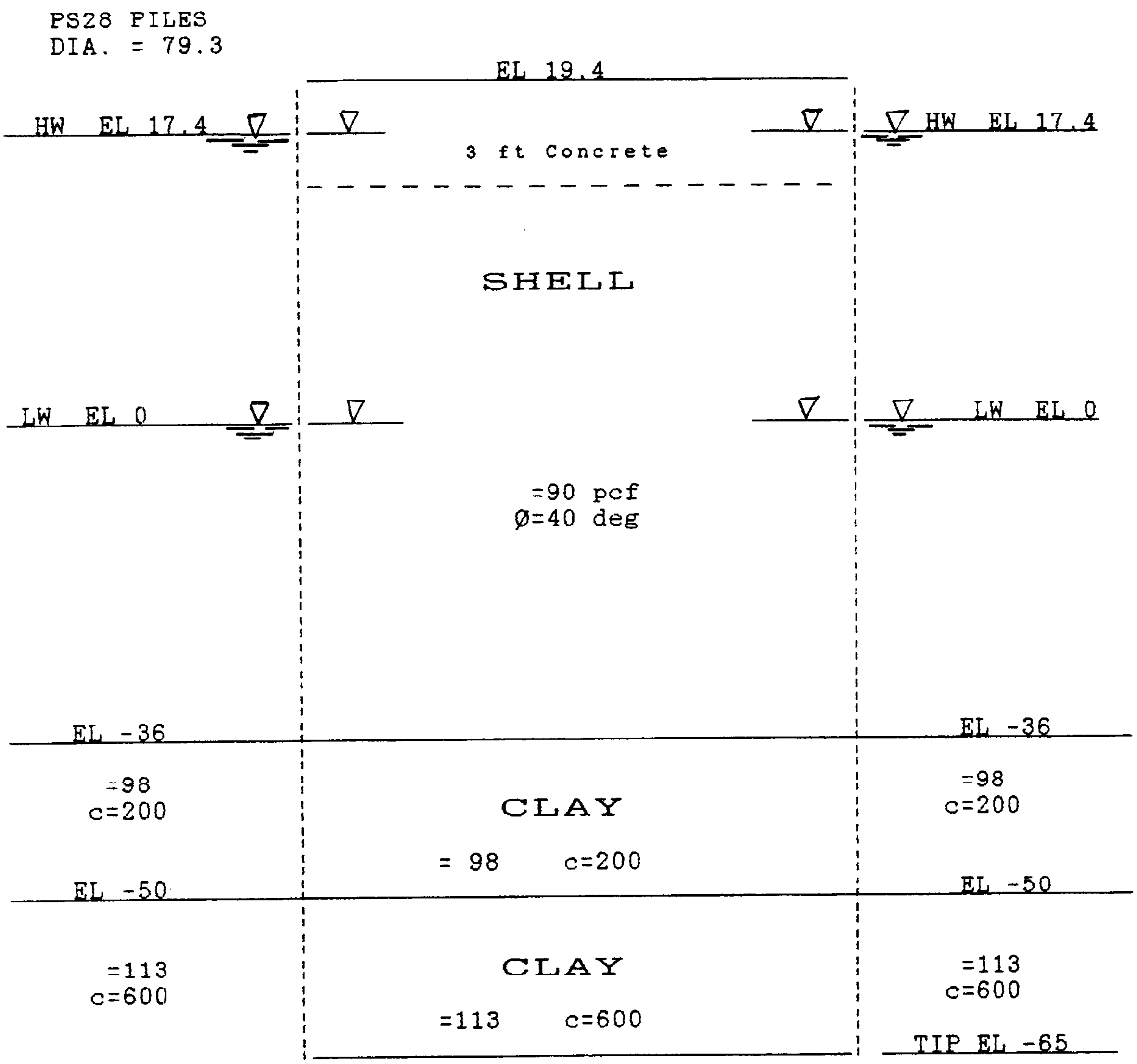
Project: IHNC Lock Replacement
Subject: MOORING CELL



MAX. IMPACT FORCE = 650K

THIS MOORING CELL WAS NOT DESIGNED FOR IMPACT LOADS

CELLULAR COFFERDAM DESIGN

IHNC MOORING CELL DIA.= 79.3

INTERLOCK TENSION (HOOP TENSION)

(see Bolwes, pg 557-558)

