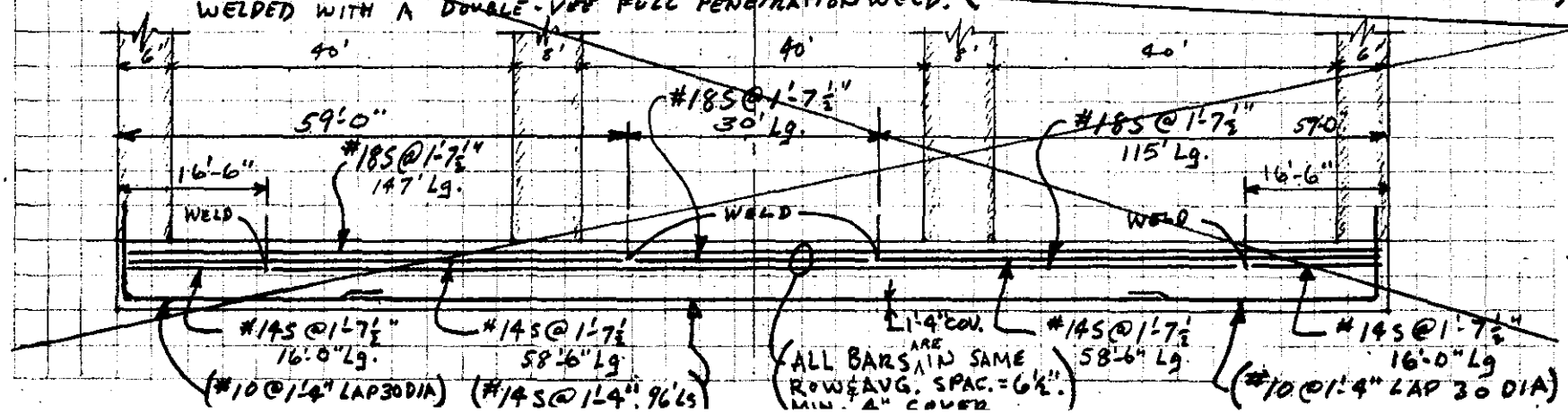
GRAPH OF AREA OF STEEL REINFORCEMENT

(ALL TRANSVERSE STEEL = #10 @ 1'-4" T&B)

(SPACING VOID)

SKETCH OF REINFORCING

NOTE: THE 3 LINES SHOWN FOR TOP STEEL ARE CONTINUOUS. ALL JOINTS SHOWN AND THOSE REQ. FOR SHIPPING TO BE FIELD WELDED WITH A DOUBLE-VEE FULL PENETRATION WELD.

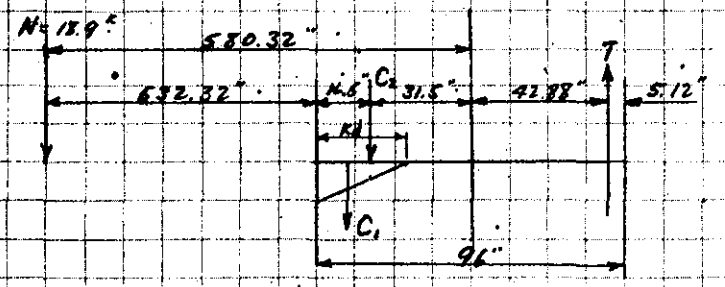


SUBJECT FOX POINT BARRIER - GATE STRUCTURE
COMPUTATION DESIGN OF BASE SLAB
COMPUTED BY BJW CHECKED BY Cmt DATE 5/23/60.

Stresses @ Center Interior Span

$M = 914^{k}$ Reinf. Top #18 S @ 7½" = 6.40 □" = A_s
$N = 18.9^{k}$ Bot. #14 S @ 16" = 1.69 □" = A'_s

$n A_s = 10(6.40) = 64.00$
$(n-1) A'_s = 9(1.69) = 15.21$ $e = \frac{12(914)}{18.9} = 580.32"$



$$0 = \frac{12\,kd\,f_c}{2}\left(532.32 + \frac{kd}{3}\right) + 15.21\left(\frac{kd-16.5}{kd}\right)f_c(548.82) - 64.00\left(\frac{90.88-kd}{kd}\right)f_c(623.20)$$

$$0 = 2\,\overline{kd}^3 + 3193.92\,\overline{kd}^2 + 8{,}347.55\,kd - 137{,}734.61 + 39{,}884.80\,kd - 3{,}624{,}730.62$$

$$0 = 2\,\overline{kd}^3 + 3193.92\,\overline{kd}^2 + 48{,}232.35\,kd - 3{,}762{,}465.23$$

$$0 = \overline{kd}^3 + 1596.96\,\overline{kd}^2 + 24{,}116.17\,kd - 1{,}881{,}232.61 \qquad kd = 27.41"$$

$$0 = 18{,}900 + 164.46 f_c + 4.05 f_c - 148.20 f_c$$

$$f_c = \frac{18{,}900}{22.31} = 847.15 \text{ psi}$$

$$f'_s = 9(847.15)\left(\frac{10.91}{27.41}\right) = 3{,}035 \text{ psi}$$

$$f_s = 10(847.15)\left(\frac{63.47}{27.41}\right) = 19{,}616 \text{ psi}$$

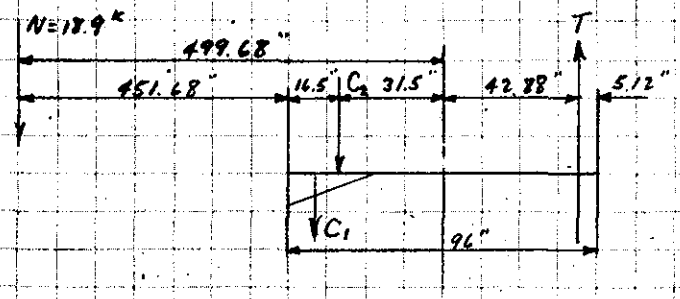
Check Shear: $V = 0$ ∴ Bond o.k.

SUBJECT: FOX POINT BARRIER - GATE STRUCTURE
COMPUTATION: DESIGN OF BASE SLAB
COMPUTED BY: BFW CHECKED BY: Cmt DATE: 5/23/60

Stresses @ Max. Mom. Section Ext. Span

$M = 787^{k}$ Reinf. Top 2-#18S @ 22½", 1-#14S @ 22½" = 5.47 □" = A_s
$N = 18.9^{k}$ Bot. #14S @ 16" = 1.69 □" = A'_s

$nA_s = 10 \times 5.47 = 54.70$
$(n-1)A'_s = 9 \times 1.69 = 15.21$ $e = \frac{12(787)}{18.9} = 499.68"$



$$0 = \frac{12\,kd\,f_c}{2}\left(451.68 + \frac{kd}{3}\right) + 15.21\left(\frac{kd-16.5}{kd}\right)f_c(468.18) - 54.70\left(\frac{90.88-kd}{kd}\right)f_c(542.56)$$

$$0 = 2\overline{kd}^3 + 2710.08\,\overline{kd}^2 + 7{,}121.02\,kd - 117{,}496.79 + 29{,}678.03\,kd - 2{,}697{,}139.55$$

$$0 = 2\overline{kd}^3 + 2{,}710.08\,\overline{kd}^2 + 36{,}799.05\,kd - 2{,}814{,}636.34$$

$$0 = \overline{kd}^3 + 1{,}355.04\,\overline{kd}^2 + 18{,}399.52\,kd - 1{,}407{,}318.17 \qquad kd = 25.95"$$

$$0 = 18{,}900 + 155.70 f_c + 5.54 f_c - 136.87 f_c$$

$$f_c = \frac{18{,}900}{24.37} = 775.54 \text{ psi}$$

$$f'_s = 9(775.54)\left(\frac{9.45}{25.95}\right) = 2{,}542 \text{ psi}$$

$$f_s = 10(775.54)\left(\frac{64.93}{25.95}\right) = 19{,}405 \text{ psi}$$

Check Shear: $V = 34.7^{k} - 1.18 \times 30 = 1.3^{k}$

$$v = \frac{1{,}300}{12 \times .885 \times 90.88} = 1.35 \text{ psi} \quad \text{O.K.}$$

Check Bond: $\Sigma_o = (14.18 + 5.32)\frac{12}{22.5} = 10.4"$

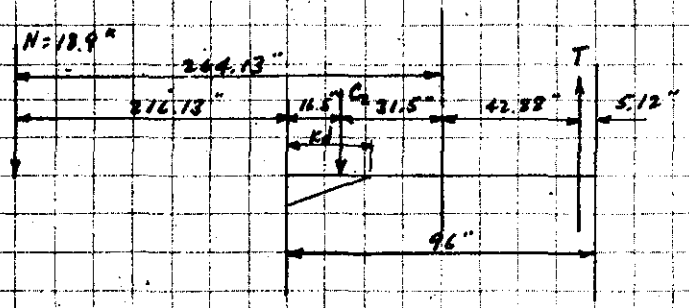
$$u = \frac{1{,}300}{10.4(.885)90.88} = 1.55 \text{ psi} \quad \text{O.K.} \quad < 210 \text{ psi}$$

SUBJECT FOX POINT BARRIER - GATE STRUCTURE
COMPUTATION DESIGN OF BASE SLAB
COMPUTED BY Bzw CHECKED BY Cmt DATE 5/23/60

Stresses at Int Face of End Span Pier

$M = 416^{k}$ Reinf. Top $2-\#14S$ @ $22\frac{1}{2}''$, $1-\#18S$ @ $22\frac{1}{2}'' = 4.53\ \square'' : A_s$
$N = 18.9^{k}$ Bot $\#10$ @ $16'' = 0.95\ \square'' : A'_s$

$nA_s = 10(4.53) = 45.30$
$(n-1)A'_s = 9(0.95) = 8.55$ $\qquad e = \frac{12(416)}{18.9} = 264.13''$



$$0 = \frac{12\,kd\,f_c}{2}\left(216.13 + \frac{kd}{3}\right) + 8.55\left(\frac{kd-16.5}{kd}\right)f_c(232.63) - 45.30\left(\frac{90.88-kd}{kd}\right)f_c(307.01)$$

$$0 = 2\,\overline{kd}^3 + 1296.78\,\overline{kd}^2 + 1{,}988.99\,kd - 32{,}818.28 + 13{,}907.55\,kd - 1{,}263{,}918.42$$

$$0 = 2\,\overline{kd}^3 + 1296.78\,\overline{kd}^2 + 15{,}896.54\,kd - 1{,}296{,}736.70$$

$$0 = \overline{kd}^3 + 648.39\,\overline{kd}^2 + 7{,}948.27\,kd - 648{,}368.35 \qquad kd = 25.67''$$

$$0 = 18{,}900 + 154.02 f_c + 3.05 f_c - 115.08 f_c$$

$$f_c = \frac{18{,}900}{41.99} = 450.11 \text{ psi}$$

$$f'_s = 9(450.11)\left(\frac{9.17}{25.67}\right) = 1{,}447 \text{ psi}$$

$$f_s = 10(450.11)\left(\frac{65.21}{25.67}\right) = 11{,}434 \text{ psi}$$

Check Shear: $V = 36.7 - 6 \times 1.18 = 29.6^{k}$

$$v = \frac{29{,}600}{12 \times 88.5 \times 90.88} = 30.7 \text{ psi} \quad \text{O.K.} < 90 \text{ psi}$$

Check Bond: $\Sigma_o = (10.64 + 7.09)\frac{12}{22.5} = 9.46''$

$$u = \frac{29{,}600}{9.46 \times 88.5 \times 90.88} = 38.9 \text{ psi} \quad \text{O.K.} < 210 \text{ psi}$$

SUBJECT FOX POINT BARRIER - GATE STRUCTURE
COMPUTATION DESIGN OF BASE SLAB
COMPUTED BY BJW CHECKED BY Cmt DATE 5/23/60

Check Principal Stresses :-

Max. Shear occurs at Section thru Int. Face of End Pier = 29.6 K

$N = 18.9^K$ $\quad s = P/A = \frac{18,900}{12(25.67) + 10(4.53) + 9(0.95)} = \frac{18,900}{361.85} = 52.2$ psi

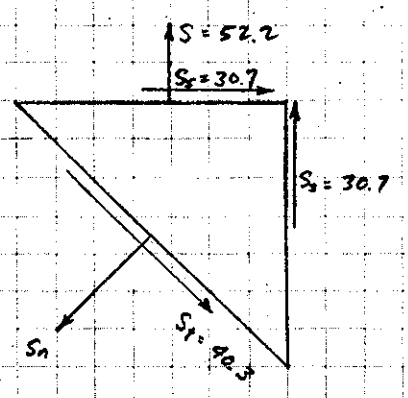
$kd = 25.67''$

$s_s = v = \frac{29,600}{12 \times .885 \times 90.88} = 30.7$ psi

$Max\ s_t = \sqrt{\left(\frac{52.2}{4}\right)^2 + (30.7)^2} = \sqrt{683 + 942} = \sqrt{1625} = 40.3$ psi

$Max\ S_n = \frac{52.2}{2} + 40.3 = 66.4$ psi (T)

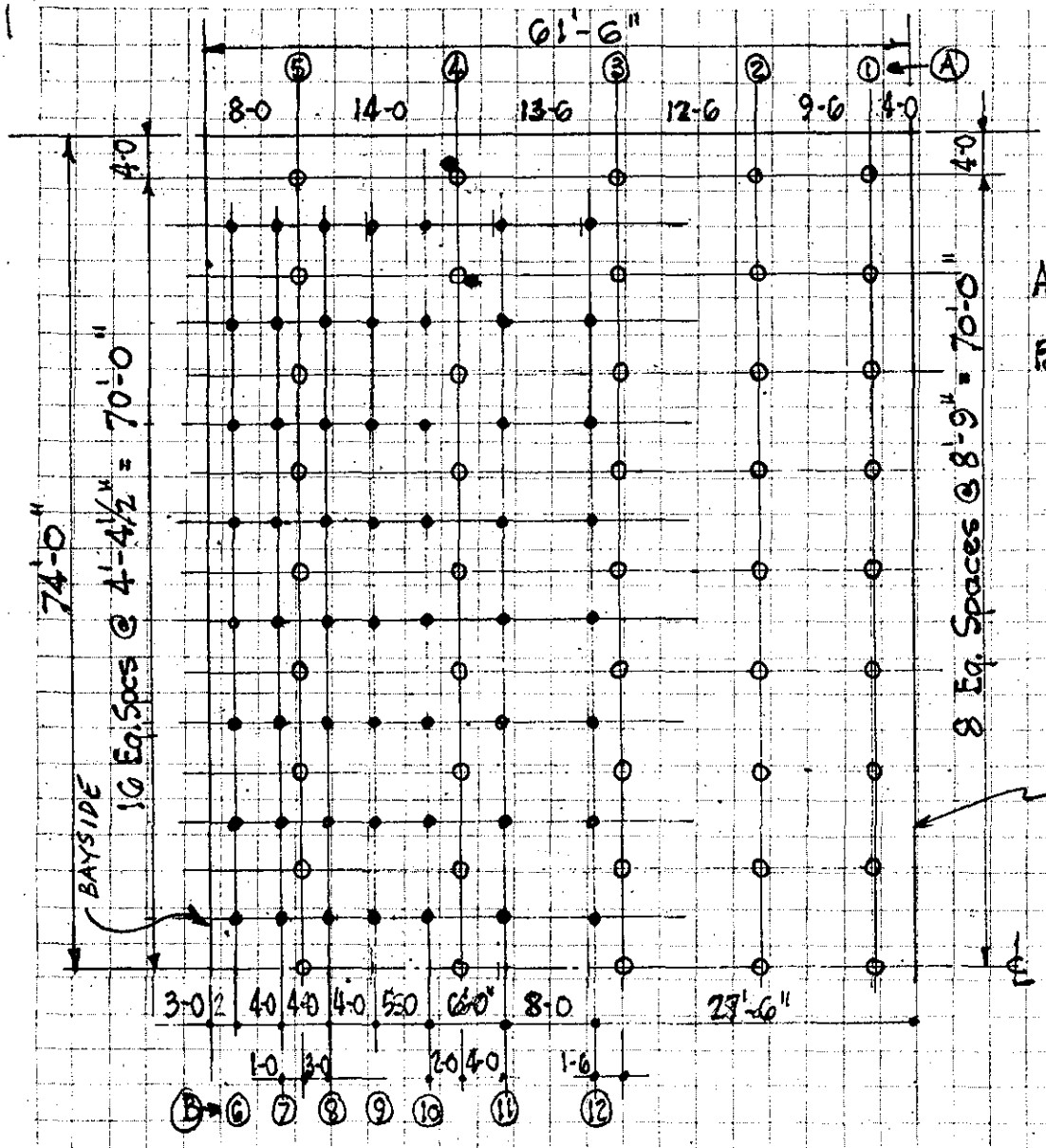
$Min\ S_n = 26.1 - 40.3 = 14.2$ psi (C)



NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT Fox Point Gate Structure
COMPUTATION Steel Piles
COMPUTED BY E.P.R. CHECKED BY Cmt DATE 29 Mar. 1960



A ⊘
B ⊘

No. of Piles

A 17 × 5 = 85
B 16 × 7 = 112
197

A c.g.

17 × 4.0	=	68
17 × 13.5	=	229
17 × 26	=	442
17 × 39.5	=	672
17 × 53.5	=	910
85		2321

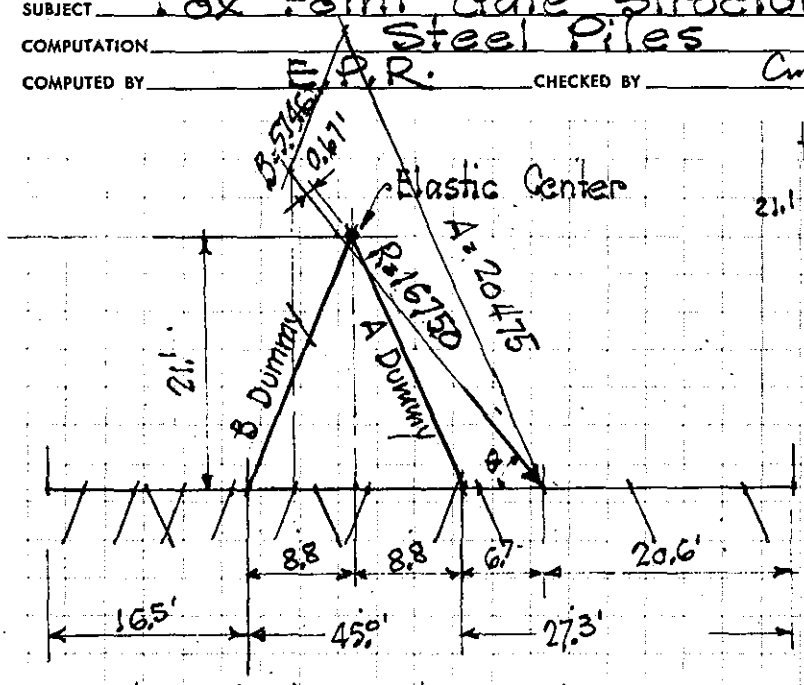
$\frac{2321}{85} = 27.3'$ from Land edge

B c.g.

16 × 27.5	=	440
16 × 35.5	=	568
16 × 41.5	=	665
16 × 46.5	=	745
16 × 50.5	=	808
16 × 54.5	=	873
16 × 58.5	=	935
112		5034

$\frac{5034}{112} = 45.0'$ from Land edge

SUBJECT Fox Point Gate Structure
COMPUTATION Steel Piles
COMPUTED BY E.P.R. CHECKED BY Cmt DATE 29 Mar. 1960



$\tan\theta = 13229 \div 10238 = 1.29$ (1.29214) $52°-10'$ ($52°-16'$)

$21.1 \times \cot\theta = 16.35'$ (0.7766)

$16.35 - 8.8 - 6.7 = 0.85'$

$0.85 \times \sin\theta = 0.67$ (0.7909; 0.7898)

$R = 13229 \div \sin\theta = 16750$

$M = 0.67 \times 16750 = 11300^{\circ K'}$

PMI (abt. elastic center - distances normal to slope of piles)

A1	$(21.5)^2$	= 462	B6	$(12.5)^2$	= 156
2	$(12.7)^2$	= 161	7	$(8.75)^2$	= 76.5
3	$(1.2)^2$	= 1.5	8	$(5.1)^2$	= 26
4	$(11.3)^2$	= 128	9	$(1.4)^2$	= 2
5	$(24.2)^2$	= 585	10	$(3.2)^2$	= 10.5
		1337.5 × 17 = 22,700°	11	$(8.8)^2$	= 77.5
		9,750°	12	$(16.1)^2$	= 260
		32,450° ft⁴			608.5 × 16 = 9750°

Case III - Hurricane V = 13229°K H = 10238°K R - 20.6' from Land edge

Axial Pile Loads .268

A1 $\frac{20475}{85} - \frac{8700 \times 21.5}{32450}$

$= 242 - 5.8 = 236.2^{K}/P$ Comp.

A2 = 242 − (0.268 × 12.7) = 238.6

A3 = 242 − (0.268 × 1.2) = 241.7

A4 = 242 + (0.268 × 11.3) = 245.0

A5 = 242 + (0.268 × 24.2) = 248.6 K/P Comp.

B6 $\frac{5746}{112}$ + (0.268 × 12.5) = −48.0 K/P Ten.

7 −51.3 + (0.268 × 8.75) = −49.0 K Ten

8 −51.3 + (0.268 × 5.1) = −50.0 K Ten

9 −51.3 + (0.268 × 1.4) = −51.0 K Ten.

10 −51.3 − (0.268 × 3.2) = −52.2 K Ten

11 −51.3 − (0.268 × 8.8) = −53.7 K Ten.

12 −51.3 − (0.268 × 16.1) = −55.6 Ten

Pile 14 BP 89
Allowable Pile Loads : 294.0 K/P Comp
based on
f = 1.5 × 7500 = 11250 psi

59.0 K/P Tension

SUBJECT Fox Point Gate Structure
COMPUTATION Steel Piles
COMPUTED BY E.P.R. CHECKED BY Cmt DATE 29 Mar. 1960

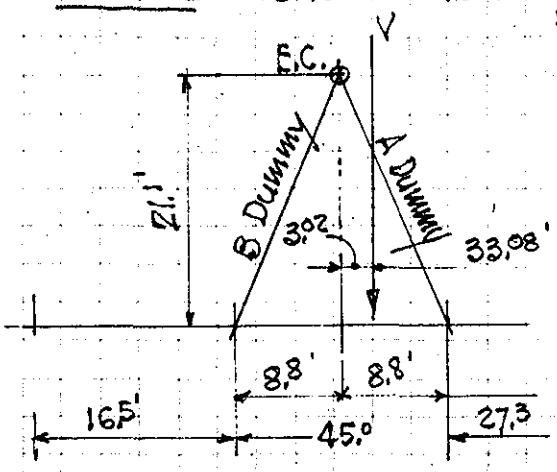
Case III (cont'd)

ΣH components of pile loads

Ⓐ 5/13 × 238.2 = 91.0
× 238.6 = 92.0
× 241.7 = 93.0
× 245.0 = 94.5
× 248.6 = 95.5
466.0 × 17
= 7920.0
2210.0
ΣH = 10130.0

Ⓑ 5/13 × −48.0 = 18.4
× −49.0 = 18.8
× −50.0 = 19.2
× −51.0 = 19.6
× −52.2 = 20.0
× −53.7 = 20.6
× −55.6 = 21.4
138.0 × 16
= 2210.0

Case I - Construction V = 21989.0 K 33.08' from Land edge
H = 0
e = 27.3 + 8.8 − 33.08 = 3.02' right of E.C.



Axial Pile Loads

A1 $\frac{21989.0}{\frac{13}{12}\times 2\times 85} + \frac{21989\times 3.02\times 21.5}{32450}$
= 140 + 43.5 = 183.5 K/P Comp

A2 = 140 + (2.03 × 12.7) = 165.8 K

A3 = 140 + (2.03 × 1.2) = 142.5 K

A4 = 140 − (2.03 × 11.3) = 117.0 K

A5 = 140 − (2.03 × 24.2) = 90.0 K

$\frac{21989.0}{2\times 112}\times\frac{13}{12}$

B6 = 107.0 − (2.03 × 12.5) = 81.6 K/P Comp

B7 = 107.0 − (2.03 × 8.75) = 89.8 K

B8 = 107.0 − (2.03 × 5.1) = 96.6 K

B9 = 107.0 − (2.03 × 1.4) = 104.2 K

B10 = 107.0 + (2.03 × 3.2) = 113.8 K

B11 = 107.0 + (2.03 × 8.8) = 125.0 K

B12 = 107.0 + (2.03 × 16.1) = 139.8 K

ΣHⒶ 5/13 × 183.5 = 70.5
× 165.8 = 64.0
× 142.5 = 55.0
× 117.0 = 45.0
× 90.0 = 35.0
269.5 × 17
= 4600.0

ΣHⒷ 5/13 × 81.6 = 31.5
× 89.0 = 34.3
× 96.6 = 37.2
× 104.2 = 40.0
× 113.8 = 43.8
× 125.0 = 48.0
× 139.8 = 53.8
288.6 × 16 = 4600.0

SUBJECT Fox Point Gate Structure
COMPUTATION Steel Piles
COMPUTED BY E.P.R. CHECKED BY CMT DATE 29 Mar. 1960

Case II Normal $V = 15329.0^K$ 33.68' from Land edge

$e = 27.3 + 8.8 - 33.68' = \underline{2.42'}$

Axial Pile Loads

A1 $\left(\frac{13}{12} \times \frac{15329.0}{2 \times 85}\right) + \left(\frac{15329 \times 2.42 \times 21.5}{32450}\right) = 96.0 + 24.5 = \underline{120.5^K/P}$ Comp

A5 $96.0 - (1.14 \times 24.2) = \underline{68.5^K/P}$ Comp

B6 $74.0 - (1.14 \times 12.5) = 59.75^K/P$ "

B12 $74.0 + (1.14 \times 16.1) = \underline{92.5^K/P}$ "

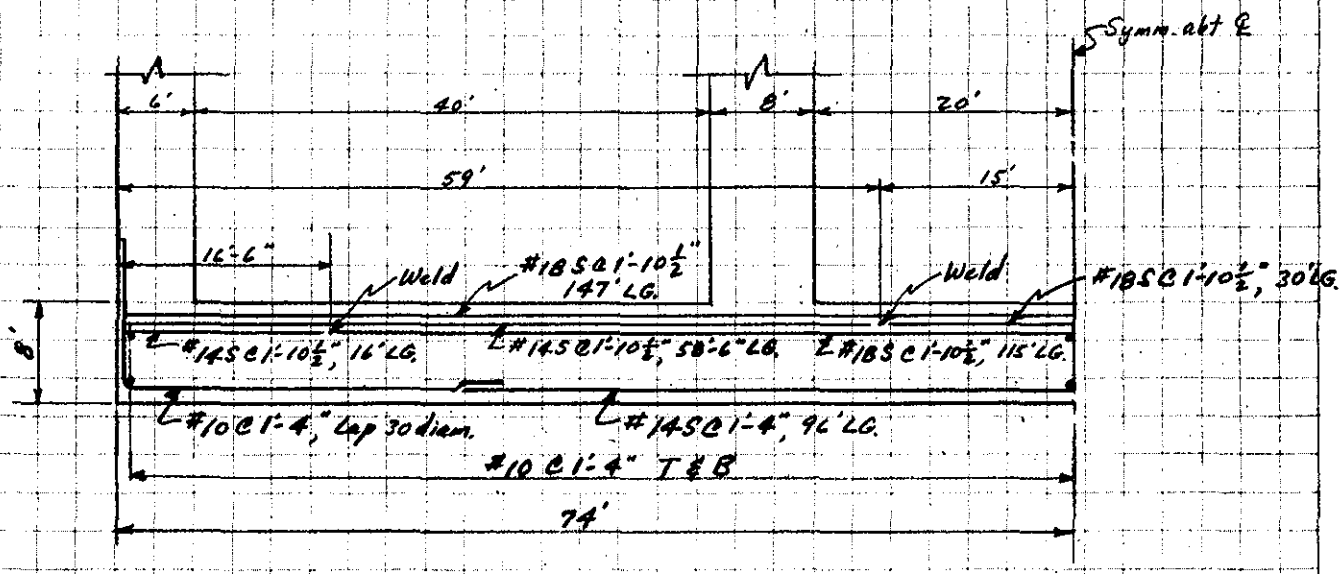
Allowable Pile Load = $\underline{196.0^K}$ max

$\frac{13}{12} \times \frac{15329.0}{2 \times 112}$

Use 14 BP 89

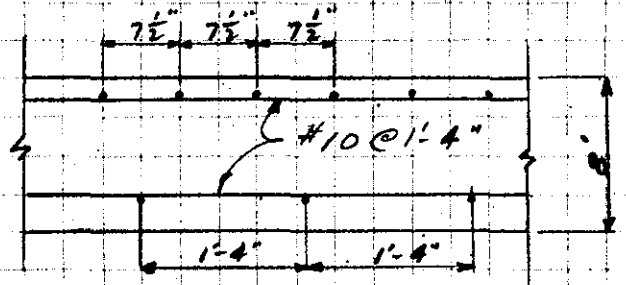
Capacity Load based on f = 7500 psi

SUBJECT FOX POINT BARRIER - GATE STRUCTURE
COMPUTATION DESIGN OF BASE SLAB
COMPUTED BY BJW CHECKED BY Cmt DATE 5/23/60



SLAB STEEL

NOTE: ALL TOP BARS ARE IN SAME ROW AND AVERAGE SPACING = 7½". MIN. 4" COVER. THE 3 LINES SHOWN FOR TOP STEEL ARE CONTINUOUS. ALL JOINTS SHOWN AND THOSE REQUIRED FOR SHIPPING TO BE FIELD WELDED WITH A DOUBLE-VEE FULL PENETRATION WELD.



TYPICAL TRANSVERSE SECT.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.

ADDRESS REPLY TO:
DIVISION ENGINEER

REFER TO FILE NO. NEDGW

29 January 1960

SUBJECT: Fox Point Hurricane Barrier, Providence, Rhode Island, Design Memorandum No. 9, River Gates

TO: Chief of Engineers
Department of the Army
Washington, D. C.
ATTENTION: ENGWE

In accordance with EM 1110-2-1150 there is submitted herewith for review and approval Design Memorandum No. 9, "River Gates", for the Fox Point Hurricane Barrier, Providence, Rhode Island.

FOR THE DIVISION ENGINEER:

JOHN WM. LESLIE
Chief, Engineering Division

Incl (10 cys)
Des Memo No. 9,
River Gates - Fox Point
Hurricane Barrier

FOX POINT HURRICANE BARRIER
PROVIDENCE, RHODE ISLAND
DESIGN MEMORANDUM NO. 9
RIVER GATES

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2	Hydrology		
	Preliminary	3 June 1959	8 Jun 59
	Final	17 November 1959	21 Dec 59
4	Hurricane Tidal Hydraulics		
5	General Design Memo	22 December 1959	
6	Embankments & Foundations		
7	Structural Section I		
8	Structural Section II		
9	River Gates		
10	Pumping Station		
10A	River Structure - Foundation Pile Design		
11	Cooling Water Canal		
12	Sewer & Utility Modification		
13	Cooling Water Considerations	8 January 1960	
14	Concrete Aggregates	3 November 1959	27 Nov 59

FOX POINT HURRICANE BARRIER
PROVIDENCE, RHODE ISLAND
DESIGN MEMORANDUM NO. 9
RIVER GATES

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FOX POINT HURRICANE BARRIER

PROVIDENCE, RHODE ISLAND

DESIGN MEMORANDUM NO. 9

RIVER GATES

A. PERTINENT DATA

Purpose. - To pass the flow of the Providence River and the cooling water discharge of the Narragansett Electric Company.

Location of Project. -

State	Rhode Island
County	Providence
City	Providence
River	On the Providence River approximately 900 feet upstream from the confluence of the Seekonk and Providence Rivers.

Drainage Area. - 77 square miles.

River Gates. -

Type	Tainter
Number	3
Size	40 ft. x 40 ft.
Elevation of Sill	-15.0, m.s.l.
Maximum vertical clearance, elevation	+25.0, m.s.l.
Elevation of operating platform	+35.0, m.s.l.
Operating mechanism	Electric motor driven hoist
Standard project flood	24,000 c.f.s.

B. INTRODUCTION

1. Purpose. - The purpose of this design memorandum is to submit for review the basic plans and design criteria river gates for the Fox Point Hurricane Barrier.

2. Location. - The river gates have been located as near the east bank of the Providence River as practicable in order to reduce to the smallest amount recirculation of warm discharge water of the Narragansett Electric Company back into the cooling water canal.

3. Description. -

a. Concrete Structure. - The supporting concrete structure for the gates will consist of a base mat 61'-6" wide by 148'-0" long by eight feet thick. The two center piers extending from the top of the base mat at elevation -15.0 will rise to a maximum elevation of +35.0 and will be 8'-0" thick. Similar end piers will be 6'-0" thick. Provisions will be made for possible future installation of stop gates on either side of the tainter gates. It is not intended to furnish a stop gate, but only to make provision in the way of slots so that, in the future, such a gate could be installed if required.

b. Foundation. - The structure will be supported on steel bearing piling, driven to virtual refusal in glacial till or rock. A steel sheet piling cutoff will be provided extending to the interbedded silt layer. For further details see Design Memorandum No. 6, "Embankments and Foundations".

c. Tainter Gates. - The general dimensions of each of the 3 tainter gates will be 40 feet wide by approximately 40 feet high. The radius of curvature will be 35 feet, measured from the center of the trunnion to the inside face of the skin plate perpendicularly to the axis of the crest. The length of the skin plate measured along the arc will be 42 feet, 7¼ inches. The component parts of the gate will be as follows: the skin plate and tee supports, the main girders and struts, trunnion and anchorage assembly. Most connections will be accomplished by shop and field welding. The bottom seal will consist of a swamp white oak beam embedded in the concrete sill. A rubber bottom seal is considered unnecessary for this type of gate. The skin plate of the gate will be in direct contact with the wooden seal beam. Embedded in each pier and abutment will be a side seal assembly consisting of a monel metal plate (selected for its resistance to cathodic corrosion) against which a molded rubber seal attached to the gate will be held by water pressure. The necessity of the rubber side seals is questionable but they are utilized to provide a better appearance under water loading and to prevent possible cavitation from water movement between the edge of the steel skin plate and the concrete pier.

4. Function. - The river gates are provided to accommodate normal river flow and tidal fluctuations, to pass the discharge flow of the cooling water from the Narragansett Electric Company power plant, and to pass a major flood flow without increasing flood levels in downtown Providence.

5. Operation. - The tainter gates will normally be open for passage of river flows and for use of small boats if the need arises. They will be closed during the period of a hurricane tide. The upstream river pool will be maintained as near as practicable to elevation 0.0 m.s.l. by pumping.

C. HYDROLOGY

6. Hydrology and Hydraulic Design. - Hydrology and hydraulic design are discussed in Design Memorandum No. 2, "Hydrology". In brief, the gate is designed to pass normal flows without change in conditions and to discharge a standard project flood of 24,000 c.f.s. without increasing flood levels in downtown Providence. Such a flow is several times the flood of record and is greatly in excess of the estimated combined channel capacity of the Moshassuck and Woonasquatucket Rivers upstream.

D. CONCRETE MATERIALS

7. Concrete Materials. - See Design Memorandum No. 14 for discussion of materials. Satisfactory sources of aggregates are nearby. Type V Cement will be used on account of the high sulphate content of the river water.

E. STRUCTURAL DESIGN

8. Purpose. - This section of the design memorandum presents the design criteria, basic data, and assumptions used in the structural design. The design procedure showing loading conditions and assumptions used in the design of the three tainter gates and their concrete supporting structure, are included herein. Plates showing the stability diagrams typical sections through the tainter gates and the reinforced concrete supporting structure, are included in the Appendix. Computations are included in the Appendix showing the design conditions investigated for the principal elements of the gate structure. Where design criteria, basic data and assumptions are the same as Design Memorandum 10, "Pumping Station", reference will be made to such paragraphs stating it is the same or amending where necessary.

9. Scope. - Hurricane wave loading, stability investigations, design of the structural steel tainter gates and trunnions as well as the reinforced concrete design of the concrete supporting structure and access bridges are included herein. Foundation pile design will be submitted in Design Memorandum 10A.

10. Design Criteria. -

a. General. - All working stresses conform to those specified in the Engineering Manual EM 1110-1-2101, "Working Stresses for Structural Design", dated 6 January 1958. General loading conditions, design assumptions and other design criteria are based on the following applicable parts of the Engineering Manual for Civil Works: Standard Practice for Concrete (Part CXX, October 1953), Tainter Gates (Part CXXVII, Chapter 2, November 1950); and Hydraulic Design, Waves and Wave Pressures (Part CXVI, Chapter 8). Technical Report No. 4 titled, "Shore Protection Planning and Design", by the Beach Erosion Board, was also used in the analysis of wave forces. Tentative recommendations for prestressed concrete by the ACI-ASCE Joint Committee has governed the design of the trunnion anchorage.

b. Concrete. - The following tables list the concrete and reinforced concrete stresses used in the design of the structure. All concrete shall have a minimum compressive stress of 3,000 lbs. per sq. in. after 28 days, except that the concrete in the pour containing the prestressed trunnion anchorage shall have 4,000 lbs. minimum compressive stress after 28 days. In each case, the Civil Works Manual exposure classification A (applicable to structures subject to moderately severe weather exposure) has been used:

(1) 3,000 lbs. per sq. in. concrete.

Flexure	Lbs. per sq. in.
Extreme fiber stresses in compression	1,050
Extreme fiber stresses in tension (plain concrete)	60
Shear - (v)	
Beams - no web reinforcement	90
Beams with properly designed web [illegible] reinforcement	240
Bond - (u) Deformed bars -	
Top bars	210
Exterior surface bars (exposed to seawater)	210
All others	300
Bearing - (fc)	
Load on entire area	750
Load on one-third area or less-maximum permissible	1,125

Modular Ratio - (n)	Lbs. per sq. in.
(2) 4000 lbs. per sq. in. concrete at trunnion anchorage	
Temporary Stresses	
Maximum fiber stresses in post tensional compression	2,200
Stresses at Design Loads	
Maximum fiber stresses in compression	1,800

c. Reinforcement. - Reinforcement will conform to the provisions of Design Memorandum No. 10, "Pumping Station", paragraph 15 c, except that subparagraph (3) is amended to include the following:

Item	Minimum Cover (Inches)
Exterior slabs	Top, 2"; Bottom $2\frac{1}{2}$"
Exterior beams	$2\frac{1}{2}$"

d. Expansion Joints. - There will be no expansion joints in the length of the gate structure, except that each section of bridge deck will be free to move on the supporting piers. Expansion joints will be provided at each end of the gate structure where it joins barrier monoliths.

e. Structural Steel. - Paragraph 15e, Design Memorandum No. 10, is applicable except that allowable design working stresses for steel in the tainter gates shall have a basic stress of 18,000 lbs. per sq. in.

f. Increase in Normal Working Stresses. - Normal allowable working stresses have been increased 33-1/3% where earthquake or wind loads govern. Normal working stresses have been used for hydrostatic pressure loadings up to S. W. L. of 20.5 and working stresses have been increased 33-1/3% for all dynamic wave loadings above S. W. L. of 20.5 depending upon which was the governing condition.

g. Waterstops. - Paragraph 15g of Design Memorandum No. 10 is applicable.

h. Steel Bearing Piles and Steel Sheet Pile Cut-off. -

(1) Bearing Piles. - Steel H bearing piles will be driven to virtual refusal in glacial till or bedrock beneath the structure to carry the load of the structure. The pile selected is a BP 14 x 117 lbs. and a 1/8 inch allowance all around has been made for loss of metal due to corrosion. Using a design stress of 7500 lbs. per sq. in. which conforms to the requirements of the Boston Building Code, the allowable bearing capacity of the pile that will be used in the design

is 90 tons. Design capacity will be increased 25% for construction and hurricane loads. Cathodic protection is being investigated to determine whether the increase in the life of the pile is economically justifiable.

(2) Sheet Pile Cut-off. - At the bayside edge of the structure, steel sheet piling type M 113 is to be used as a seepage cut-off. This piling will extend approximately 5 feet into the interbedded silt layer. No cathodic protection is contemplated.

i. Post Tensioned Steel for Anchorage and Appurtenant Items. -

(1) Grade and Physical Properties. - The post tensioned steel rods (or bars or tendons) used to anchor the thrust girders of the tainter gate anchorage will conform to the requirements of ASTM-A 322, Grade 5160 and shall conform to the following physical properties:

Minimum ultimate tensile strength	145,000 psi
Minimum yield strength (0.2 percent offset)	130,000 psi
Minimum modulus of elasticity	25,000,000 psi
Minimum elongation at rupture in 20 diameters	4 percent
Minimum reduction of area at rupture	25 percent
Bar diameter tolerances	plus 0.03 inch minus 0.010 inch

(2) Working Stresses. -

Temporary normal design load stress (immediately after sealing)	101,500 psi
Temporary overstressing for a short period	116,000 psi
Effective steel stresses at design loads after losses	87,000 psi

(3) Appurtenant Steel Items. - Wedges, nuts, plates or any other appurtenant item will have suitable physical properties to develop the minimum ultimate tensile strength of the steel rods (or bars or tendons).

(4) Sealing Material. - Material used to seal the rods (or bars or tendons) in their pipe sleeves will be No-Ox-Id or an approved equal.

11. Basic Data and Assumptions. -

a. Controlling Elevations. -

Deck elevation, m.s.l.	35.0
Invert of gate opening, m.s.l.	-15.0

Bottom of structural base slab, m.s.l.	-23.0
Top of bayside pier, m.s.l.	+6.0
Top of riverside pier, m.s.l.	+3.0
Centerline of trunnion, m.s.l.	+6.0

b. Hurricane Wave Data. - For discussion of hurricane wave data see paragraph 16 b of Design Memorandum No. 10.

c. Loads. -

(1) Dead Loads. - Same as paragraph 16 b of Design Memorandum No. 10.

(2) Live Loads. - The following live loads have been used:

Water (salt)	64.2 lbs. per sq. ft.
Wind	30 lbs. per sq. ft.
Live load on deck	Fork Lift Truck (10^k Total Load)
Live load on equipment platforms	As required by equipment

d. to i. inclusive. - For discussion of external water pressures, earth pressures, earthquake forces, ice pressure, wind pressure, and frost protection see paragraphs 16 d to i, Design Memorandum No. 10.

j. Wave Pressures. - The gate structure will not be subject to breaking waves and the gate and its supporting structure have been investigated for loading produced by a maximum wave in a train (10.27) with crest height at Elevation 33.31. Wave forces were computed by the Sainflow Method.

k. to l. For discussion of location of resultant and factor of safety resistance to sliding see paragraphs 16 k and 16 l of Design Memorandum No. 10.

12. Tainter Gates. -

a. Loading Conditions. - Analysis of the tainter gates and anchorages were based on the following loading conditions:

Case I - Water on bayside considered at S. W. L. elevation of 20.5 and on riverside at elevation -3.0. Pressure on gate is considered as straight hydrostatic loading and normal design stresses are used.

Case II - Maximum hurricane condition with water at S. W. L. of 20.5 using maximum wave with crest of clapotis at elevation 33.31 and water on the riverside assumed at elevation -3.0. Lateral pressures figured by the Sainflow Method and design stresses increased by 33-1/3 percent.

Case III - Water on the riverside assumed at elevation +5.0 and at 0.0 on the bayside. Normal stresses were used in the design.

b. Design of Gate. -

(1) Skin Plate. - The skin plate is designed to span continuously over the vertical tee supports which are spaced 2'-0" center to center. The thickness of the skin plate has been increased in 1/16 inch increments from the top to the bottom of the gate starting with a 3/8 inch thick plate at the top. The skin plate has not been increased in thickness to guard against excessive corrosion because the gate will normally be suspended above the water and paint is considered to give adequate protection.