K_a = (use Rankine or Coulomb K_a)

Case I : Low water at el. 0

t_{max} = Interlock Tension Force = $\frac{\sigma_T \times R}{12}$

where $\sigma_T = K_a \gamma (H_c - H_1) + K_a \gamma' (H_1 - H_c/4) + \gamma_w (H_3 - H_c/4)$

H_c= free height of cofferdam = 55.4 ft

H_1= avg. height of saturation inside cofferdam = 36 ft

H_3= height of saturation line at inboard face = 36 ft

K_a= coefficient of active earth pressure (Rankine)

= $\tan^2(45-\emptyset/2$ = 0.217 for $\emptyset$=40 deg

Utimate interlock stress = 8000 pli (use F.S. = 2)

(see USS Manual, 1975, pg 77 for PS 28 sheetpile)

σ_T= 0.217(90)(55.4-36) + 0.217(27.5)(36-55.4/4)

= 511 psf

$t_{max} = \frac{511 \times 39.7}{12}$ = 1690 lbs/in

F.S. = $\frac{\text{Utimate interlock stress}}{t_{max}} = \frac{8000}{1690}$ = 4.7 >2 OK

SLIDING:

F.S. = $\frac{\text{Resisting}}{\text{Driving}} = \frac{cL + P_p}{P_a}$ > 1.5

bottom of cell assumed to slide on clay with c=600 psf

L = R = 79.3 ft

p_p (psf) = $K_p \gamma' H_s + 2c$

p_a (psf) = $K_a \gamma' H_s - 2c$

K_a= coefficient of active earth pressure (Rankine)

= $\tan^2(45-\emptyset/2$ = 1 for clay

K_p= coefficient of passive earth pressure (Rankine)

= $\tan^2(45-\emptyset/2$ = 1 for clay

Resisting Forces:

P_p = 35100 lbs/ft (see diagram 1)

cL = (600)(79.3) = 47600 lbs/ft

Driving Forces:

Pa = 350 lbs/ft (see diagram 1)

F.S. = $\frac{47600 + 35100}{350}$ > 236 OK

BEARING CAPACITY:

$q_{ult} = 1.3 N_c c + \gamma' D$

where N_c = 5.7 (Terzagi & Peck)
c = 800 psf
$\gamma' D$ = (40.5)(29) = 1175 psf

q_{ult} = (1.3)(5.7)(800) + 1175 = 7100 psf

$$F.S. = \frac{q_{ult}}{W_{cell} + 6M_o/B^2}$$

<u>CASE I</u>: Water = El 0
Bearing Load = W_{cell}
= 3(150) + 16.4(90) + 36(27.5) + 29(49.5)
= 4350 psf

where $P_w = P_{wR} - P_{wL} = 0$
P_p = 35100 lbs/ft
P_a = 350 lbs/ft

M_o = overturning moment = (350 x 15.9 - 35100 x 11.6)
= -401600 ft-lbs

$$F.S. = \frac{7100}{4350 + 6(401600)/(79.3)^2} = \frac{7100}{4350 + 380} = 1.5 \quad \text{OK}$$

<u>CASE II</u>: Water = El 17.4
Bearing Load = W_{cell}
= 2(150) + 1(87.5) + 52.4(27.5) + 29(49.5)
= 3100

$$F.S. = \frac{7100}{3100 + 380} = 2.0 \quad \text{OK}$$

SHEAR FAILURE ON CENTERLINE OF CELL: (VERTICAL SHEAR):

For simplicity, assume cell filled with shell down to bottom:

CASE II: Water = El 17.4

$$F.S. = \frac{S_T}{Q} \quad \text{and} \quad Q = 3M_o/2B$$

$$K_a = \frac{\cos^2(\emptyset)}{2-\cos^2(\emptyset)} = 0.415$$

$$S_T = P_s\tan(\emptyset) + fP_T$$

where f = 0.3 (friction between steel interlocks)
because of clay foundation, $P_s = P_T$ (see USS Manual, 1975, pg 77)
$P_s = P_T = 60725$ (see diagram 2)
$S_T = 60725 \times \tan(40) + (0.3)(60725) = 69{,}200$ lbs/ft

M_o = overturning moment = 401600 ft-lbs

where $P_w = 0$

$$F.S. = \frac{S_T}{Q} = \frac{S_T \times 2B}{3M} = \frac{(69200)(2)(79.3)}{(3)(401600)} = 9.1 \quad \text{OK}$$