(2) Tee Supports. - The vertical tee supports to which the skin plate is attached are spaced on 2'-0" centers and are designed to utilize the skin plate as an additional flange. These vertical tee supports bear on three horizontal rolled sections that are located so that the negative moments in the vertical tees at the three horizontal girders are approximately equal.

(3) Frames. - The reactions of the vertical tees are carried back to the trunnion through three rigid frames each consisting of a horizontal girder and two struts. These frames are considered to be fixed at the trunnions. The struts are framed to the horizontal girders approximately 8'-0" from the ends of the girders in order to minimize the moment in the struts. Connecting the struts to the trunnion assembly will be a cast steel bearing arm that will revolve on a steel pin. The diameter of this pin and of the bearing arm was governed by the allowable bearing stress on the bronze bushing of the bearing arm.

c. Trunnion Assembly Design. -

(1) Pin. - The forged steel pin carrying the load from the gate to the anchorage assembly was designed as described in the preceding paragraph and then was checked for shear and moment.

(2) Bearing Shoe. - The legs of the bearing shoe were designed to take the thrust transmitted by the pin. The base of the shoe was designed for bending.

(3) Thrust Washers. - The thrust washers were designed for the thrust loads induced in the trunnion by the gate struts.

d. Anchorage. - The entire anchorage assembly is sloped to make the anchorage parallel to the resultant of the maximum Case I or Case II loading. The component of the trunnion thrust parallel to the channel was assumed to be transmitted to the post tensioned anchorage through a thrust girder of welded steel plate construction. This girder has also been designed to resist the torsion induced in it by the gate when suspended at its highest opening. Torsion stresses induced by the hydrostatic loads will also be checked to make sure that no greater torsional stresses are possible. The bolts attaching the bearing shoe to the thrust girder have been designed to resist the tension stresses induced by the Case III loading.

e. Post Tensioned Anchorage. - The post tensioned anchorages at the intermediate piers are designed for the maximum Case II loadings on both adjacent gates and for the maximum Case II loading on one gate and with a hydrostatic head 5' below the maximum Case II loading on the adjacent gate. The post tensioned anchorages at the end piers are designed for the maximum Case II loading. No increase in allowable stresses has been made for the post tensioned rods or the concrete.

13. Concrete Gate Structure. -

a. Stability. -

(1) Loading Conditions. - The gate structure has been investigated for the following conditions of loading:

Case I - Construction period with cofferdam in place; no hydrostatic loading and gates down. Cases Ia through Ie the same as Case I, but considering the gates in various positions and arrangements and with wind loads applied.

Case II - The normal operating condition with full dead load, water at elevation +3.0, and all gates up. Case IIa investigated with gates down and water at elevation +3.0 in the riverside and elevation -3.0 on the oceanside. Case IIb investigated with all gates down and water at elevation -3.0 on the riverside and elevation +3.0 on the oceanside.

Case III - Hurricane and high water condition with stillwater at elevation 20.5 using a maximum wave with crest of clapotis at elevation 33.32. Tailwater on the riverside assumed at elevation -3.0, full hydrostatic pressure on the base varying from

stillwater level on the oceanside to tailwater level on the riverside. Full lateral pressure as determined by the Sainflow Method.

Case IV - Construction conditions same as Case I, but with earthquake and no wind forces.

Case V - Normal operating condition but with earthquake loading.

(2) Critical Conditions. - Stability investigations show that Case I will govern the design of the bayside portion of the base slab and pile design. Case III was found to give the critical loading for the design of the riverside portion of the base slab and piling. Plate 9-3 in the Appendix illustrates the loading conditions found to be critical.

b. Design of Structure. - The base slab was designed as a continuous slab over four supports using a uniform distribution for bearing pressure. If final pile design indicates that a concentrated pile load should be used rather than a uniform bearing, the base slab will be reinvestigated on this basis. Typical sections have been analyzed at both the bayside and riverside ends. The end piers were investigated for the effect of the gate trunnion and also considering there was water in the channel to the top of the gate and no water in the expansion joint openings separating the gate structure from the rest of the barrier. All piers and base slab have been investigated for a condition of loading where stop gates are in place for one gate opening creating a condition of no loading on one side of the pier and water to elevation +3.0 on the other side.

c. Equipment Platform. - At the top of each pier a structural steel platform will be provided to support the operating equipment. The design will follow conventional methods.

14. Access Bridge. -

a. Description. - In order to provide necessary access to the tainter gate operating equipment, three bridge spans have been provided across the gate openings. Each span is 40 feet clear between abutments. The bridge deck will be 10'-0" clear between curbs, and was so selected in order to meet the 7'-0" doorway width at the pumping station. The deck will be supported on two carrying beams with a lubrite type bearing at each end.

b. Design. - The bridge spans have been designed for the possible future use of a fork lift truck with total load of 10 kips that could be used to remove parts of the operating equipment. Maximum design wheel load used was 3.25 kips spaced 3'-0" center to center. Because of the slenderness of the bridge spans relative to the massive piers, it was considered advisable to design them free of the piers in order to prevent cracking.

F. MECHANICAL DESIGN

15. Gate Hoists. - Electric motor-driven gate hoisting machinery will be located on the piers between the gates and also on the end walls, well above the extreme high water at elevation 35.00 m.s.l. Each hoist will be operated by push-button controls, one control point being at the gates and the other control point located within the Pump House. The use of steel cable was considered for lifting the gates, however, after considering the factors of corrosion resistance, maintenance and replacement, tension and adjustment and reliability against failure, preference has been given to the chain and sprocket mechanism. Corrosion-resistant steel link chains, engaging in a steel sprocket type hoist system, will be used. The hoisting speed of the gate will be approximately 6 inches per minute and the closing speed approximately 18 inches per minute. Gate position indicators will not be required since the gates will be either in the open or closed position, however, limit switches will be provided for both open and closed positions of the gates. These positions will be indicated remotely in the pump house by colored lights.

16. Design Computations. -

Estimated weight of gate		112,000 lbs.
Weight of gate at pick-up point (112,000 x 29)/35		92,800 "
Side seal friction 8 x 12 x 42 x 2		48,000 "
Trunnion friction 66,675 x .3		6,000 "
Lifting chain 100 x 60 x 2		11,000 "
	Total	157,800 lbs.
Load each chain 157,800/2		78,900 lbs.
Motor Horse Power (157,800 x .416)/33000 x .75	=	2.65
Motor Rating @ 1620 R. P. M. +12%	=	3 HP
Stalling Torque 3 x 2.8		8.4 HP

G. ELECTRICAL DESIGN

17. Electrical Design. - The 3 HP tainter gate motors will be supplied with power at 480 volts from station-service load center B in the pumping station. A combination magnetic starter and fused disconnecting switch for each motor will be located on the wall above the elevation 35.0' platform at the east end of the pumping station. Each motor may be controlled either from a cover mounted pushbutton station in its starter or from a control station at the motor.

Lighting for the river gate structure will be supplied from the pumping station lighting panels.

H. CORROSION PROVISIONS

18. Corrosion Provisions. - The tainter gates will be stored in an open position and immersed in salt water only for the few hours during operation of the project at the time of a hurricane alert and for a shorter time at the periodic operation of the gate for maintenance purposes. Centerline of the trunnion will be at elevation +6.0 and the lowest exposed metal on the trunnion bearing support will be +3.0. Inasmuch as elevation of mean high tide is +2.35 only occasional submergence will be experienced. The lower part of the trunnion will be in the splash zone; periodic maintenance by painting will be sufficient to protect this. It is proposed to use a grease-lubricated bronze bearing in the trunnion. Periodic greasing will preclude deteriorating effects of salt water splash. The embedded lower seal will be treated wood held in place with Monel bolts. The side seals will be of rubber on the gate, bearing on flush metal seals on the piers. The embedded seals will be constructed of Monel metal up to elevation +3.0 and of mild steel, painted, above that elevation.

I. COORDINATION WITH LOCAL AUTHORITIES

19. Coordination With Local Authorities. - During early consideration of type of opening for passage of river flow, the State of Rhode Island showed interest in preserving the area upstream of the Barrier for navigation, insofar as practicable. After study of alternate schemes of gates, including a submersible type of flap gate, and after consideration of the dangers of attempting to operate the gates both as a small boat refuge in case of a hurricane and for protection of the City, it was agreed to adopt the layout presented herewith. This type of gate is most economical, both in initial cost and in maintenance cost.

J. CONSTRUCTION SCHEDULE

20. Construction Schedule. - Construction of the river gates station will be included under a continuing type general contract to be advertised in the Fall of 1960, subject to the availability of funds.

It is anticipated that construction will be initiated as soon as the cooling water canal is in service, the foundation prepared, and the area unwatered, and that the gate structure will be used to pass river flows during the subsequent construction of the concrete barrier section.

CORPS OF ENGINEERS

U. S. ARMY

SOUTH STREET STATION

POINT ST. BRIDGE

EAST BRIDGE

WEST BRIDGE

RAMP

NARRAGANSETT ELEC. CO. FRANKLIN SQUARE SUB-STATION

MANCHESTER STREET STATION

DUST

Work by Power Co.

Electrical Duct Line 6-5" Ducts each-3-600 MCM 2-5" Ducts-spare 2-5" Ducts-Control

Access Road

Work by Contractor

NARRAGANSETT ELECTRIC CO. GATE

WEST EMBANKMENT

GLOBE ST.

CRARY ST.

CRARY

EDDY

JAMES AVE.

CALLENS AVE. GATE

HENDERSON ST.

WEST ABUTMENT

PUMPING STATION

Electrical Bay

CONCRETE BARRIER WITH SERVICE BRIDGE OVER

RIVER GATES

CONCRETE BARRIER

EAST EMBANKMENT

48" Syphon

28" Sewer

SOUTH MAIN ST. GATE

TOCKWOTTON

PIKE

MAIN

SOUTH

INDIA

BLANDING

DOCK

GEO. M. COHAN BLVD.

ST.

BALLARD

FOX

N268,000

N267,000

N266,000

E557,000

E558,000

N

1 2 3 4 5 6 7 8

A B C D E F G H

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY

SUBMITTED
PROJECT ENGINEER

APPROVED:
CHIEF DESIGN BRANCH

APPROVED
CHIEF, ENGINEERING DIVISION

FOX POINT HURRICANE BARRIER
RIVER GATES
GENERAL PLAN

PROVIDENCE RHODE ISLAND

DATE JAN. 1960

SCALE 1" = 100'

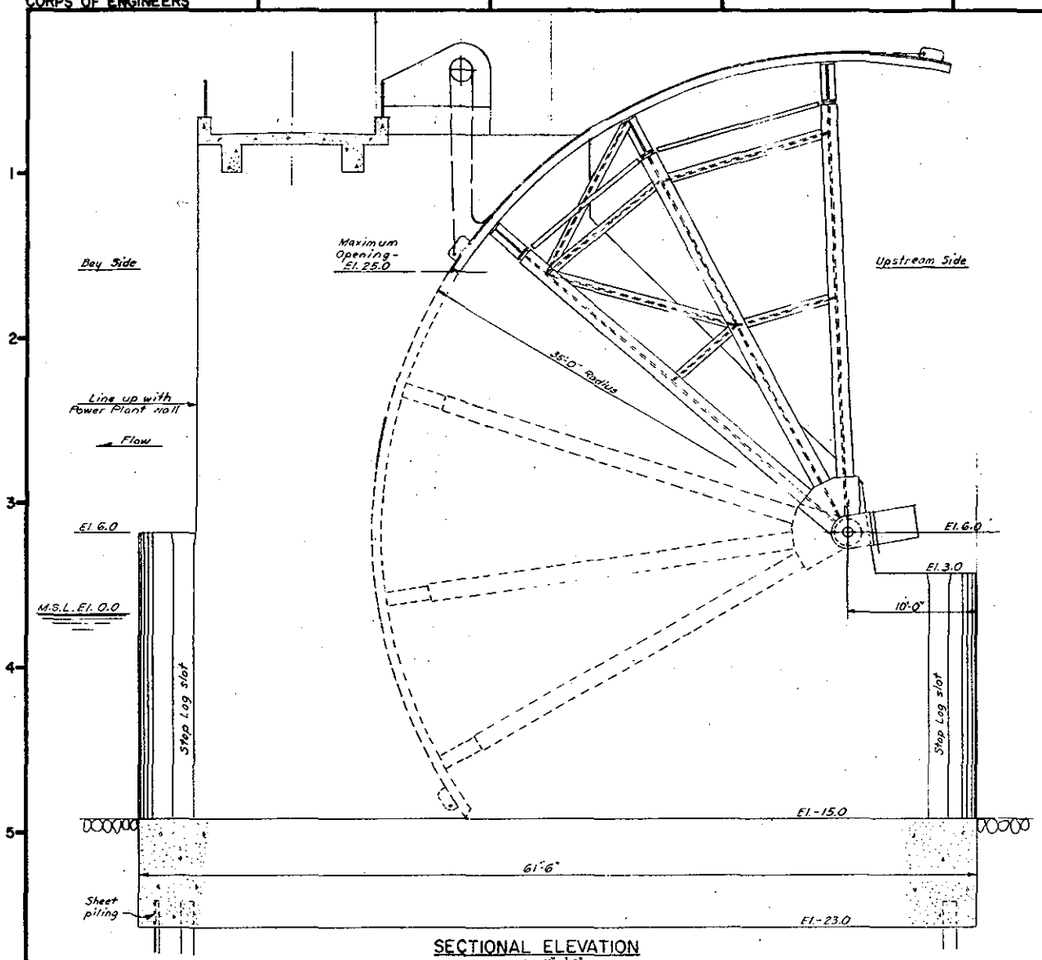
SPEC. NO.

DRAWING NUMBER FP-1-1019

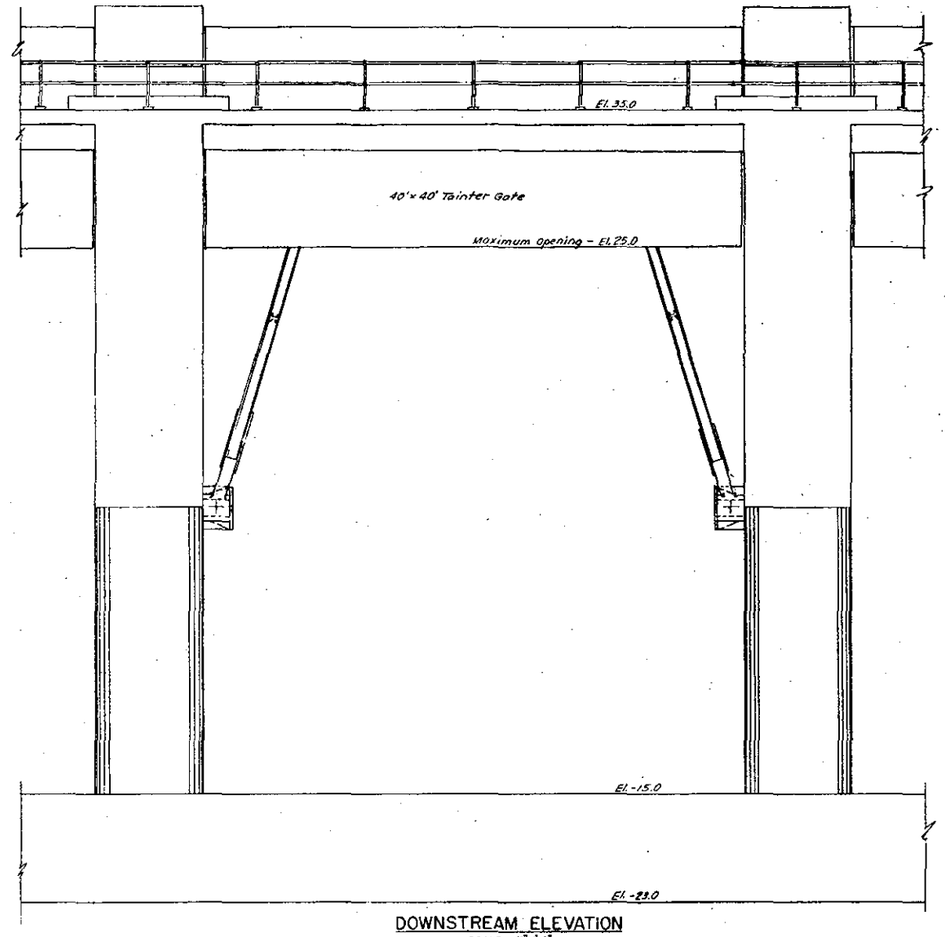
SHEET 1

PLATE NO. 9-1

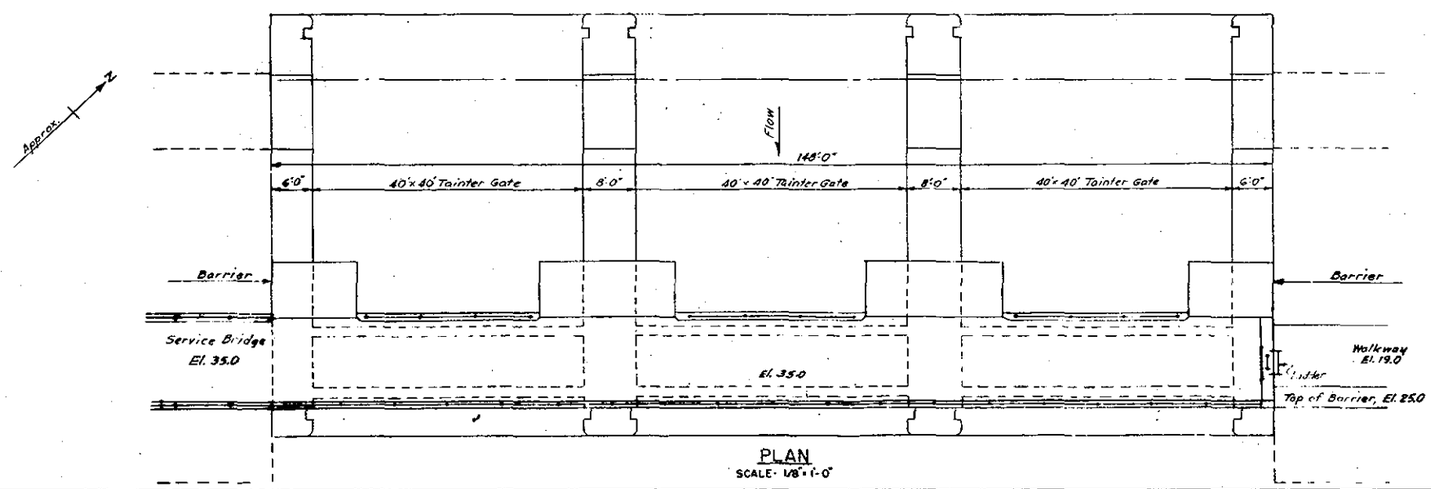
CORPS OF ENGINEERS U. S. ARMY



SECTIONAL ELEVATION
SCALE- 1/4" = 1'-0"



DOWNSTREAM ELEVATION
SCALE- 1/4" = 1'-0"



PLAN
SCALE- 1/8" = 1'-0"

NOTE:
For General Notes see Plate No. 9-A

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS

DES. BY R.S.M. | DR. BY K.M.K. | CK. BY

PROJECT ENGINEER

DIVISION ENGINEER — RECOMMENDED — APPROVED

CHIEF ENGINEERING DIVISION

FOX POINT HURRICANE BARRIER
RIVER GATES
CONCRETE
PLAN & ELEVATIONS

PROVIDENCE RHODE ISLAND

DATE JAN. 1960

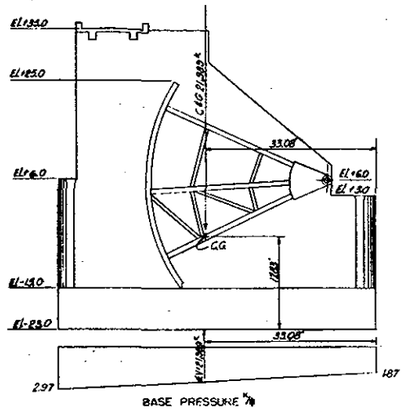
SCALE AS SHOWN | SPEC. NO.

DRAWING NUMBER
FP-1-1020

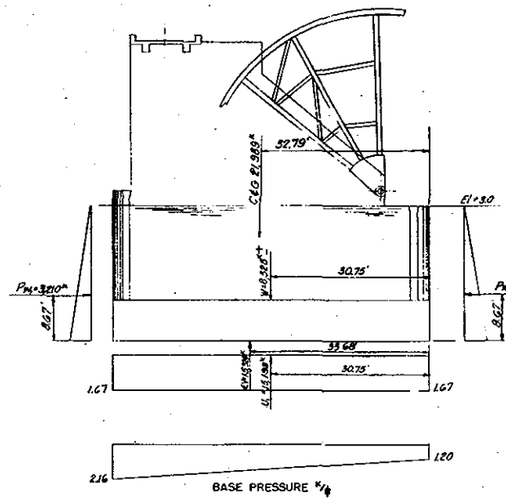
SHEET 8

PLATE NO. 9-2

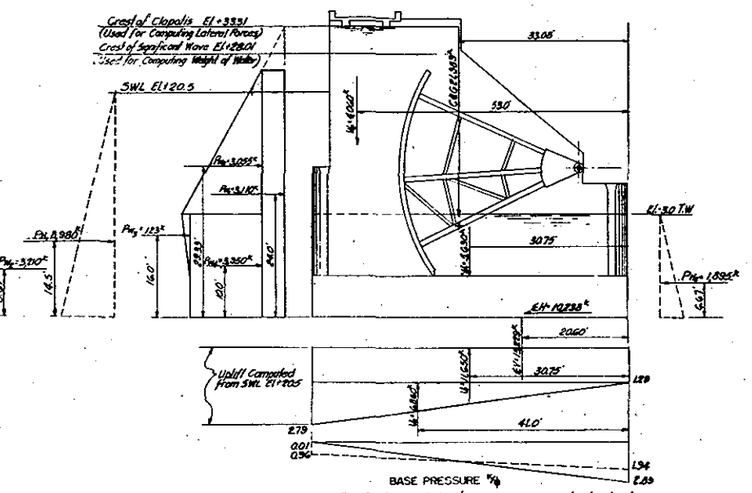
CORPS OF ENGINEERS U. S. ARMY



CASE I CONSTRUCTION CONDITION

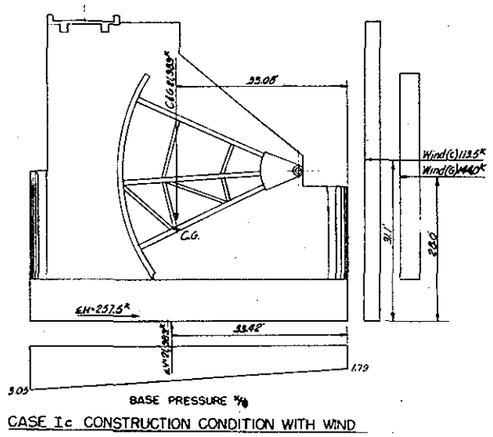


CASE II NORMAL OPERATING CONDITION

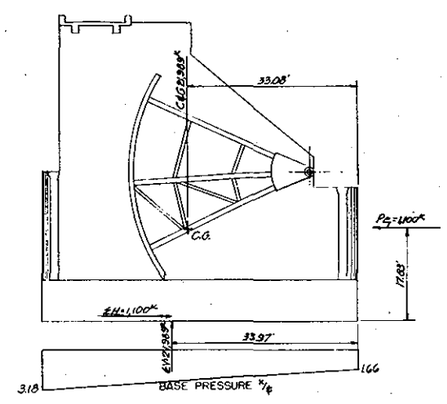


NOTE: Dash lines indicate base pressures due to dead loads and hydrostatic pressures at SWL and TW El only. (also shown by dash lines above)

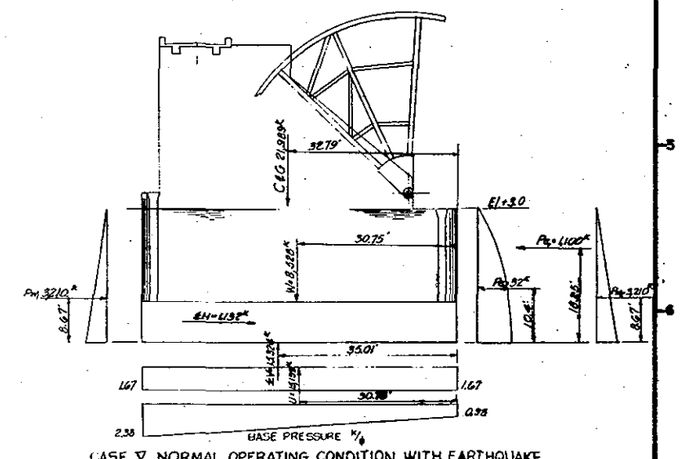
CASE III HURRICANE CONDITION



CASE Ic CONSTRUCTION CONDITION WITH WIND



CASE IV CONSTRUCTION CONDITION WITH EARTHQUAKE



CASE V NORMAL OPERATING CONDITION WITH EARTHQUAKE

NOTE:
Elevations refer to Mean Sea Level.

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY B.F.W. | DR. BY W.G.L. | CK. BY B.F.W.

PROJECT ENGINEER

APPROVED: CHIEF SECTION BRANCH

APPROVED: CHIEF ENGINEERING DIVISION

FOX POINT HURRICANE BARRIER
RIVER GATES
STRUCTURAL
CRITICAL STABILITY DIAGRAMS

PROVIDENCE RHODE ISLAND

DATE JAN. 1960

SCALE

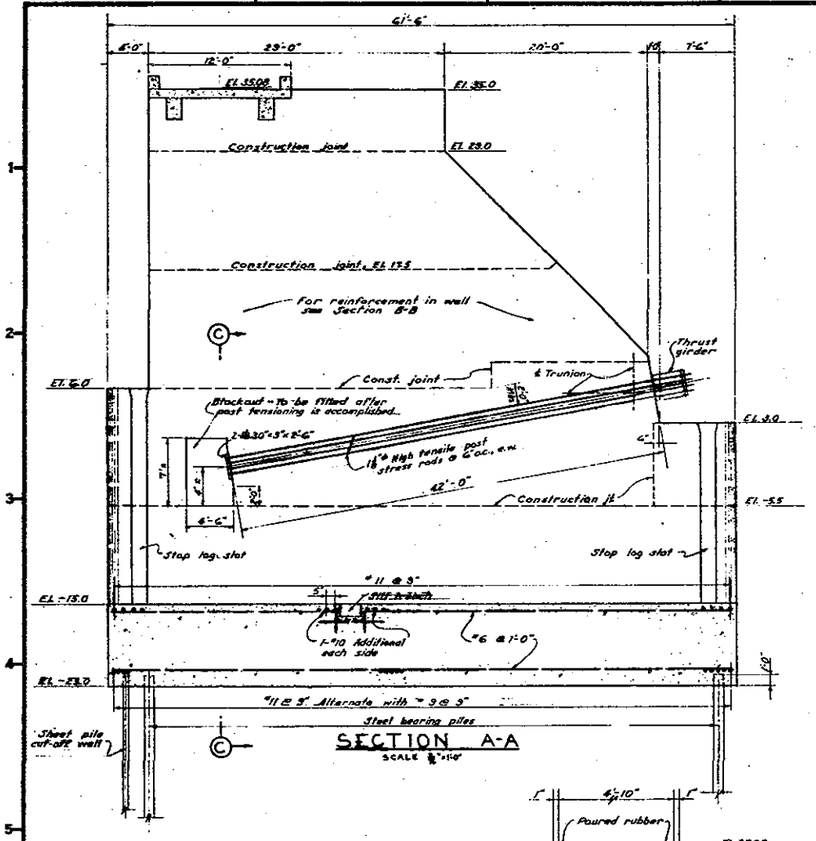
SPEC. NO. ENG-18-016-

DRAWING NUMBER FP-1-1021

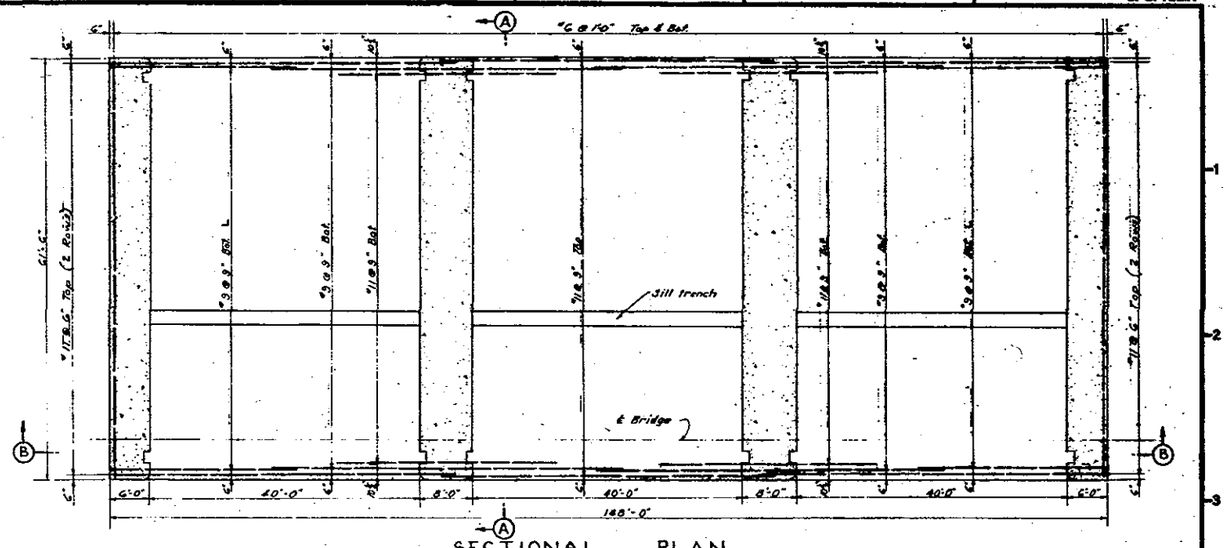
SHEET 3

PLATE NO.9-3

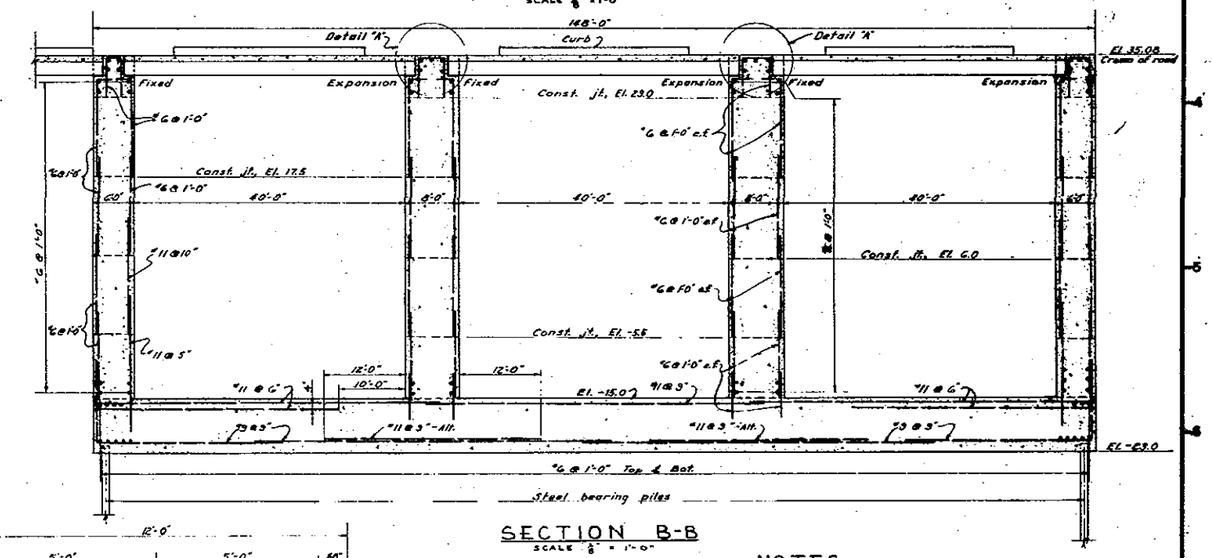
CORPS OF ENGINEERS U. S. ARMY



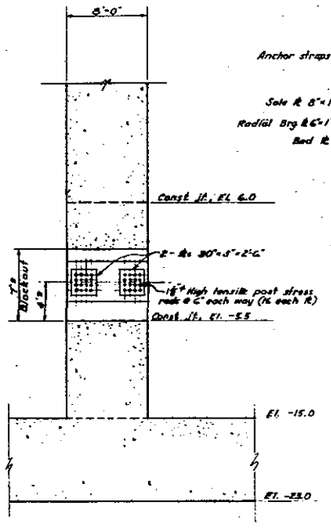
SECTION A-A
SCALE 1/8" = 1'-0"



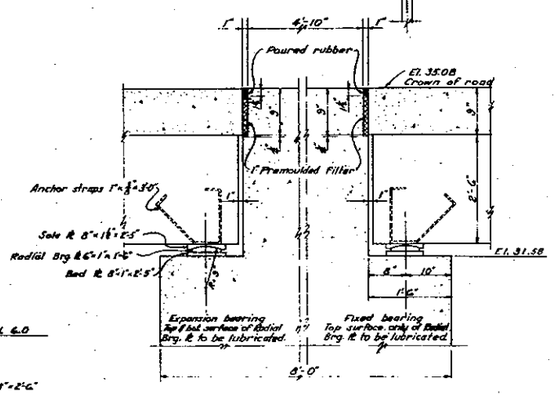
SECTIONAL PLAN
SCALE 1/8" = 1'-0"



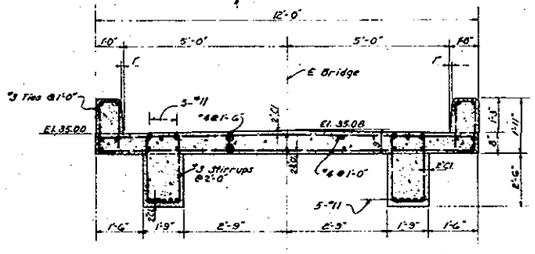
SECTION B-B
SCALE 1/8" = 1'-0"



SECTION C-C
SCALE 1/8" = 1'-0"



DETAIL "A"
SCALE 1" = 1'-0"



Note: Bridge spans shall be cambered 1/4".

TYPICAL BRIDGE SECTION
SCALE 1/4" = 1'-0"

NOTES

1. Elevations refer to Mean Sea Level.
2. All reinforcing laps are 30 diameters except as otherwise noted.

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY F.J.T. | CK. BY

PROJECT ENGINEER

APPROVED — CHIEF DESIGN BRANCH

APPROVED — CHIEF ENGINEERING DIVISION

DATE JAN. 1960

FOX POINT HURRICANE BARRIER
RIVER GATES
STRUCTURAL
REINFORCING DETAILS

PROVIDENCE RHODE ISLAND

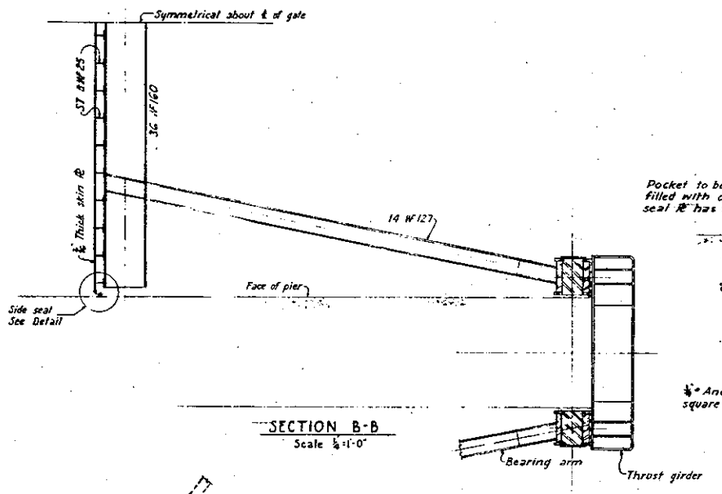
SCALE: AS SHOWN | SPEC. NO. ENG.-10-016-

DRAWING NUMBER FP-1-1022

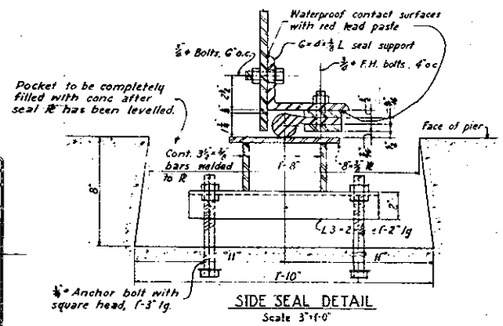
SHEET 4

PLATE NO. 9-4

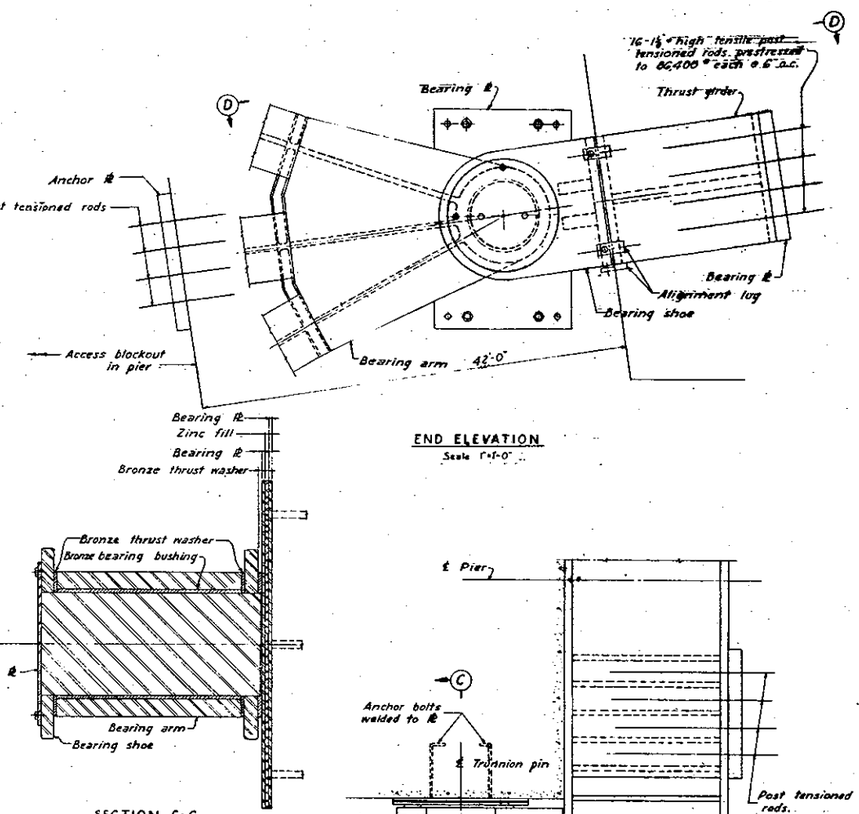
CORPS OF ENGINEERS U. S. ARMY



SECTION B-B
Scale ¼"=1'-0"

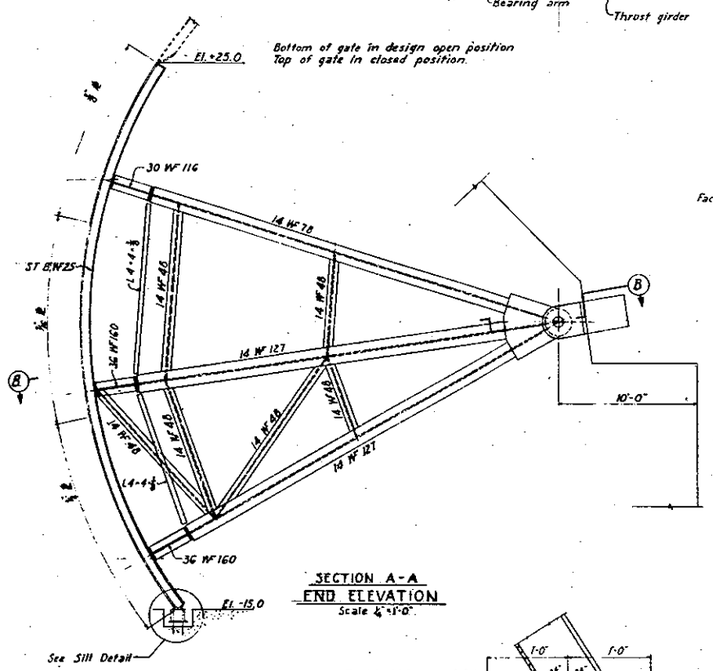


SIDE SEAL DETAIL
Scale 3"=1'-0"

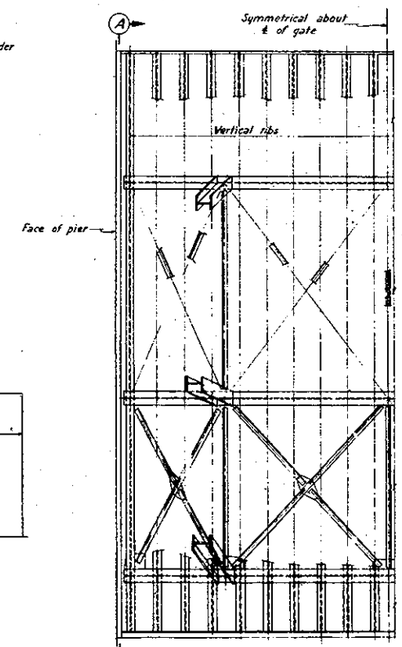


END ELEVATION
Scale 1"=1'-0"

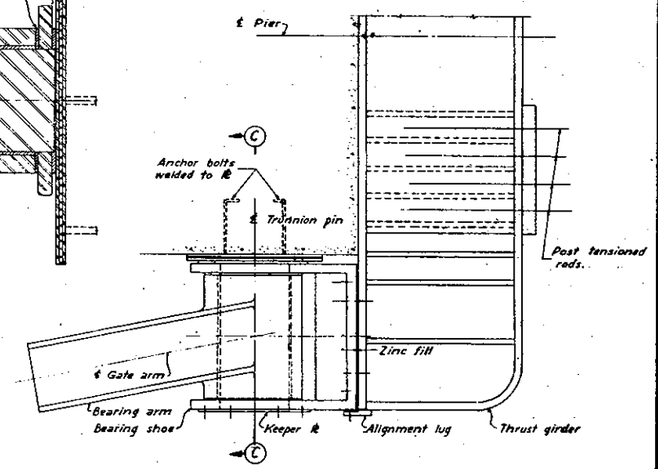
SECTION C-C
Scale 1½"=1'-0"



SECTION A-A
END ELEVATION
Scale ¼"=1'-0"

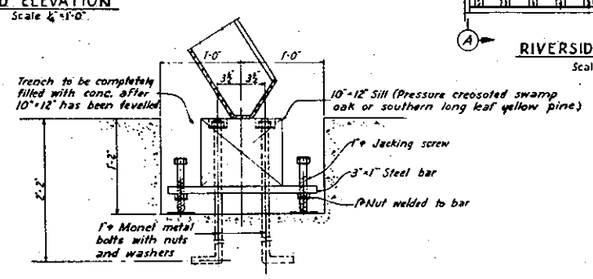


RIVERSIDE ELEVATION
Scale ¼"=1'-0"



PLAN D-D
Scale 1"=1'-0"

TRUNNION DETAILS



SILL DETAIL
Scale 1½"=1'-0"

NOTES

Elevations refer to Mean Sea Level.
All connections shall be welded unless otherwise shown.

Revision	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY E.T.S. F.B.B. | DR. BY A.A.B. | CK. BY P.D.M.