CASE I: Water = El 0

$K_a = 0.415$
$P_s = P_T = 112300$ (see diagram 3)
$S_T = 112300 \times \tan(40) + (0.3)(112300) = 128{,}000$ lbs/ft
M_o = overturning moment = 401600 ft-lbs
f = 0.3

$$F.S. = \frac{S_T}{Q} = \frac{S_T \times 2B}{3M} = \frac{(128000)(2)(79.3)}{(3)(401600)} = 16.8 \quad \text{OK}$$

SLIPPING - SHEETING AND CELL FILL:

For simplicity, assume cell filled with shell down to bottom:

$$F.S. = \frac{B(P_w + P_a)\tan\delta + P_pH_p}{(P_wH/3 + P_aH_a)}$$

P_p = 35100 lbs/ft
P_a = 350 lbs/ft
$P_w = P_{wR} - P_{wL} = 0$
H_a = 15.9 ft
H_p = 11.6 ft
$\delta = 2/3(\emptyset) = 26.7$ deg (NAVFAC 7.2)

$$F.S. = \frac{79.3[(0 + (350)(0.50)] + 35100(11.6)}{0 + (350)(15.9)} = 75.7 \quad \text{OK}$$

HORIZONTAL SHEAR (CUMMINGS METHOD):

For simplicity, assume cell filled with shell down to bottom:

$$F.S. = \frac{M_r + M_i + P_p H_p}{P_w H/3 + P_a H_a}$$

where $M_r = \frac{ab^2}{2} + \frac{b^3}{3}$ = resisting moment from cell fill friction

$b = \tan\emptyset(B) = \tan(40)(79.3) = 66.5$ ft

$a = H-b = 84.4 - 66.5 = 17.9$ ft

so $M_r = \frac{(17.9)(66.5)^2(55)}{2} + \frac{66.5^3(55)}{3} = 7568000$ lb-ft

and $M_i = P_T(B)(f)$ = resisting moment from sheetpile friction

for High water = 17.4 -- $P_T = 60725$

for Low water = 0 ------ $P_T = 112300$

M_i (Low water) = (112300)(84.4)(0.3) = 2830000 lb-ft

M_i (High water) = (60725)(84.4)(0.3) = 1537600 lb-ft

$P_w = P_{wR} - P_{wL} = 0$

$P_p = 35100$ lbs/ft

$P_a = 350$ lbs/ft

$H_a = 15.9$ ft

$H_p = 11.6$ ft

so F.S. (Low water) = $\frac{7568000 + 2830000 + (35100)(11.6)}{0 + (350)(15.9)} = 1940$ **OK**

and F.S. (High water) = $\frac{7568000 + 1537550 + (35100)(11.6)}{0 + (350)(15.9)} = 1700$ **OK**

PULL-OUT OF OUTER SHEETING:

$$F.S. = \frac{Q_u}{Q_p} > 1.5$$

for clay, Q_u = ca x perimeter x embedded length

where ca= 400 psf (avg)

perimeter = 79.3 x pi = 249 ft and embedded length = 29 ft

$Q_u = 2890000$ lbs

$$Q_p = \frac{P_a H_s - P_p H_B + P_w H}{3B(1 + B/4L)}$$

$P_w = 0$

$P_p = 35100$ lbs/ft and $P_a = 350$ lbs/ft

$H_s = H_B = 29$ ft

$$Q_p = \frac{350(29) - 35100(29)}{3(79.3)[1 + (79.3/(4)(79.3)]} = -3400$$

F.S. = 2890000/3400 = 850 **OK**

PENETRATION OF INBOARD SHEETING:

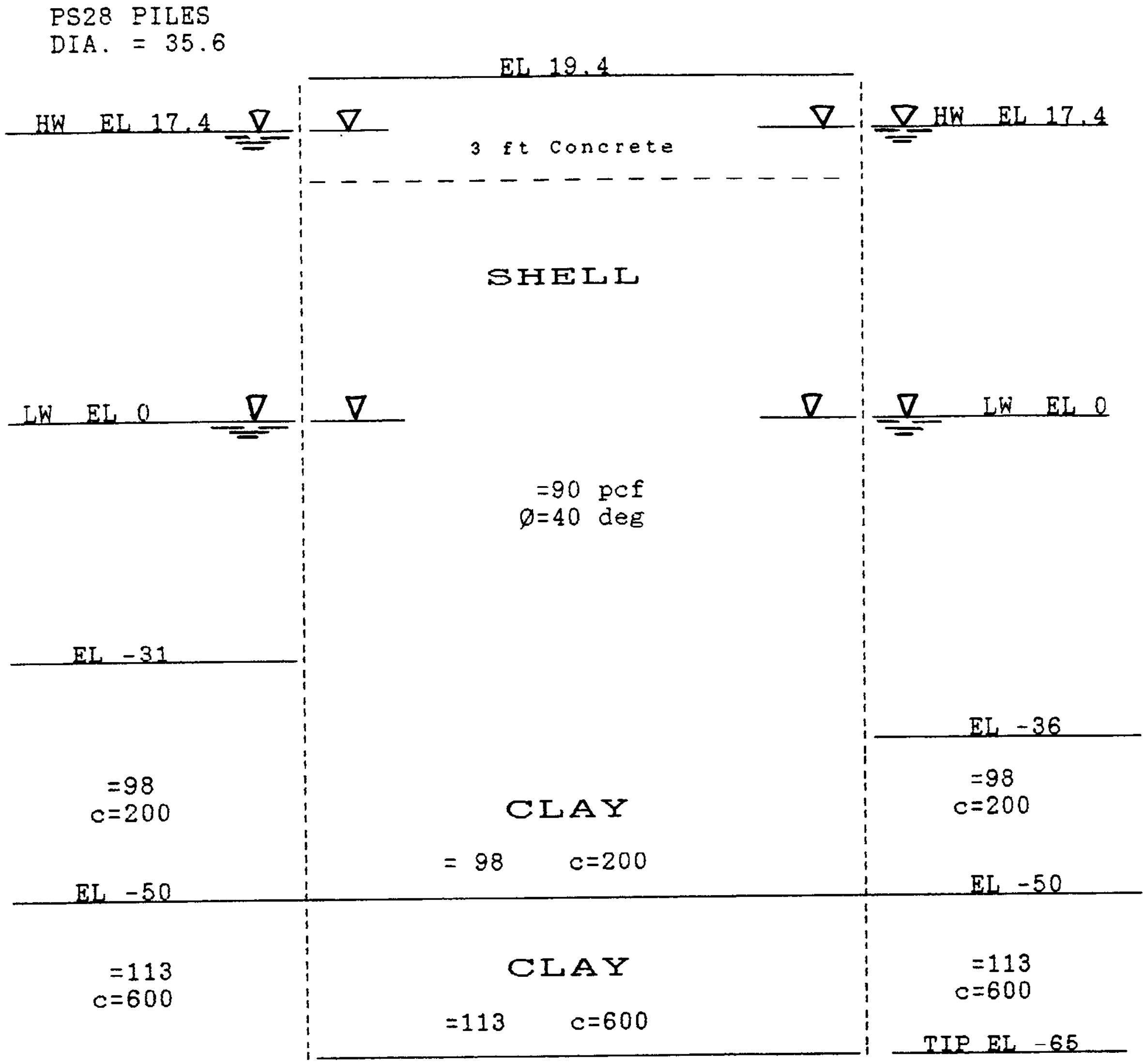
$$F.S. = \frac{(P_p + P_s)\tan \delta_o)}{P_d\tan(\delta_f)} = \frac{P_p\tan\delta_o + cL_s}{P_d\tan(\delta_f)}$$

where δ_f = angle of friction between sheetpile and cell fill
δ_o = angle of friction between sheetpile and soil
P_d = cell fill pressure on inboard sheeting above dredgeline
P_s = soil pressure inside of inboard sheeting below dredgeline
P_p = soil pressure outside of inboard sheeting

P_p = 35100 lbs/ft
P_s = 71800 lbs/ft
P_d = 40500 lbs/ft
δ_o = 0 for clay
δ_f = 26.7 deg

$$F.S. = \frac{400(29) + 400(29)}{40500\tan(26.7)} = 1.14$$

Project: IHNC Lock Replacement
Subject: GUIDEWALL DOLPHIN



MAX. IMPACT FORCE DURING HIGH WATER (17.4) = 270^K

MAX. IMPACT FORCE DURING LOW WATER (0.0) = 230^K

THIS GUIDEWALL DOLPHIN WAS NOT DESIGNED FOR IMPACT LOADS

CELLULAR COFFERDAM DESIGN

IHNC GUIDEWALL CELL DIA.= 35.6

INTERLOCK TENSION (HOOP TENSION)