PROJECT ENGINEER

APPROVED:

CHIEF DESIGN BRANCH

FOX POINT HURRICANE BARRIER
RIVER GATES
STRUCTURAL DETAILS

PROVIDENCE RHODE ISLAND

APPROVED: DATE JAN 1960

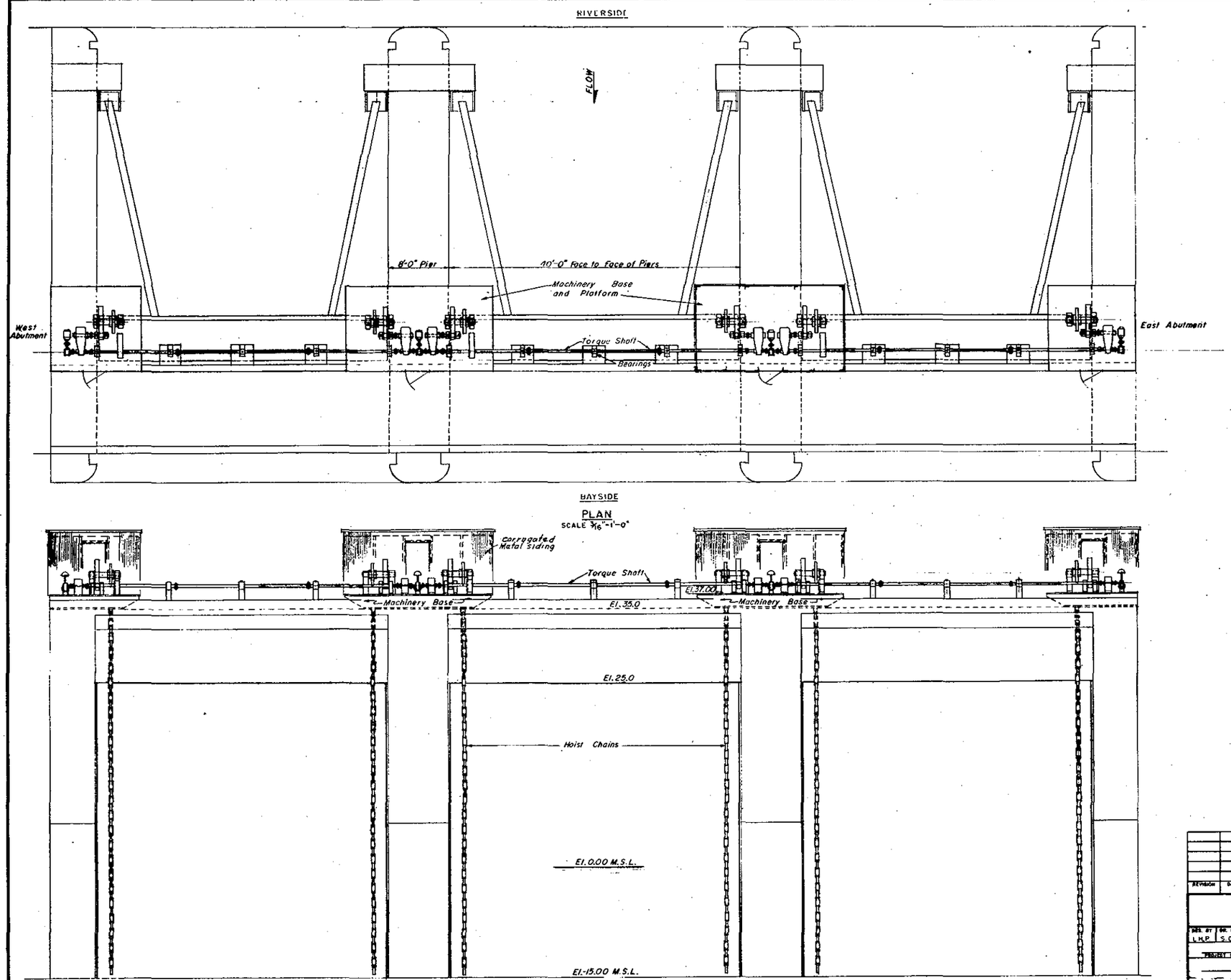
CHIEF, ENGINEERING DIVISION

SCALE: AS SHOWN | SPEC. NO. ENG.-18-016-

DRAWING NUMBER FP-1-1023

SHEET 5

PLATE NO. 9-5



REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY L.H.P. | DR. BY S.G. | CK. BY

PROJECT ENGINEER

APPROVED:

APPROVED

FOX POINT HURRICANE BARRIER
RIVER GATES
MECHANICAL
TAINTER GATES AND HOIST
PROVIDENCE RHODE ISLAND

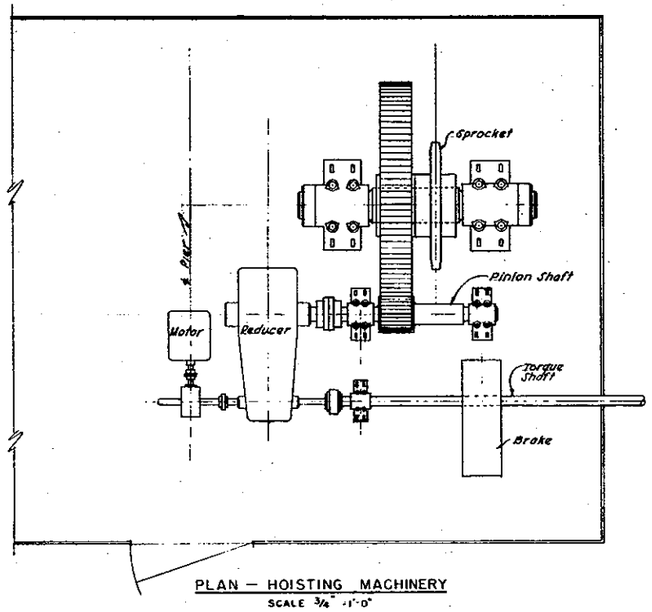
DATE JAN. 1960

SCALE AS SHOWN | SPEC. NO. ERG.-19-046-

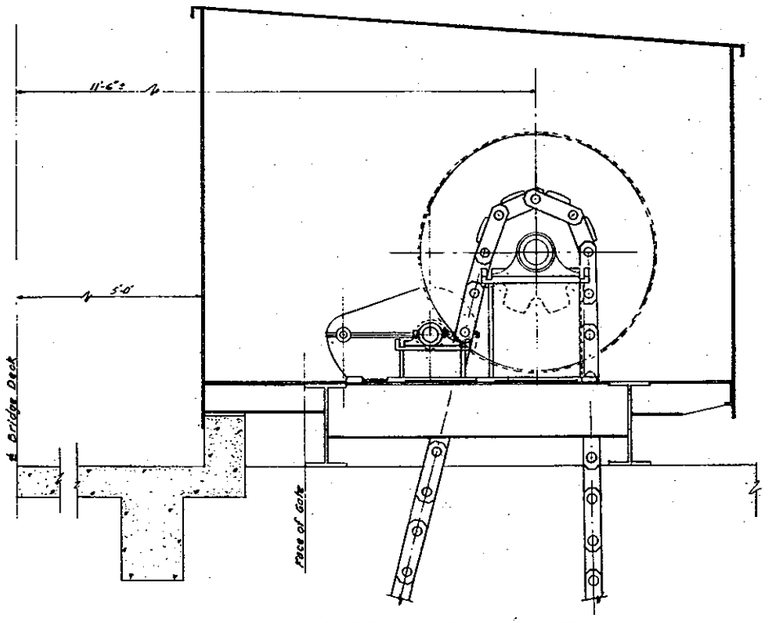
DRAWING NUMBER
FP-1-1024

SHEET 6

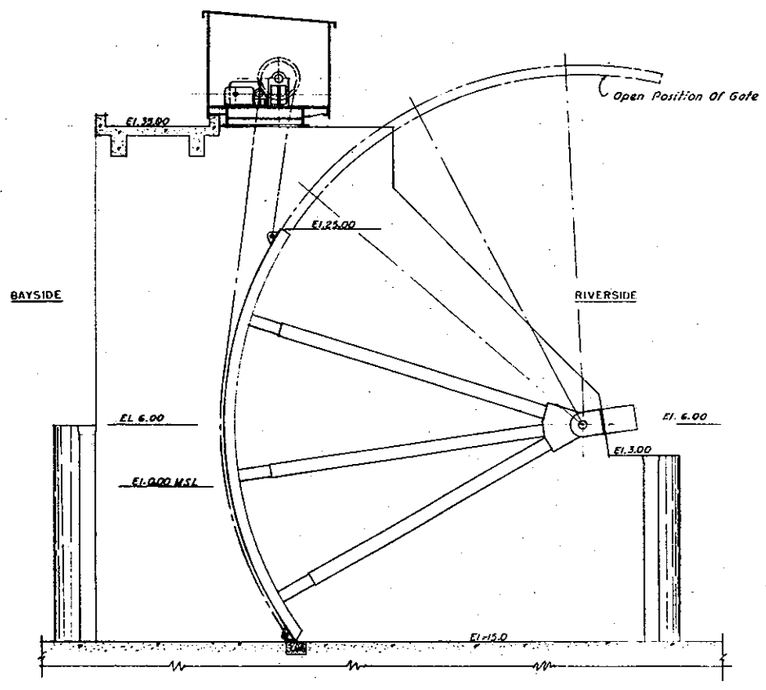
CORPS OF ENGINEERS U. S. ARMY



PLAN – HOISTING MACHINERY
SCALE 3/4" = 1'-0"



ELEVATION – HOISTING MACHINERY
SCALE 3/4" = 1'-0"



GATE ELEVATION
SCALE 3/16" = 1'-0"

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY L.K.P. | DR. BY T.E.V. | CK. BY

PROJECT ENGINEER

DESIGNED | APPROVED | DATE JAN. 1960

DESIGN ENGINEER BRANCH | DESIGN ENGINEER DIVISION

SCALE AS SHOWN | SPEC. NO. EXC.-19-010-

Drawing Number
FP-1-1025

SHEET 7

FOX POINT HURRICANE BARRIER
RIVER GATES
MECHANICAL
TAINTER GATE DETAILS

PROVIDENCE RHODE ISLAND

PLATE NO.9-7

Structural Computations
Fox Point
Gate Section

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Trigonometric Values	5 - 7
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Case II Loading	9
Combined Case I & II Loading	10
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Gate Weight and Center of Gravity	62 - 70
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Gate Structure - Slab Reinforcing	84 - 94
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SUBJECT FOX POINT GATE STRUCTURE - PROVIDENCE, R.I.
COMPUTATION HYDRAULIC LOADS ON GATE
COMPUTED BY P.D.M CHECKED BY Cmt DATE 11/23/59

ASSUMPTIONS

Crest of Gate	El. +25.00
Sill of Gate	El. -15.00
Minimum Elevation of bottom of Gate in raised position	El. +25.00
Mean Low Water	El. - 3.00
Significant Wave Height, H_F	6.5 ft.
Period	5.5 sec.
Still Water Level	El. +20.5
Elevation of Shore at Structure	El. -15.00
Depth of Water at Still Water Level at Structure, d	35.5 ft.

To find Deep Water Wave Length, L_0

$L_0 = 5.12\,T^2$ where T = period of wave in seconds
See Page 118, Part II, Chap. 4, S.P.P&D.

$L_0 = 5.12 \times 5.5^2 = 155$ ft.

To find Max. Wave Height in train, H

$H = 1.58 \times H_F$ See EM 1110-2-2904, 31 Jan, 1957, "Design
$H = 1.58 \times 6.5 = 10.27'$ of Breakwaters and Jetties, P. 5.

Clapotis

$$\frac{d}{L_0} = \frac{35.5}{155} = .22903$$

$$\frac{d}{L} = .2498$$ See Table D-1, Appendix D in S.S.P.&D

$$L = \frac{35.5}{.2498} = 142.1'$$

$$h_0 = (\pi H^2/L)\coth(2\pi d/L)$$ See P. 118, Part II, Chap. 4, S.S.P.&D

$$= .3142 \times \frac{10.3^2}{142.1} \times \frac{1}{.9170}$$

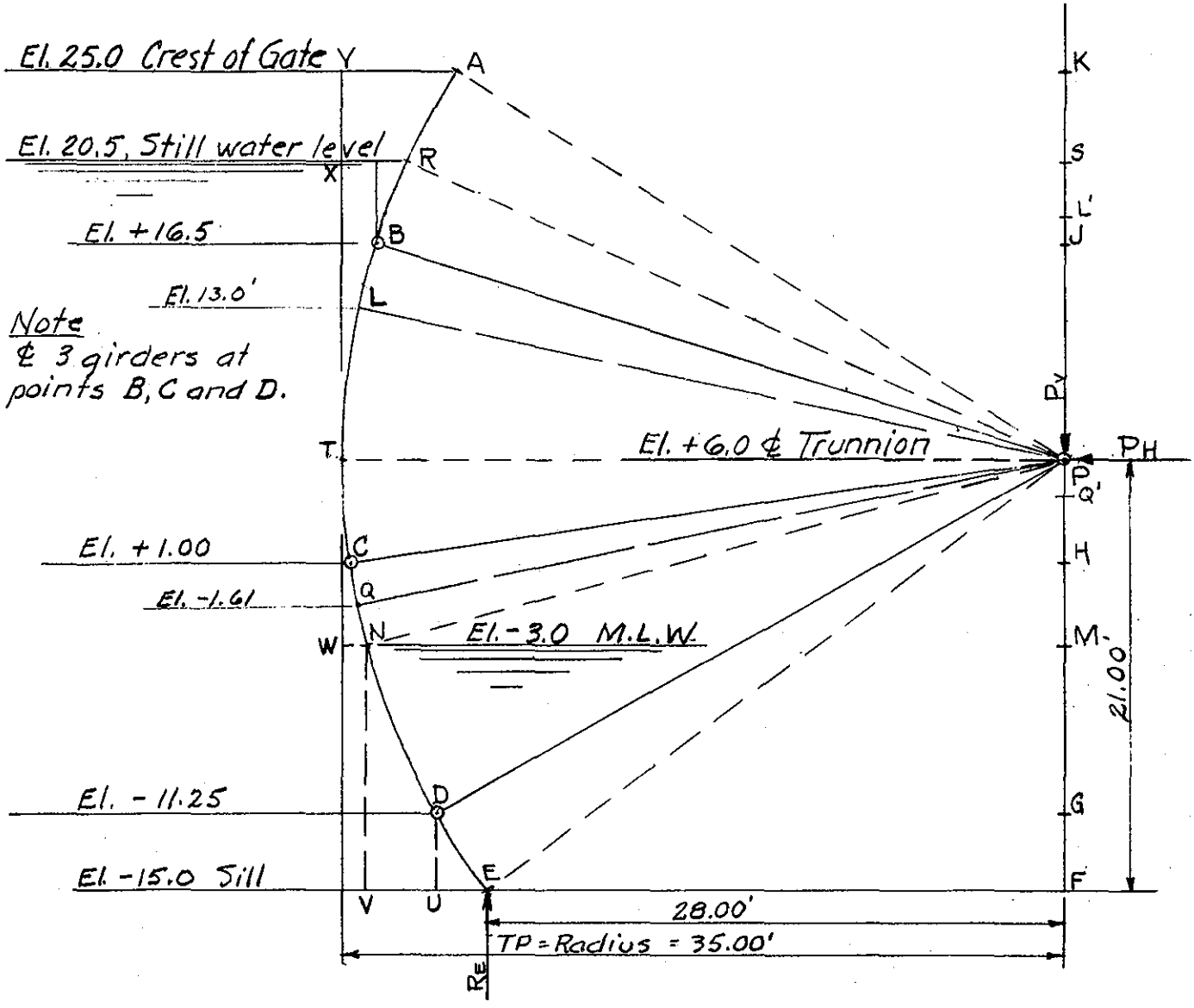
$$h_0 = 2.54'$$

Note S.P.P.&D. stands for "Shore Protection Planning and Design," Technical Report No. 4 of the Beach Erosion Board, O.C.E.

$$P_1 = \frac{wH}{\cosh \frac{2\pi d}{L}}$$ See Table D-1, Appendix D in S.S.P.&D

$$P_1 = \frac{64.2 \times 10.27}{2.506} = 263\ \#/\text{sq. ft.}$$

SUBJECT Fox Point Gates
COMPUTATION Hydraulic Loads on Gates
COMPUTED BY P.D.M. CHECKED BY GTS DATE 11/23/59



Case I

Assume still water level on bay side (downstream) at El. 20.5. Assume water level on opposite side (upstream) at mean low water, El. -3.0.
Allowable stress = 18000 psi.

Case II

Assume crest of clapotis at gate on bay side (downstream) at El. 33.31. Assume water level on opposite side (upstream) at mean low water, El. -3.0
Allowable stress = 18,000 x 1.33 = 24,000 psi.

SUBJECT FOX POINT GATE STRUCTURE - PROVIDENCE R.I.
COMPUTATION HYDRAULIC LOADS.
COMPUTED BY GTS CHECKED BY P.D.M. DATE 11/23/59

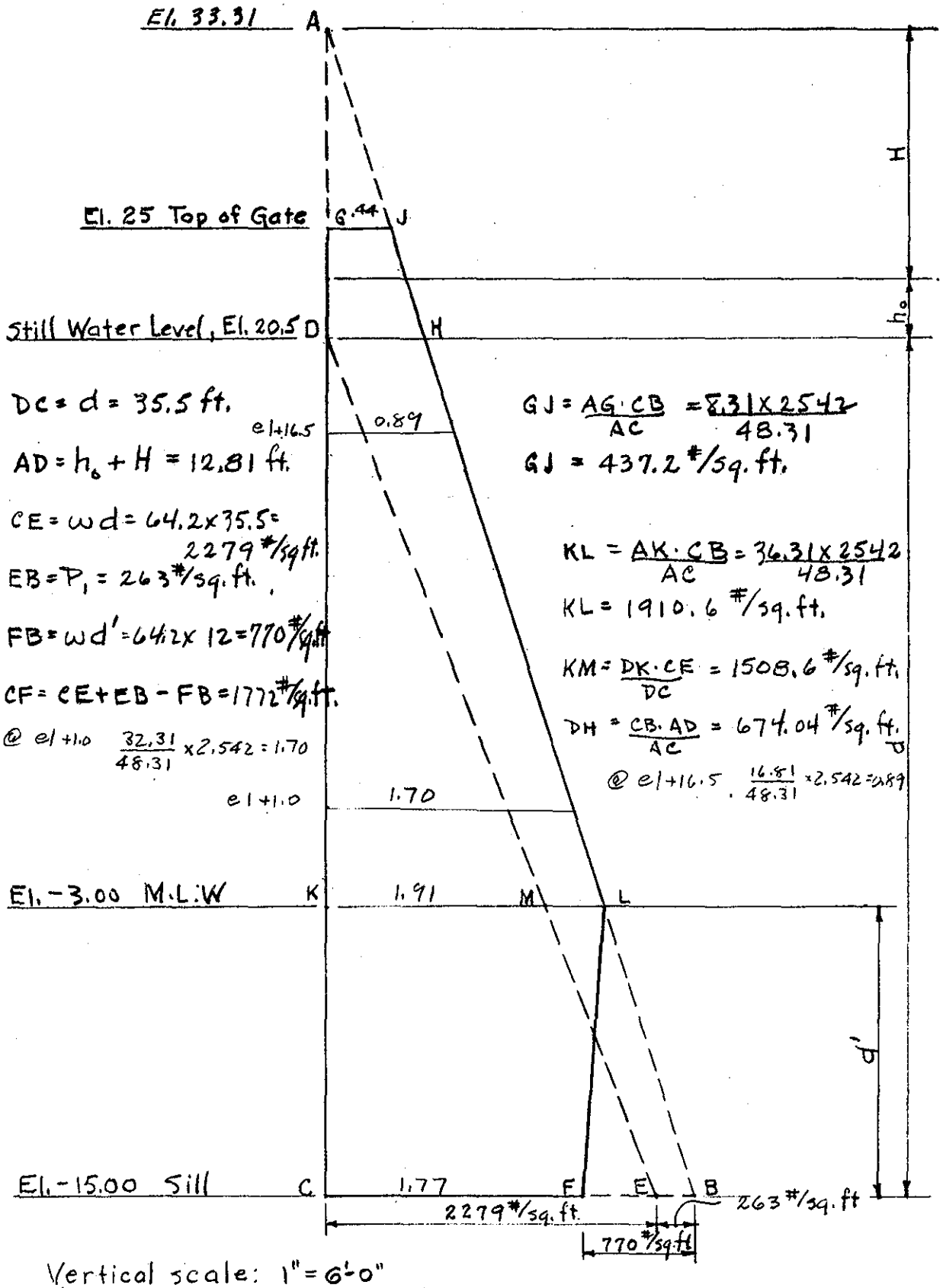
Case III

Assume still water level on bay side at El. 0.0. Assume water level on opposite side of gate at El. +5.0
Allowable stress = 18000 psi
Allowable stress on bolts attaching bearing shoe to thrust girder 40,000 psi. (Yield strength of steel 74000 psi)

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U.S. ARMY

SUBJECT FOX POINT GATE STRUCTURE - PROVIDENCE, R.I.
COMPUTATION HYDRAULIC LOADS ON GATES
COMPUTED BY P.D.M. CHECKED BY GTS DATE 11/23/59



$DC = d = 35.5$ ft.

$AD = h_o + H = 12.81$ ft.

$CE = wd = 64.2 \times 35.5 = 2279$ #/sq ft.

$EB = P_1 = 263$ #/sq. ft.

$FB = wd' = 64.2 \times 12 = 770$ #/sq ft

$CF = CE + EB - FB = 1772$ #/sq. ft.

@ el +1.0 $\frac{32.31}{48.31} \times 2.542 = 1.70$

$GJ = \frac{AG \cdot CB}{AC} = \frac{8.31 \times 2.542}{48.31}$

$GJ = 437.2$ #/sq. ft.

$KL = \frac{AK \cdot CB}{AC} = \frac{36.31 \times 2.542}{48.31}$

$KL = 1910.6$ #/sq. ft.

$KM = \frac{DK \cdot CE}{DC} = 1508.6$ #/sq. ft.

$DH = \frac{CB \cdot AD}{AC} = 674.04$ #/sq. ft.

@ el +16.5 $\frac{16.81}{48.31} \times 2.542 = 0.89$

Vertical scale: 1" = 6'-0"
Horizontal scale: 1" = 1000#

SUBJECT FOX POINT GATES
COMPUTATION Trigonometric Values
COMPUTED BY D.D.M. CHECKED BY GTS DATE 11/24/59

Assumed weight of gate
Gate weighs 70#/sq.ft. of skin plate
W = 40x40 x 70 = 112000#

Assume C. of G of gate @ 83% of radius.
.83 x 35 = 29.05' Say 29' from trunnion.

See sketch on Sheet 2

$\cos \angle EPF = \frac{21}{35} = .60000$ $\angle EPF = 53° - 7.811'$

$\sin \angle 53° - 7.811 = .80000$
$EF = EP \sin 53° - 7.811' = 35 \times .8 = 28.00000$

$\cos \angle DPG = \frac{17.25}{35} = .49257$ $\angle DPG = 60° - 29.423$

$\sin \angle 60° - 29.423 = .87027$
$DG = DP \sin 60° - 29.423 = 35 \times .87027 = 30.45945$

$\cos \angle NPM = \frac{9}{35} = .25714$ $\angle NPM = 75° - 5.979'$

$\sin 75° - 5.979' = .96637$
$NM = NP \sin 75° - 5.979' = 35 \times .96637 = 33.82295'$

$\cos \angle CPH = \frac{5}{35} = .14286$ $\angle CPH = 81° - 47.206'$

$\sin 81° - 47.206 = .98974$
$CH = CP \sin 81° - 47.206' = 35 \times .98974 = 34.64090$

$\cos \angle BPJ = \frac{10.5}{35} = .30000$ $\angle BPJ = 72° - 32.535'$

$\sin 72° - 32.535' = .95394$
$BJ = BP \sin 72° - 32.535' = 35 \times .95394 = 33.38790$

$\cos \angle RPS = \frac{14.5}{35} = .41429$ $\angle RPS = 65° - 31.509$

$\sin 65° - 31.509 = .91014$
$RS = RP \sin 65° - 31.509 = 35 \times .91014 = 31.85490$

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT Fox Point Gates
COMPUTATION Trigonometric Values
COMPUTED BY P.D.M. CHECKED BY GTS DATE 11/24/59

$\cos \angle APK = \frac{19}{35} = .54286$ $\angle APK = 57° - 7.295'$

$\sin 57° - 7.295' = .83982$

$AK = AP \sin 57° - 7.295' = 35 \times .83982 = 29.39370'$

$\angle DPE = \angle DPG - \angle EPF$

$$\begin{array}{r} 60° - 29.423' \\ - \ 53° - 7.811' \\ \hline 7° - 21.612' \end{array}$$

$\angle NPD = \angle NPM - \angle DPG$

$$\begin{array}{r} 75° - 5.979' \\ - \ 60° - 29.423' \\ \hline 14° - 36.556 \end{array}$$

$\angle CPN = \angle CPH - \angle NPM$

$$\begin{array}{r} 81° - 47.206' \\ 75° - 5.979' \\ \hline 6° - 41.227 \end{array}$$

$\angle CPD = \angle CPH - \angle DPG$

$$\begin{array}{r} 81° - 47.206' \\ - \ 60° \ 29.423' \\ \hline 21° - 17.783' \end{array}$$

$\angle BPC = (90° - \angle BPJ) + (90° - \angle CPH)$

$$\begin{array}{r} 89° - 60.000 \\ - \ 72° \ 32.535 \\ \hline 17° - 27.465 \end{array} \qquad \begin{array}{r} 89° - 60.000 \\ - \ 81° \ 47.206 \\ \hline 8° - 12.794 \end{array} \qquad \begin{array}{r} 17° - 27.465 \\ 8° - 12.794' \\ \hline 25° - 40.259' \end{array}$$

$\angle RPB = \angle BPJ - \angle RPS$

$$\begin{array}{r} 72° - 32.535 \\ 65° - 31.509' \\ \hline 7° - 1.026' \end{array}$$

$\angle APR = \angle RPS - \angle APK$

$$\begin{array}{r} 65° - 31.509 \\ 57° - 7.295 \\ \hline 8° - 4.214' \end{array}$$

$\angle APB = \angle BPJ - \angle APK$

$$\begin{array}{r} 72° - 32.535 \\ 57° - 7.295' \\ \hline 15° - 25.240' \end{array}$$

$\angle APE = (90° - EPF) + (90° - APK)$

$$\begin{array}{r} 89° - 60.000' \\ - \ 53° - 7.811 \\ \hline 36° - 52.189 \end{array} \qquad \begin{array}{r} 89° - 60.000' \\ - \ 57° - 7.295' \\ \hline 32° - 52.705' \end{array} \qquad \begin{array}{r} 36° - 52.189 \\ 32° - 52.705 \\ \hline 68° - 104.894 \\ 69° - 44.894' \end{array}$$

SUBJECT Fox Point Gates
COMPUTATION Trigonometric Values
COMPUTED BY P.D.M. CHECKED BY GTS DATE 11/25/59

$\angle APE = \angle APB + \angle BPC + \angle CPD + \angle DPE$

$\angle APB =$ 15° - 25.240'
25° - 40.259'
21° - 17.783'
7° - 21.612'
69° - 44.894

Check - see value for $\angle APE$ on Sh. 6

Length of Arcs. Length = Ra where R = radius and 'a' equals the central $\angle$ in radians.

Arc	Central $\angle$ in Degrees	R	a	Ra	
DE	$\angle DPE$ = 7°-21.612'	35	.1285'	4.4975	
CN	$\angle CPN$ 6 41.227	35	.1167		4.08
CD	$\angle CPD$ = 21°- 17.783	35	.3717'	13.0095	
ND	14°-36.556	35	.2559		8.93
BC	$\angle BPC$ = 25°- 40.259	35	.4480	15.6800	
RB	$\angle RPB$ = 7°- 1.026	35	.1225		4.2875
AB	$\angle APB$ = 15°-25.240	35	.2692	9.4220	
				42.6090	Check
AE	$\angle APE$ = 69°-44.894	35	1.2173	42.6055	

Horizontal Projections

WN WN = 35 - NM NM = 35 sin $\angle NPM$ = 35 x .96637 = 33.8230
WN = 35 - 33.8230 = 1.1770'

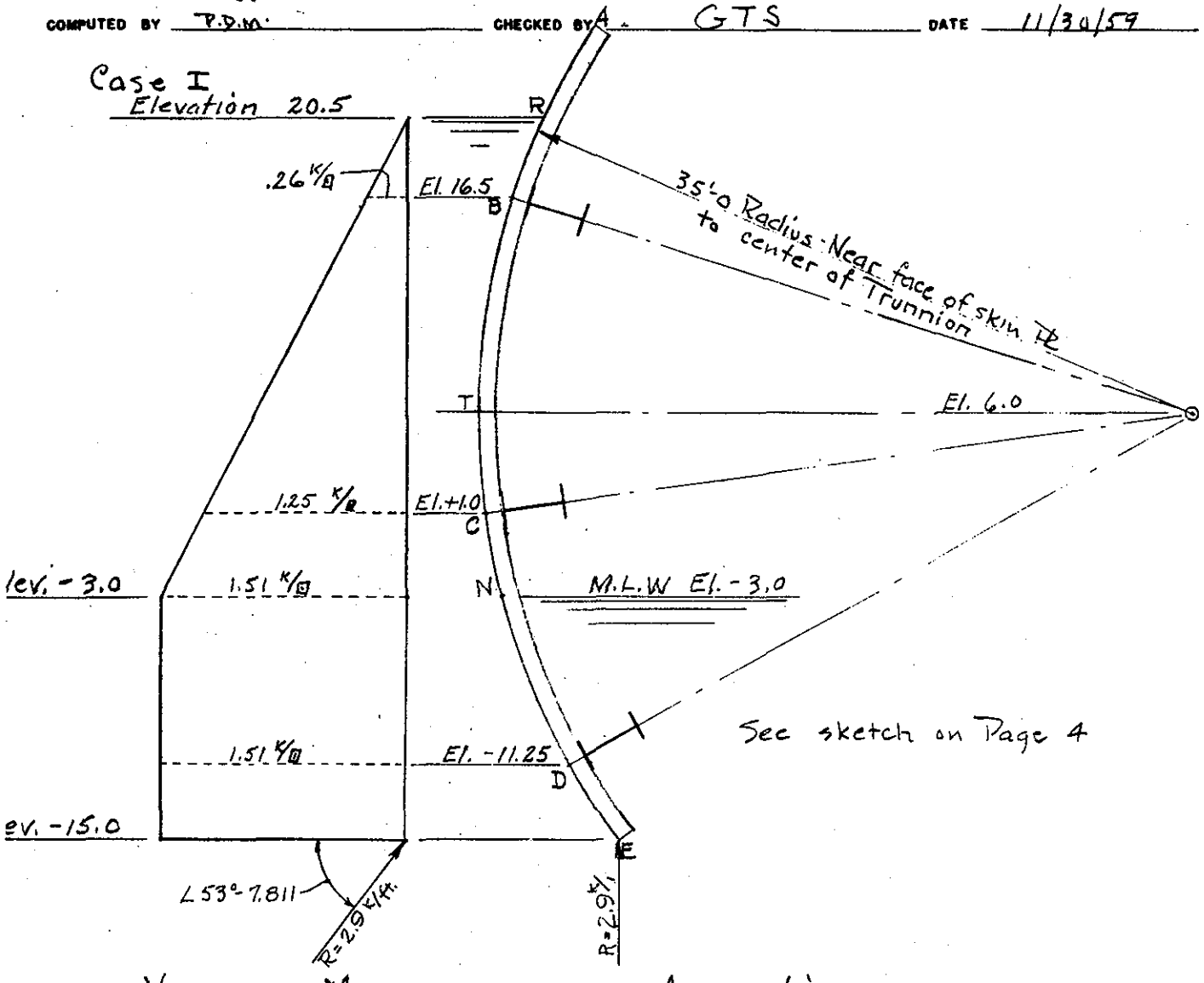
VE VE = 35 - WN - EF = 35 - 1.1770 - 28.0000 = 5.8230

UE UE = DG - 28 = 35 sin $\angle DPG$ - 28 = 35 x .87027 - 28
UE = 30.4595 - 28.0000 = 2.4595'

XR XR = 35 - RS RS = 35 sin $\angle RPS$ = 35 x .91014 = 31.8549
XR = 35.0000 - 31.8549 = 3.1451

YA YA = 35 - AK AK = 35 sin $\angle APK$ = 35 x .83982 = 29.3937
YA = 35 - 29.3937 = 5.6063'

SUBJECT FOX POINT GATE STRUCTURE
COMPUTATION CASE I LOADING
COMPUTED BY P.D.M. CHECKED BY A. GTS DATE 11/30/59



VERTICAL MEMBERS

Arc lengths

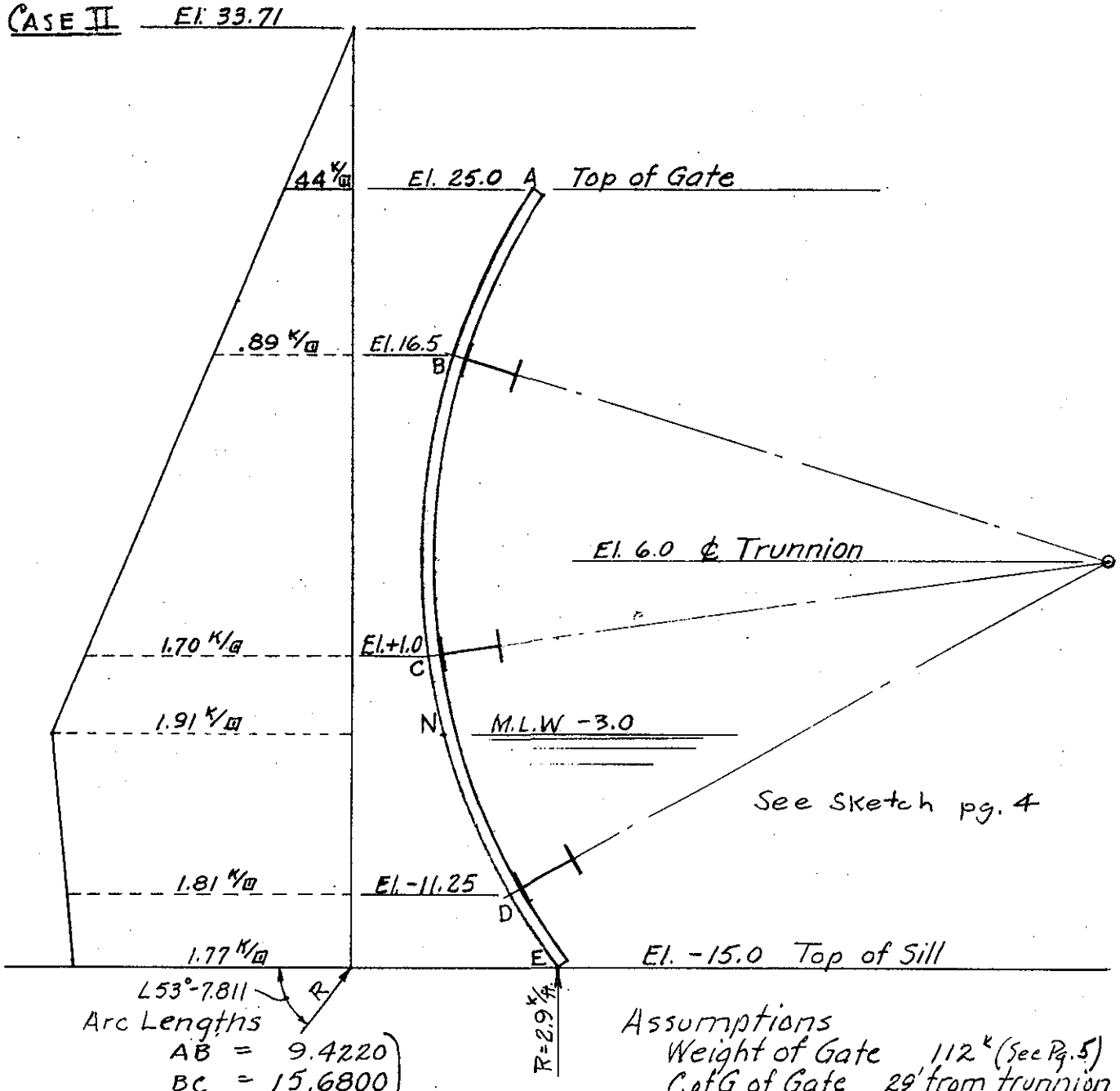
AB	9.4220'
BC	15.6800'
CD	13.0095'
DE	4.4975'
RB	4.29
CN	4.08

See Page 7.

Assumptions
Weight of Gate 112^k (See Pg. 5)
C. of G of Gate 29' from trunnion (See Pg. 5)
Spacing of Vertical Members 2'-0" c.c.
Sill Reaction $\frac{112}{40} \times \frac{29}{28} = 2.9$ K/'
Still Water Level, El. 20.5 (Bay side)

SUBJECT FOX POINT GATE STRUCTURE
COMPUTATION CASE II LOADING
COMPUTED BY P.D.M. CHECKED BY GTS DATE 12/2/59

CASE II



Arc Lengths

AB	=	9.4220
BC	=	15.6800
CD	=	13.0095
DE	=	4.4975
CN	=	4.08
ND	=	8.93

See Page 7

Assumptions

Weight of Gate 112^k (See Pg. 5)
C. of G of Gate 29' from trunnion (See Page 5)
Spacing of Vertical Members 2'-0" c.c.
Sill Reaction 2.9 K/ft (See Pg. 8)

SUBJECT FOX POINT GATE STRUCTURE
COMPUTATION COMBINED CASE I + II
COMPUTED BY P.J.M. CHECKED BY GTS DATE

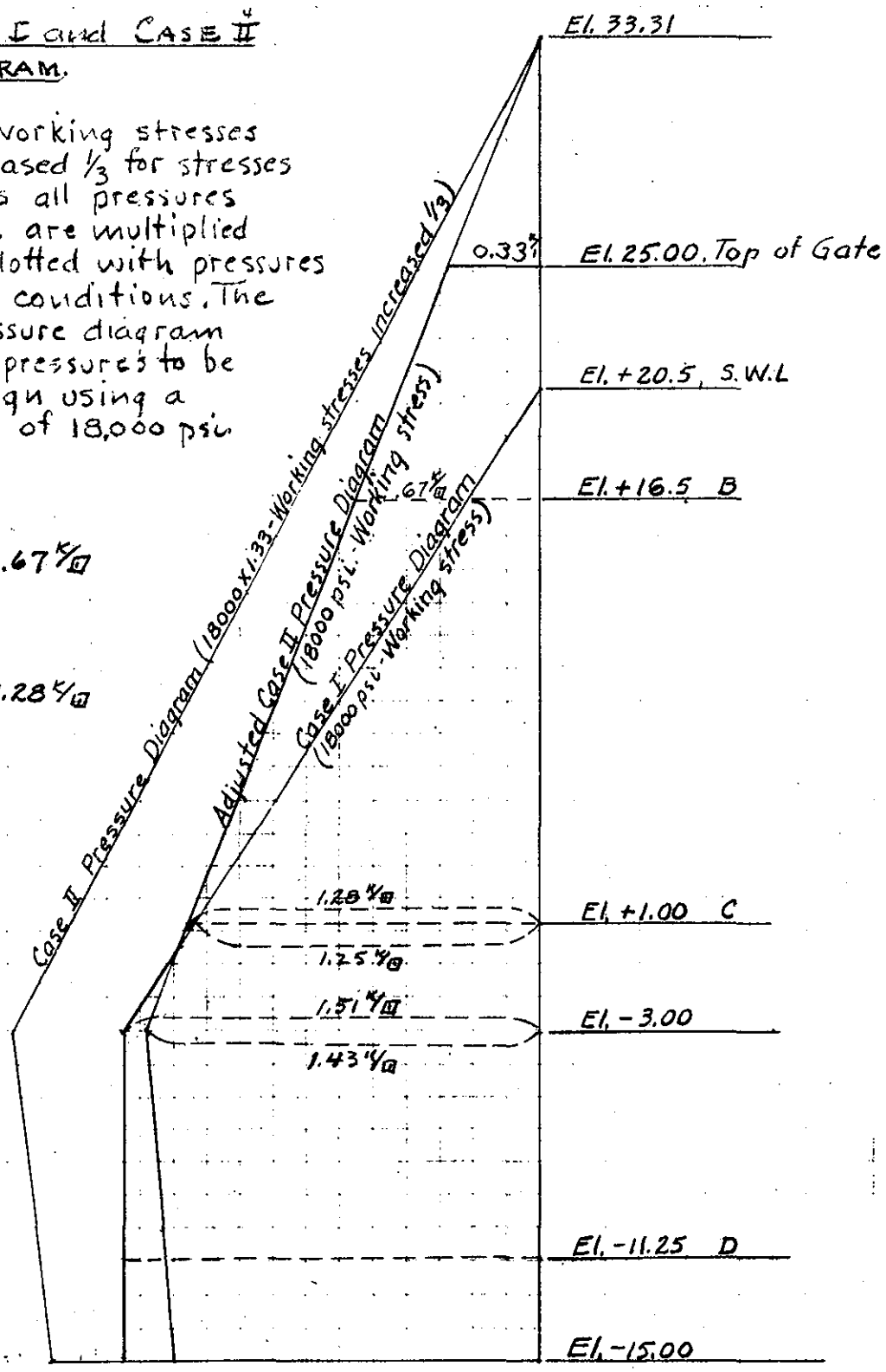
COMBINED CASE I and CASE II
LOADING DIAGRAM.

Since all working stresses may be increased 1/3 for stresses due to waves all pressures due to waves are multiplied by .75 and plotted with pressures due to Case I conditions. The resulting pressure diagram indicates the pressures to be used for design using a basic stress of 18,000 psi.

Pressure @ B
$1.43 \times \frac{16.81}{36.31} = .67^{k}/\square$

Pressure @ C
$1.43 \times \frac{32.31}{36.31} = 1.28^{k}/\square$

Pressure @ D
$1.51^{k}/\square$



COMBINED PRESSURE DIAGRAM

SUBJECT FOX POINT GATE STRUCTURE
COMPUTATION Vertical Stiffeners
COMPUTED BY P.D.M. CHECKED BY GTS DATE

Combined Case I and Case II

Arc lengths - AB = 9.42, BC = 15.68, CD = 13.01, DE = 4.50,
RB = 4.29, CN = 4.08, ND = 8.93 - See Page 9.

FEM.

$M_{BA} = .33 \times \frac{9.42^2}{2} + .35 \times \frac{9.42^2}{6} = 14.79 + 5.18 = \underline{19.97}^{1-K}$

$M_{FBC} = \frac{1}{12} \times .68 \times 15.68^2 + \frac{1}{30} \times .6 \times 15.68^2 = 13.93 + 4.92 = \underline{18.85}^{1-K}$

$M_{FCB} = \frac{1}{12} \times .68 \times 15.68^2 + \frac{1}{20} \times .6 \times 15.68^2 = 13.93 + 7.38 = \underline{21.31}^{1-K}$

$M_{FCD} = \frac{1}{12} \times 1.28 \times 13.01^2 + .12 \times \frac{4.08}{2} \times .23 \times 13.01 + .077 \times .23 \times 8.93 \times 13.01 =$
$18.05 + .73 + 2.06 = \underline{20.84}^{1-K}$

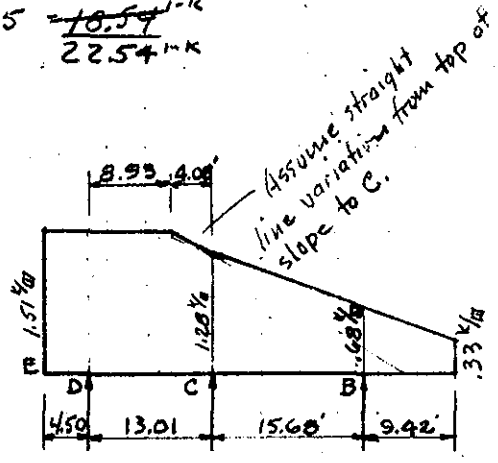
$M_{FDC} = 18.05 + .036 \times \frac{4.08}{2} \times .23 \times 13.01 + .11 \times 8.93 \times .23 \times 13.01 =$
$18.05 + .22 + 2.94 = \underline{21.21}^{1-K}$

$M_{DE} = 1.51 \times \frac{4.50^2}{2} + 2.9 \times 2.5 = \cancel{11.29} + 7.25 = \cancel{18.54}^{1-K}$
15.29 22.54^{1-K}

RELATIVE STIFFNESS

$CB = \frac{13.01}{15.68} = .83$ 5

$CD = \frac{15.68}{15.68} = 1$ 6



DISTRIBUTION FACTOR

$D_{FA} = 1$

$D_{FCB} = \frac{.83}{1.83} = .45$

$DF_{CD} = \frac{1}{1.83} = .55$

$DF_E = 1$

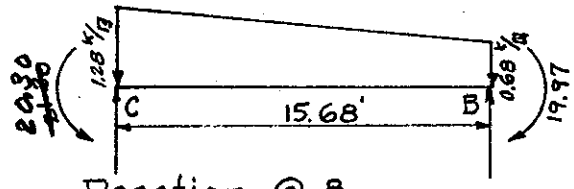
JOINT		D		C		B	
MEMBER			DC	CD	CB	BC	
K			6	6	5	5	
CYCLE	D.F.		1	.55	.45	1	
1	FEM	22.54 ~~-18.54~~	+ 21.21	- 20.84	+ 21.31	- 18.85	+ 19.97
	BAL.		~~+ 2.33~~	- .26	- .21	- 1.82	
2	CO		- .13	~~+ 0.67~~	- .91	- .11	
	BAL.		+ .13	+ 0.13	~~+ 0.11~~	+ .11	
3	CO		+ ~~0.06~~	+ .07	+ .06	+ ~~0.05~~	
	BAL	- 22.54	- ~~0.06~~	- .07	- .06	- ~~0.05~~	
		~~-18.54~~	~~18.54~~	~~-21.20~~	~~+21.20~~	- 19.97	+19.97
			+22.54	-20.30	+20.30		

SUBJECT FOX POINT GATE STRUCTURE
COMPUTATION VERTICAL STIFFENERS
COMPUTED BY P.D.M. CHECKED BY GTS DATE

COMBINED CASE I and CASE II
Member BC

M = 0 From B @: $\cancel{6.83}$ 6.87 $x = 19.97 + \left(0.68\frac{x^2}{2}\right) + \left(\frac{0.60}{15.68} \times \frac{x^3}{6}\right)$

$x = 3.62' \pm$



Reaction @ B
Mom. about C

$R_B = \frac{1}{15.68}\left(-\cancel{21.20}\ 20.30 + 19.97 + .68 \times \frac{15.68^2}{2} + .6 \times \frac{15.68^2}{6}\right)$

$R_B = \frac{1}{15.68}\left(\cancel{-1.23}\ -0.33 + 83.59 + 24.59\right) = \cancel{6.83}\ 6.87^K$

Reaction @ C
Mom. about B

$R_C = \frac{1}{15.68}\left(+\cancel{21.20}\ 20.30 - 19.97 + .68 \times \frac{15.68^2}{2} + .6 \times \frac{15.68^2}{3}\right)$

$R_C = \frac{1}{15.68}\left(\cancel{1.23}\ 0.33 + 83.59 + 49.18\right) = \cancel{8.54}\ 8.52^K$

Shear = 0 @ 8.16' from B toward C

$\cancel{6.83}\ 6.87 - .68x - xy \qquad y = \frac{.6x}{2 \times 15.68}$

$.6x^2 + 21.32x - 214.19 = 0$

$x = 8.16'$

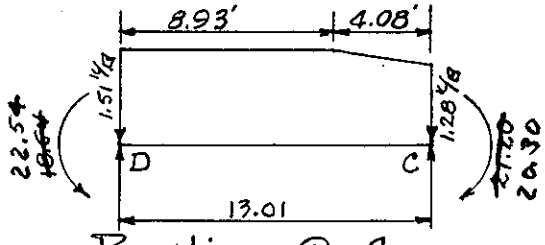
Positive Moment (max.)

$+M = -\cancel{6.83}\ 6.87 \times 8.16 + .68 \times \frac{8.16^2}{2} + \frac{.1 \times 8.16^3}{15.68} + 19.97$

$+M = \cancel{55.99}\ 56.0 - 22.64 - 3.47 - 19.97 = \cancel{9.65}\ 9.92^{1-K}$

Member CD

M = 0 @ "x" from C



$\cancel{9.61}\ 9.24 = x = 21.20 + 1.28\frac{x^2}{2} + \frac{0.23}{4.08}\frac{x^3}{6}$

$x = 2.70 \pm$

Reaction @ C
Mom. about D

$R_C = \frac{1}{13.01}\left(1.28 \times \frac{13.01^2}{2} + .23 \times \frac{8.93^2}{2} + .23 \times \frac{4.08}{2} \times 10.29 - \cancel{18.54}\ -22.54 + \cancel{21.20}\ +20.30\right)$

$R_C = \frac{1}{13.01}\left(108.33 + 9.17 + 4.83 \cancel{+4.66}\ -2.24\right) = \frac{\cancel{124.99}\ 120.09}{13.01} = \cancel{9.61}^K\ 9.24^K$

SUBJECT FOX POINT GATE STRUCTURE
COMPUTATION VERTICAL STIFFENERS
COMPUTED BY PDM. CHECKED BY GTS DATE

COMBINED CASE I and CASE II
Member CD
Reaction @ D
Mom. about C 22.54 - 20.30

$R_D = \frac{1}{13.01}\left(\cancel{+15.54 - 21.70} + 1.28 \times \frac{13.01^2}{2} + .23 \times \frac{4.08^2}{3} + .23 \times 8.93 \times 8.55\right.$

$R_D = \frac{1}{13.01}\left(\cancel{-2.66}\ +2.24 + 108.33 + 1.28 + 17.56\right) = \frac{\cancel{124.51}\ 129.41}{13.01} = \cancel{9.57}^K\ 9.94^K$

Shear = 0 @ 6.34' from D towards C

$\cancel{9.57}\ 9.94 - 1.51x = 0$ 9.94 6.59'

$x = \frac{\cancel{9.57}\ 9.94}{1.51} = \cancel{6.34'}$

Positive Moment (max.) 22.54 $\overline{6.59}^2$

$+M = \cancel{9.57} \times \cancel{6.34}\ 9.94 \times 6.59' - \cancel{18.54} - 1.51 \times \frac{\cancel{6.34}\ 6.59^2}{2}$

$65.6 - 22.54 - 32.85 = 11.21^{1-K}$

$+M = \cancel{60.67} - \cancel{18.54} - \cancel{30.95} = \cancel{11.78}^{1-K}$

Total Reactions

E	D	C	B	A
6.80	~~9.57~~ 9.94	~~9.61~~ 9.24 ~~8.54~~ 8.52	~~6.83~~ 6.87	4.76
(Sill Reaction) 1.89	.94	.52		
	~~9.57~~ 9.94	~~8.54~~ 8.52	4.76	
	6.80	~~9.61~~ 9.24	~~6.83~~ 6.87	
	~~1.89~~	~~+8.15~~	~~11.59~~	
	~~18.23~~ 18.80 K	17.76 K	11.63 K	

$\frac{7}{16}$" PL: Arc length = 9.42 + 3.62 (p. 12) = 13.00'

∡ APT = 32° - 51.25' = 32.854° ∡ APL = 13.00 ÷ 35 rad = $180° \times \frac{13}{35\pi}$ = 21.28°

∴ ∡ LPT = 32.85 - 21.28 = 11.57° = 11° - 34.2'

y = 35' x sin 11°-34.2' = 35' x 0.20057 = 7.0' elev. = +6.0 +7.0 = +13.0'

$\frac{1}{2}$" PL: Arc length = 13.01 + 4.50 - 2.70 (p. 12) = 14.83'

∡ TPE = 36° - 51.80' = 36.863° ∡ QPE = 14.83 ÷ 35 rad = $180° \times \frac{14.83}{35\pi}$ = 24.28°

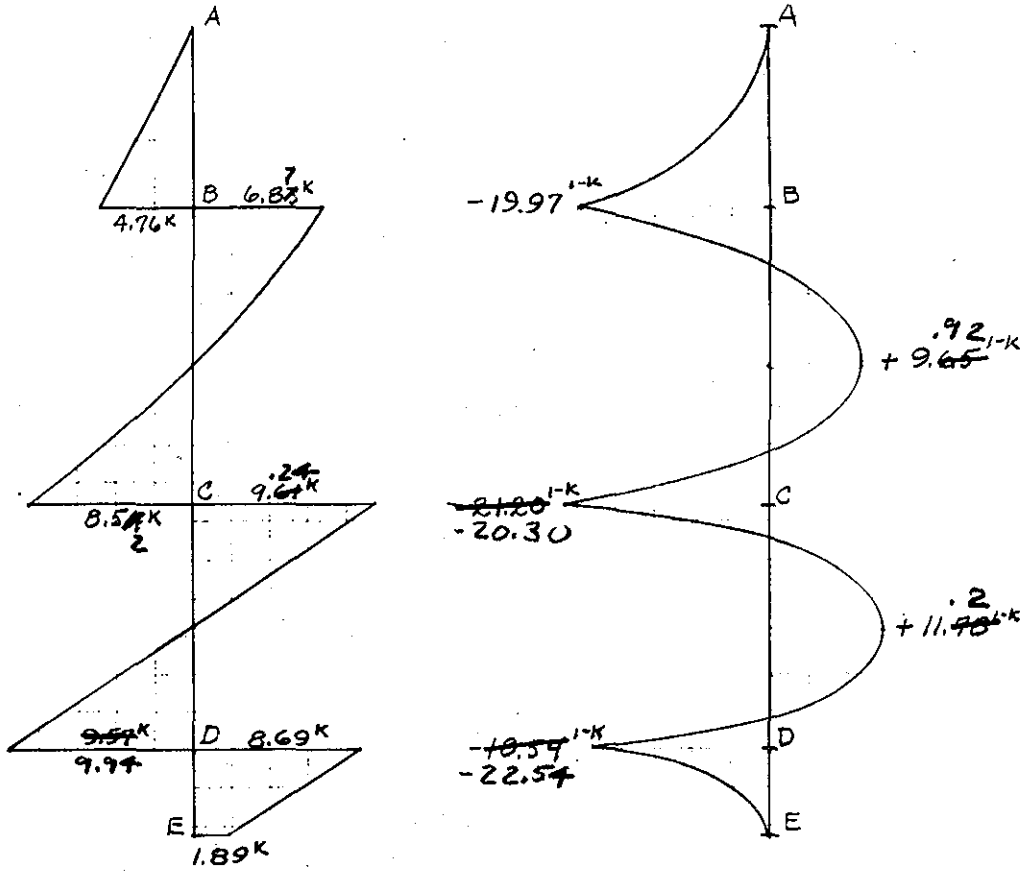
∴ ∡ TPQ = 36.86° - 24.28° = 12.58°

y = 35' x sin 12.58° = 35' x 0.2175 = 7.61' elev. = +6.00 - 7.61 = -1.61'

NED FORM 225
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT FOX POINT GATE STRUCTURE
COMPUTATION VERTICAL STIFFENERS
COMPUTED BY T.D.M. CHECKED BY GTS DATE



SHEAR PER FT.

MOMENT PER FT.

SUBJECT FOX POINT GATE STRUCTURE
COMPUTATION SKIN PLATES
COMPUTED BY P.D.M. CHECKED BY GTS DATE

COMBINED CASE I and CASE II
Skin Pl Design

Assume skin Pl to be continuous member spanning horizontally across vertical members that are spaced 2'-0" c.c. The first vertical member at each end is located 1'-0" from the face of the pier.

Compute moment for a loading of 1 K/1 on a 1 ft. wide strip.

F.E.M.

$M_{BA} = 1 \times \frac{1^2}{2} = 0.5^{1-K}$ $\frac{1}{1.75} = .57$ $\frac{.75}{1.75} = .43$

$M_{FBC} = 1 \times \frac{2^2}{12} = 0.33^{1-K}$

A	B		C		D		E	F	G
	3/4	.57	.43	1		1	1	1	
-.50	+.33	-.33	+.33	-.33	+.33	-.33	+.33		
	+.17	0	0	0	0	0	0		
	0	+.09	0	0	0	0	0		
	0	-.05	-.04	0	0	0	0		
	-.03	.0	0	-.02	0	0	0		
	+.03	0	.0	+.01	+.01	0	0		
	+.50	-.29	+.29	-.34	+.34	-.33	+.33		

$+M_{BC} = 1 \times \frac{(2)^2}{8} - (.50 + .29)\frac{1}{2} = .11^{1-K}$

$+M_{CD} = 0.5 - (.29 + .34)\frac{1}{2} = .18^{1-K}$

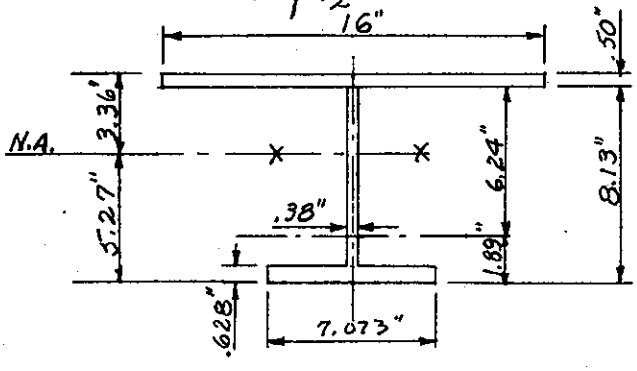
$+M_{DE} = 0.5 - (.34 + .33)\frac{1}{2} = .16^{1-K}$

$+M_{EF} \quad 0.5 - (.33 + .33)\frac{1}{2} = .17^{1-K}$

Design skin Pl for maximum moment of $.34^{1-K}$ and provide stiffeners at cantilever end of plate.

SUBJECT FOX POINT GATE STRUCTURE
COMPUTATION SKIN PLATES
COMPUTED BY P.D.M. CHECKED BY GTS DATE

COMBINED CASE I and CASE II
Skin Pl Design
Try ½" Pl with ST8WF25 at El-11.25 (Pt. D)



Effective width of ½" Pl
$\frac{1}{2} \times 16 \times 2 = 16"$

12" width $S_{Pl} = \frac{bd^2}{6} = \frac{12 \times .5^2}{6} = .50 \text{ in.}^3$

16" width $S_{Pl} = \frac{bd^2}{6} = \frac{16 \times .5^2}{6} = .667 \text{ in.}^3$

$I_{Pl} = \frac{bd^3}{12} = \frac{16 \times .5^3}{12} = .167 \text{ in.}^4$

½ Pl.

$w = 1.51$

$M_{HOR} = 1.51 \times .34 = .513^{1\text{-}K}$

$f_{HOR} = \frac{.513 \times 12}{.5} = 12.31^{K}/\square < 18.0^{K}/\square$ O.K.

½ Pl with ST8WF25
Location of neutral axis
Mom. about edge of flange of ST8WF

ST8WF25
$A = 7.35 \text{ in}^2$
$I_x = 42.2 \text{ in}^4$

$(\frac{1}{2} \times 16 \times 8.38 + 7.35 \times 1.89)\frac{1}{8 + 7.35} = y_0 = 5.27"$

$I_{xx} = I_0 + Ad^2$

	I_0 =	A	d	Ad^2
½ Pl	.17	8.00	3.11	77.4
ST8WF25	42.2	7.35	3.38	84.1
	42.37			161.5

$I_{xx} = 203.9 \text{ in}^4$

$S_{MIN} = \frac{203.9}{5.27} = 38.6 \text{ in}^3$

Max M_{VERT} = $2 \times$ ~~18.54~~ 22. = ~~37.08~~ 45.08 $^{1\text{-}K}$ for 2' width See Page 14

$f_{vert} = \frac{\cancel{37.08}\ 45. \times 12 \times 3.36}{203.9} = \cancel{7.71}\ 8.92^{K}/\square < 18^{K}/\square$ O.K.

Tension

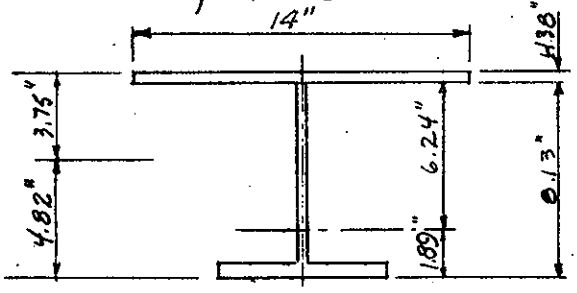
Combined stresses

$f_{max} = \frac{1}{2}(\sigma_{max} - \sigma_{max}) = \frac{1}{2}[+12.31 - (-\cancel{7.71}\ -8.92)]$

$f_{max} = \cancel{9.52}\ 10.61^{K}/\square < 12^{K}/\square$ O.K.

SUBJECT FOX POINT GATE STRUCTURE
COMPUTATION SKIN PLATES
COMPUTED BY P.J.M. CHECKED BY GTS DATE

COMBINED CASE I and CASE II
Skin Pl Design
Try 7/16" Pl with ST8WF25 at El. -11.25 (Pt. D)



Effective width of 7/16" Pl.
$7/16 \times 16 \times 2 = 14"$

12" width $S_{Pl} = \frac{bd^2}{6} = \frac{12 \times .438^2}{6} = .384 \text{ in}^3$

14" width $S_{Pl} = \frac{bd^2}{6} = \frac{14 \times .438^2}{6} = .448 \text{ in}^3$

$I_{Pl} = \frac{bd^3}{12} = \frac{14 \times .438^3}{12} = .098 \text{ in}^4$

$A_{PL} = 14 \times .438 = 6.125$

7/16 Pl

$w = 1.51 \text{ K/ft}$

$M_{HOR} = 1.51 \times .34 = .513 \text{ 1-K}$

$f_{HOR} = \frac{.513 \times 12}{.384} = 15.87 \text{ K/□} < 18 \text{ K/□}$ O.K.

ST8WF25
$A = 7.35 \text{ in}^2$
$I_{xx} = 42.2 \text{ in}^3$

7/16 Pl with ST8WF25 at El. -11.25 (Pt. D)
Location of neutral axis
Mom. about edge of flange of ST8WF25

$(7.35 \times 1.89 + 6.125 \times 8.75) \frac{1}{7.35 + 6.125} = y_0 = \frac{65.1}{13.48} = 4.82"$

$I_{x-x} = I_0 + Ad^2$

	I_0	A	d	Ad^2
1/2 Pl	.10	6.13	3.53	76.4
ST8WF25	42.20	7.35	2.93	63.2

$I_{xx} = 42.3 + 137.6 = 181.9 \text{ in}^4$

Max. $M_{VERT} = 2 \times \cancel{18.54}\ 22 = \cancel{37.08}\ 45. \text{ 1-K}$ for 2' width See Page 14

$f_{VERT} = \frac{\cancel{37.08}\ 45. \times 12 \times 3.75}{181.9} = \cancel{4.18}\ 11.18 \text{ K/□}$ tension $< 18 \text{ K/□}$

Combined Stress

$f_{max} = \frac{1}{2}(\sigma_{max} - \sigma_{min}) = \frac{1}{2}[+15.87 - (\cancel{-4.18}\ 11.18)]$

$f_{max} = \cancel{12.5}\ 13.52 \text{ K/□} > 12 \text{ K/□}$ Use 1/2" Pl at Point D.

SUBJECT FOX POINT GATE STRUCTURE
COMPUTATION SKIN FRAMES
COMPUTED BY P.D.M. CHECKED BY GTS DATE

COMBINED CASE I and CASE II
Skin Pl Design
Try 7/16" Pl with ST8WF25 at El +1.00 (Pt. C)

7/16 Pl
$\omega = 1.28^{k}/\square$
$M_{HOR} = 1.28 \times .34 = .435^{1\text{-}k}$

$f_{HOR} = \frac{M_{HOR}}{S} = \frac{.435 \times 12}{.384} =$ For value of S see Page 17
$f_{HOR} = 13.60^{k}/\square < 18^{k}/\square$ O.K

7/16 Pl with ST8WF25
For properties of combined 7/16 Pl and ST8WF25 see Page 17

$Max. M_{VERT} = 2 \times \cancel{21.20}\ 20.30 = \cancel{42.40}\ 40.6^{1\text{-}k}$ for 2' width See Page 14

$f_{vert} = \frac{\cancel{42.40}\ 40.6 \times 12 \times 3.75}{181.9} = 10.8^{k}/\square$ tension $< 18^{k}/\square$ O.K

Combined Stresses.
$f_{max} = \frac{1}{2}(\sigma_{max} - \sigma_{min}) = \frac{1}{2}[13.800 - (-13.600)] = \cancel{12.05}\ 11.8^{k}/\square$

Try 7/16" Pl with ST8WF25 at El. +16.5 (Pt. B)
$\omega = .67^{k}/\square$
$M_{HOR} = .67 \times .34 = .228^{1\text{-}k}$
$f_{hor} = \frac{M_{HOR}}{S} = \frac{.228 \times 12}{.384} = 7.12^{k}/\square < 18000$ O.K

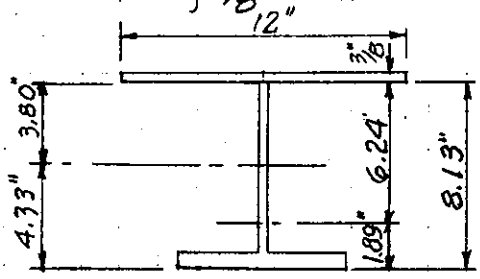
7/16 Pl with ST8WF25
$Max. M_{VERT} = 2 \times 19.97 = 39.94^{1\text{-}k}$ for 2' width See Page 14

$f_{VERT} = \frac{39.94 \times 12 \times 3.75}{181.9} = 9.89^{k}/\square$ tension $< 18^{k}/\square$ O.K

Combined Stresses
$f_{max} = \frac{1}{2}(\sigma_{max} - \sigma_{min}) = \frac{1}{2}[7.120 - (-9.890)] = \underline{8.51^{k}/\square} < 12^{k}/\square$

SUBJECT FOX POINT GATE STRUCTURE
COMPUTATION SKIN PLATES
COMPUTED BY PDM CHECKED BY GTS DATE

Combined Case I and Case II
Skin Pl. Design
Try 3/8" Pl with ST8WF25 at El. +16.5 (Pt. B)



Effective width of 3/8" Pl
$3/8 \times 16 \times 2 = 12"$

12" width $S_{Pl} = \frac{bd^2}{6} = \frac{12 \times .375^2}{6} = .281 \text{ in}^3$

$I_{Pl} = \frac{bd^3}{12} = .053 \text{ in}^4$

$A_{Pl} = .375 \times 12 = 4.5 \text{ sq. in}$

ST8WF25
$A = 7.35 \text{ in}^2$
$I_{xx} = 42.2 \text{ in}^3$

3/8" Pl
$w = .67 \text{ K/ft}$
$M_{HOR} = .67 \times .34 = .228 \text{ ft-K}$
$f_{HOR} = \frac{.228 \times 12}{.281} = 9.74 \text{ K/in}^2 < 18 \text{ K/in}^2$ O.K.

3/8" Pl with ST8WF25 at El. +16.5 (Pt. B)
Location of neutral axis
Mom. about edge of flange of ST8WF
$(7.35 \times 1.89 + 4.5 \times 8.32) \frac{1}{7.35 + 4.50} = y_0 = 4.33"$

$I_{x-x} = I_0 + Ad^2$

	I_0	A	d	Ad^2
3/8 Pl	.05	4.50	~~3.62~~ 3.98	~~59.0~~ 71.4
ST8WF25	42.20	7.35	2.44	43.8
				~~102.8~~ 115.2

I_{xx} $42.3 + \cancel{102.8} = \cancel{144.1}$ 115.2 42.3 157.5 in^4

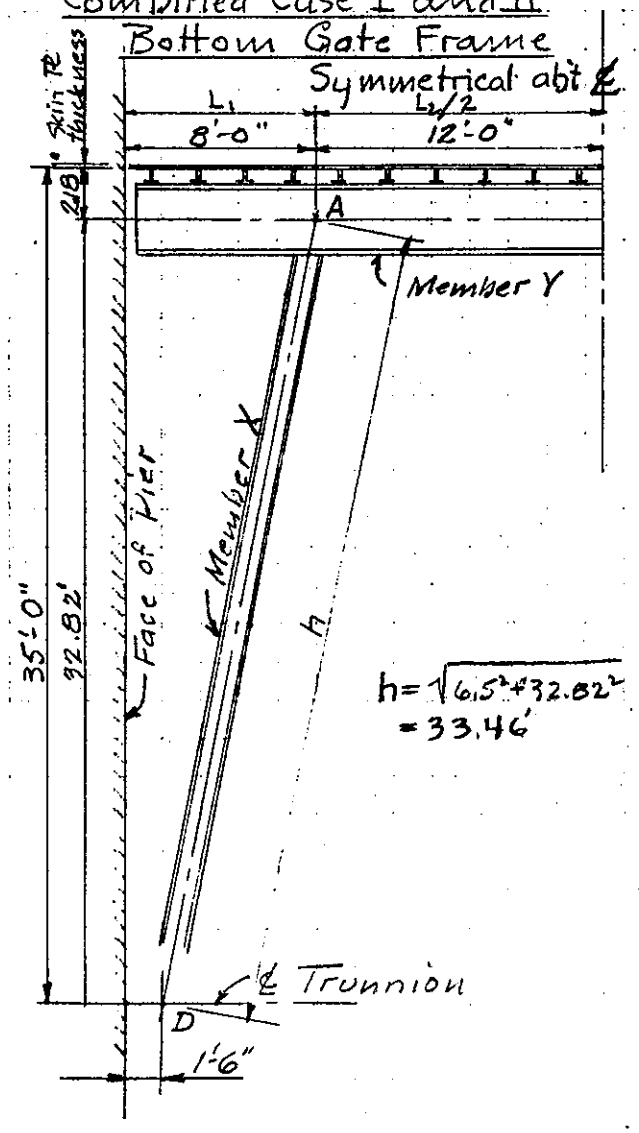
Max $M_{VERT} = 2 \times 19.97 = 39.94 \text{ ft-K}$ for 2' width See Page 14

$f_{VERT} = \frac{39.94 \times 12 \times 3.75}{\cancel{144.1} + 157.5} = \cancel{12.40}$ 11.4 K/in² tension < 18 K/in² O.K.

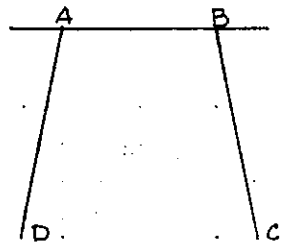
Combined Stress
$f_{max} = \frac{1}{2}(\sigma_{max} - \sigma_{min}) = \frac{1}{2}[\cancel{12.40} \; 11.4 - (-9.74)] = \cancel{11.07}$ 10.57 K/in² < 12 K/in²

SUBJECT FOX POINT GATE STRUCTURE
COMPUTATION GATE FRAMES - BOTTOM
COMPUTED BY P.D.M. CHECKED BY GTS DATE

Combined Case I and II
Bottom Gate Frame
Symmetrical abt ℄



$h = \sqrt{6.5^2 + 32.82^2}$
$= 33.46'$



Assume Member X is 14WF136
Member Y is 36WF160

$I_{AB} = 9738.8 \text{ in}^4$

$I_{AD} = 1593.0 \text{ in}^4$

$w = 18.\cancel{26}\,63 \text{ K/ft.}$ See Page 13
change negligible use 18.26

Moment from Cantilever
Ref. Hool & Kinne "Stresses in Framed Structures" Page 592.

$M_{CANT} = \frac{wL_1^2}{2} = \frac{18.26 \times 64}{2} = 584^{1-K}$

$M_{AD} = \frac{2M}{n+2}$ $\qquad n = \frac{I_{AB}\,h}{L_2\,I_{AD}}$

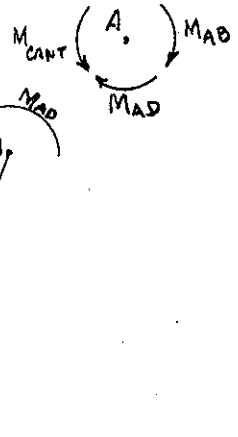
$M_{AB} = \frac{nM}{n+2}$ $\qquad n = \frac{9738.8 \times 33.46}{24 \times 1593.0}$

$M_{DA} = \frac{M}{n+2}$ $\qquad n = 8.52$

$M_{AD} = \frac{2 \times 584}{8.52+2} = 111^{1-K}$

$M_{AB} = \frac{8.52 \times 584}{8.52+2} = 473^{1-K}$

$M_{DA} = \frac{584}{8.52+2} = 55.5^{1-K}$

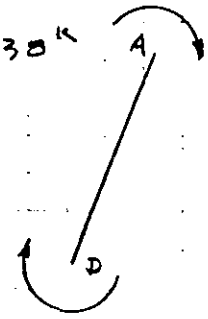


SUBJECT FOX POINT GATE
COMPUTATION BOTTOM GATE FRAME
COMPUTED BY P.J.M. CHECKED BY GTS DATE

Combined Case I and Case II
Bottom Gate Frame

Moment from load between supports.
Ref. Hool & Kinne - "Stresses in Framed Structures" Page 590

$n = 8.52 \quad W = 18.26 \times 24 = 438^{K}$



$$M_{AD} = \frac{WL_2}{6(n+2)} = \frac{438 \times 24}{6(8.52+2)} = 167^{1-K}$$

$$M_{DA} = \frac{WL_2}{12(n+2)} = 83.5^{1-K}$$

Moment due to temperature change
Ref. Kleinlogel "Rigid Frame Formulas" P. 277

Modulus of Elasticity $= E = 29{,}000{,}000$
Moment of Inertia $= I_{AB} = 9738.8\ in^4$
Coeff. of thermal exp. $= \epsilon = 6.5 \times 10^{-6}$
Change of temp in degrees $= t = 90°$
$K = n$ in previous calculations
$l = 37$ ft. (distance between centers of trunnions)

Constant $T = \dfrac{3 E I_{AB} \epsilon \Delta t\, l}{b h K N_1}$

$h = 32.82'$
$b = 24.00'$
$K = 8.52$
$N_1 = K + 2 = 10.52$

$$T = \frac{3 \times 29 \times 10^6 \times 9738.8 \times 6.5 \times 10^{-6} \times 90 \times 37 \times 12}{24 \times 12 \times 32.82 \times 12 \times 8.52 \times 10.52} = 21647$$

$$M_{DA} = T(K+1) = 21{,}647 \times 9.52 \times \frac{1}{12} = 17.2^{1-K}$$

$$M_A = -TK = 21{,}647 \times 8.52 \times \frac{1}{12} = 15.4^{1-K}$$

SUBJECT FOX POINT GATE STRUCTURE
COMPUTATION BOTTOM GATE FRAME
COMPUTED BY T.D.M. CHECKED BY GTS DATE

Combined Case I and Case II
Bottom Gate Frame
Total moments
Member AD

$M_A = -111 + 167 \pm 15 = +56 \pm 15$ $\quad \underline{+71}\,) \quad +41\,)$

$M_D = -55.5 + 83.5 \pm 17 = +28 \pm 17$ $\quad \underline{+45}\,) \quad +11\,)$

Member AB (Point A)

$M_A = -584 - 56 \pm 15 = -655^{1\text{-}K}\,) \quad -625^{1\text{-}K}\,)$

$+M = \frac{1}{8} \times 18.26 \times 24^2 - 625 = 690^{1\text{-}K}$

Axial load, P
Member AB

$20 \times 18.26 \times \frac{6.5}{32.82} + \left(\frac{71+45}{33.46}\right)\frac{32.82}{33.46}$

$72.3 + 3.4 = 77.7$ Say $\underline{78}^K = P$

Member AD

$20 \times 18.26 \times \frac{33.46}{32.82} = 372^K$

Horizontal Member stresses (AB)

$M_{MAX} = 690^{1\text{-}K} \qquad P = 78^K$

36WF160 $\quad A = 47.09$ sq. in $\quad S = 541.0$

$f_b = \frac{M}{S} = \frac{690 \times 12}{541} = 15.3$ ksi < 18 O.K

F_A = Allowable compressive stress. $= 16000 - K$ (EM 1110-1-2101)

$K = 0.485 \frac{l^2}{r^2} \qquad$ 36WF160 $\quad r_{xx} = 14.38 \quad r_{yy} = 2.42$

$K_{xx} = .485 \frac{(24 \times 12)^2}{14.38^2} = 125$

$K_{yy} = .485 \frac{(12 \times 12)^2}{2.42^2} = 1720$

Allowable comp. stress $= 16000 - 1720 = 14280$ psi or $\underline{14.28}$ ksi

$f_a = \frac{78}{47.09} = 1.66$ ksi

$\frac{f_a}{F_A} + \frac{f_b}{F_B} = \frac{15.3}{18} + \frac{1.66}{14.28} = .850 + .116 = .966 < 1$ O.K

Use 36WF160

SUBJECT FOX POINT GATE STRUCTURE
COMPUTATION BOTTOM GATE FRAME
COMPUTED BY P.D.M. CHECKED BY GTS DATE

Combined Case I and Case II
Bottom Gate Frame
Strut member stresses (AD)
$M = 71^{1\cdot K}$ $P = 372^{K}$

14WF 136 $A = 39.98$ $S_{xx} = 216.0\ in^3$ $S_{yy} = 77\ in^3$
$r_{xx} = 6.31''$ $r_{yy} = 3.77''$

$\frac{ld}{bt} = \frac{33.46 \times 12 \times 14.75}{14.74 \times 1.063} = 378 < 667$ $F_b = 18$ ksi

$16000 - K$ $K = .485 \frac{l^2}{r^2}$

$K_{xx} = .485 \frac{(33.46 \times 12)^2}{(6.31)^2} = 1970$ Critical

$K_{yy} = .485 \frac{(13 \times 12)^2}{(3.77)^2} = 830$ Not critical

$16000 - 1970 = 14030$ psi or 14.03 ksi

$f_b = \frac{71 \times 12}{216} = 3.94$ ksi $F_b = 18000$

$f_a = \frac{P}{A} = \frac{372}{39.98} = 9.31$ ksi $F_A = 14.03$

$\frac{f_a}{F_a} + \frac{f_b}{F_b} = \frac{9.31}{14.03} + \frac{3.94}{18} = .664 + .219 = .883$

Too low. Try 14WF127

SUBJECT: Fox Point Gate Structure
COMPUTATION: Bottom Gate Frame
COMPUTED BY: PDM CHECKED BY: GTS DATE:

Combined Case I and Case II
Bottom Gate Frame
See sketch on Page 20

Assume Member X is 14WF127
Member Y is 36WF160

$I_{AB} = 9738.8 \text{ in}^4$
$I_{AD} = 1476.7 \text{ in}^4$
$w = 18.26 \text{ k/ft}$ See Page 13

Moment from Cantilever
Ref. Hool & Kinne "Stresses in Framed Structures" Page 592

$$M_{CANT.} = \frac{wL_1}{2} = \frac{18.26 \times 64}{2} = \underline{584}^{1\text{-k}}$$

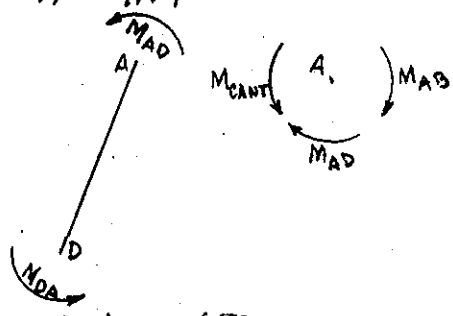
$$M_{AD} = \frac{2M}{n+2}$$

$$M_{AB} = \frac{nM}{n+2}$$

$$M_{DA} = \frac{M}{n+2}$$

$$n = \frac{I_{AB}\, h}{L_2 I_{AD}} = \frac{9738.8 \times 33.46}{24 \times 1476.7}$$

$$n = 9.19$$



$$M_{AD} = \frac{2 \times 584}{9.19+2} = \underline{104}^{1\text{-k}}$$

$$M_{AB} = \frac{9.19 \times 584}{9.19+2} = \underline{480}^{1\text{-k}}$$

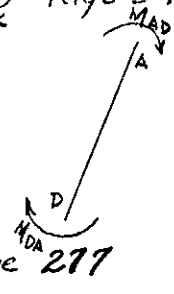
$$M_{DA} = \frac{584}{9.19+2} = \underline{52}^{1\text{-k}}$$

Moment from load between supports
Ref. Hool & Kinne "Stresses in Framed Structures" Page 590

$n = 9.19 \quad W = 18.26 \times 24 = 438^{k}$

$$M_{AD} = \frac{WL_2}{6(n+2)} = \frac{438 \times 24}{6(9.19+2)} = \underline{157}^{1\text{-k}}$$

$$M_{DA} = \frac{WL_2}{12(n+2)} = \underline{78.5}^{1\text{-k}}$$



Moment due to temperature change
Ref. Kleinlogel - "Rigid Frame Formulas" Page 277

$k = n$ = previous calculations
$E = 29 \times 10^6, \ \varepsilon = 6.5 \times 10^{-6}, \ t = 90°, \ \ell = 37$

$$T = \frac{3 E I_{AB} \varepsilon t \ell}{b h k N_1} \qquad h = 32.82, \ b = 24.00, \ k = 9.19, \ N_1 = 11.19$$

$$T = \frac{3 \times 29 \times 10^6 \times 9738.8 \times 6.5 \times 10^{-6} \times 90 \times 37 \times 12}{24 \times 12 \times 32.82 \times 12 \times 9.19 \times 11.19} = 18867$$

$$M_{DA} = T(k+1) = 18867 \times 10.19 \times 1/12 = 16.0^{1\text{-k}}$$

$$M_{AD} = Tk = 18867 \times 9.19 \times 1/12 = 14.4^{1\text{-k}}$$

SUBJECT FOX POINT GATE STRUCTURE
COMPUTATION BOTTOM GATE FRAME
COMPUTED BY P.D.M. CHECKED BY GTS DATE

Combined Case I and Case II
Bottom Gate Frame
Total moments
Member AD

$M_A = -104 + 157 \pm 14.4 = +67.4^{1\text{-}K} \quad +38.6^{1\text{-}K}$

$M_D = -52 + 78.5 \pm 16 = \quad +42.5^{1\text{-}K} \quad +10.5^{1\text{-}K}$

Member AB (Point A)

$M_A = -584 - 53 \pm 14.4 = -652 \quad -622$

$+M = \frac{1}{8} \times 18.26 \times 24^2 - 622 = 693^{1\text{-}K}$

Axial load, P
Member AB

$20 \times 18.26 \times \frac{6.5}{32.82} + \frac{(67+43)\ 32.82}{33.46 \times 33.46} =$

$72.3 + 3.2 = \underline{75.5^K}$

Member AD

$20 \times 18.26 \times \frac{33.46}{32.82} = \underline{372^K}$

Horizontal Member Stresses (AB)

$M_{max} = 693^{1\text{-}K} \quad P = 75.5^K$

36WF160 $\quad A = 47.09$ sq. in. $\quad S = 541.0$

$f_b = \frac{M}{S} = \frac{693 \times 12}{541} = 15.4$ ksi < 18 ksi $\quad$ O.K.

$F_A = 14.28$ ksi $\quad$ See Page 22

$f_a = \frac{75.5}{47.09} = 1.61$ ksi

$\frac{f_a}{F_a} + \frac{f_b}{F_b} = \frac{1.61}{14.28} + \frac{15.4}{18} = .113 + .855 = .968 < 1$ O.K.

SUBJECT FOX POINT GATE
COMPUTATION BOTTOM GATE FRAME
COMPUTED BY PDM CHECKED BY GTS DATE

Combined Case I and Case II
Bottom Gate Frame
Strut Member stresses (AD)
$M = 67.4 \quad P = 372^K$

14WF127 $\quad A = 37.33 \quad S_{xx} = 202.0\ in^3 \quad S_{yy} = 71.5\ in^3$

$r_{xx} = 6.29'' \quad r_{yy} = 3.76''$

$\frac{ld}{bt} = \frac{33.46 \times 12 \times 14.62}{14.69 \times .998} = 400 < 667 \quad F_b = 18\ ksi$

$16000 - K \quad K = .485 \frac{l^2}{r^2}$

$K_{xx} = .485 \times \frac{(33.46 \times 12)^2}{6.31^2} = 1970$ critical

$K_{yy} = .485 \times \frac{(13 \times 12)^2}{3.76^2} = 835$

$F_a = 16000 - 1970 = 14030$ psi or 14.03 ksi

$f_b = \frac{67.4 \times 12}{202.0} = 4.00\ ksi \quad F_b = 18\ ksi$

$f_a = \frac{P}{A} = \frac{372}{37.33} = 9.98\ ksi \quad F_a = 14.03$

$\frac{f_a}{F_a} + \frac{f_b}{F_b} = \frac{9.98}{14.03} + \frac{4}{18} = .711 + .222 = .933 < 1$

Lower Gate Frame
Horizontal member (AB) 36WF160
Struts (AD) 14WF127

SUBJECT FOX POINT GATE STRUCTURE
COMPUTATION MIDDLE GATE FRAME
COMPUTED BY PDM CHECKED BY GTS DATE

Combined Case I and Case II
Middle Gate Frame

See Sketch on Page 20

Assume Member "X" is 14WF136
Member "Y" is 36WF160

$I_{AB} = 9738.8 \text{ in.}^4$

$I_{AD} = 1476.7 \text{ in.}^4$

$w = 18.15^{K}/\text{ft.}$ See Page 13
17.76 however use above

Moment from Cantilever
Ref. Hool & Kinne "Stresses in Framed Structures" Page 592.

$M_{CANT} = \frac{wL_1}{2} = \frac{18.15 \times 64}{2} = 581^{1-K}$

$n = \frac{I_{AB} h}{L_2 I_{AD}} = \frac{9738.8 \times 33.46}{24 \times 1476.7}$

$n = 9.19$

$M_{AD} = \frac{2M}{n+2} = \frac{2 \times 581}{9.19+2} = 104^{1-K}$

$M_{AB} = \frac{nM}{n+2} = \frac{9.19 \times 581}{9.19+2} = 477^{1-K}$

$M_{DA} = \frac{M}{n+2} = \frac{581}{9.19+2} = 52^{1-K}$

Moment from load between supports
Ref. Hool & Kinne "Stresses in Framed Structures" Page 590

$n = 9.19 \quad W = 24w = 24 \times 18.15 = 436^{K}$

$M_{AD} = \frac{WL_2}{6(n+2)} = \frac{436 \times 24}{6(9.19+2)} = 156^{1-K}$

$M_{DA} = \frac{WL_2}{12(n+2)} = 78^{1-K}$

Moment due to temperature change

$M_{DA} = 16.0^{1-K}$

$M_{AD} = 14.4^{1-K}$

See Page 24

SUBJECT FOX POINT GATE STRUCTURE
COMPUTATION MIDDLE GATE FRAME
COMPUTED BY R.D.M. CHECKED BY GTS DATE

Combined Case I and Case II
Middle Gate Frame
Total moments.

Member AD

$M_A = -104 + 156 \pm 14.4 = +66.4^{1-K} + 38.6^{1-K}$

$M_D = -52 + 78 \pm 16.0 = +42^{1-K} + 10^{1-K}$

Member AB (Point A)

$M_A = -581 - 52 \pm 14.4 = -648^{1-K} - 619^{1-K}$

$+M = \frac{1}{8} \times 18.15 \times 24^2 - 619 = 688^{1-K}$

Axial load, P

Member AB

$20 \times 18.15 \times \frac{6.5}{32.82} + \frac{(66.4 + 42)}{33.46} \times \frac{32.82}{33.46}$

$71.9 + 3.2 = 75.1^K$

Member AD

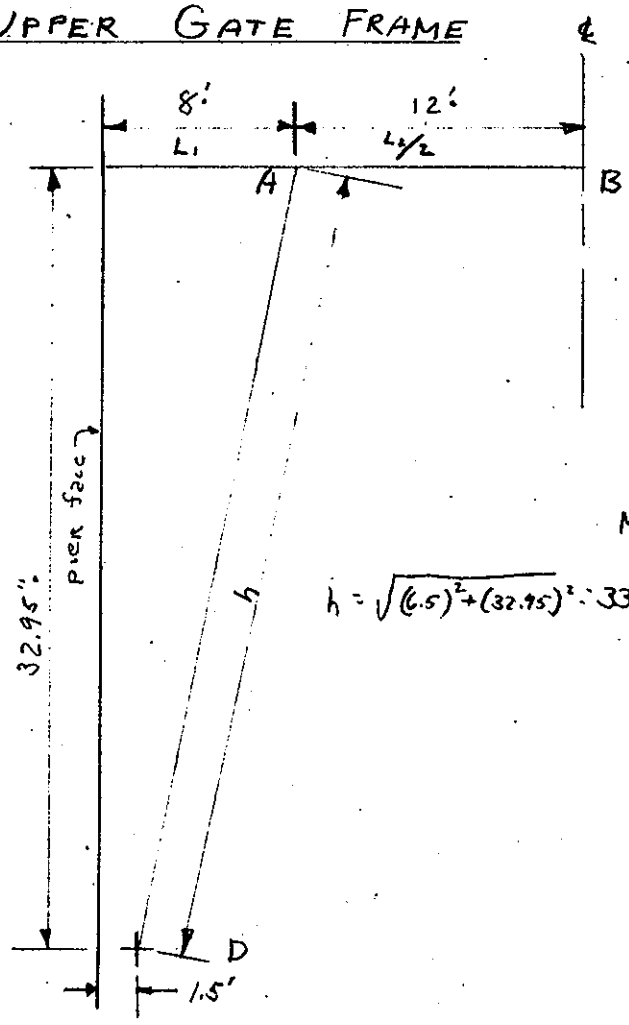
$20 \times 18.15 \times \frac{33.46}{32.82} = 370^K$

For size of members use same as bottom frame since loading is slightly less for middle frame than for bottom frame (18.15 K/ft. against 18.26 K/ft.)

Middle Gate Frame
Horizontal member (AB) 36 WF 160
Struts (AD) 14 WF 127

SUBJECT Fox Point Gates
COMPUTATION Upper Gate Frame
COMPUTED BY GTS CHECKED BY T.D.M. DATE

Upper Gate Frame



$h = \sqrt{(1.5)^2 + (32.95)^2} = 33.51'$

$w = 11.59$ k/'

member AB - 33WF130

member AD - 14WF 87

$I_{AB} = 6699$

$I_{AD} = 966.9$

Moment from Cantilever

$M = \frac{w L_2^2}{2}$

$M_{AD} = \frac{2M}{n+2}$

$M_{AB} = \frac{nM}{n+2}$

$M_{DA} = \frac{M}{n+2}$

$n = \frac{I_{AB} \times h}{L_2 \times I_{AD}}$

$n = \frac{6699 \times 33.51}{966.9 \times 24} = 9.67$

$M_{cant} = \frac{11.59 \cdot (8)^2}{2} = 371'^{-k}$

$M_{AD} = \frac{2 \times 371}{11.67} = 63.5'^{-k}$

$M_{AB} = \frac{9.67 \times 371}{11.67} = 307.5'^{-k}$

$M_{DA} = \frac{371}{11.67} = 31.8'^{-k}$

SUBJECT: Fox Point Gates
COMPUTATION: Upper Gate Frame
COMPUTED BY: GTS CHECKED BY: P.D.M. DATE:

Moment from Load between Supports

$$M_{AD} = \frac{WL_2}{6(n+2)} \qquad n = 9.67 \quad L_2 = 24'$$

$$M_{DA} = \frac{WL_2}{12(n+2)} \qquad W = 11.59 \times 24 = 278^K$$

$$M_{AD} = \frac{278 \times 24}{6 \times 11.67} = 95.4'^{-K}$$

$$M_{DA} = \frac{278 \times 24}{12 \times 11.67} = 47.7'^{-K}$$

Moment due to Temp. Change

$$T = \frac{3 E I_{AB} \varepsilon \Delta t L}{b \times h \times k \times N_1}$$

$$k = \frac{I_{AB}}{I_{AD}} \times \frac{S}{b}$$

$$= \frac{6699}{966.9} \times \frac{33.51}{24} = 9.67$$

$$N_1 = k + 2 = 11.67$$

$E = 29 \times 10^6$
$\Delta t = 90°$
$\varepsilon = 6.5 \times 10^{-6}$
$I_{AB} = 6699$
$b = 24'$
$L = 37'$
$h = 32.95'$
$S = 33.51'$
$I_{AD} = 966.9$

$$T = \frac{3 \times 29 \times \cancel{10^6} \times 6699 \times 6.5 \times \cancel{10^{-6}} \times 90 \times 37 \times \cancel{12}}{24 \times 12 \times 32.95 \times \cancel{12} \times 9.67 \times 11.67}$$

$$= 11{,}750$$

$$M_D = T(k+1) \times \frac{1}{12} = 11.75\ (10.67)\ \frac{1}{12} = 10.4'^{-K}$$

$$M_A = T(k) \times \frac{1}{12} = 11.75\ (9.67)\ \frac{1}{12} = 9.5'^{-K}$$

SUBJECT Fox Point Gates
COMPUTATION Upper Gate Frame
COMPUTED BY GTS CHECKED BY R.D.M. DATE

Combined Loading

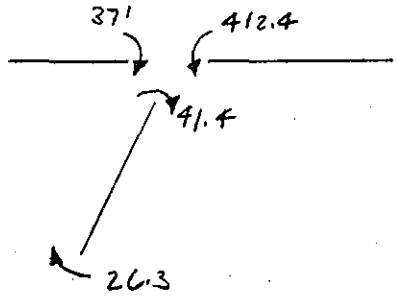
member AD

$M_A = 95.4 - 63.5 + 9.5 = 41.4^{'-k}$

$M_D = 47.7 - 31.8 + 10.4 = 26.3^{'-k}$

member AB

$M_A = 371 + 41.4 = 412.4^{'-k}$



$+M = 11.59 \times (24)^2 \times \frac{1}{8} - 307.5 - 95.4 + 9.5$

$= 834 - 393.4 = 441^{'-k}$

Axial load

member AB

$20 \times (11.59) \times \tan\theta + \frac{41.4 + 26.3}{33.51} \times \cos\theta$

$231.8 \times 0.198 + 2.02 \times 0.984$

$45.8 + 2.0 = 47.8^{k}$

member AD

$\frac{231.8}{\cos\theta} = \frac{231.8}{.984} = 235^{k}$

$\frac{231.8}{.984} + 2.02 \times \frac{6.5}{32.95} = 236$ Neglect

SUBJECT: Fox Point Gates
COMPUTATION: Upper Gate Frame
COMPUTED BY: GTS CHECKED BY: PDM DATE:

Girder Stresses (AB)

Max. M = 441'-K P = 47.8 K.

33 WF 130
A = 38.26 in². S = 404.8.

$$f_s = \frac{47.8}{38.26} + \frac{441 \times 12}{404.8}$$

$$1.25 + 13.1 = 14.35 \text{ K/in}^2 < 18$$

try 30 WF 116
A = 34.13 S = 327.9

$$f_s = \frac{47.8}{34.13} + \frac{441 \times 12}{327.9}$$

$$1.4 + 16.2 = 17.6 \text{ K/in}^2 < 18 \quad \text{O.K.}$$

Strut Member (AD)

M = 41.4'-K P = 235 K

14 WF 87
A = 25.56 S = 138.1 r = 6.15

$$\frac{Ld}{bt} = 33.51 \times 12 \times 1.4 = 562 < 667$$

$$F_b = 18 \text{ K/in}^2$$

$$f_b = \frac{41.4 \times 12}{138.1} = 3.6$$

$$\frac{f_b}{F_b} = \frac{3.6}{18} = 0.20$$

$$\frac{L}{r} = \frac{33.51 \times 12}{6.15} = 65.4 \quad F_a = 14.93 \text{ K/in}^2$$

$$f_a = \frac{235}{25.56} = 9.2 \text{ K/in}^2$$

$$\frac{f_a}{F_a} = \frac{9.2}{14.93} = 0.62$$

$$0.20 + 0.62 = 0.82 < 1$$

SUBJECT FOX POINT GATES
COMPUTATION UPPER GATE FRAME
COMPUTED BY GTS CHECKED BY PDM DATE

TRY 14WF78

$A = 22.94 \quad S = 121.1 \quad r = 6.09$

$$\frac{Ld}{bt} = 33.51 \times 12 \times 1.63 = 655 < 667$$

$$f_b = \frac{41.4 \times 12}{121.1} = 4.1$$

$$\frac{f_b}{F_b} = \frac{4.1}{18} = 0.23$$

$$\frac{L}{r} = \frac{33.51 \times 12}{6.09} = 66 \qquad F_a = 14.89 \ ^{k}/_{in^2}$$

$$f_a = \frac{235}{22.94} = 10.3 \ ^{k}/_{in^2}$$

$$\frac{f_a}{F_a} = \frac{10.3}{14.89} = 0.69$$

$$0.23 + 0.69 = 0.92 < 1.0 \quad \text{O.K.}$$

Use 30WF116 and 14WF78

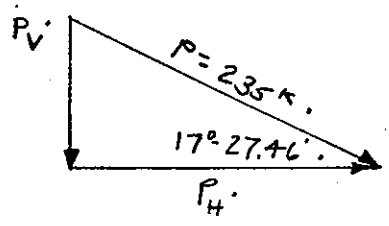
SUBJECT Fox Point Gates
COMPUTATION Trunnion Reactions
COMPUTED BY GTS CHECKED BY CCC DATE

Trunnion Reaction.

Top frame

$P = 235^K$. $M = 26.3'^{-K}$ $T = 47.8^K$.

$\angle BPJ = 72° - 32.54'$. $\angle TPB = 90 - [72° - 32.54'] = 17° - 27.46'$.



$P_V = \sin(17° 27.46') \times 235$
$= 0.300 \times 235 = 70.5^K \downarrow$

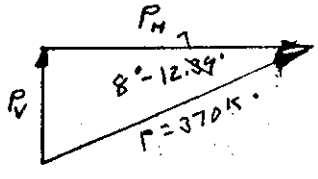
$P_H = \cos(17° 27.46') \times 235$

$0.954 \times 235 = 224^K \rightarrow$

Middle frame

$P = 370^K$. $M = 42'^{-K}$. $T = 75.1^K$.

$\angle CPH = 81° - 47.21'$. $\angle TPC = 90 - [81° - 47.21'] = 8° - 12.39'$



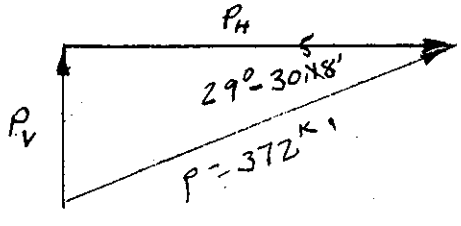
$P_V = \sin(8° - 12.39') \times 370$
$0.143 \times 370 = 53^K \uparrow$

$P_H = \cos(8° - 12.39') \times 370$
$.990 \times 370 = 366^K \rightarrow$

Lower frame

$P = 372^K$. $M = 42.5'^{-K}$. $T = 75.5^K$.

$\angle DPG = 60° - 29.42'$. $\angle TPD = 90 - [60° - 29.42] = 29° - 30.18'$



$P_V = \sin(29° 30.18) \times 372$
$= 0.498 \times 372 = 183^K \uparrow$

$P_H = \cos(29° - 30.18) \times 372$

$0.870 \times 372 = 324^K \rightarrow$

SUBJECT Fox Point Gates
COMPUTATION Trunnion Reactions
COMPUTED BY GTS CHECKED BY CCC DATE

Combined Reactions

$R_V = 183^k + 53^k - 70.5^k = 165.5^k \uparrow$

$R_H = 324^k + 366^k + 224^k = 914^k$

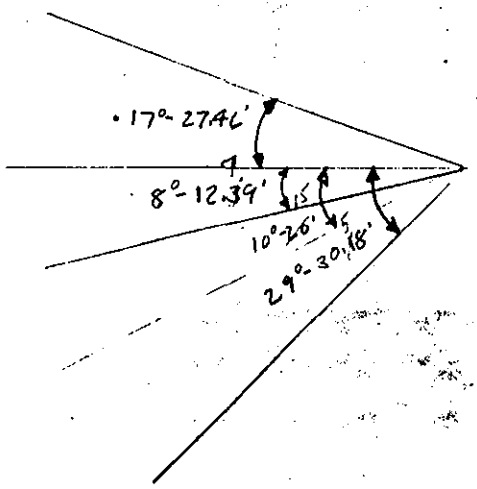
$$\text{Resultant} = \left[(165.5)^2 + (914)^2\right]^{1/2} = 929^k$$

$$\tan\theta = \frac{R_V}{R_H} = \frac{165.5}{914} = 0.181$$

$$\theta = 10^\circ - \cancel{20'}\ 15'$$

Moment on Trunnion Pin

Resolve moment components into plane of resultant



top frame

$26.3^k(\cos 27^\circ - \cancel{4}\ 2\ 46')$

$26.3^k \times 0.88\cancel{4}\ 5 = 23.3^k$

middle frame

$42^k(\cos 2^\circ - \cancel{7}\ 2\ 21')$

$42^k \times 0.999 = 42^k$

lower frame

$42.5^k(\cos 19^\circ - \cancel{10.18'}\ 15.58')$

$42.5^k \times 0.944 = 40^k$

$105.3^{k'}$

SUBJECT Fox Point Gates
COMPUTATION Post Tensioning
COMPUTED BY GTS CHECKED BY CCC DATE

Design Criteria for Post Tensioning (See Page 45 for revised criteria)

Steel Stress

temporary stress (jacking force)

$0.8\ f'_s$

f'_s - ultimate steel strength

design stress (working force)

$0.6\ f'_s$

Concrete Stress

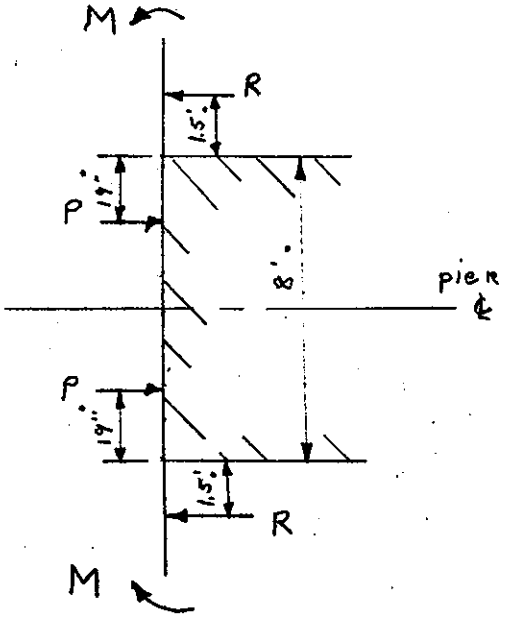
$f'_c = 4000\ \#/in^2$

temporary stress - $0.55\ f'_c$
design stress - $0.45\ f'_c$

Assume 32 - 1 1/8" ϕ high tensile post tensioned rods

$f'_s = 156{,}000\ \#/Rod$

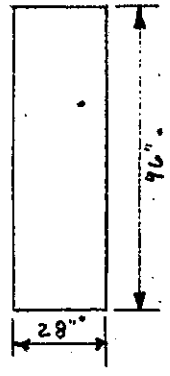
working force = $0.6\ f'_s = 93.6\ ^k/Rod$; however use max. of $90\ ^k/Rod$ for design load



$P = 16 \times 90 = 1440^k$
$R = 929^k$
$M = 105.3\ ^{1-k}$

$A = 96 \times 28 = 2688\ in^2$

$S = \frac{28 \times (96)^2}{6} = 43{,}008\ in^3$



SUBJECT Fox Point Gates
COMPUTATION Post-Tensioning
COMPUTED BY GTS CHECKED BY C.C.C. DATE

Resultant $F = [1440 - 929] \times 2 = 1022^{K}$

Bearing Pressure $= \frac{1022}{2688} = 0.380\ ^{K}/_{in^2}$

allowable bearing $= 0.45 f'_c$

$0.45 \times 4 = 1.80\ ^{K}/_{in^2} > 0.380$ O.K.

Check bearing with jacking force

Jacking force $= 0.8 \times 156 = 124.8\ ^{K}/_{rod}$

$32 \times 124.8 = 4000^{K}$

$B.P. = \frac{4000}{2688} = 1.49\ ^{K}/_{in^2}$

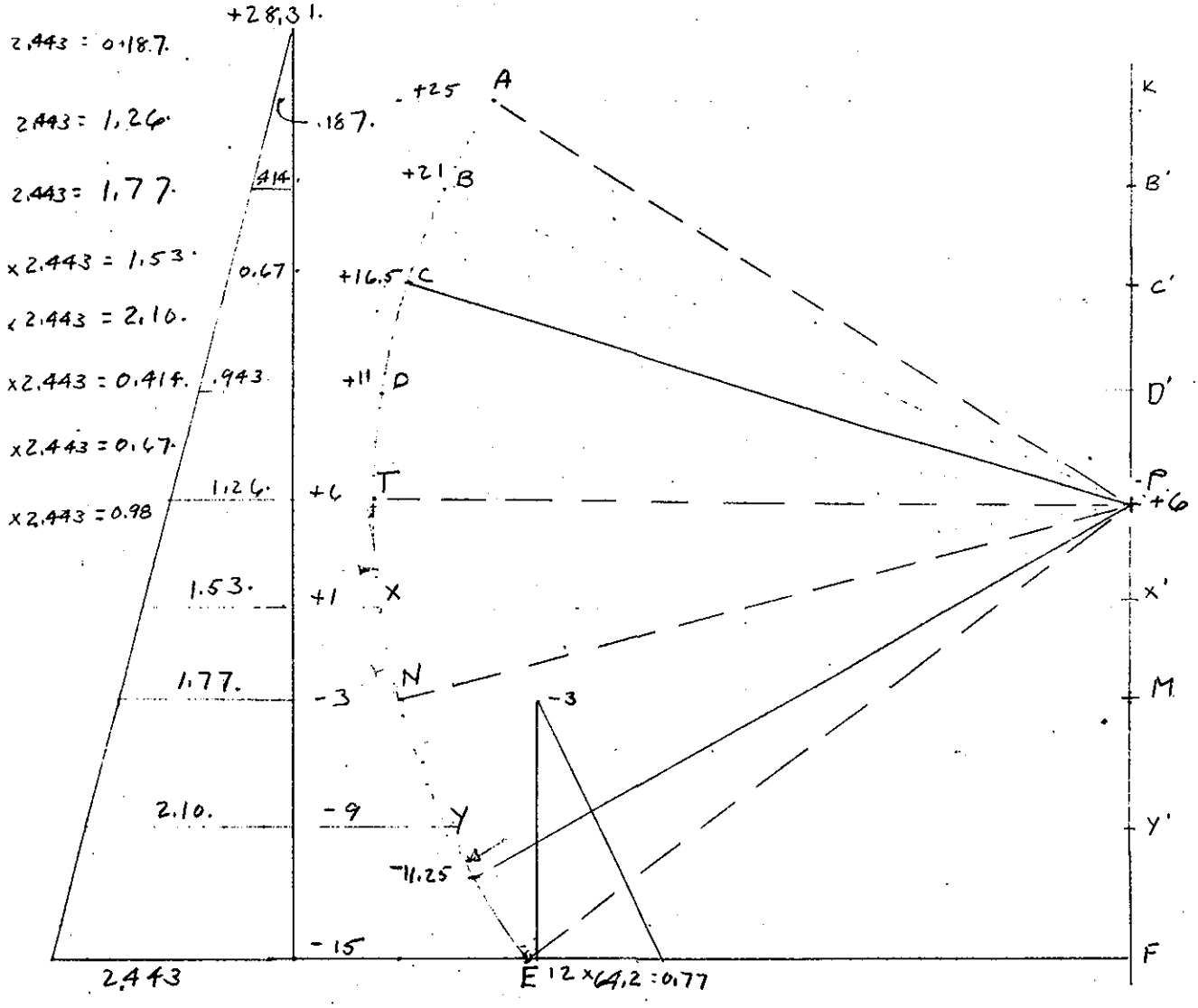
allowable $B.P. = 0.55 f'_c$

$0.55 \times 4 = 2.20\ ^{K}/_{in^2} > 1.49$ O.K.

SUBJECT: Fox Point Gates
COMPUTATION: Post Tensioning
COMPUTED BY: GTS CHECKED BY: GEH DATE:

Unequal Loading on Adjacent Gates.

wave el +28.31 on gate; wave el +33.31 on adjacent gate. determine effect on pier anchorage due to unequal trunnion reaction; upstream el -3.0..



SUBJECT Fox Point Gates
COMPUTATION Post-Tensioning
COMPUTED BY GTS CHECKED BY GFH + PDM DATE

From gate hydraulic loads

still water @ el 20.5 — See diagram on Page 4.

$P = 2279$ #/sF.

wave @ el 33.31

additional $P = 263$ #/sF.

wave @ el 28.31

$$P = \frac{\overset{7.81}{8.31}}{\underset{12.81}{13.31}} \times 263 = \overset{160}{164} \text{ \#/sF}$$

total $P = 2279 + \overset{160}{164} = \overset{2439}{2443}$ #/sF.

VERTICAL FORCE

Area of circle segment

$$\frac{r^2}{2}\left(\frac{\pi\theta}{180} - \sin\theta\right).$$

SEGMENT NE

$\angle NPE = \angle NPM - \angle EPF$

$\angle NPE = 21^\circ - 58.168'$.

$\angle NPM = 75^\circ - 5.979'$
$\angle EPF = 53^\circ - 7.811$
$21^\circ - 58.168'$

hor proj. NE = 5.823:

water wgt for segment NE

$$64.2 \times \left(\frac{1}{2}\left[12 \times 5.823\right] + \frac{(35)^2}{2}\left[\overset{.383.}{\frac{\pi(21.97)}{180}} - \overset{.374.}{\sin(21^\circ - 58.168)}\right]\right)$$

$64.2\,(34.9 + 5.5) = 2.59.^k$ ↓

SEGMENT AT

$\angle APT = 90 - \angle APK$

$\angle APT = 32^\circ - 52.705'$

hor projection TA = 5.6063

$\angle APK = \overset{89-60}{57^\circ - 7.295'}$
$32 - 52.705$

SUBJECT: FOX POINT GATES
COMPUTATION: POST-TENSIONING
COMPUTED BY: GTS CHECKED BY: GFH DATE:

water wgt.

$$64.2\left[\tfrac{1}{2}(5.6063\times 19) - \frac{(35)^2}{2}\left[\frac{\pi(32.88)}{180} - \sin(32^\circ - 52.705')\right]\right]$$

$$64.2\left[53.2 - 19.6\right] = 2.16^K \downarrow$$

total downward load $\frac{2.59}{4.75^K}$

See later page

UPLIFT

$\cos \angle XPX' = \frac{5}{35} = 0.14286$ $\angle XPX' = 81^\circ - 7.19'$

hor proj $TX = 35 - XX'$

$XX' = 35 \sin 81^\circ - 7.19'$

$= 35(.98801) = 34.58'$

$TX = 35 - 34.58' = 0.42'$

hor proj $TN = 1.18'$

hor proj $XN = TN - TX = 1.18 - 0.42 = 0.76'$

$\cos \angle YPY' = \frac{15}{35} = 0.42857$ $\angle YPY' = 64^\circ - 37.37'$

hor proj $TY = 35 - YY'$

$YY' = 35 \sin(64^\circ - 37.37')$

$= 35 \times 0.90349 = 31.62'$

$TY = 35 - 31.62 = 3.38'$

hor proj $NY = TY - TN = 3.38 - 1.18 = 2.20'$

hor proj $YE = TE - TY = 7 - 3.38 = 3.62'$

TX	=	0.42
XN	=	0.78
NY	=	2.20
YE	=	3.62
		7.00

SUBJECT: FOX POINT GATE
COMPUTATION: POST-TENSIONING
COMPUTED BY: GTS CHECKED BY: GFH DATE:

$$\frac{1.26+1.53}{2}(0.48) + \frac{1.53+1.77}{2}(0.78) + \frac{1.77+2.10}{2}(2.20) + \frac{2.10+2.44}{2}(3.62)$$

$$0.56 + 1.29 + 4.26 + 8.21 = 14.35 \uparrow$$
$$14.32$$

SEGMENT AT

$\angle DPD' = 81° - 7.19' = \angle XPX'$

hor proj TD = 0.48

$\cos \angle CPC' = \frac{10.5}{35} = 0.30000 \quad \angle CPC' = 72° - 32.56'$

hor proj TC = 35 − CC'

$CC' = 35 \sin(72° \cdot 32.56') = 35 \times 0.954 = 33.39'$

$TC = 35 - 33.39' = 1.61'$

hor proj DC = TC − TD = 1.61 − 0.48 = ~~1.19~~ 1.21'

$\cos \angle BPB' = \frac{15}{35} = 0.42857 \quad \angle BPB' = 64° - 37.37'$

$BB' = 31.62'$

$TB = 35 - 31.62 = 3.38'$

hor proj CB = TB − TC = 3.38 − 1.61 = 1.77'

hor proj TA = 5.61

hor proj BA = TA − TB = 5.61 − 3.38 = 2.23'

TD	=	0.48
DC	=	~~1.19~~ 1.21
CB	=	1.77
BA	=	2.23
		5.61

SUBJECT Fox Point Gate
COMPUTATION Post-Tensioning
COMPUTED BY GTS CHECKED BY GFH DATE

$$\frac{.943+1.26}{2}(0.48) + \frac{.943+0.67}{2}(1.19) + \frac{0.67+0.414}{2}(1.77) + \frac{0.414+0.187}{2}(2.23)$$

$$0.484 + 0.968 + 0.96 + 0.67 = 3.05^{K/'} \downarrow$$

$$\begin{array}{r} 2.59 \\ 3.05 \\ \hline 5.64^{K/'} \downarrow \end{array} \qquad \begin{array}{r} 14.35 \\ 5.64 \\ \hline P_V = 8.71^{K/'} \uparrow \end{array}$$

HORIZONTAL FORCE

$$P_H = \frac{.187+2.443}{2} \times 40 - \frac{1}{2} \times 0.77 \times 12$$

$$52.60 - 4.62 = 47.98^{K/'} \rightarrow$$

Resultant

$$\left[(8.71)^2 + (47.98)^2\right]^{1/2} = \left[2376\right]^{1/2} = 48.66^{K/'}$$

Trunnion Reaction $= 48.66 \times 20 = 973^{K}$

NOTE:

FINAL DESIGN ANALYSIS WILL HAVE HYDRAULIC LOADS RESOLVED AT TRUNNION THROUGH GATE FRAME DESIGN.

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION

CORPS OF ENGINEERS, U. S. ARMY

SUBJECT: FOX POINT GATE

COMPUTATION: POST-TENSIONING

COMPUTED BY: GTS CHECKED BY: GEH DATE:

$\frac{1}{1} = \frac{x}{2.542}$

$= 1.71$

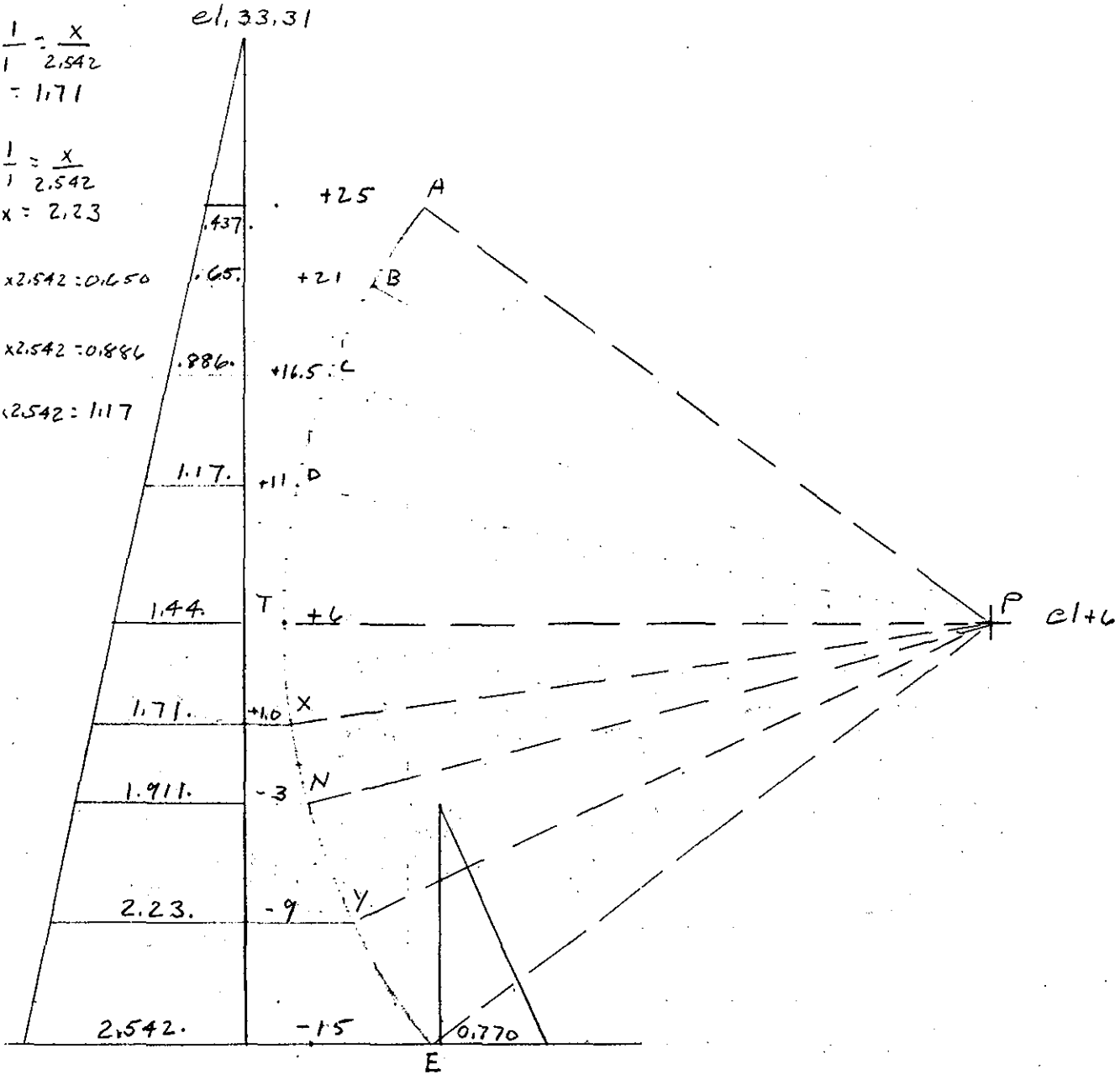
$\frac{1}{1} = \frac{x}{2.542}$

$x = 2.23$

$x 2.542 = 0.650$

$x 2.542 = 0.886$

$x 2.542 = 1.17$



SUBJECT: FOX POINT GATE
COMPUTATION: POST-TENSIONING
COMPUTED BY: GTS CHECKED BY: GFH DATE:

HORIZONTAL FORCE

$$[.437 + 2.542] \times \tfrac{1}{2} \times 40 - \tfrac{1}{2} \times 0.77 \times 12$$

$$59.58 - 4.62 = 54.96^{K/'} \rightarrow$$

VERTICAL FORCE

SEGMENT AT

$$\frac{.437+0.65}{2}(2.23) + \frac{.65+0.886}{2}(1.77) + \frac{0.886+1.17}{2}(1.\overset{21}{19}) + \frac{1.17+1.44}{2}(0.\overset{40}{42})$$

$$1.21 + 1.36 + 1.2\underset{4}{3} + 0.5\underset{2}{5} = 4.35^{K/'} \downarrow$$

$$4.33$$

SEGMENT NE

$$2.59^{K/'} \downarrow$$
$$4.35 \downarrow$$
$$6.9\underset{2}{4}^{K/'} \downarrow$$

Uplift

$$\frac{1.44+1.71}{2}(0.4\overset{0}{8}) + \frac{1.71+1.911}{2}(0.7\overset{8}{8}) + \frac{1.911+2.23}{2}(2.20) + \frac{2.23+2.542}{2}(3.62)$$

$$0.6\underset{3}{6} + 1.3\underset{11}{8} + 4.56 + 8.64 = 15.24^{K/'} \uparrow$$

$$P_v = 15.24 - 6.94 = 8.30^{K/'} \uparrow$$

Resultant

$$\left[(54.96)^2 + (8.30)^2\right]^{1/2} = (3089)^{1/2} = 55.5^{K/'}$$

trunnion Reaction

$$55.5 \times 20 = 1110^{K}$$

SUBJECT: Fox Point Gate
COMPUTATION: Post-Tensioning
COMPUTED BY: GTS CHECKED BY: GFH DATE:

Revise design criteria

$f'_s = 145^{K}/_{SI}$ $1\frac{1}{8}''\phi$ $A = 0.994$. $S'_s = 144.1$.

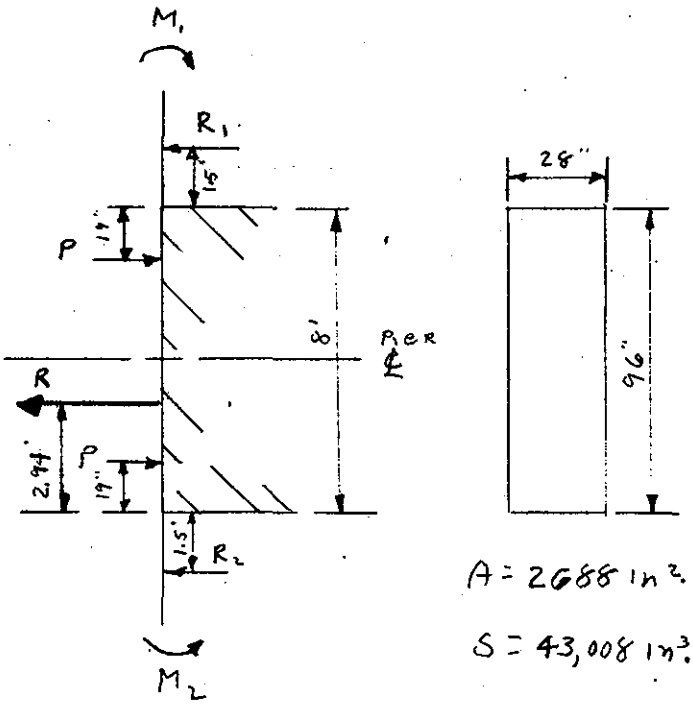
Jacking force

$0.8\ f'_s = 115.3\ ^{K}/_{Rod}$

Working force

$0.6\ f'_s = 86.4\ ^{K}/_{Rod}$

Trunnion Reaction + Working force



$A = 2688\ in^2$.

$S = 43{,}008\ in^3$.

$P = 16 \times 86.4 = 1382^{K}$

$R_1 = 1110^{K}$.

$R_2 = 973.^{K}$

assume $M_1 = M_2$; difference is negligible

Resultant F

$1382 \times 2 - 1110 - 973 = 681^{K} \rightarrow$

Resultant Location

$$\frac{973 \times 1.5 + 1382 \times 1.58 + 1382 \times 6.42 - 1110 \times 9.5}{}$$

$$\frac{1975}{681} = 2.9'$$

Bearing Pressure

$$\frac{681}{2688} \pm \frac{1.09 \times 681 \times 12}{43{,}008} = 0.253. \pm 0.207. = 0.460.\ ^{K}/_{in^2}$$

$$0.046\ ^{K}/_{in^2}$$

SUBJECT Fox Point Gate
COMPUTATION Post-Tensioning
COMPUTED BY GTS CHECKED BY GFH DATE

Equal Trunnion Reaction

Resultant $F = (1382-1110)\,2 = 544^{k}$

$$B.P = \frac{544}{2688} = 0.203\ ^{k}/in^2.$$

Check Bearing with Jacking force alone

Jacking force $= 0.8 f'_s = 115.3\ ^{k}/Rod.$

32 Rods - assume $1\frac{1}{2}''\phi$ holes in base PL

$A = 2688 - 32(1.77) = 2631\ in^2.$

$P = 32 \times 115.3 = 3690.^{k}$

$$B.P. = \frac{3690}{2631} = 1.40\ ^{k}/in^2.$$

allow $B.P = 0.55 f'_c = 0.55 \times 4 = 2.20\ ^{k}/in^2 > 1.40$ O.K.

Check Bearing with Working force alone

Working force $= 0.6 f'_s = 0.6 \times 144.1 = 86.4\ ^{k}/Rod$

$P = 32 \times 86.4 = 2765.^{k}$

$$B.P. = \frac{2765}{2631} = 1.05\ ^{k}/in^2.$$

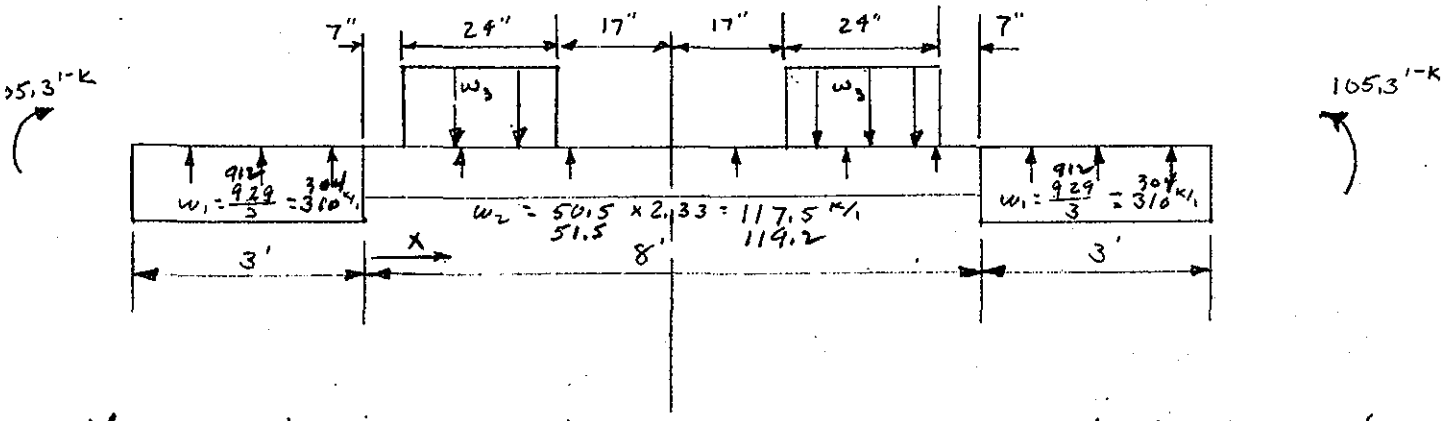
allow $B.P = 0.45 f'_c = 0.45 \times 4 = 1.80\ ^{k}/in^2 > 1.05$ O.K.

SUBJECT: Fox Point Gate
COMPUTATION: Thrust Girder
COMPUTED BY: GTS CHECKED BY: P.D.M. 1/19/60 DATE:

THRUST GIRDER

28" wide

$w_3 = \frac{1392}{2} = 696$ K/' (1382, 691)



Use adjusted loading diagram + basic steel stress of 18 K/in²

In plane of struts

Trunnion Reaction = 929 K See Page 35 $929 \times \frac{32.52}{33.46} = 912$ K

M = 105.3'-K See Sh. 35

See Page 45

Resultant F = (1382 - 929) 2 = 906 K (912, 940)

$B.P. = \frac{906}{2631} = 0.345$ K/in² (940, .358)

0.345 K/in² $\times 144 = 50.5$ K/ft² (.358, 51.5)

V = 0

$929 + 117.5(x) - 696(x - 0.58) = 0$ (912, 119.2, 691)

$578.5x = 1335$ (571.8, 1312.8)

$x = 2.31'$ (2.29)

Max. M

$105.3 + 929(3.81) + 117.5(2.31)^2 - 696(1.73)^2$ (912, 3.79, 2.29, 691, 1.71)

$105.3 + 3540 + 314 - 1040 = 2919$ '-K (3456, 308, 1010.2, 2859, 2)

Max. V

$929 + 0.58 \times 117.5 = 998$ K (912, 119.2, 981)

SUBJECT Fox Point Gate
COMPUTATION Thrust Girder
COMPUTED BY GTS CHECKED BY T.D.M. 1/19/60 DATE

Girder Section

$$\text{web area} = \frac{V}{\text{Shear Stress}} = \frac{\overset{981}{998}}{12^{\#}/in^2} = \overset{81.7}{83}\ in^2$$

assume 36" deep × 2 3/8" web PL

$$A = 36 \times 2\tfrac{3}{8} = 85.5\ in^2.$$

$$I = \frac{2.375 \times (36)^3}{12} = 9240\ in^4.$$

flange plate

$$I = \overset{\text{flange}}{2 \times A \times (19)^2} + \overset{\text{web}}{9240} = 722A + 9240$$

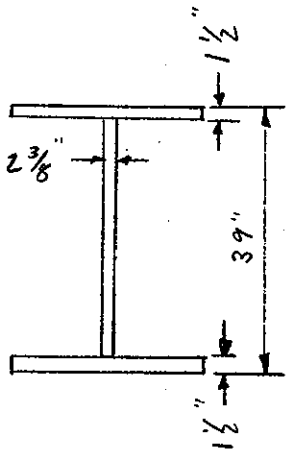
$$I = \frac{Mc}{f}$$

$$722A + 9240 = \frac{\overset{2.859}{2,919} \times 12 \times 19}{\underset{1.8}{18}}$$

$$722A + 9240 = \overset{36200}{37,000}$$

$$A = \frac{\overset{26960}{27,760}}{722} = \overset{37.4}{38.5}\ in^2$$

28 × 1 1/2 flange plate.



web PL

$$\frac{2.375 \times (36)^3}{12} = 9240\ in^4.$$

flange

$$2 \times \frac{28 \times (1.5)^3}{12} = 16$$

$$2 \times 28(1.5)(18.75)^2 = 29500$$

$$38,756\ in^4$$

$$S_{avail} = \frac{38,756}{19.5} = 1985\ in^3.$$

$$S_{Req} = \frac{\overset{2859}{2919} \times 12}{18} = 1950 \cdot in^3 \quad \text{O.K.}$$

SUBJECT: Fox Point Gate
COMPUTATION: Thrust Girder
COMPUTED BY: GTS CHECKED BY: T.P.M 11/20/60 DATE:

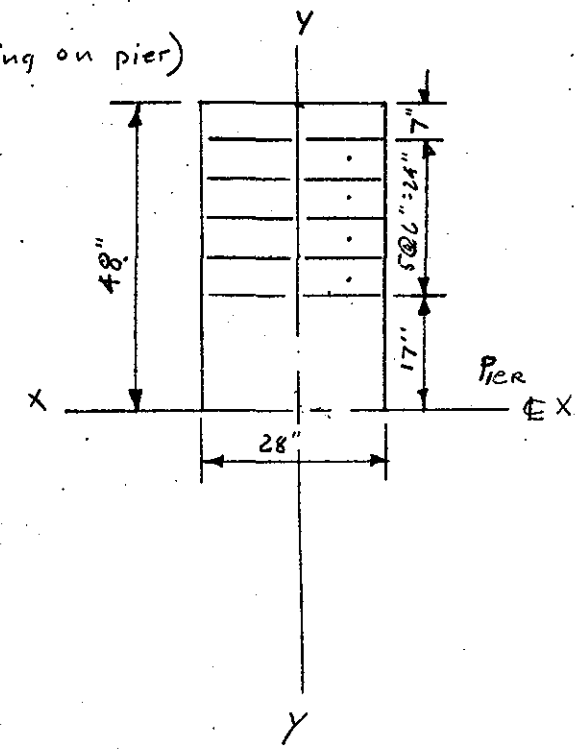
Stiffeners

$$\frac{h}{t} = \frac{36}{2.375} = 15.2 < 70. \quad \text{AISC Sect 26e}$$

max. load occurs at jacking

Jacking force $= 32 \times 116 = 3718^{K}$ (115.3, 3690)

web plate - 96 x 2 3/8 (Portion in bearing on pier)
stiffener pls - 12½ x 1"



I about x-x axis

	A	Y	Ay^2	I
96 x 2 3/8	228.			174,500 175100
12½ x 1	50.	17.	14,400.	4.17.
	50.	23.	26,500.	4.17.
	50.	29.	42,000.	4.17.
	50.	35.	61,300.	4.17.
	50.	41.	84,000	4.17.
	478.		228,200	174,520
			174,520	175121

$I_{x-x} = 402,720 \text{ in}^4$

$$r = \sqrt{\frac{I}{A}} = \sqrt{\frac{402,720}{478}} = \sqrt{845} = 29.$$

$$\frac{\frac{3}{4}l}{r} = \frac{\frac{3}{4} \times 36}{29} = \cancel{1.24}\ .93 \qquad \text{allow } f_a = 16^{K}/\text{in}^2.$$

$$\text{actual } F_a = \frac{3718}{478} = 7.76\ (7.72)\ ^{K}/\text{in}^2 < 16^{K}/\text{in}^2 \text{ O.K.}$$

$$\frac{2 \text{ rods}}{1 \text{ ft}} \cdot \frac{2 \times 115.3}{12} = 19.2^{K}/\square \text{ bearing} < 24000 \text{ psi. Allowable bearing.}$$

I about y-y axis

	A	Y	Ay^2	I
stiffeners	250.	7.75 (7.5)	15,000 (14,062)	$\frac{1}{12} \times 1 \times (12.5)^3 \times 2 = 3260.$
			3260.	
			18,260	
			17,322	

in^4

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NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U.S. ARMY

SUBJECT: Fox Point Gate
COMPUTATION: Thrust Girder
COMPUTED BY: GTS CHECKED BY: P.D.M 1-20-60 DATE:

$$r = \sqrt{\frac{18{,}260}{478}} = \sqrt{38.2} = 6.2$$

17322 6.1 36.2

$$\frac{3/4 \times 36}{6.2} = 4.36$$

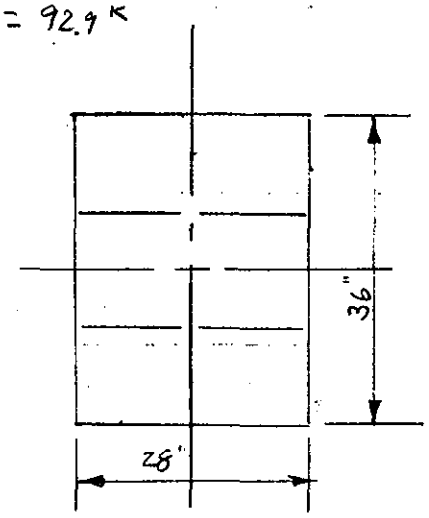
4.42

allow $f_a = 16.$ K/in²

Stiffeners at Trunnion Shoe

stiffeners 4 - 12½ x 1" PL
web 1 - 36 x 2⅜
flange 1 - 28 x 1½

P = 92.9 K



I about y-y axis

	A	y	Ay²	I
6 - stiff 36 x 2⅜	75	7.5	4220	972
	85.5	—	—	40
	160.5		4220	1012
			1012	
			5232	

$$r = \sqrt{\frac{I}{A}} = \sqrt{\frac{5232}{160.5}} = 5.6$$

$$\frac{3/4 \times 36}{5.6} = 4.83$$

allow $f_a = 15.99$

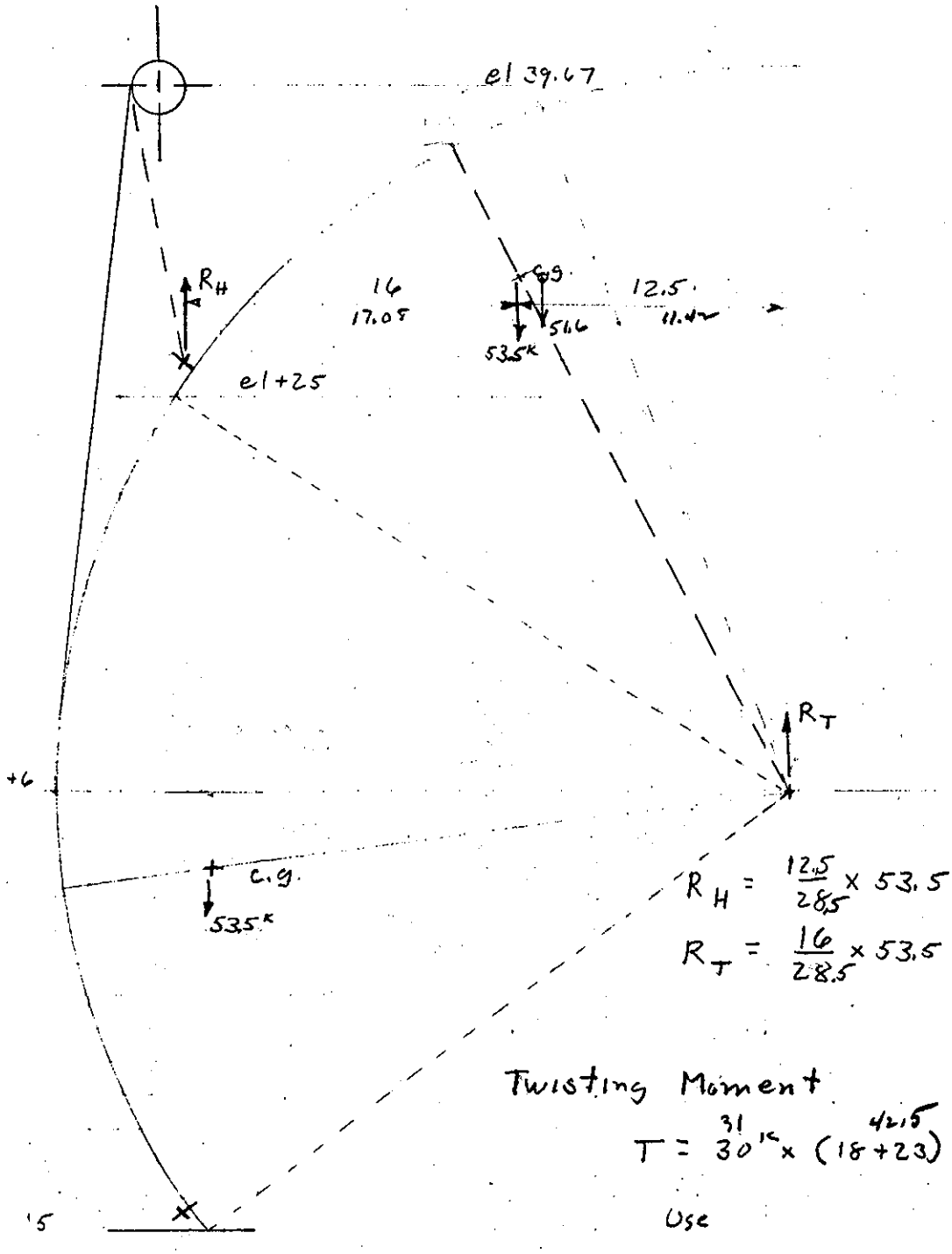
$$\text{actual } F_a = \frac{929}{160.5} = 5.2 \text{ K/in}^2$$

912 929 5.69 < 15.99

$$\frac{R}{\phi t_1} = \frac{912}{6 \times 12} = 12.6 \text{ K/in}^2 \text{ bearing} < 24000 \text{ psi Allowable bearing}$$

SUBJECT Fox Point Gates
COMPUTATION Thrust Girder
COMPUTED BY GTS CHECKED BY P.J.M. DATE

GATE REACTIONS IN RAISED POSITION



$$R_H = \frac{12.5}{28.5} \times 53.5 = 23.5^K$$

$$R_T = \frac{16}{28.5} \times 53.5 = \overset{31}{30}^K$$

Twisting Moment

$$T = \overset{31}{30}^K \times (\overset{42.5}{18+23}) = \overset{1320}{1230}^{\prime\prime-K}$$

Use

SUBJECT: Fox Point Gate
COMPUTATION: Thrust Girder
COMPUTED BY: G.T.S. CHECKED BY: R.D.M. DATE:

Ref.- Seely + Smith - Adv. Mech. of Mat. p. 284-291

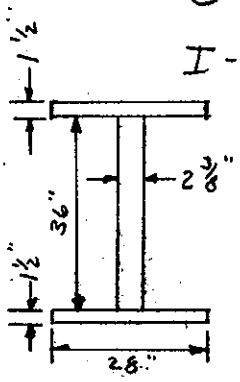
Lateral Bending Stress

$$\sigma_1 = \frac{M_T \frac{b}{2}}{I_{f1}} \qquad M_T = \frac{Ta}{h}\tanh\left(\frac{l}{a}\right)$$

$E - 30\times10^6$ #/in²
$G - 12\times10^6$ #/in²
I - abt. Y-Y

$$a = \frac{h}{2}\left[\frac{EI}{JG}\right]^{1/2}$$

$$J = \frac{1}{3}\Sigma b t^3$$



$$J = \frac{1}{3}\left[2\times28\times(1.5)^3 + 36\times(2.375)^3\right] = \overset{221}{223}$$

$$a = \frac{37.5}{2}\left[\frac{30\times10^6}{12\times10^6}\times\frac{5528}{223}\right]^{1/2} = \overset{147.0}{147.5}$$

$$I_{x-x} = 2\times\frac{1.5\times(28)^2}{12} + 40 = 5528 \text{ in}^4$$

$$M_T = \frac{1230\times\overset{148}{147.5}}{37.5}\tanh\left(\frac{36}{2\times147.5}\right)$$

$$= \overset{5200}{4840}\tanh(\overset{245}{0.122}) = \overset{5200}{4840}\times(\overset{.240}{0.129}) = \overset{1250}{625} \text{ "-K}$$

$$\sigma_1 = \frac{\overset{1250}{625}\times\frac{28}{2}}{\frac{1}{12}\times1.5\times(28)^3} = \overset{7.07}{3.19} \text{ K/in}^2$$

$$\sigma_2 = \frac{M_b\times\frac{h}{2}}{I} \qquad M_b = 30\times\overset{30}{18} = \overset{940}{540} \text{ "-K}$$

$$\sigma_2 = \frac{\overset{940}{540}\times\frac{28}{2}}{2\times\frac{1}{12}\times1.5\times(28)^3} = \overset{2.40}{2.75} \text{ K/in}^2$$

Maximum Stress

Tension $\sigma = \sigma_1 + \sigma_2 = \overset{7.07}{3.19} + \overset{2.40}{2.75} = \overset{9.47}{5.94}$ K/in² < 15000

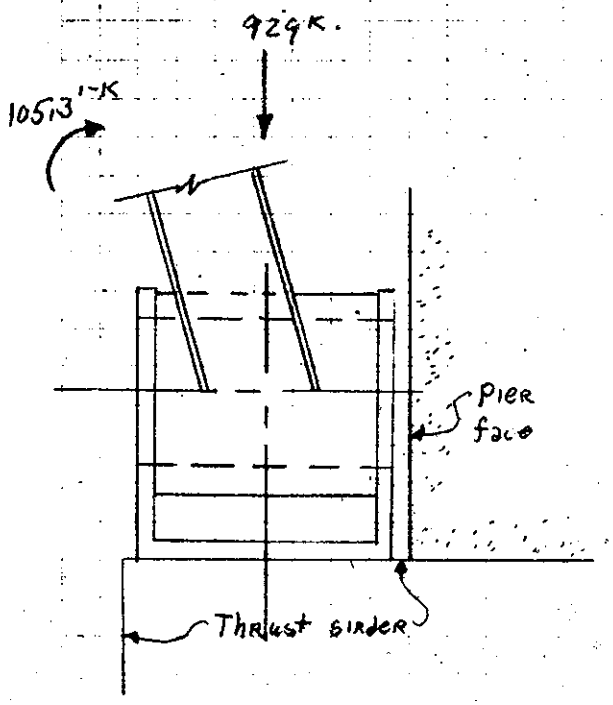
Shear $\frac{3\times35.2}{2\times1.5\times28} = 1.26$ K/□

$\frac{3\times14.5}{2\times1.5\times28} = \overset{.52}{1.78}$ K/□ < 12000

Max shearing stresses occur where max tension stresses are 0.

SUBJECT: FOX POINT GATE
COMPUTATION: TRUNNION ASSEMBLY
COMPUTED BY: GTS CHECKED BY: R.A.K. DATE:

TRUNNION FITTING & PIN



$N = 929^K$
$M = 105.3'^{-K}$

Note N should be equal to 912K but 920K is on the safe side ∴ ok

$$e = \frac{M}{N} = \frac{105.3 \times 12}{929} = 1.36''$$

allowable bearing stress on bearing material - $3\ ^K/_{in^2}$

$$A_{Req} = \frac{929}{3} = 310\ in^2$$

try 15" x 32" long pin

actual bearing pressure

$$\frac{929}{15 \times 32}\left[1 \pm \frac{6 \times 1.36}{32}\right]$$

$$1.94\left[1 \pm 0.255\right] = 2.44\ ^K/_{in^2}$$
$$1.45\ ^K/_{in^2}$$

Check shear on Trunnion Pin

max v on circular section

$$v = \frac{4}{3}\frac{V}{A}$$

max allowable pin $v = 13.5\ ^K/_{in^2}$

$$V_{max} = 1.45 \times \frac{32}{2} \times 15 + 0.99 \times \frac{32}{2} \times \frac{2}{3} \times 15$$
$$= 350 + 158 = 508^K$$

$$v = \frac{4}{3} \times \frac{508}{\frac{\pi(15)^2}{4}} = \frac{1.33 \times 508}{176} = 3.84\ ^K/_{in^2} \quad \text{O.K.}$$

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SUBJECT: FOX POINT GATE
COMPUTATION: TRUNNION ASSEMBLY
COMPUTED BY: GTS CHECKED BY: R.A.K. DATE:

Side Bearing Plate of Trunnion Shoe

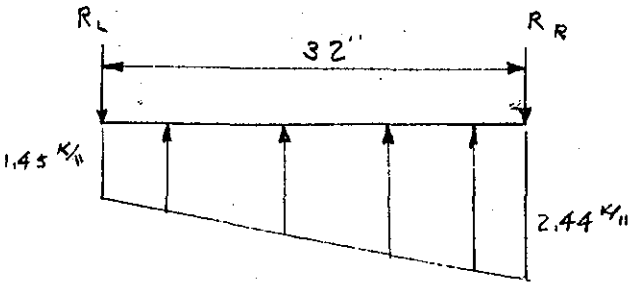
allowable bearing - $27^{k}/in^2$

Reqd. area = $\frac{929}{27}$ = $34.4\ in^2$ for both sides

thickness of 1 side = $\frac{17.2}{15}$ = 1.15"

use 2" min side PL.

Base of Trunnion Shoe



$R_L = 1.45 \times \frac{32}{2} + \frac{1}{2} \times 0.99 \times 32 \times \frac{1}{3}$

$= 23.2 + 5.3 = 28.5^{k}$

$V = 0$

$28.5 - 1.45x - \frac{0.99}{32} x \frac{x}{2} = 0$

$0.0155x^2 + 1.45x = 28.5$

$x^2 + 93.5x = 1840$

2180

$(x + 46.7)^2 = 4020$

$x + 46.7 = 63.5$

$x = 16.8"$

Max $M = 28.5(16.8) - 1.45\frac{(16.8)^2}{2} - \frac{0.99}{32}\frac{(16.8)^2}{2}\frac{(16.8)}{3}$

$= 479 - 205 - 24.4 = \cancel{254.6}\ 249.6$ "-k/in. width of pin

$M = \cancel{254.6}\ 249.6 \times 15 = \cancel{3830}\ 3745$ "-k

$S_{Req} = \frac{\cancel{3830}\ 3745}{18} = \cancel{212}\ 208\ in^3$

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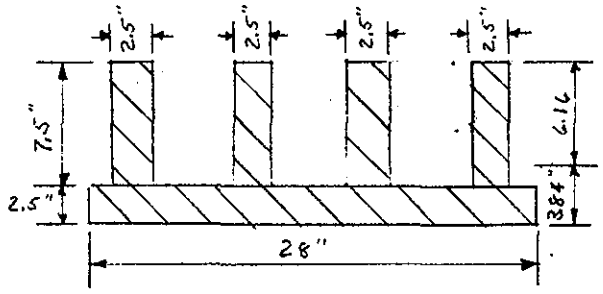
NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT: FOX POINT GATE
COMPUTATION: TRUNNION ASSEMBLY
COMPUTED BY: GTS CHECKED BY: R.A.K. DATE:



c.g. location

$4(2.5 \times 7.5) = 75 \times 6.25 = 468.75$
$2.5 \times 28 = 70 \times 1.25 = 87.5$
$145 \qquad 556.25$

$\frac{556.25}{145} = 3.84"$

$I_{c.g.}$

$4 \times \frac{2.5(7.5)^3}{12} + 75(2.41)^2 = 352 + 436 = 788$

$\frac{28 \times (2.5)^3}{12} + 70(2.59)^2 = 36 + 470 = 506$

1294 in^4

$S = \frac{I}{c} = \frac{1294}{6.16} = 210$ O.K.

Bearing Lining (Babbit Metal)

thickness = 0.01d + 1/8 in. Ref - p.359 Meleev Machine Design

d = 15" (pin diameter)

0.01(15) + 0.125 = 0.275 inches

use 3/8" thickness lining

Trunnion Fitting Casting

wall thickness = 0.15d

t = 0.15 × 15 = 2.25" use 2 1/2"

O.D. of casting = pin 15 + bear 3/4 + shell 5 = 20 3/8

say 21" O.D.

SUBJECT Fox Point Gate
COMPUTATION Anchor Base Plate
COMPUTED BY GTS CHECKED BY R.A.K. DATE

End Anchor Base Plate

16 - 1 1/8" ϕ Rods

Jacking force = 115.3 K/Rod

$P = 16 \times 115.3 = 1845^K$

assume 28" x 28" plate

deduct 16 - 1 1/8" ϕ holes

$A = 28 \times 28 - 16(1.77) = 756 \text{ in}^2$

bearing stress

$B.P. = \frac{1845}{756} = 2.44 \text{ K/in}^2$

max allowable anchorage bearing stress

Ref: Sect. 207.3.4 ACI Recommendations for Prestressed Concrete

$$f_{cp} = 0.6 f'_{ci} \sqrt[3]{\frac{A_c}{A_b}}$$

edge of ⊕ located 5" from pier edge
add 5" around bearing plate to obtain similar concrete area

$A_b = 756 \text{ in}^2$

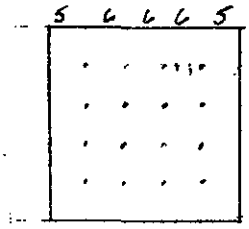
$A_c = 38 \times 38 = 1444 \text{ in}^2$

$f_{cp} = 0.6 \times 4 \sqrt[3]{\frac{1444}{756}} = 2.97 \text{ K/in}^2 > 2.44$

SUBJECT: FOX POINT GATE

COMPUTATION: ANCHOR BASE PLATE

COMPUTED BY: GTS CHECKED BY: R.A.K. DATE:



$$S = \frac{bt^2}{6} = \frac{(6-1.5)\,t^2}{6} = 0.75\,t^2$$

$$M = \frac{2.44 \times 4.5 \times (5)^2}{2} = 137''\text{-}^{k}$$

$$S = \frac{137}{18} = 7.63 \text{ in}^3$$

$$0.75\,t^2 = 7.63$$

$$t^2 = 10.19$$

$$t = 3.18 \text{ in} \qquad \text{use } 3\tfrac{1}{4}'' \text{ PL}$$

try 26x26 plate

$$A = 26 \times 26 - 16(1.77) = 648 \text{ in}^2$$

$$B.P = \frac{1845}{648} = 2.85 \text{ k/in}^2$$

allow B.P.

$$A_b = 648 \text{ in}^2$$
$$A_c = 38 \times 38 = 1444 \text{ in}^2$$

$$f_{cp} = 0.6 \times 4 \times \sqrt[3]{\frac{1444}{648}} = 3.13 \text{ k/in}^2 > 2.85$$

$$M = \frac{2.85 \times (4.5) \times (4)^2}{2} = 103''\text{-}^{k}$$

$$S = \frac{103}{18} = 5.71 \text{ in}^3$$

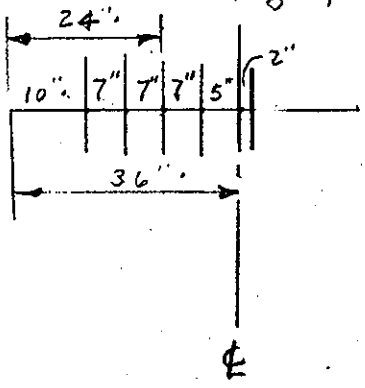
$$0.75\,t^2 = 5.71$$

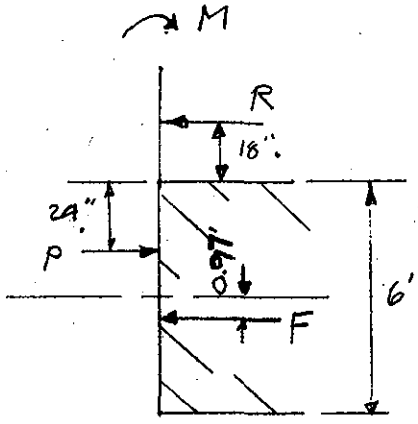
$$t = 2.76 \qquad \text{use } 2\tfrac{3}{4}'' \text{ PL}$$

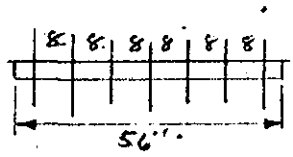
SUBJECT: Fox Point Gate
COMPUTATION: End Pier Post-Tensioning
COMPUTED BY: GTS CHECKED BY: C.C.C. DATE:

Single Trunnion Reaction at End Pier.

Try 56 x 72" base plate Trunnion Reaction = 1110^k
35 - 1 1/8" ϕ Rods @ 86.4^k/rod







$M = 105.3^{k'}$
$R = 1110^k$
$P = 35 \times 86.4 = 3024^k$

$F = 3024 - 1110 = 1914^k$

$$\frac{1110 \times 1.5 + 3024 \times 2.0 - 105.3}{1914}$$

$$\frac{7608}{1914} = 3.97'$$

$e = 0.97'$

Bearing Pressure

$A = 56 \times 72 = 4030 \text{ in}^2$

$S = \frac{56 \times (72)^2}{6} = 48{,}400 \text{ in}^3$

$$\frac{1914}{4030} \pm \frac{1914 \times 0.97 \times 12}{48{,}400}$$

$0.475 \pm 0.461 = 0.936 \text{ k/in}^2$
$\qquad\qquad\qquad\quad 0.014 \text{ k/in}^2$

Check Bearing with Jacking Force Alone

$P = 35 \times 115.3 = 4035^k$

Area of base,
deduct 35 holes

SUBJECT Fox Point Gates
COMPUTATION End Pier Post-Tensioning
COMPUTED BY GTS CHECKED BY CCC DATE

assume $1\frac{1}{2}$" ϕ holes

$$A = 4030 - 35(1.77) = 3968 \text{ in}^2$$

Bearing Pressure $e = 1.0'$

$$\frac{4035}{3968} \pm \frac{4035 \times 1.0 \times 12}{48{,}400}$$

$$1.02 \pm 1.02 = 2.04 \text{ K/in}^2$$

$$\text{allow } B.P = 0.55 f'_c = 2.2 \text{ K/in}^2$$

Check Bearing with Working Force Alone

Design Load = 86.4 K/Rod

$$P = 35 \times 86.4 = 3024^K$$

Bearing Pressure

$$\frac{3024}{3968} \pm \frac{3024 \times 1.0 \times 12}{48{,}400}$$

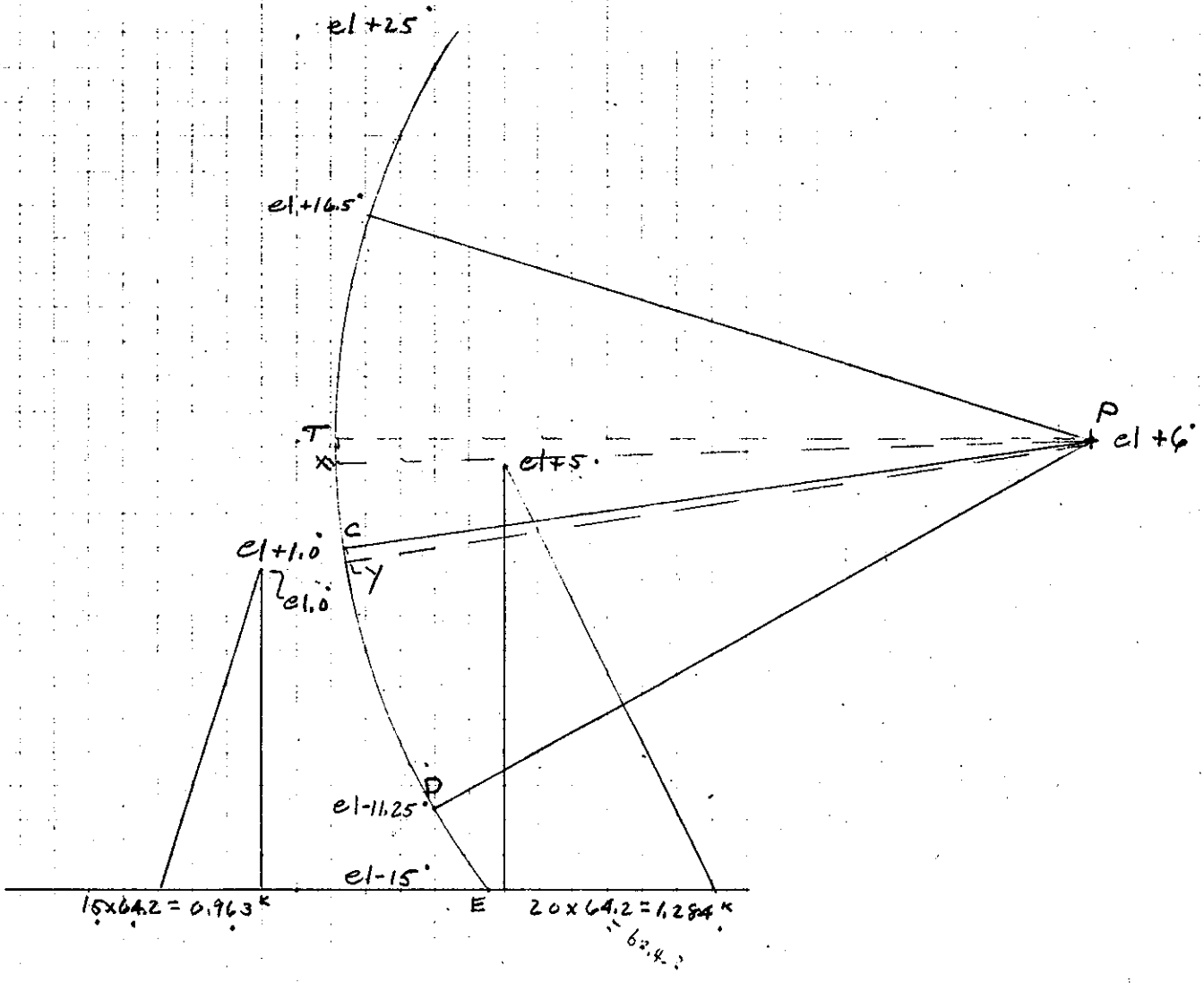
$$0.763 \pm 0.763 = 1.526 \text{ K/in}^2$$

$$\text{allow } B.P = 0.45 f'_c = 1.80 \text{ K/in}^2$$

SUBJECT: Fox Point Gates
COMPUTATION: Reverse Head Loading - Case III
COMPUTED BY: GTS CHECKED BY: C.C.C. DATE:

REVERSE HEAD

Ocean elev. 0' (downstream) Pool side elev +5.0 (upstream).



HOR. PROJECTION

Pt. x $\sqrt{(35)^2-(1)^2} = \sqrt{1224} = 35'$ PROJ = 0.

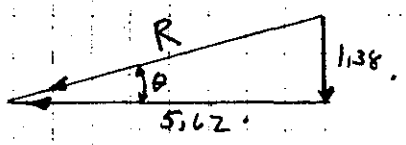
Pt y $\sqrt{(35)^2-(6)^2} = \sqrt{1189} = 34.48'$. PROJ = 0.52'.

PROJ at E = 7'

SUBJECT: Fox Point Gates
COMPUTATION: Reverse Head Loading - Case III
COMPUTED BY: GTS CHECKED BY: CCC DATE:

$P_H = \frac{1}{2} \times 20 \times 1.284 - \frac{1}{2} \times 15 \times 0.963 = 12.84 - 7.22 = 5.62^{K/'} \leftarrow$

$P_V = \frac{1}{2} \times 1.284 \times 7 - \frac{1}{2} \times 648 \times 0.963 = 4.49 - 3.11 = 1.38^{K/'} \downarrow$



$\tan\theta = \frac{1.38}{5.62} = 0.24555$

$\theta = 13^\circ - 47.75'$

$R = \sqrt{(5.62)^2 + (1.38)^2} = \sqrt{33.4} = 5.78^{K/'}$

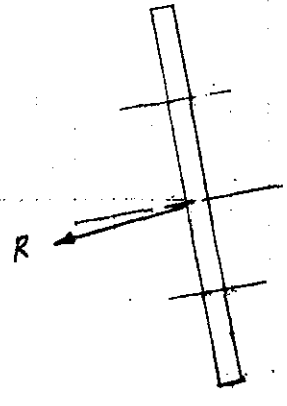
Trunnion Reaction

$R = 20 \times 5.78 = 115.6^K$

BOLTS - Bearing Shoe to Thrust Girder

try 4-1½" ϕ high strength bolts
yield strength 74,000 #/in²

for steel with yield of 33,000 #/in², allowable tension stress is 18,000 #/in²



find allowable stress for 74 #/in² yield

$\frac{18,000}{33,000} = \frac{x}{74,000}$

$x = 40,400$ #/in²

stress area of 1½" ϕ bolt - 1.404 in².

allow $P = 1.404 \times 40.4 = 56.6^K$.

SUBJECT Fox Point Gates
COMPUTATION Gates - C. of G. AND WEIGHT
COMPUTED BY GFH CHECKED BY R.A.K. DATE 17 Nov. 59

Refer to Sheet No. 2 ; C. of G. to be computed about horizontal + vertical axes thru Trunnion, with gate closed.

$\frac{3}{8}$" ⌀ : $\sin \measuredangle APT = \frac{19}{35.0} = 0.5425$ $\measuredangle APT = 32°-51.25'$

$\overset{\frown}{AL}$ $\sin \measuredangle LPT = \frac{7}{35.0} = 0.200$ $\measuredangle LPT = 11°-34.2' = 11.57°$

$\measuredangle APL = 32°-51.25'$ minus $11°-34.2' = 21°-17.05'$

$\measuredangle ① = \measuredangle LPT + \frac{1}{2}\measuredangle APL =$ $11°-34.2'$ plus $10°-38.52' =$ $22°-12.72'$

$\sin \measuredangle ① = 0.37803$ $\cos \measuredangle ① = 0.92579$

Radial dist. to C.G. $= R - R\left(1 - \frac{\sin\alpha}{\alpha}\right) = R\,\frac{\sin\alpha}{\alpha}$ $\alpha = \frac{1}{2}\measuredangle APL = 10°-38.52'$
(Roark - p. 70) $= \frac{\pi}{180} \times 10.642 = 0.1860$ Rad.

$= 35.0\,\frac{0.18467}{0.1860}$ $\sin\alpha = 0.18467$

$= 34.75'$

$\bar{x} = 35.0 \cos \measuredangle ① = 34.75 \times 0.92579 = 32.15'$
$\bar{y} = 35.0 \sin \measuredangle ① = 34.75 \times 0.37803 = 13.15'$
Arc length A-L $= 13.00'$

$\frac{7}{16}$" ⌀ : $\sin \measuredangle TPQ = \frac{7.61}{35.0} = 0.2175$ $\measuredangle TPQ = 12.58°$

$\overset{\frown}{LQ}$

$\measuredangle LPQ = 11.57° + 12.58° = 24.15°$

$\measuredangle ② = \frac{1}{2}\measuredangle LPQ - \measuredangle TPQ = 12.075° - 12.58° = -0.505°$
assume horizontal.

Radial dist. to C.G. $= R\,\frac{\sin\alpha}{\alpha}$ $\alpha = \frac{1}{2}\measuredangle LPQ = 12.075°$

$= 35 \times \frac{0.20919}{0.2105}$ $= \frac{\pi}{180} \times 12.075° = 0.2105$ Radian

$\sin\alpha = 0.20919$

$= 34.80'$

$\bar{x} = 34.80'$ $\bar{y} = 0$ Arc length L-Q $= 14.75'$

SUBJECT Fox Point Gates
COMPUTATION Gates - C. of G. AND Weight
COMPUTED BY GFH CHECKED BY R.A.K. DATE 18 Nov. 59

$\frac{1}{2}$" PL ; $\sin \measuredangle TPE = \frac{21.0}{35.0} = 0.600$ $\measuredangle TPE = 36^\circ - 51.80' = 36.863^\circ$

$\overset{\frown}{QE}$ $\measuredangle QPE = 36.863^\circ - 12.58^\circ = 24.283^\circ$

$\measuredangle ③ = \measuredangle TPQ + \frac{1}{2}\measuredangle QPE = 12.58^\circ + 12.14^\circ = 24.72^\circ = 24^\circ - 43.2'$

$\sin \measuredangle ③ = 0.41818$ $\cos \measuredangle ③ = 0.90836$

Radial dist to C.G. $= R \frac{\sin \alpha}{\alpha}$ $\alpha = \frac{1}{2}(24.28^\circ) = 12.14^\circ = 12^\circ - 8.4'$

$= 35.0 \times \frac{0.21031}{0.212}$ $\sin \alpha = 0.21031$

$\alpha = \frac{\pi}{180} \times 12.14 = 0.212$ Radian

$= 34.7'$

$\bar{x} = 34.70 \cos \measuredangle ③ = 34.70 \times 0.90836 = 31.50'$
$\bar{y} = 34.70 \sin \measuredangle ③ = 34.70 \times 0.41818 = -14.50'$
Arc length Q-E = 14.83'.

ST 8 WF 25

$\measuredangle APT = 32^\circ - 51.25'$ $\alpha = \frac{1}{2}\measuredangle APT = 16^\circ - 25.62'$

Radial dist $= R \frac{\sin \alpha}{\alpha}$ $\sin \alpha = 0.28280$ $\cos \alpha = 0.95918$

$\alpha = \frac{\pi}{180} \times 16.427 = 0.2870$ Rad

$R = 35.00 - \left(\frac{8.13 - 1.89}{12}\right)$

$= 35.00 - 0.52 = 34.48'$

Radial Dist. $= 34.48 \times \frac{0.2828}{0.2870} = 34.0'$

$\bar{x}_T = 34.0 \times 0.95918 = 32.60'$
$\bar{y}_T = 34.0 \times 0.28280 = +9.62'$
Arc length$_T$ $= 34.48 \times 0.5740 = 19.80'$

SUBJECT Fox Point
COMPUTATION Gates - C. of G. and weight
COMPUTED BY GFH CHECKED BY R.A.K. DATE 18 Nov. 59

$\measuredangle TPE = 36°-51.80'$ $\alpha = \frac{1}{2}\measuredangle TPE = 18°-25.90'$

$\sin\alpha = 0.31617$ $\cos\alpha = 0.94870$

$R = 34.48'$ $\alpha = \frac{\pi}{180} \times 18.431 = 0.322$ Radian

$$\text{Radial Dist.} = 34.48 \times \frac{0.31617}{0.322} = 33.85'$$

$\bar{x}_B = 33.85 \times 0.94870 = 32.10'$
$\bar{y}_B = 33.85 \times 0.31617 = -10.70'$
Arc length$_B$ $= 34.48 \times 0.644 = 22.20'$

$$\bar{x} = \frac{(32.60 \times 19.80) + (32.10 \times 22.20)}{19.80 + 22.20} = \frac{645 + 713}{42} = 32.30'$$

$$\bar{y} = \frac{(9.62 \times 19.80) - (10.70 \times 22.20)}{42.0} = \frac{190.5 - 237.5}{42.0} = -1.120'$$

Total arc length $= 22.20 + 19.80 = 42.0'$

30 WF116

$\measuredangle BPT = \text{arc}\sin\frac{10.5}{35.0} = 0.3000 = 17°-27.45'$

$\cos\measuredangle BPT = 0.95394$

$$R = 35.00' - \frac{8.13'}{12} - \frac{15.00}{12} = 35.00 - (.677 + 1.250) = 33.07'$$

$\bar{x} = 33.07 \times 0.95394 = 31.50'$
$\bar{y} = 33.07 \times 0.3000 = +9.92'$

SUBJECT Fox Point
COMPUTATION Gates - C. of G. and weight
COMPUTED BY GFH CHECKED BY R.A.K. DATE 18 Nov. 59

36 WF 160

$\measuredangle TPC = \arcsin \frac{5}{35} = 0.14286 = 8^\circ - 12.79'$

$\cos \measuredangle TPC = 0.98974$

$R = 35.00 - 0.677 - \frac{18.00}{12} = 35.00 - (0.677 + 1.500) = 32.82'$

$\bar{x} = 32.82 \times 0.98974 = 32.50'$
$\bar{y} = 32.82 \times 0.14286 = -4.69'$

36 WF 160

$\measuredangle TPD = \arcsin \frac{17.25}{35.0} = 0.49257 = 29^\circ - 30.58'$

$\cos \measuredangle TPD = 0.87027$

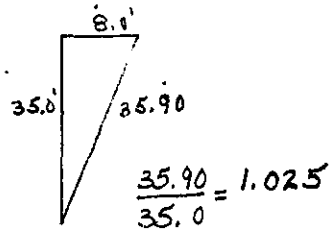
$R = 35.00 - 0.677 - 1.500 = 32.82'$

$\bar{x} = 32.82 \times 0.87027 = \cancel{31.45'}\ 28.56'$
$\bar{y} = 32.82 \times 0.49257 = -16.18'$

14 WF 78

$$R = \frac{35.00' - 0.677' - \frac{30.00'}{12} - 4.00'}{2} + 4.00 = 13.91 + 4.00 = 17.91'$$

$\bar{x} = 17.91 \times 0.95394 = 17.11'$
$\bar{y} = 17.91 \times 0.3000 = +5.39'$
length $= 1.025 \times 27.82 = 28.50'$



14 WF 127

$$R = \frac{35.00 - 0.677 - \frac{36.00}{12} - 4.00}{2} + 4.00 = 17.66'$$

$\bar{x} = 17.66 \times 0.98974 = 17.47'$
$\bar{y} = 17.66 \times 0.14286 = -2.52'$
length $= 1.025 \times 27.32 = 28.00'$

SUBJECT Fox Point
COMPUTATION Gates C. of G. and weight
COMPUTED BY GFH CHECKED BY R.A.K DATE 18 Nov. 59

14WF127

$R = \frac{35.00 - 0.677 - 7.00}{2} + 4.00 = 13.66 + 4.00 = 17.66'$

$\bar{x} = 17.66 \times 0.87027 = 15.37'$
$\bar{y} = 17.66 \times 0.49257 = -8.70'$
length $= 1.025 \times 27.32 = 28.00'$

① 14WF48

$\measuredangle BPC = 25° - 40.26'$ $\quad \frac{1}{2} \measuredangle BPC = 12° - 50.13'$

$R = 29.0' \cos 12° - 50.13' = 29.0 \times 0.97501 = 28.25'$

$\alpha = 12° - 50.13'$ minus $8° - 12.79' = +4° - 37.34'$

$\bar{x} = 28.25 \cos\alpha = 28.25 \times 0.99674 = 28.15'$
$\bar{y} = 28.25 \sin\alpha = 28.25 \times 0.08059 = +2.28'$
length $= 2 \times 28.25 \sin 12° - 50.13' = 56.50 \times 0.222 = 12.53'$

② 14WF48

$R = 17.0 \times 0.97501 = 16.57'$

$\bar{x} = 16.57 \times 0.99674 = 16.50'$
$\bar{y} = 16.57 \times 0.08059 = +1.34'$
length $= 2 \times 16.57' \times 0.222 = 7.35'$

③ 14WF48

$\alpha = \frac{1}{2} \measuredangle CPD + \measuredangle TPC = 10° - 38.89'$ plus $8° - 12.79' = \cancel{19}\,18° - 51.68'$

$R = 28.25'$

$\bar{x} = R \cos\alpha = 28.25 \times 0.\cancel{94051}\ 94630 = 26.\cancel{60}\ 7'$
$\bar{y} = R \sin\alpha = 28.25 \times 0.\cancel{33975}\ 32328 = -9.\cancel{60}\ 14'$
length $= 2 \times 28.25 \times 0.18477 = \cancel{11.42}\ 10.44'$

④ 14WF48

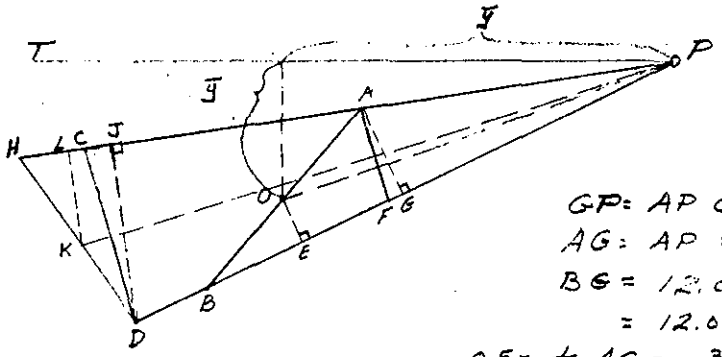
$R = 16.57'$

$\bar{x} = 16.57 \times 0.\cancel{94051}\ 94637 = 15.\cancel{58}\ 65'$
$\bar{y} = 16.57 \times 0.\cancel{33975}\ 32328 = -5.\cancel{62}\ 35'$

length $= 2 \times 16.57 \times 0.18477 = 6.11'$

SUBJECT Fox Point Barrier
COMPUTATION Gates - C. of G. and weight
COMPUTED BY G.F.H. CHECKED BY R.A.E. DATE 19 Nov. 59

(5) 14WF48 (AB)



$\measuredangle TPD = 29°-30.58'$
$AP = FP = 17.00'$
$BF = 12.00'$
$\measuredangle CPD = 21°-17.78'$

$GP = AP \cos \measuredangle CPD = 17.00 \times 0.93171 = 15.84'$
$AG = AP \sin \measuredangle CPD = 17.00 \times 0.36319 = 6.17'$
$BG = 12.00 + (17.00 - 15.84)$
$= 12.00 + 1.16 = 13.16'$
$OE = \frac{1}{2} AG = 3.08'$
$EP = \frac{1}{2} BG + GP = 6.58 + 15.84 = 22.42'$

$\measuredangle OPE = \text{arc tan} \frac{3.08}{22.42} = \text{arc tan } 0.1375 = 7°-50'$

$\measuredangle TPD = 29°-30.58$ minus $7°-50' = 21°-40.58'$

$OP = \frac{OE}{\sin \measuredangle OPE} = \frac{3.08}{0.13629} = 22.60'$

$\bar{x} = OP \cos \measuredangle TPO = 22.60 \times 0.92929 = 21.00'$
$\bar{y} = OP \sin \measuredangle TPO = 22.60 \times 0.36937 = -8.34'$
$\text{length} = 1.025 \sqrt{6.17^2 + 13.16^2} = 1.025 \times 14.53 = 14.90'$.

(6) 14WF48 (HD)

see above sketch

$CP = DP = 31.32'$ $HC = 3.00'$
$JP = DP \cos \measuredangle CPD = 31.32 \times 0.93171 = 29.15'$
$HJ = 3.00 + (31.32 - 29.15) = 3.00 + 2.17 = 5.17'$
$JD = DP \sin \measuredangle CPD = 31.32 \times 0.36319 = 11.36'$
$LK = \frac{1}{2} JD = 5.68'$ $LP = \frac{1}{2} HJ + JP = 2.58 + 29.15 = 31.73'$

$\measuredangle LPK = \text{arc tan} \frac{5.68}{31.73} = \text{arc tan } 0.1790 = 10°-10'$

$\measuredangle TPK = \measuredangle TPH + \measuredangle LPK = 8°-12.79'$ plus $10°-10' = 18°-22.79'$

$KP = \frac{5.68}{\sin 10°-10'} = \frac{5.68}{0.17651} = 32.15'$

$\bar{x} = KP \cos \measuredangle TPK = 32.15 \times 0.94898 = \cancel{27.30}\ 30.51'$
$\bar{y} = KP \sin \measuredangle TPK = 32.15 \times 0.31531 = -10.12'$.
$\text{length} = 1.025 \sqrt{5.17^2 + 11.36^2} = 1.025 \times 12.48 = 12.80'$

SUBJECT Fox Point Barrier
COMPUTATION Gates - C. of G. and weight
COMPUTED BY GFH CHECKED BY R.A.K. DATE 19 Nov. 59

① - 4 x 4 x 3/8 L

$\measuredangle \alpha = \frac{1}{2}\measuredangle BPC - \measuredangle TPC = 12^\circ - 50.13'$ minus $8^\circ - 12.79' = 4^\circ - 37.34'$

$R = \left(35.00 - 0.677 - \frac{34.50}{12}\right) \cos \frac{1}{2}\measuredangle BPC$

$= 31.45 \times 0.97501 = 30.65'$

$2R \sin \frac{1}{2}\measuredangle BPC =$
$2 \times 31.45 \times 0.22212 = 13.97$

$\sqrt{8.0^2 + 13.97^2} = 16.10' =$ length of L

$\bar{x} = R \cos\alpha = 30.65 \times 0.99674 = 30.55'$
$\bar{y} = R \sin\alpha = 30.64 \times 0.08059 = +2.47'$

② - 4 x 4 x 3/8 L

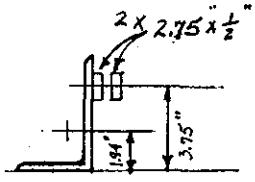
$\measuredangle \alpha = \overset{18}{\cancel{19}}^\circ - 51.68'$ $\qquad \frac{1}{2}\measuredangle CPD = 10^\circ - 38.89'$

$R = (35.00 - 3.68) \cos \frac{1}{2}\measuredangle CPD = 31.32 \times 0.98278 = 30.\overset{.78}{\cancel{55}}'$

$\bar{x} = R \cos\alpha = 30.\overset{.78}{\cancel{55}} \times 0.\overset{.94630}{\cancel{94051}} = \overset{29.13}{\cancel{28.96}}'$
$\bar{y} = R \sin\alpha = 30.\overset{.78}{\cancel{55}} \times 0.\overset{.32327}{\cancel{33975}} = -\underset{9.95}{\cancel{10.44}}'$

$2R \sin \frac{1}{2}\measuredangle CPD = 2 \times 30.\overset{.78}{\cancel{55}} \times 0.18477 = 11.\overset{.37}{\cancel{29}}'$

$\sqrt{11.29^2 + 8.0^2} = 13.\overset{.90}{\cancel{82}}' =$ length of L



Seal Support

$\bar{x} = \frac{(3.61)(1.94) + (2.75)(3.75)}{(3.61 + 2.75)} = \frac{7.00 + 10.31}{6.36} = 2.72''$
$= 0.23'$

$\measuredangle$ below horizontal axis $= \frac{\measuredangle TPE - \measuredangle APT}{2} = -\frac{4^\circ - 0.55'}{2} = -2^\circ - 0.28'$
$\sin = .03490$
$\cos = .99939$

Total Arc Angle $= \measuredangle TPE + \measuredangle APT = 69^\circ - 44.89' = 3.14 \times \frac{69.748}{180} = 1.216$ rad.

Radius to C. of G. of section $= 35.00' - 0.23' = 34.77'$

$\alpha = 0.608$ rad $\quad \sin\alpha = \sin 34^\circ - 52.45' = 0.57178$

Radius to C. of G. of member $= 34.77 \times \frac{0.57178}{0.608} = 32.70'$

$\bar{x} = 32.70' \times 0.99939 = 32.70'$ $\quad \bar{y} = 32.70' \times .0349 = -1.14'$ $\quad$ Length $= 42.0'$

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NEW ENGLAND DIVISION
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SUBJECT Fox Point Barrier
COMPUTATION Gates - C. of G. and weight
COMPUTED BY GFH CHECKED BY R.A.K. DATE 19 Nov. 59

Member	Volume Factors	V cu. ft.	$\bar{x}$	$\bar{y}$	$V\bar{x}$	$V\bar{y}$
3/8" PL	$13.0 \times \frac{0.375}{12} \times 19.67$	7.99	32.15	13.13	257.0	105.0 1 0.5
7/16" PL	$14.75 \times \frac{0.4375}{12} \times 19.67$	10.58	34.80	0	368.0	0
1/2" PL	$14.83 \times \frac{0.50}{12} \times 19.67$	12.15	31.50	-14.50	383.0	- 176.1
ST 8WF25	$10 \times 42.0 \times \frac{7.35}{144}$	21.45	32.30	-1.12	693.0	- 24.0
30WF116	$19.67 \times \frac{34.13}{144}$	4.66	31.50	9.92	146.8	46.2
36WF160	$19.67 \times \frac{47.09}{144}$	6.43	32.50	-4.69	209.0	- 30.1
36WF160	$19.67 \times \frac{47.09}{144}$	6.43	~~31.45~~ 28.56	-16.18	~~202.0~~ 183.4	- 103.9
14WF 78	$28.50 \times \frac{22.94}{144}$	4.54	17.11	5.39	77.7	24.4
14WF127	$28.00 \times \frac{37.33}{144}$	7.26	17.47	-2.52	126.9	- 18.3
14WF127	$28.00 \times \frac{37.33}{144}$	7.26	15.37	-8.70	111.5	- 63.1
14WF48-①	$12.53 \times \frac{14.11}{144}$	1.23	28.15	2.28	34.6	2.8
" -②	7.35 × "	0.72	16.50	1.34	12.2 11.9	~~0.1~~ 1.0
" -③	~~11.42~~ 10.44 × "	~~1.12~~ 1.02	26.60 7	-9.~~60~~ 14	29.8 27.3	- ~~10.8~~ - 9.3
" -④	6.11 × "	0.60	15.~~58~~ 65	-5.~~62~~ 35	9.~~8~~ 9.4	- 3.~~4~~ - 3.2
" -⑤	14.90 × "	1.46	21.00	-8.34	30.7	- 12.2
" -⑥	12.80 × "	1.25	~~29.30~~ 30.51	-10.12	~~34.1~~ 38.3	- 12.7

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COMPUTATION Gates - C. of G. and Weight
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4x4x3/8 L ①	$16.10 \times 5 \times \frac{2.86}{144}$	1.60	30.55	2.47	48.9	4.0
" - ②	$13.\cancel{82}^{90} \times 5 \times$ "	1.40	28.90 29.13	-~~10.44~~ -9.95	~~39.7~~ 40.2	-14.3 -13.7
Trunnion Hub	$2.08\pi(1.0^2 - 0.67^2)$	3.63	0	0	0	0
+ Plates	$0.208\left[(4.0 \times 2.5) - \left(\pi \times \frac{1.0^2}{2}\right)\right]$	1.75	3.0±	0±	5.2	0
Seal Support	$\frac{6.36}{144} \times 42.0$	1.86	32.70	-1.14	60.8	-2.1
		6 10 8 ~~105.37~~ 105.27			7 11 8 2,880.2 2,863.60	88.0 -471.0 ~~-383.0~~ -285.30

$$\bar{x} = \frac{2{,}863.6 \;\; 2880.2}{105.\cancel{37}\;105.27} = 27.\cancel{35}\,.20'$$

$$\bar{y} = \frac{285.30 \;\; -383.0}{105.\cancel{37}\;105.27} = -3.\cancel{64}\,2.71'$$

$$R = \sqrt{27.\cancel{35}^{2} + \cancel{3.64}^{2}} = 27.\cancel{6}\,4'$$

Total Wt. = $105.\cancel{3}\,2 \times 490 \times 2 = 103.2^{K}$

SUBJECT Narragansett Bay - Fox Point Barrier
COMPUTATION Gate Structure - Stability
COMPUTED BY CMT & BEN CHECKED BY DATE 26 OCT 1958

LOADING CONDITIONS

CASE I:- Construction Condition, Dry, No Wind, Gates Down
Ia:- " " " , With Wind, No Gates
Ib:- " " " " " , All Gates Up
Ic:- " " " " " , All Gates Down
Id:- " " " " " , 1 Gate Down, 2 Up
Ie:- " " " " " , 2 Gates Down, 1 Up

CASE II:- Normal Operating Condition, All Gates Up, Water at El. +3.0
IIa:- Gates Down, Water at El. +3.0 on River Side and El. -3.0 on Bay Side
IIb:- Gates Down, Water at El. -3.0 on River Side and El. +3.0 on Bay Side

CASE III:- Hurricane and High Water Condition, Still Water Level at El. +20.5. Max. Wave with Crest of Clapotis at El. +33.32. Tailwater on River Side at El. -3.0

CASE IV:- Construction Condition same as CASE I but with Earthquake

CASE V:- Normal Operating Condition with Earthquake

NED FORM 223
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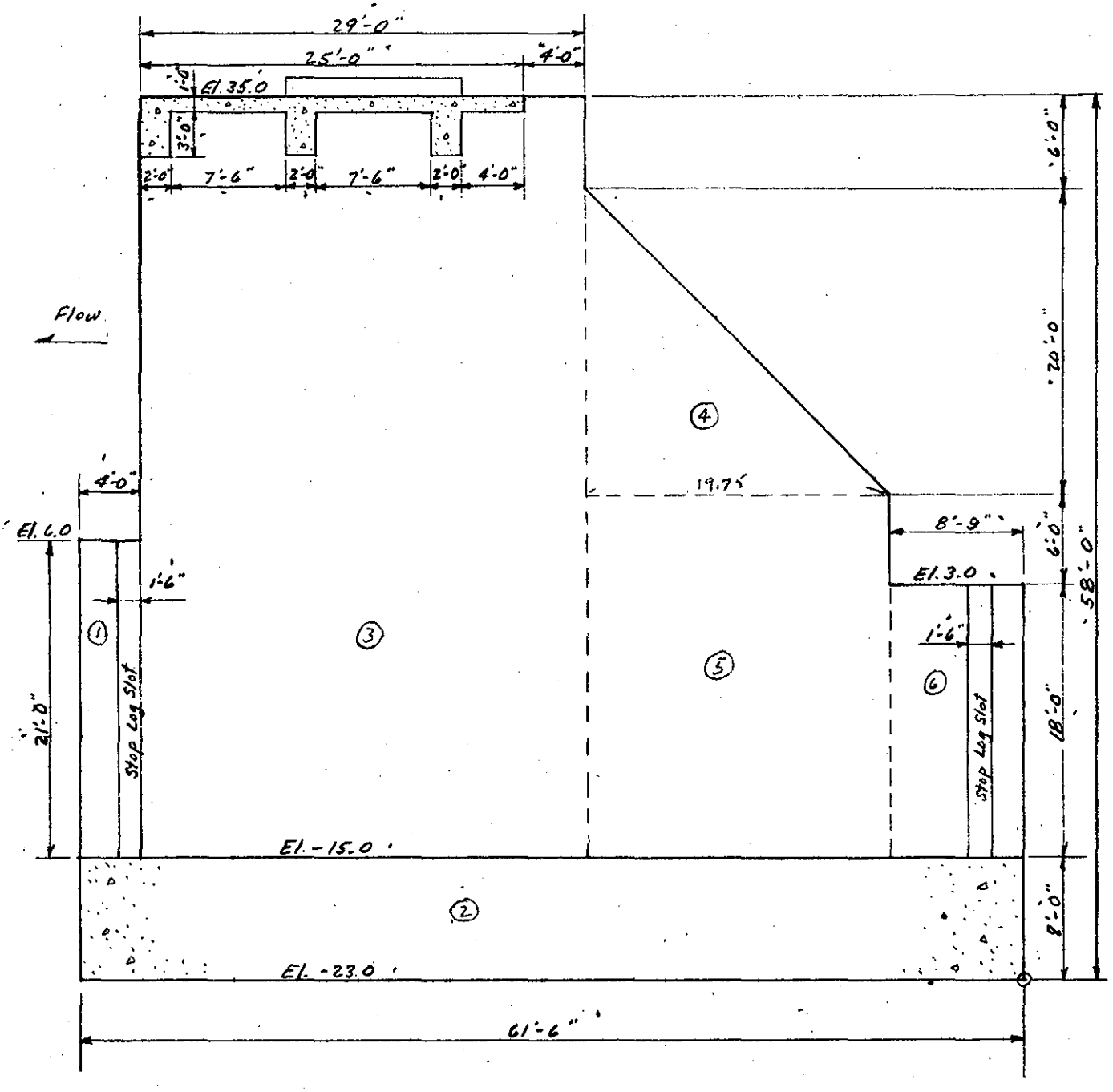
NEW ENGLAND DIVISION

CORPS OF ENGINEERS, U. S. ARMY

SUBJECT Narragansett Bay - Fox Point Barrier

COMPUTATION Gate Structure - Stability

COMPUTED BY BJW CHECKED BY Cmt DATE 26 Oct 1959



NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U.S. ARMY

SUBJECT Narragansett Bay - Fox Point Barrier
COMPUTATION Gate Structure - Stability
COMPUTED BY BFov CHECKED BY CWS DATE 26 Oct. 1959

Weight of Concrete Only

		WGT. K	V.A.'	M_{CG} 'K	H.A.'	M_{OV} 'K
1	.15 x 4.0 x 21.0 x 28.0	353	18.5	6,530	59.5	21,000
2	.15 x 61.5 x 8.0 x 148.0	10,920	4.0	43,680	30.75	335,800
3	.15 x 29.0 x 50.0 x 28.0	6,090	33.0	201,000	43.0	262,000
4	.15 x 19.75 x 20.0/2 x 28.0	830	38.67	32,100	21.92	18,200
5	.15 x 19.75 x 24.0 x 28.0	1,990	20.0	39,800	18.62	37,100
6	.15 x 8.75 x 18.0 x 28.0	662	17.0	11,250	4.37	2,890
Plat. Slab	.15 x 25.0 x 1.0 x 120.0	450	57.5	25,850	45.0	20,250
" Bms.	.15 x 6.0 x 3.0 x 120.0	324	55.5	18,000	47.0	15,230
Motor Bases	.15 x 11.5 x 1.25 x 40.0 (38.0)	86	58.63	5,050	42.25	3,650
Less Stop Log Slots	.15 x 1.5 x 18.0 x 6.0	- 24	17.0	- 413	2.75	- 67
	.15 x 1.5 x 21.0 x 6.0	- 28	18.5	- 525	58.25	- 1,650
	Σ	21,653	17.66	382,322	32.99	714,403

$e = 32.99 - 30.75 = 2.24'$

$f = \frac{21,653}{61.5 \times 148}\left(1 \pm \frac{6 \times 2.24}{61.5}\right) = 2.38\,(1 \pm 0.218)$

$f_{max.} = 2.38\,(1.218) = 2.90$ K/□
$f_{min.} = 2.38\,(0.782) = 1.86$ K/□ } O.K.

CASE I Construction Condition, Dry, No Wind, Gates Down

		WGT	V.A.	M_{CG}	H.A.	M_{OV}
Conc		21,653		382,322		714,403
Gates	112 x 3	336	29.0	9,750	38.5	12,940
		21,989	17.83	392,072	33.08	727,343

$e = 33.08 - 30.75 = 2.33'$

$f = \frac{21,989}{61.5 \times 148}\left(1 \pm \frac{6 \times 2.33}{61.5}\right) = 2.42\,(1 \pm 0.227)$

$f_{max} = 2.42\,(1.227) = 2.97$ K/□
$f_{min} = 2.42\,(0.773) = 1.87$ K/□

SUBJECT Narragansett Bay - Fox Point Barrier
COMPUTATION Gate Structure - Stability
COMPUTED BY BJW CHECKED BY Cmt DATE 27 Oct 1959

CASE Ia Construction Condition, Dry with Wind (No Gates)

(1) Wind Acting Horizontally toward Bay

		HOR.	VER.		Mov
Conc.			21,653 ↓		+ 714,403
Wind	.030 × 8.0 × 148.0	35.5 ←		4.0	+ 142
	.030 × 50.0 × 28.0	42.0 ←		33.0	+ 1386
	.030 × 4.0 × 120.0	14.4 ←		56.0	+ 806
	.030 × 3.0 × 120.0 × 2	21.6 ←		55.5	+ 1200
		113.5 ←		33.16	+ 717937

$\Sigma M/\Sigma V = 717937/21653 = 33.16'$

$e = 33.16 - 30.75 = 2.41'$

$\Sigma H/\Sigma V = \frac{113.5}{21653} = .005$ ok

$f = \frac{21,653}{61.5 \times 148}\left(1 \pm \frac{6 \times 2.41}{61.5}\right) = 2.38(1 \pm 0.235)$

$f_{max} = 2.38(1.235) = 2.94$ K/□
$f_{min} = 2.38(0.765) = 1.82$ K/□ } O.K.

(2) Wind Acting Vertically Upward

			VER.		Mov
Conc.			21,653 ↓		714,403
Wind	.030 × 25.0 × 120.0		90 ↑	45.0	− 4050
			21,563 ↓	32.94	710353

$e = 32.94 - 30.75 = 2.19'$

$f = \frac{21563}{61.5 \times 148}\left(1 \pm \frac{6 \times 2.19}{61.5}\right) = 2.37(1 \pm 0.214)$

$f_{max.} = 2.37(1.214) = 2.88$ K/□
$f_{min.} = 2.37(0.786) = 1.86$ K/□ } o.k.

CASE Ib Construction Condition, Dry with Wind Vertical Up (All gates up)

		HOR.	VER.		Mov
Conc+Gates			21,989 ↓		+ 720,983
Wind - C			90 ↑		− 4050
" - G	(.030 × 40.0 × 120.0) sin 68° (144.0 = 144.0, .927)		133 ↑	19.75	− 2627
	(144.0) cos 68° (.375)	54 ←		58.5	+ 3159
			21,766 ↓	32.96	+ 717,465

$e = 32.96 - 30.75 = 2.21'$

$f = \frac{21766}{61.5 \times 148}\left(1 \pm \frac{6 \times 2.21}{61.5}\right) = 2.39(1 \pm .216)$ (.216)

$f_{max.} = 2.39(1.216) = 2.91$ K/□
$f_{min.} = 2.39(0.784) = 1.87$ K/□ } ok

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT Narragansett Bay - Fox Point Barrier
COMPUTATION Gate Structure - Stability
COMPUTED BY RPW CHECKED BY Cmt DATE 27 OCT. 1958

CASE Ic Const. Cond., Dry with Wind (All Gates Down) toward bay

		HOR	VER.	ARM	MOM
Conc. & Gates			21,989		727,343
Wind - C		113.5		31.1	3534
" - G	.030 x 40.0 x 120.0	144.0		28.0	4032
		257.5	21,989	33.42	734,909

$e = 33.42 - 30.75 = 2.67'$

$f = \frac{21,989}{61.5 \times 148}\left(1 \pm \frac{6 \times 2.67}{61.5}\right) = 2.42(1 \pm .260)$

$f_{max} = 2.42\ (1.260) = 3.05\ ^{k}/\phi$
$f_{min} = 2.42\ (0.740) = 1.79\ ^{k}/\phi$ } ok

CASE Id Const. Cond., Dry with Wind (1 Gate Down, 2 Up) toward bay

		HOR	VER.		ARM	MOM
Conc.			21,653 ↓			714,403
1 D. Gate			112 ↓		38.5	4,310
2 U. Gates			224 ↓		19.58	4,380
Wind - C		113.5 ←				3534
" - 1 D.G.	.030 x 40.0 x 40.0	48.0 ←			28.0	1,344
" - 2 U.G.	2 x 48.0 cos 68.375°	36.0 ←			58.5	2,106
		197.5 ←	21,989 ↓		33.20	730,077

$e = 33.20 - 30.75 = 2.45'$

$\frac{\Sigma H}{\Sigma V} = \frac{197.5}{21989} = .008$ ok

$f = \frac{21989}{61.5 \times 148}\left(1 \pm \frac{6 \times 2.45}{61.5}\right) = 2.42(1 \pm .239)$

$f_{max} = 2.42\ (1.239) = 3.00\ ^{k}/\phi$
$f_{min} = 2.42\ (0.761) = 1.84\ ^{k}/\phi$ } ok.

SUBJECT Narragansett Bay - Fox Point Barrier
COMPUTATION Gate Structure - Stability
COMPUTED BY BM CHECKED BY Cmb DATE 27 OCT. 1958

CASE Ic Const. Cond, Dry with Wind (2 Gates Down, 1 Up) toward bay

		HOR.	VER	ARM	MOM
Conc.			21,653 ↓		714,403
2 D. Gates			224 ↓	38.5	8,620
1 U. Gate			112 ↓	19.58	2,190
Wind - C		113.5 ←			3534
" - 2 D.G.		96.0 ←		28.0	2688
" - 1 U.G.					
	48.0 cos 68° (.375)	18.0 ←		58.5	1053
		227.5 ←	21,989 ↓	33.31	732,488

$e = 33.31 - 30.75 = 2.56'$

$\frac{\Sigma H}{\Sigma V} = \frac{227.5}{21989} = .01$ ok

$f = \frac{21989}{61.5 \times 148}\left(1 \pm \frac{6 \times 2.56}{61.5}\right) = 2.42'\,(1 \pm .250)$

$f_{max} = 2.42\,(1.25) = 3.02'\,\text{k/ft}$
$f_{min} = 2.42\,(0.75) = 1.82'\,\text{k/ft}$ } ok

SUBJECT Narragansett Bay - Fox Point Barrier
COMPUTATION Gate Structure - Stability
COMPUTED BY CMT CHECKED BY BPW DATE 10/28/59

CASE II :- Normal Operating Condition, All Gates Up, Water at El. +30

ITEM		WEIGHT	ARM	MOMENT
Conc. &	Gates	21,989 ↓	32.79	+ 720,983
W	.0642 x 61.5 x 18.0 x 120	8,528 ↓	30.75	+ 262,246
U	.0642 x 61.5 x 26.0 x 148	15,193 ↑	30.75	- 467,187
	ΣV	15,324 ↓	ΣM	+ 516,042

$$\frac{\Sigma M}{\Sigma V} = \frac{516,042}{15,324} = 33.68' \qquad e = 33.68 - 30.75 = 2.93'$$

$$f = \frac{15324}{61.5 \times 148}\left(1 \pm \frac{6 \times 2.93}{61.5}\right) = 1.68(1 \pm .286)$$

$$\left.\begin{aligned} f_{max} &= 1.68(1.286) = 2.16 \text{ KSF} \\ f_{min} &= 1.68(0.714) = 1.20 \text{ KSF} \end{aligned}\right\} \text{O.K.}$$

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27 Sept 49.

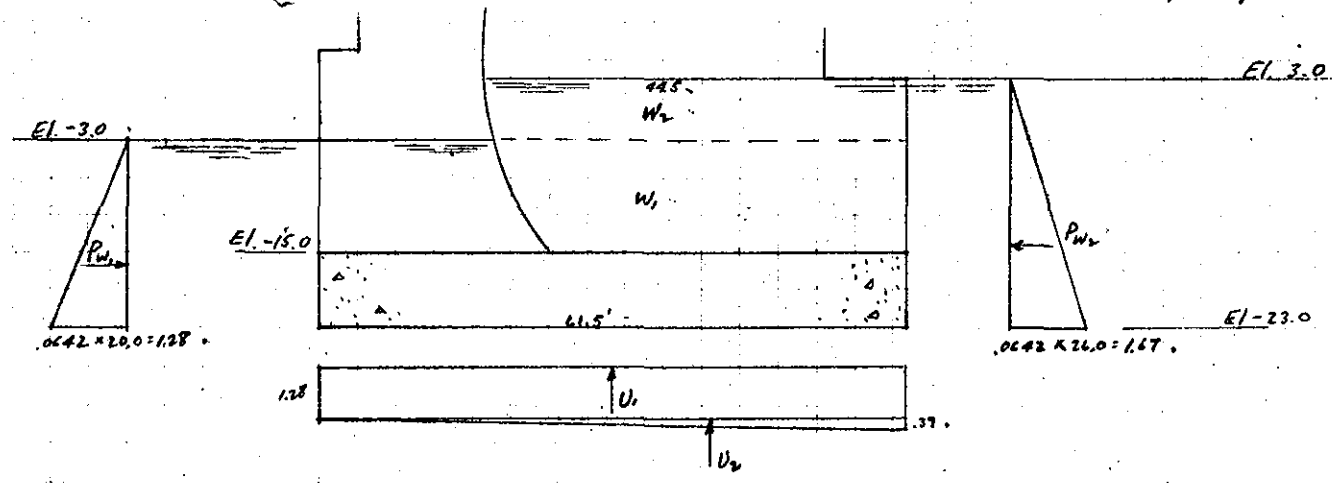
NEW ENGLAND DIVISION

CORPS OF ENGINEERS, U. S. ARMY

SUBJECT Narragansett Bay - Fox Point Barrier

COMPUTATION Gate Structure - Stability

COMPUTED BY BFM CHECKED BY CMT DATE 10/30/59



CASE IIa Normal Operating Condition - All Gates Down - High Tide +3.0 M.S.L. on River Side, Low Tide -3.0 M.S.L. on Bay Side

		HOR.	VER.	ARM	M_{OV}
Conc. & Gates			21,989 ↓		727,343
W_1	.0642 × 12.0 × 61.5 × 120.0		5,690 ↓	30.75	175,000
W_2	.0642 × 6.0 × 44.5 × 120.0		2,060 ↓	22.25	45,800
U_1	1.28 × 61.5 × 148.0		11,650 ↑	30.75	- 358,200
U_2	.39 × 61.5/2 × 148.0		1,775 ↑	20.5	- 36,400
P_{W_1}	1.28 × 20.0/2 × 148.0	1,895 →		6.67	- 12,630
P_{W_2}	1.67 × 26.0/2 × 148.0	3,210 ←		8.67	27,800
		1,315 ←	16,314 ↓	34.86	568,713

$$e = 34.86 - 30.75 = 4.11$$

$$f = \frac{16,314}{61.5 \times 148}\left(1 \pm \frac{6 \times 4.11}{61.5}\right) = 1.79\,(1 \pm .401)$$

$$\left.\begin{aligned} f_{max} &= 1.79\,(1.401) = 2.51 \text{ K/□'} \\ f_{min} &= 1.79\,(.599) = 1.07 \text{ K/□'} \end{aligned}\right\} \text{ ok.}$$

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U. S. ARMY

SUBJECT Narragansett Bay - Fox Point Barrier
COMPUTATION Gate Structure - Stability
COMPUTED BY BPW CHECKED BY Cwt DATE 11/12/59

CASE IIb Normal Operating Condition - All Gates Down - High Tide +3.0 M.S.L. on Bay Side, Low Tide -3.0 M.S.L. on River Side

		HOR.	VER.	ARM	MOM
Conc. & Gates			21,989 ↓		727,343
W_1			5,690 ↓		175,000
W_2	.0642 x 6.0 x 17.0 x 120.0		786 ↓	53.0	41,660
U_1			11,650 ↑		- 358,200
U_2	.39 x 61.5/2 x 148.0		1,775 ↑	41.0	- 72,770
P_{W1}		3,210 →		8.67	- 27,800
P_{W2}		1,895 ←		6.67	12,630
		1,315 →	15,040 ↓	33.10	497,863

$e = 33.10 - 30.75 = 2.35'$

$f = \frac{15,040}{61.5 \times 148.0}\left(1 \pm \frac{6 \times 2.35}{61.5}\right) = 1.65\,(1 \pm .229)$

$f_{max} = 1.65\,(1.229) = 2.03\ ^k/\square'$
$f_{min.} = 1.65\,(.771) = 1.27\ ^k/\square'$

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION

CORPS OF ENGINEERS, U. S. ARMY

SUBJECT Narragansett Bay - Fox Point Barrier

COMPUTATION Gate Structure - Stability

COMPUTED BY BPW CHECKED BY RDR DATE 11/3/59

CASE III Hurricane & High Water Condition, SWL El. +20.5. Max. Wave with Crest of Clapotis at El. +33.32. Tailwater at El. -3.0 All Gates Down. Wt. of Water Computed from Crest of Significant Wave (6.5') at El. +28.02. Uplift Computed from SWL.

		H.	V.	ARM	Mov.
Conc. & Gates			21,989 ↓		727,343
W_1	.0642 × 12.0 × 61.5 × 120.0		5,690 ↓		175,000
W_2	.0642 × 31.0 × 17.0 × 120.0		4,060 ↓	53.0	215,200
U_1	1.28 × 61.5 × 148.0		11,650 ↑	30.75	- 358,200
U_2	1.51 × 61.5/2 × 148.0		6,860 ↑	41.0	- 281,260
P_1	.437 × 48.0 × 148.0	3,110 →		24.0	- 74,600
P_2	1.474 × 28.0/2 × 148.0	3,055 →		29.33	- 89,500
P_3	.139 × 12.0/2 × 148.0	123 →		16.0	- 1,970
P_4	1.335 × 20.0 × 148.0	3,950 →		10.0	- 39,500
		10,238 →	13,229 ↓	20.60	272,513

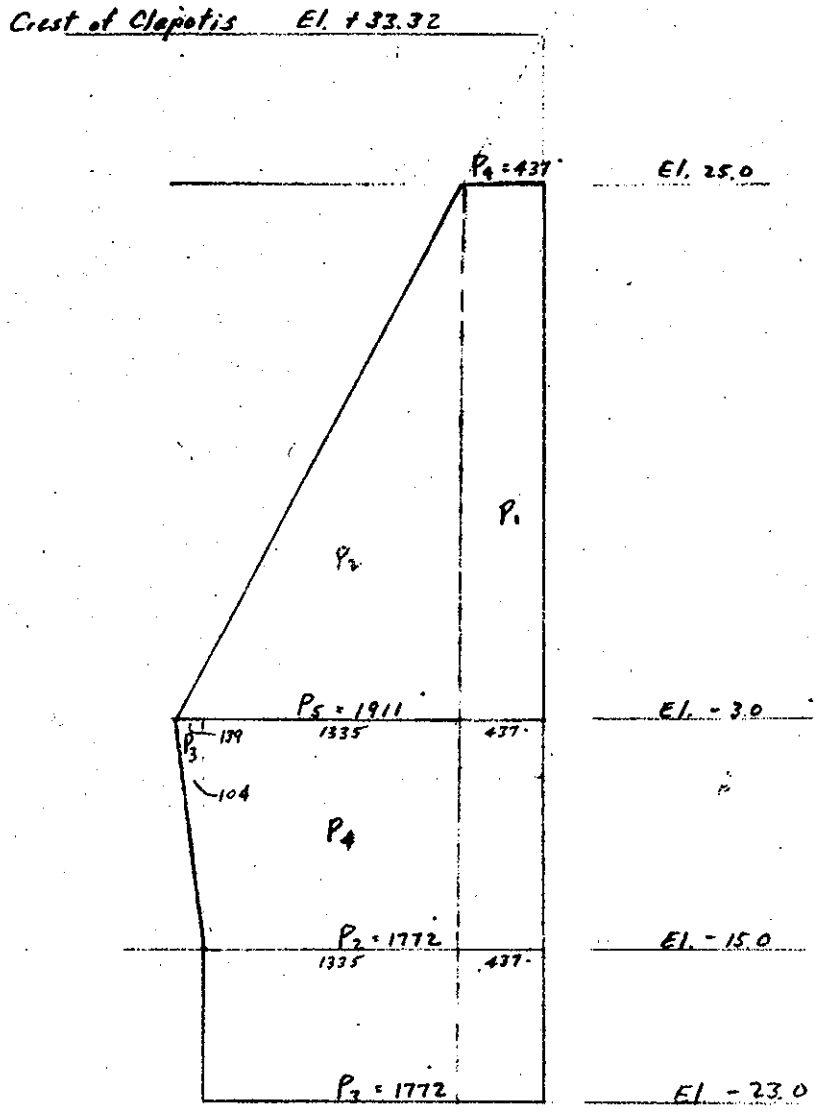
$$\frac{\Sigma H}{\Sigma V} = \frac{10,238}{13,229} = 0.77 \quad \text{Without Piles}$$

$$e = 30.75 - 20.60 = 10.15''$$

$$f = \frac{13,229}{61.5 \times 148}\left(1 \pm \frac{6 \times 10.15}{61.5}\right) = 1.45(1 \pm .990)$$

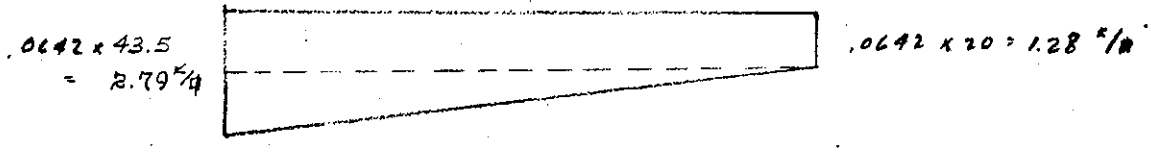
$$\left.\begin{aligned} f_{max} &= 1.45(1.990) = 2.89 \ ^{k}/_{\square'} \\ f_{min} &= 1.45(.010) = 0.01 \ ^{k}/_{\square'} \end{aligned}\right\} \text{o.k.}$$

SUBJECT Narragansett Bay - Fox Point Barrier
COMPUTATION Gate Structure - Stability
COMPUTED BY BFW CHECKED BY CMT DATE 11/4/59



$wd_2 = 64.2 \times 43.5 = 2793$
$wd_3 = 64.2 \times 20.0 = 1284$
$P_3 = wd_2 + P_1 - wd_3$
$= 2793 + 263 - 1284 = 1772$

CASE III PRESSURE DIAGRAM - CLAPOTIS



UPLIFT DIAGRAM - COMPUTED FROM SWL El. +20.5

NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION

CORPS OF ENGINEERS, U. S. ARMY

SUBJECT Narragansett Bay - Fox Point Barrier

COMPUTATION Gate Structure - Stability

COMPUTED BY BHW CHECKED BY Cmto DATE

CASE III Hurricane & High Water Condition SWL El. +20.5 Tail-water at El -3.0. Max. Wave with Crest of Clapotis at El. +33.32 Compute Bearing Pressures for Dead Loads and Hydrostatic Pressure from SWL on Bay Side and from T.W. on River Side.

		H	V	ARM	M_{ov}
Conc. & Gates			21,989 ↓		727,343
W_1	.0642 x 12.0 x 61.5 x 120.0		5,690 ↓		175,000
W_2	.0642 x 31.02 x 17.0 x 120.0		4,060 ↓	53.0	215,200
U_1	1.28 x 61.5 x 148.0		11,650 ↑	30.75	- 358,200
U_2	1.51 x 61.5/2 x 148.0		6,860 ↑	41.0	- 281,260
P_{W_1}	2.79 x 43.5/2 x 148.0	8,980 →		14.5	- 130,200
P_{W_2}	1.28 x 20.0/2 x 148.0	1,895 ←		6.67	12,630
		7,085 →	13,229 ↓	27.25	360,513

$$\frac{\Sigma H}{\Sigma V} = \frac{7,085}{13,229} = 0.54 \qquad e = 30.75 - 27.25 = 3.50'$$

$$f = \frac{13,229}{61.5 \times 148}\left(1 \pm \frac{6 \times 3.50}{61.5}\right) = 1.45\,(1 \pm .341)$$

$f_{max.} = 1.45\,(1.341) = 1.94$ k/□
$f_{min.} = 1.45\,(.659) = 0.96$ k/□

} B.P. not including addit. pressure due to crest of clapotis on structure

SUBJECT Narragansett Bay - Fox Point Barrier
COMPUTATION Gate Structure - Stability
COMPUTED BY BTW CHECKED BY DATE 10/30/59

CASE IV Construction Condition with Earthquake, Dry, No Wind, Gates Down

		H	V	ARM	M_{ov}
Conc. &	Gates		21,989 ↓		727,343
P_{e_1}	.05 × 21,989	1,100 ←		17.83	19,610
				33.97	746,953

$e = 33.97 - 30.75 = 3.22'$

$f = \frac{21,989}{61.5 \times 148}\left(1 \pm \frac{6 \times 3.22}{61.5}\right) = 2.42(1 \pm .314)$

$f_{max} = 2.42\ (1.314) = 3.18\ ^k/\square$
$f_{min} = 2.42\ (.686) = 1.66\ ^k/\square$ } o.k.

CASE V Normal Operating Condition with Earthquake, Gates Up

$C_e = \frac{51}{\sqrt{1 - 0.72\left(\frac{26}{1000 \times 1}\right)^2}} = \frac{51}{\sqrt{1 - .000486}} = \frac{51}{.999} = 51$

		H	V	ARM	M_{ov}
Σ CASE IV			15,324 ↓		516,042
P_{e_1}	.05 × 21,989	1,100 ←		18.25	20,070
P_{e_2}	$\frac{2}{3} \times \frac{51}{1000} \times .05 \times 26.0\sqrt{26.0^2} \times 28.0$	32 ←		10.4	334
		1,132 ←		35.01	536,446

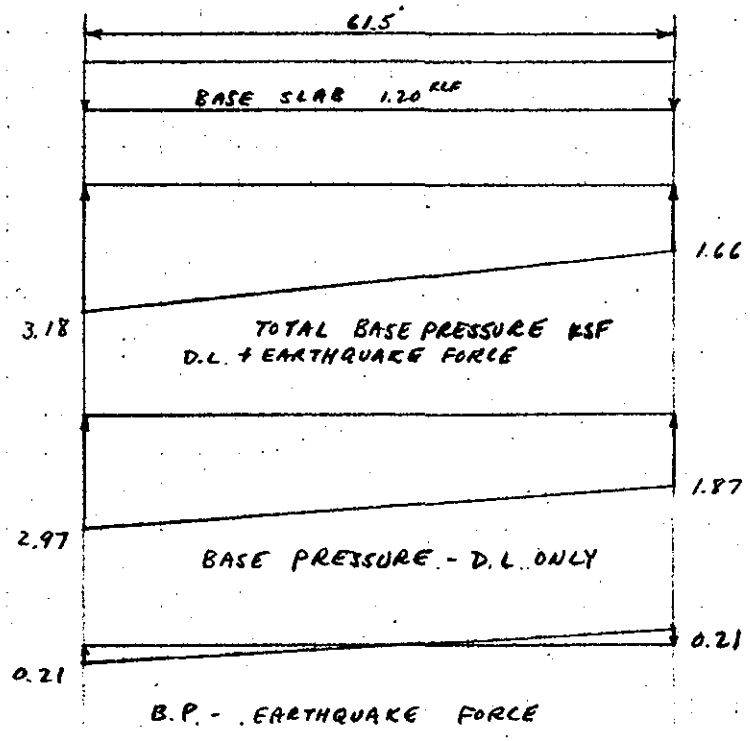
$e = 35.01 - 30.75 = 4.26'$

$f = \frac{15,324}{61.5 \times 148}\left(1 \pm \frac{6 \times 4.26}{61.5}\right) = 1.68(1 \pm .416)$

$f_{max.} = 1.68\ (1.416) = 2.38\ ^k/\square$
$f_{min.} = 1.68\ (.584) = 0.98\ ^k/\square$ } o.k.

SUBJECT Narragansett Bay - Fox Point Barrier
COMPUTATION Gate Structure - Slab Reinf.
COMPUTED BY BAW CHECKED BY R.A.K. DATE 1/8/60

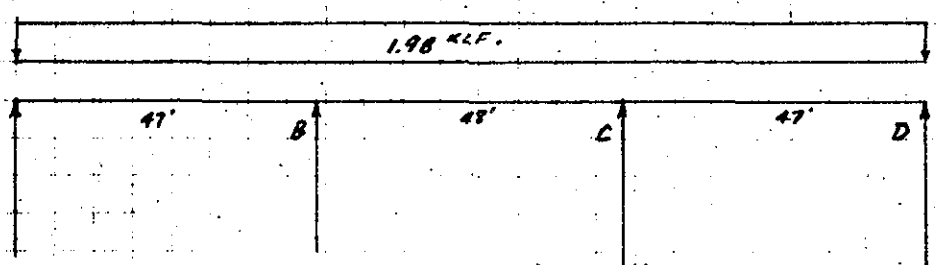
CASE IV Construction Condition with Earthquake



LOADING FOR NORMAL STRESS = 2.97 - 1.20 = 1.77 KLF

" " INC. STRESS = 0.21 KLF

SUBJECT Narragansett Bay - Fox Point Barrier
COMPUTATION Gate Structure - Slab Reinforcing
COMPUTED BY BPW CHECKED BY R.A.K. DATE 12/11/59



LOADING COND.:- CASE IV Const. Cond. with Earthquake.

$M^F_{AB} = M^F_{BA} = M^F_{CD} = M^F_{DC} = \frac{1}{12} \times 1.98 \times \overline{47}^2 = 365^{K}$.

$M^F_{BC} = M^F_{CB} = \frac{1}{12} \times 1.98 \times \overline{48}^2 = 380^{K}$.

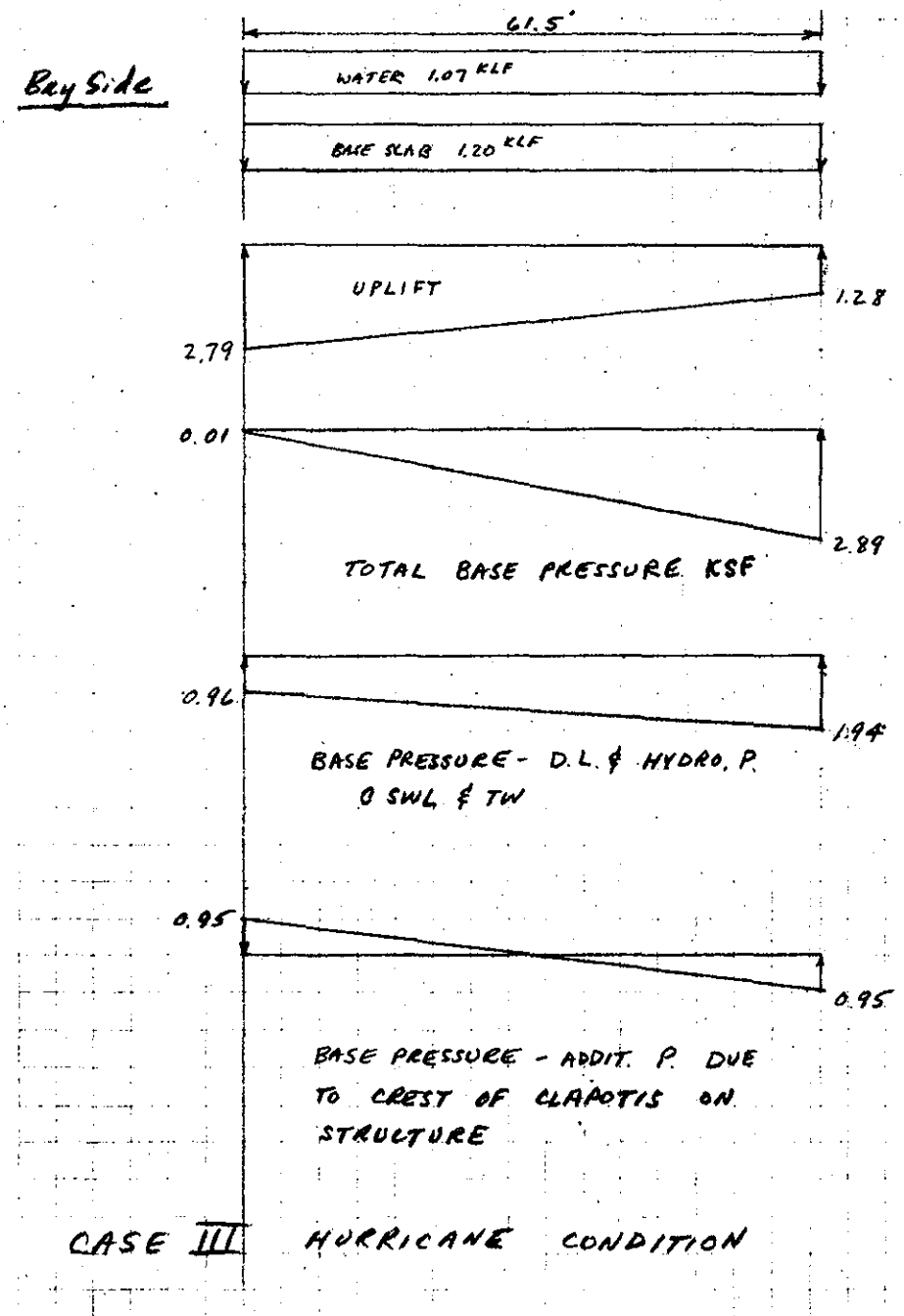
$K_{BA} = \frac{100}{47} = 2.13$ 50.6 %
$K_{BC} = \frac{100}{48} = 2.08$ 49.4 %
4.21 100.0 %

K/EK	0	50.6%	49.4%	49.4%	50.6%	0		
	-365	+365	-380	+380	-365	+365		
	+365	+ 8	+ 7	- 7	- 8	-365		
	+ 4	+182	- 3	+ 3	-182	- 4		
	- 4	- 91	-88	+88	+91	+ 4		
	- 45	- 2	+44	-44	+ 2	+45		
	+ 45	- 21	-21	+21	+21	-45		
	- 10	+ 22	+10	-10	-22	+ 10		
	+ 10	- 16	-16	+16	+16	- 10		
	- 8	+ 5	+ 8	- 8	- 5	+ 8		
	+ 8	- 7	- 6	+ 6	+ 7	- 8		
	- 3	+ 4	+ 3	- 3	- 4	+ 3		
	+ 3	- 4	- 3	+ 3	+ 4	- 3		
	0	+445	-445	+445	-445	0		
$\frac{wl^2}{8} - \frac{\Sigma E_n d_n}{2} + \frac{\Delta H}{l_n}$		546 -222 23 = 347	570 -445 = 125			546 -222 23 = 347		
Shear	37	56	47	47	56	37		
$\frac{1}{3}$ or $\frac{1}{2}$ $V_{4/2}$	0	19 75	63	31	63	75	19	0
DES. MOM.	-82 = $\frac{1}{4}$(+M)	+328	+370	-382	+94	+382	-370	+328	+82 = $\frac{1}{4}$(+M)

BY PROPORTION MAX. NEG. DES. MOM. FOR NORM. STRESS $= \frac{1.77}{1.98} \times 382 = 342^{K}$

" " " " " INC. " $= \frac{0.21}{1.98} \times 382 = 40^{K}$

SUBJECT Narragansett Bay - Fox Point Barrier
COMPUTATION Gate Structure - Slab Reinforcing
COMPUTED BY BJW CHECKED BY R.A.K. DATE 1/7/60

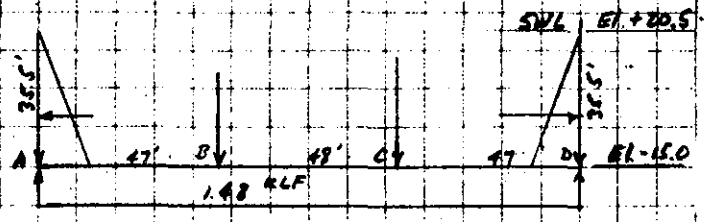


SUBJECT Narragansett Bay - Fox Point Barrier
COMPUTATION Gate Structure - Slab Reinf
COMPUTED BY BRW CHECKED BY CWB DATE 1/7/60

CASE III Hurricane Condition - Design of Slab on Bayside of Structure

Design as Continuous Beam over Supports

Loading:- Uplift +2.79 KLF
B.P. +0.96
Slab -1.20
Water -1.07
Total Load 1.48 KLF



Assume Unif. Load of 1.48 KLF Using Normal Allowable Stress. Neglect Additional B.P. due to Crest of Clapotis on Structure Since it Reduces the Unif. Load at this Section.

$M^F_{AB} = M^F_{BA} = M^F_{CD} = M^F_{DC} = \frac{1}{12} \times 1.48 \times \overline{47}^2 = 272^{1K}$.

$M^F_{BC} = M^F_{CB} = \frac{1}{12} \times 1.48 \times \overline{48}^2 = 284^{1K}$.

Cantilever Mom. $= .0642 \times \frac{\overline{35.5}^3}{2} = 479^{1K}$.

	A		B		C		D	
	0		50.6%	49.4%	49.4%	50.6%	0	
+479	-272		+272	-284	+284	-272	+272	-479
	-207		+ 6	+ 6	- 6	- 6	+207	
	+ 3		-103	- 3	+ 3	+103	- 3	
	- 3		+ 54	+ 52	- 52	- 54	+ 3	
	+ 27		- 1	- 26	+ 26	+ 1	- 27	
	- 27		+ 14	+ 13	- 13	- 14	+27	
	+ 7		- 13	- 6	+ 6	+ 13	- 7	
	- 7		+ 10	+ 9	- 9	- 10	+ 7	
	+ 5		- 3	- 4	+ 4	+ 3	- 5	
	- 5		+ 4	+ 3	- 3	- 4	+ 5	
$\frac{wl^2}{8} + \frac{\Sigma \text{End Mom}}{2} + \frac{\Delta M}{16 M_0}$	+479	-479	+240	-240	+240	-240	+479	-479
		+409 +119 +79 +607			+426 -240 +186		+409 +71.9 +7.9 +607	
Shear $\frac{1}{3}$ or $\frac{1}{6}$ Vale	0	19.5 0	0	50.1 67	34 48	24	36 48	50.1 67	19.5 0
DET. MOM	+479	-479	+607	+173	-192	+162	+192	-173	+607	+479	-479

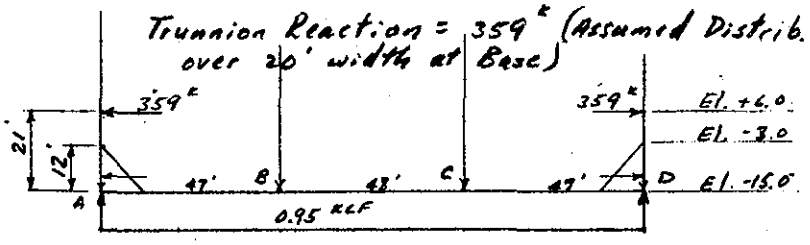
NED FORM 223
27 Sept 49

NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U.S. ARMY

SUBJECT: Narragansett Bay - Fox Point Barrier
COMPUTATION: Gate Structure - Slab Reinforcing
COMPUTED BY: BAW CHECKED BY: R.A.K. DATE: 1/7/60

CASE III Hurricane Condition - Design of Slab on River Side of Structure

Uplift	+1.28 KLF
B.P.	+1.94
Slab	-1.20
Water	-1.07
Tot. Load	0.95 KLF



LOADING DIAG. - NORMAL ALLOWABLE STRESS.

In Addition to Loads Shown on Diagram Above, There is An Additional Load of 0.95 KLF Assumed as Uniformly Distributed Due to Lateral Forces Acting Above SWL. Increased Allowable Stress Will Be Used For This Load. Trunnion Reaction: 100% Used at Normal Stress (Conservative)

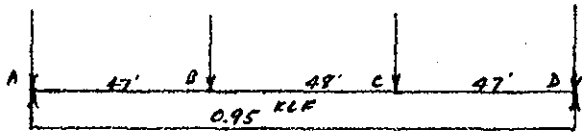
$$M^F_{AB} = M^F_{BA} = M^F_{CD} = M^F_{DC} = \frac{1}{12} \times 0.95 \times \overline{47}^2 = 175^{'k}$$
$$M^F_{BC} = M^F_{CB} = \frac{1}{12} \times 0.95 \times \overline{48}^2 = 182^{'k}$$

$$\text{Cantilever Mom.} = \frac{359}{20} \times 21 + .0642 \times \frac{\overline{12}^3}{6} = 395^{'k}$$

			50.6%	49.4%		49.4%	50.6%			
+395	-175		+175	-182		+182	-175		+175	-395
	-220		+4	+3		-3	-4		+220	
	+2		-110	-1		+1	+110		-2	
	-2		+56	+55		-55	-56		+2	
	+28		-1	-27		+27	+1		-28	
	-28		+14	+14		-14	-14		+28	
	+7		-14	-7		+7	+14		-7	
	-7		+11	+10		-10	-11		+7	
	+5		-3	-5		+5	+3		-5	
	-5		+4	+4		-4	-4		+5	
+395	-395		+136	-136		+136	-136		+395	-395
$\frac{wl^2}{8} - \frac{\Sigma \text{End Mom}}{2} + \frac{Pl}{4}$		+262 +129 +67 +458			+274 -136 +128			+262 +129 +67 +458		
Shear	11		34	23		23	34			
$\frac{1}{3}$ or $\frac{1}{2}$ $V_{a/2}$ 0	0	0	45	31	15	31	45	0	0	0
DES. MOM +395	-395	+458	+91	-105	+123	+105	-91	+458	+395	-395

SUBJECT Naccagansett Bay - Fox Point Barrier
COMPUTATION Gate Structure - Slab Reinforcing
COMPUTED BY BJW CHECKED BY R.A.K. DATE 1/7/60

CASE III Hurricane Condition - Design of Slab on River Side of Structure



LOADING DIAG. - INCREASED ALLOWABLE STRESS

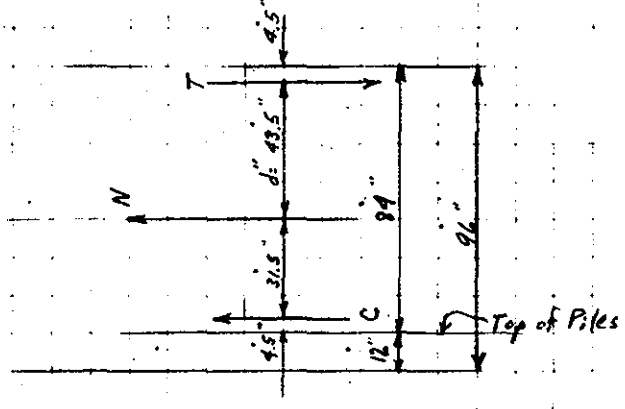
$M^F_{AB} = M^F_{DA} = M^F_{CD} = M^F_{DC} = \frac{1}{12} \times 0.95 \times \overline{47}^2 = 175^{'K}$

$M^F_{BC} = M^F_{CB} = \frac{1}{12} \times 0.95 \times \overline{48}^2 = 182^{'K}$

		50.6%	49.4%		49.4%	50.6%		
	-175	+175	-182		+182	-175		+175
	+175	+ 4	+ 3		- 3	- 4		-175
	+ 2	+ 87	- 1		+ 1	- 87		- 2
	- 2	- 44	- 42		+ 42	+ 44		+ 2
	- 22	- 1	+ 21		- 21	+ 1		+ 22
	+ 22	- 10	- 10		+ 10	+ 10		- 22
	- 5	+ 11	+ 5		- 5	- 11		+ 5
	+ 5	- 8	- 8		+ 8	+ 8		- 5
	- 4	+ 2	+ 4		- 4	- 2		+ 4
	+ 4	- 3	- 3		+ 3	+ 3		- 4
$\frac{wl^2}{8}$ ± End Mom ± ½Mo.	0	+262 -106 +11 +167	+213 -213	+274 -213 +61	+213	-213	+262 -106 +11 +167	0
Shear	18		27	23		23	27		18
$\frac{1}{3}$ or $\frac{1}{2}$ $V_{a/2}$	0	9	36	31	15	31	36	9	
DES. MOM.	-39 = ½(+M)	+158	+177	-182	+46	+182	-177	+158	+39 = ½(+M)

SUBJECT Narragansett Bay - Fox Point Barrier
COMPUTATION Gate Structure - Slab Reinf
COMPUTED BY BJW CHECKED BY DATE

Base Slab Design - Section on Bayside - End Pier



$M = 607^{'k}$

$N = .0642 \times \frac{35.5}{2}^{k} = 40.5^{k}$

$M_s = M - N\frac{d''}{12}$

$= 607 - 40.5 \times \frac{43.5}{12}$

$= 607 - 147 = 460^{'k}$

$d = \sqrt{\frac{12 M_c}{Kb}} = \sqrt{\frac{12 \times 460{,}000}{160 \times 12}} = \sqrt{2875}$

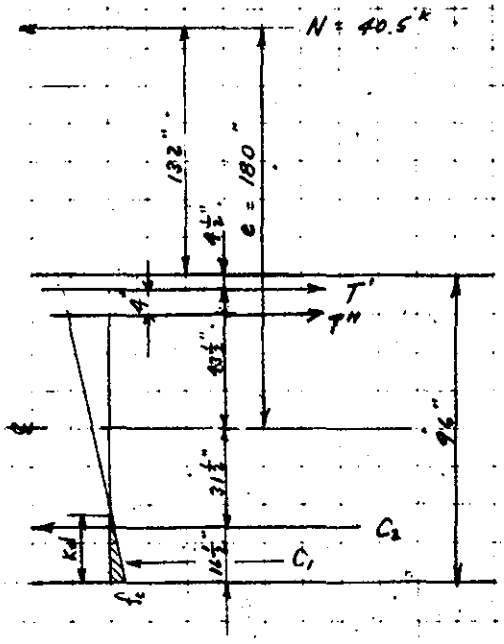
$= 53.6''$ O.K. $d_{turn} = 91.5''$

$A_s = \frac{12 M_s}{f_s j d} + \frac{N}{f_s} = \frac{12 \times 460}{20 \times .885 \times 91.5} + \frac{40.5}{20} = 3.41 + 2.02 = 5.43^{\square''}$

Use 2 layers #11 @ 6" $A_s = 3.12^{\square''}$ each layer
" #9 @ 9" $A'_s = 1.33^{\square''}$

Check Stresses

$e = 12\frac{M}{N} = 12 \times \frac{607}{40.5} = 180''$



$A'_s = \#9 @ 9 = 1.33$ $(n-1)A'_s = 1.33(9) = 11.97$

$A_{s_1} = \#11 @ 6 = 3.12$ $n A_{s_1} = 3.12(10) = 31.20$

$A_{s_2} = \#11 @ 6 = 3.12$ $n A_{s_2} = 3.12(10) = 31.20$

SUBJECT NARRAGANSETT BAY - FOX POINT BARRIER

COMPUTATION GATE STRUCTURE - BASE SLAB REINF

COMPUTED BY Cmf CHECKED BY BFW DATE 1/21/60

$\Sigma M_N = 0 \qquad C_1 a_1 + C_2 a_2 - T'a' - T''a'' = 0$

$$0 = 6 f_c kd\left(228 - \frac{kd}{3}\right) + 11.97(211.5)\frac{kd - 16.5}{kd} f_c - 31.20(136.5)\frac{91.5 - kd}{kd} f_c - 31.20(140.5)\frac{87.5 - kd}{kd} f_c$$

$$0 = 1368\,kd^2 - 2\,kd^3 + 2532\,kd - 41772 - 389680 + 4259\,kd - 383{,}565 + 4384\,kd$$

$$0 = 2\,kd^3 - 1368\,kd^2 - 11175\,kd + 815{,}017$$

$$kd^3 - 684\,kd^2 - 5587\,kd + 407{,}508 = 0 \qquad kd = 20.93''$$

$\Sigma V = 0 \qquad N + C_1 + C_2 - T' - T'' = 0$

$$40.5 + 11.97\left(\overset{4.43}{\frac{20.93 - 16.5}{20.93}}\right) f_c + 6(20.93) f_c - 31.20\left(\overset{70.57}{\frac{91.5 - 20.93}{20.93}}\right) f_c - 31.20\left(\overset{66.57}{\frac{87.5 - 20.93}{20.93}}\right) f_c$$

$$f_c = \frac{40500}{-2.53 - 125.58 + 105.20 + 99.23} = \frac{40500}{76.32} = 530.66$$

SAY $\underline{531}$ PSI ok

$$f'_s = 9(531)\frac{4.43}{20.93} = 1012 \text{ PSI ok}$$

$$f_{s_1} = 10(531)\frac{70.57}{20.93} = 17904 \text{ PSI ok}$$

$$f_{s_2} = 10(531)\frac{66.57}{20.93} = 16889 \text{ PSI ok}$$

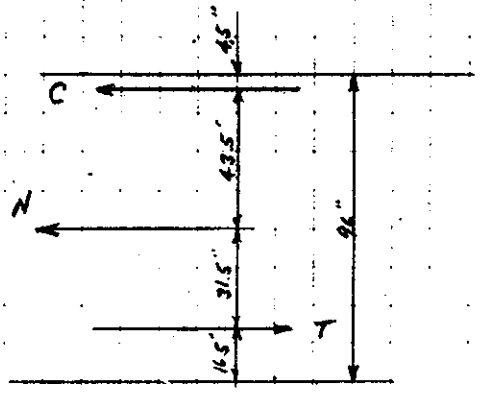
SUBJECT Narragansett Bay - Fox Point Barrier
COMPUTATION Gate Structure - Slab Reinf.
COMPUTED BY BPW CHECKED BY CMB DATE 1/21/60

Base Slab Design - Bayside - Section @ Int. Pier

Max. Neg. Moms.

	For Normal Stress	For Inc. Stress
CASE III	192 ^'k^	0
CASE IV	342 ^'k^	40 ^'k^

CASE III



$M = 192^{'k}$

$N = 40.5^{k}$ (T)

$M_s = M - N\frac{d''}{12} = 192 - 40.5 \times \frac{31.5}{12}$

$= 192 - 106 = 86^{'k}$

$A_s = \frac{12 M_s}{f_s j d} + \frac{N}{f_s} = \frac{12 \times 86}{20 \times .885 \times 79.5} + \frac{40.5}{20}$

$= 0.73 + 2.02 = 2.75^{\square''}$

CASE IV

$A_s = \frac{342}{1.44 \times 79.5} + \frac{40}{2.00 \times 79.5} = 2.99 + 0.25 = 3.24^{\square''}$ Governs

∴ Use #9 @ 9" and alternate with #11 @ 9"

$A_s = 1.33 + 2.08 = 3.41^{\square''}$

Positive Reinf. in Ctr. Span

CASE III Max. Pos. Mom. = $162^{'k}$ $N = 40.5^{k}$ (T)

$M_s = 162 - 40.5 \times \frac{43.5}{12} = 162 - 147 = 15^{'k}$

$A_s = \frac{12 \times 15}{20 \times .885 \times 91.5} + \frac{40.5}{20} = 0.11 + 2.02 = 2.13^{\square''}$

Use #11 @ 9" $A_s = 2.08^{\square''}$

SUBJECT Narragansett Bay - Fox Point Barrier
COMPUTATION Gate Structure - Slab Reinf.
COMPUTED BY BPW CHECKED BY Cmft DATE 1/21/60

Base Slab Design - Riverside - Section @ Int. Pier

	Max Neg. Moms. For Normal Stress	Max Neg. Moms. For Inc. Stress	Loading KSF For N.S.	Loading KSF For I.S.
CASE III	105 ^k	182 ^k	0.95	0.95
CASE IV	Not Critical By Inspection		0.67	0.21

$$N = \frac{359}{20} + .0042 \times \frac{12^2}{2} = 18 + 4.6 = 22.6^k \ (T)$$

$$M_s = 105 - 22.6 \times \frac{31.5}{12} = 105 - 59.4 = 45.6^{'k}$$

$$A_{s_{N.S.}} = \frac{12 M_s}{f_s j d} + \frac{N}{f_s} = \frac{12 \times 45.6}{20 \times .885 \times 79.5} + \frac{22.6}{20} = 0.39 + 1.13 = 1.52^{\square''}$$

$$A_{s_{I.S.}} = \frac{M}{a d} = \frac{182}{2.0 \times 79.5} = 1.14^{\square''}$$

Total $A_{s_{reqd}} = 2.66^{\square''}$

This amount of steel 2.66 □" is less than that required on the bayside section. ∴ Use same steel as bayside which is #9 @ 9" and alternate with #11 @ 9"

SUBJECT Narragansett Bay - Fox Point Barrier
COMPUTATION Gate Structure - Slab Reinf.
COMPUTED BY BJW CHECKED BY R.A.K. DATE 1/8/60

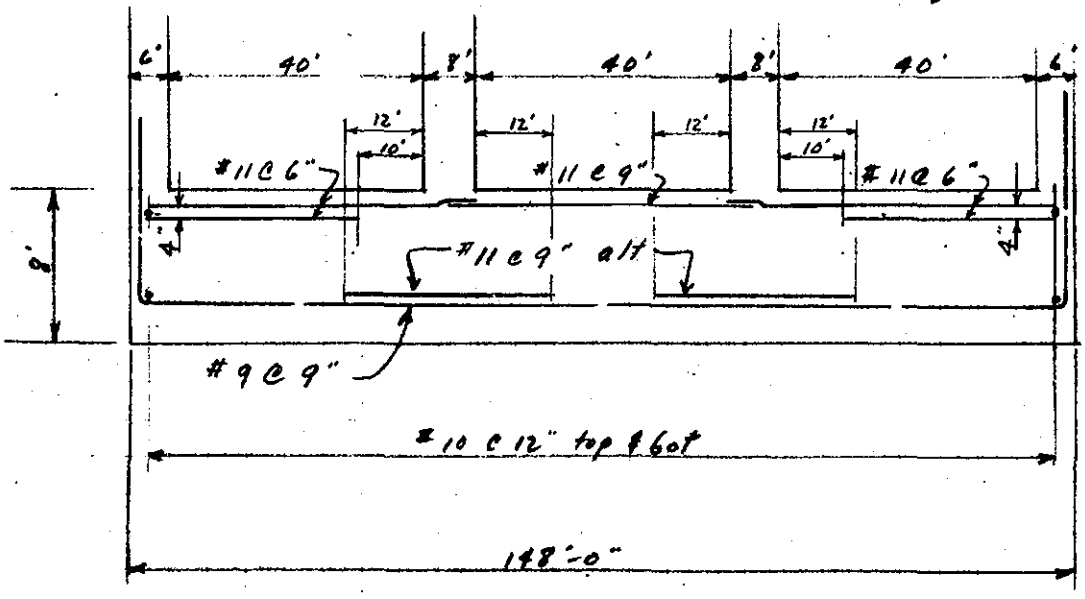
Slab Steel

Neg. Reinf. Use #9 @ 9" entire length of slab

Alt. #11 @ 9" @ Int Piers and run 12' beyond both faces of pier

Pos. Reinf. Use 2 layers #11 @ 6" on End Spans
Run bot. layer 4" under top layer to 10' of face of Int. Pier
Run top layer entire length of span

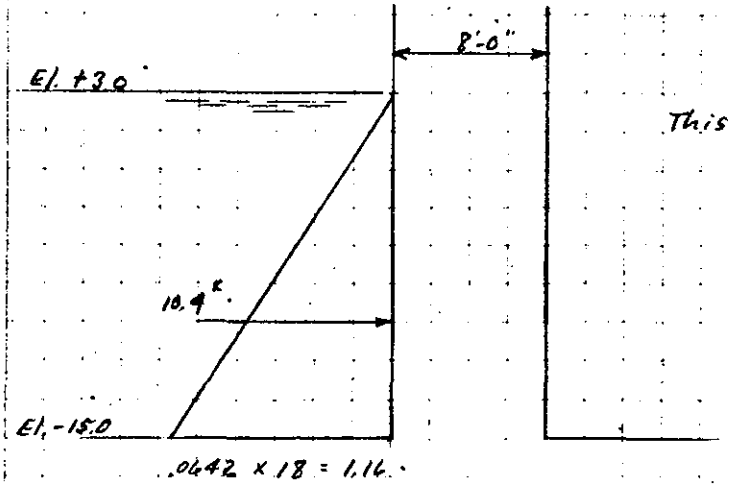
Use #11 @ 9" entire length of ctr. span

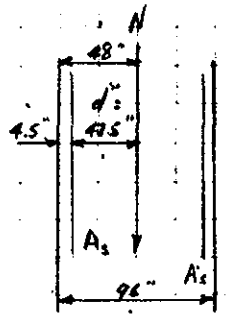


SUBJECT Narragansett Bay - Fox Point Barrier
COMPUTATION Gate Structure - Pier Reinf
COMPUTED BY BZW CHECKED BY Cmt DATE 1/13/60

Design of Interior Piers (8'-0" wide)

Condition creating max. flexure would be with stop logs in position on both downstream & upstream faces of one bay, and the water pumped out. With the water elev. at high tide el. +3.0, a hydrostatic head of 18 ft would be imposed on the pier.





$$\text{Max. Mom.} = .0642 \times \frac{18^3}{6} = 62.4^{'k}$$

$$N = .15 \times 50.0 \times 8.0 \times 1.0 = 60.0^{k}$$

$$M_s = M + \frac{d''}{12} N = 62.4 + \frac{43.5}{12} \times 60.0 = 62.4 + 217.5 = 279.9^{'k}$$

$$d = \sqrt{\frac{12 M_s}{Kb}} = \sqrt{\frac{12 \times 279900}{160 \times 12}} = \sqrt{1750} = 41.8'' \quad \text{O.K.} \quad d_{furn.} = 91.5''$$

$$A_s = \frac{12 M_s}{f_s j d} - \frac{N}{f_s} = \frac{12 \times 279.9}{20 \times .885 \times 91.5} - \frac{60.0}{20.0}$$

$$= 2.08 - 3.0 = -0.92^{\#''} \quad \text{No STEEL REQ.}$$

∴ Use Min. Steel #6 @ 12".

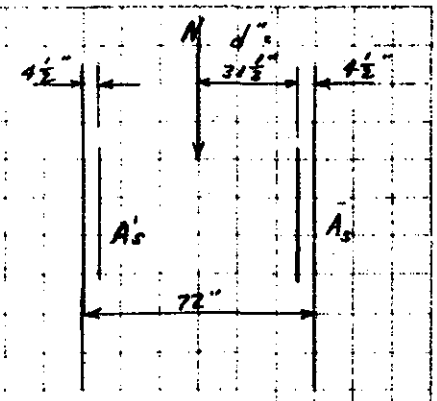
Check Shear $V = 10.4^{k}$

$$v = \frac{10,400}{12(.885)91.5} = 10.7 \text{ PSI} < 90 \text{ PSI O.K.}$$

Check Bond $\Sigma_o = \frac{10,400}{210(.885)91.5} = .61''$ O.K. 2.4" furn.

SUBJECT Naccagansett Bay - Fox Point Barrier
COMPUTATION Gate Structure - Pier Reinf
COMPUTED BY BJW CHECKED BY DATE 1/15/60

End Pier Design - Section @ Top of Base Slab



$M = 479^{'k}$

$N = .15 \times 50.0 \times 6.0 \times 1.0 = 45.0^{k}$

$M_s = M + N\frac{d''}{12}$

$= 479 + 45^{k} \times \frac{31.5''}{12} = 597^{'k}$

$d = \sqrt{\frac{12 M_s}{Kb}} = \sqrt{\frac{12 \times 597{,}000}{160 \times 12}} = \sqrt{3730} = 61''$ O.K. $d_{Assm} = 67.5''$

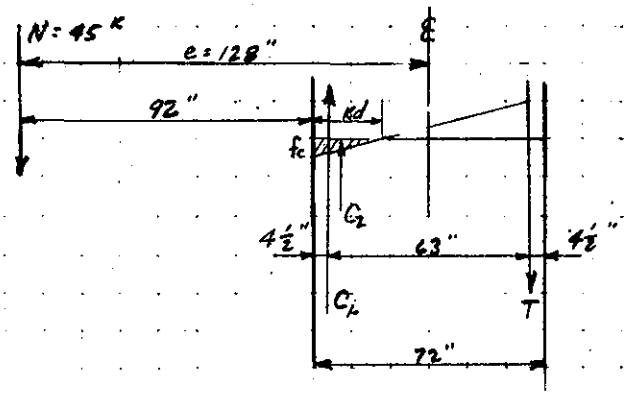
$A_s = \frac{12 M_s}{f_s j d} - \frac{N}{f_s} = \frac{12 \times 597}{20 \times .885 \times 67.5} - \frac{45}{20} = 6.0 - 2.25 = 3.75^{\square''}$

Use #11 @ 5" $A_s = 3.74^{\square''}$

$A'_s = 0.44^{\square''}$ #6 @ 12"

Check Stresses

$e = 12\frac{M}{N} = 12 \times \frac{479}{45} = 128''$



SUBJECT Narragansett Bay - Fox Point Barrier
COMPUTATION Gate Structure - Pier Reinf.
COMPUTED BY BJW CHECKED BY Cmt DATE 1/15/60

$\Sigma M_x = 0 \qquad C_1 a + C_2 a_1 - T a_2 = 0$

$= (n-1) A_s \times 96.5 \left(\frac{kd-4.5}{kd}\right) f_c + bkd\left(92 + \frac{kd}{3}\right)\frac{f_c}{2} - n A_s \times 159.5 \left(\frac{67.5-kd}{kd}\right) f_c = 0$

$= 9 \times 0.44 \times 96.5 \left(\frac{kd-4.5}{kd}\right) + 12\,kd\left(92 + \frac{kd}{3}\right)\frac{1}{2} - 10 \times 3.74 \times 159.5 \left(\frac{67.5-kd}{kd}\right) = 0$

$= 382\,kd - 1720 + 552\,kd^2 + 2\,kd^3 - 402{,}658 + 5965\,kd = 0$

$= kd^3 + 276\,kd^2 + 3173\,kd - 202{,}189 = 0$

Try $kd = 21.0$

$\Sigma M_x = 9261 + 121{,}716 + 66{,}633 = 202{,}189$
$197{,}610 = 202{,}189.$

Try $kd = 21.3$

$\Sigma M_x = 9664 + 125{,}218 + 67{,}585 = 202{,}189$
$202{,}467 = 202{,}189$ o.k.

$\Sigma V = 0 \qquad N - C_1 - C_2 + T = 0$

$N = C_1 + C_2 - T$

$45.0 = 9 \times 0.44 \left(\frac{21.3-4.5}{21.3}\right) f_c + 12 \times 21.3 \times \frac{f_c}{2} - 10 \times 3.74 \left(\frac{67.5-21.3}{21.3}\right) f_c$

$f_c = \frac{45.0}{3.12 + 127.8 - 81.12} = \frac{45.0}{49.80} = 0.904$ k/□".

$f_s' = 9 f_c \frac{16.8}{21.3} = 7.09 \times 0.904 = 6.41$ k/□"

$f_s = 10 f_c \frac{46.2}{21.3} = 21.69 \times 0.904 = 19.61$ k/□"

∴ USE #11 @ 5" TENSION FACE
#6 @ 12" COMP. FACE

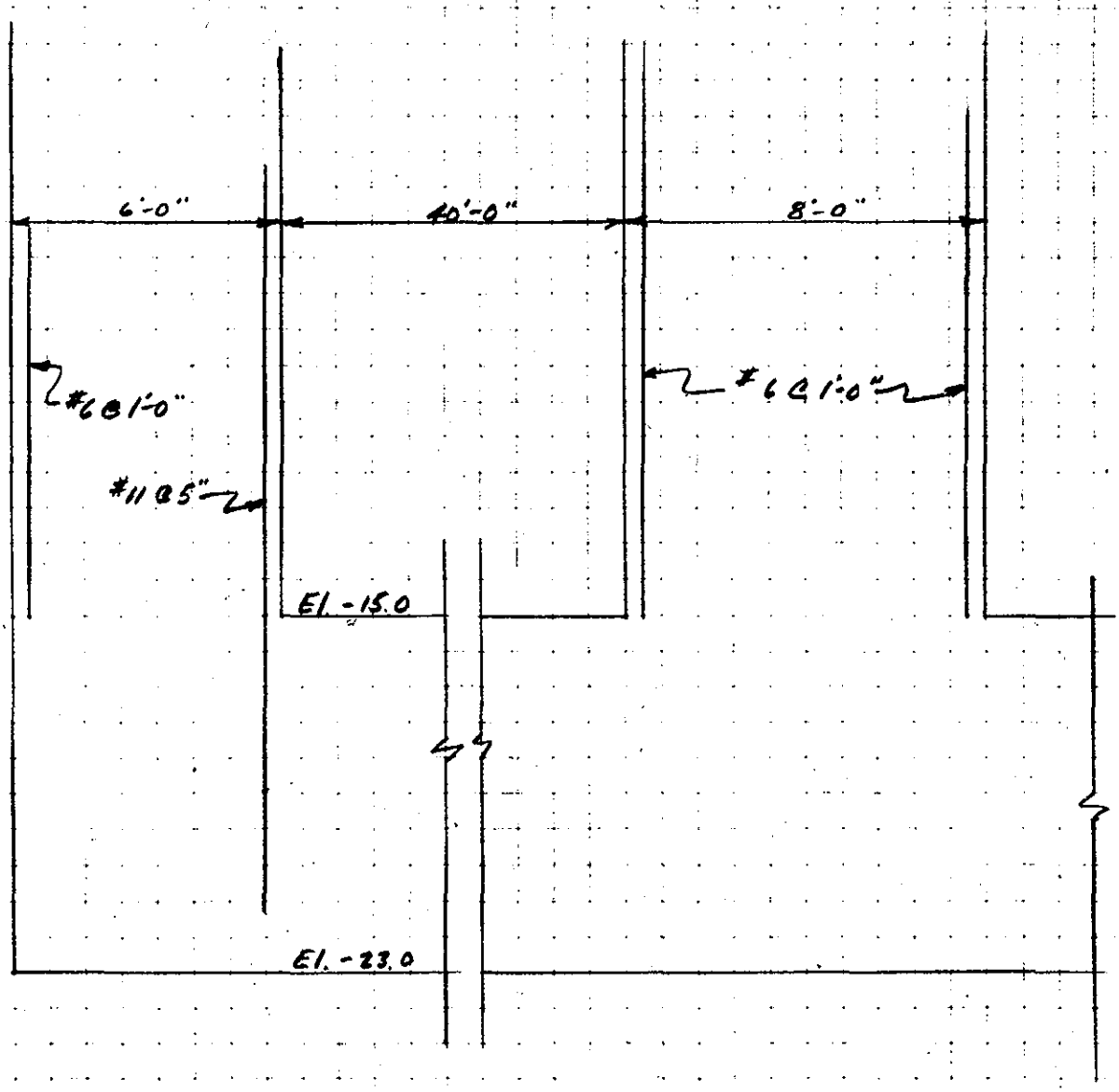
$V = 40.5^k$

$v = \frac{40{,}500}{12(.885)67.5} = 56.5$ PSI < 90 ok

$\Sigma_o = \frac{40500}{210(.885)67.5} = 3.23" < 10.6"$ ok

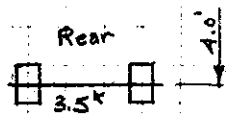
SUBJECT Narragansett Bay - Fox Point Barrier
COMPUTATION Gate Structure - Pier Reinf.
COMPUTED BY BMW CHECKED BY DATE 1/15/60

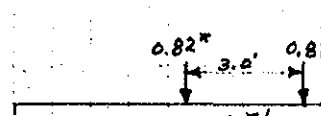
Pier Steel



All #6 Bars Continue to Top of Piers

On Inside Face of End Piers #11 @ 5" Bars Run 30d Beyond Const St. @ El.-5.5. From El-5.5 to 30d Beyond Const. St. @ El. +6.0 Use #11 @ 10". From El. +6.0 to Top of Piers Use #6 @ 1'-0"





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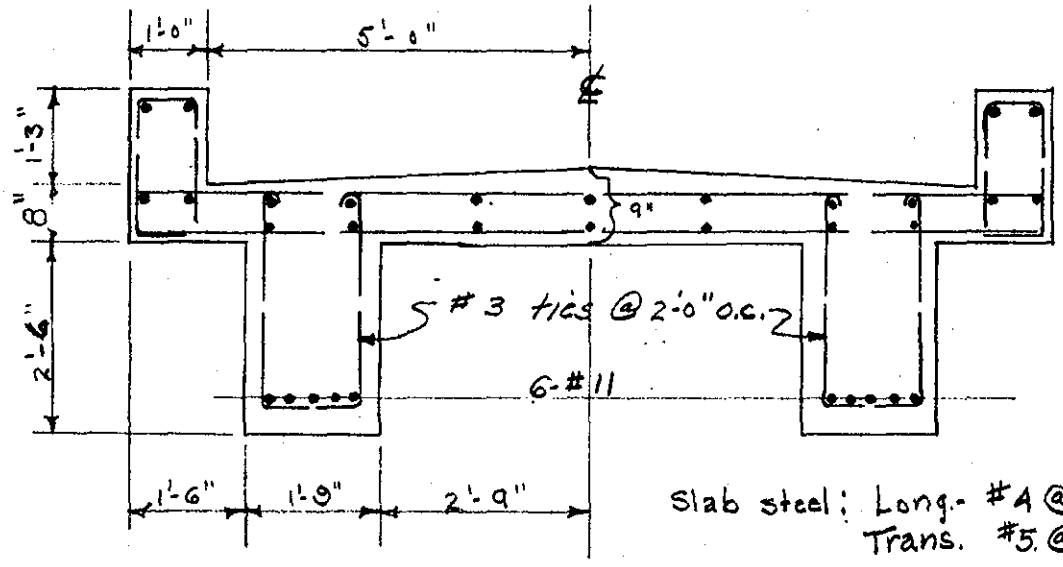


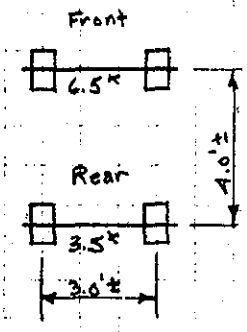
Slab steel: Long.- #4 @ 1'-6"
Trans. #5 @ 1'-0"

Assumptions:

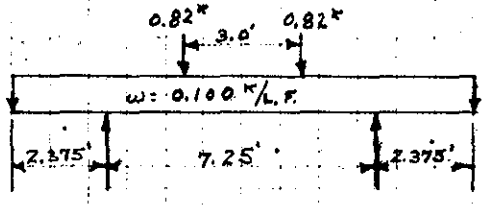
Concrete cover: Beam - Bottom = $2\frac{1}{2}$"; Side = 2". Slab-Bottom = $2\frac{1}{2}$"; Top = 2".
F'_c = 3000 psi F_c = 0.40 F'_c = 1200 psi F_s = 20,000 psi v = 90 psi
u, top bars = 210 psi; others = 300 psi j = 0.875 k = 197 psi k = 0.375

Simple span = 42'± . Live load obtained from loaded fork-lift truck. Total load = 10^K with 65/35 front/rear axle distribution; wheel base = 4.0'±; center to center of tires = 3.0'± . 3/4 of live load can be placed on one stringer.

Transverse Span



Assume the load on each tire to be distributed over 4.0' longitudinally ∴ $\frac{3.25^K}{4'} = 0.82^{K'}$



Try 8" thick slab

$$Max.+M = \left(\tfrac{1}{8} \times .100 \times 7.25^2\right) + \left(0.82 \times 2.125\right) - \left(0.100 \times 2.375^2/2\right)$$
$$= 0.657 + 1.742 - 0.282 = 2.117^{K'}$$

$$Max-M = 0.282 + (0.82 \times 0.5) = 0.692^{K'}$$

$$+A_s = \frac{2.117 \times 12}{20 \times .875 \times 6.25} = 0.232 \text{ in}^2 \qquad M_c = 0.197 \times 1.0 \times 6.0^2 = 7.10^{K'} > 2.07^{K'} \text{ OK}$$

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$$\text{Max. } V = 0.82 + \left(0.82 \times \frac{2.5}{5.5}\right) + \left(.100 \times \frac{5.5}{2}\right) = 0.82 + 0.37 + 0.28 = 1.47^{k}$$

$$v = \frac{1470}{12 \times .875 \times 4} = 35 \text{ psi} \qquad \Sigma_0 = \frac{1470}{210 \times .875 \times 4} = 2.00 \text{ in}$$

Use #5 @ 1'-0" transverse.

Longitudinal Span

Dead Wt. of $\frac{1}{2}$ bridge:

$$W = 0.150\left[(1.25 \times 1.0) + (6.0 \times 0.667) + (1.75 \times 2.33)\right] = 0.150 \times 9.33 = 1.40^{k}/\text{L.F.}$$

$$\text{Max. } +M = \left(\frac{1}{8} \times 1.40 \times 42.0^2\right) + \left(0.75 \times 10.0 \times \frac{42.0}{4}\right) = 309 + 79 = 388^{k'}$$

$$\text{Max. Conc. Mom. (neglect comp. in stem)} = \frac{f_c b t j}{2k}(2kd - t)$$

$$= \frac{1.20 \times 72 \times 6 \times .875}{2 \times .375}\left(2 \times .375 \times 32 - 6\right) = 605 \times \frac{18}{12} = 908^{k'} > 388^{k'}$$

no Comp. steel needed

$$V = (1.40 \times 21.0) + 7.5 = 29.4 + 7.5 = 36.9^{k}$$

$$A_s = \frac{388 \times 12}{20 \times .875 \times 35} = 7.60 \text{ in}^2 \qquad 5 - \#11 \text{ bars}$$

Max. allow. Shear w/o stirrups $= 90 \times 21 \times .875 \times 35 = 57.9^{k} > 36.9^{k}$.

No diagonal tension steel needed.

At support: $v = \dfrac{36900}{21 \times .875 \times 35} = 57.4 \text{ psi} < 90 \text{ psi}$ O.K.

$$\Sigma_0 = \frac{36900}{300 \times .875 \times 35} = 4.02 \text{ in} \quad \text{ok}$$

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$$\text{Max. } V = 0.82 + \left(0.82 \times \frac{2.5}{5.5}\right) + \left(.100 \times \frac{5.5}{2}\right) = 0.82 + 0.37 + 0.28 = 1.47^{k}$$

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Cross-section C. of G.: (w/o curbs)

$$\bar{y} = \frac{(3.5 \times 2.33 \times 1.167) + (0.67 \times 12.0 \times 2.67) + (.0833 \times 5.0 \times 3.0417)}{8.15 + 8.00 + 0.42}$$

$$= \frac{9.51 + 21.36 + 1.27}{16.57} = \frac{32.14}{16.57} = 1.94'$$

$$I = \left(\tfrac{1}{12} \times 3.5 \times 2.33^3\right) + \left(8.15 \times 0.77^2\right) + \left(\tfrac{1}{12} \times 12.0 \times 0.667^3\right) + \left(8.0 \times 1.50^2\right)$$

$$= 3.69 + 4.84 + 0.30 + 18.00 = 26.83 \text{ ft}^4$$

uniform dead load $= 1.40 \times 2 = 2.80$ K/L.F.

$$\Delta = \frac{5 \times 2.80 \times 42.0^4}{384 \times 3000 \times 26.83 \times 144} \quad 0.00978' = 0.1172''$$