(see Bolwes, pg 557-558)

K_a = (use Rankine or Coulomb K_a)

Case I : Low water at el. 0

t_{max} = Interlock Tension Force = $\frac{\sigma_T \times R}{12}$

where $\sigma_T = K_a \gamma (H_c - H_1) + K_a \gamma' (H_1 - H_c/4) + \gamma_w (H_3 - H_c/4)$

H_c= free height of cofferdam = 52.9 ft

H_1= avg. height of saturation inside cofferdam = 33.5 ft

H_3= height of saturation line at inboard face = 33.5 ft

K_a= coefficient of active earth pressure (Rankine)

= $\tan^2(45-\phi/2$ = 0.217 for ϕ=40 deg

Utimate interlock stress = 8000 pli (use F.S. = 2)

(see USS Manual, 1975, pg 77 for PS 28 sheetpile)

σ_T= 0.217(90)(52.9-33.5) + 0.217(27.5)(33.5-52.9/4)

= 500 psf

$t_{max} = \frac{500 \times 17.8}{12}$ = 740 lbs/in

F.S. = $\frac{\text{Utimate interlock stress}}{t_{max}}$ = $\frac{8000}{740}$ = 10.8 >2 OK

SLIDING:

F.S. = $\frac{\text{Resisting}}{\text{Driving}} = \frac{cL + P_p}{P_a}$ > 1.5

bottom of cell assumed to slide on clay with c=600 psf

L = R = 79.3 ft

p_p (psf) = $K_p \gamma' H_s + 2c$

p_a (psf) = $K_a \gamma' H_s - 2c$

K_a= coefficient of active earth pressure (Rankine)

= $\tan^2(45-\phi/2$ = 1 for clay

K_p= coefficient of passive earth pressure (Rankine)

= $\tan^2(45-\phi/2$ = 1 for clay

Resisting Forces:

P_p = 47275 lbs/ft (see diagram 4)

cL = (600)(35.6) = 21360 lbs/ft

Driving Forces:

P_a = 350 lbs/ft (see diagram 4)

F.S. = $\frac{21360 + 47275}{350}$ > 196 OK

BEARING CAPACITY:

$q_{ult} = 1.3N_c c + \gamma' D$

where $N_c = 5.7$ (Terzagi & Peck)
$c = 800$ psf
$\gamma' D = (40.5)(29) = 1175$ psf

$q_{ult} = (1.3)(5.7)(800) + 1175 = 7100$ psf

$$F.S. = \frac{q_{ult}}{W_{cell} + 6M_o/B^2}$$

CASE I: Water = El 0
Bearing Load = W_{cell}
= 3(150) + 16.4(90) + 33.5(27.5) + 31.5(49.5)
= 4400 psf

where $P_w = P_{wR} - P_{wL} = 0$
$P_p = 47275$ lbs/ft
$P_a = 350$ lbs/ft

M_o = overturning moment = (350 x 15.9 - 47275 x 11.8)
= -552300 ft-lbs

$$F.S. = \frac{7100}{4400 + 6(552300)/(35.6)^2} = \frac{7100}{4400 + 2600} = 1.0$$

CASE II: Water = El 17.4
Bearing Load = W_{cell}
= 2(150) + 1(87.5) + 49.9(27.5) + 31.5(49.5)
= 3300

$$F.S. = \frac{7100}{3300 + 2600} = 1.2$$

SHEAR FAILURE ON CENTERLINE OF CELL: (VERTICAL SHEAR):

For simplicity, assume cell filled with shell down to bottom:

CASE II: Water = El 17.4

$$F.S. = \frac{S_T}{Q} \quad \text{and} \quad Q = 3M_o/2B$$

$$K_a = \frac{\cos^2(\emptyset)}{2-\cos^2(\emptyset)} = 0.415$$

$$S_T = P_s\tan(\emptyset) + fP_T$$

where f = 0.3 (friction between steel interlocks)
because of clay foundation, $P_s = P_T$ (see USS Manual, 1975, pg 77)
$P_s = P_T = 62570$ (see diagram 5)
$S_T = 62570 \times \tan(40) + (0.3)(62570) = 71{,}270$ lbs/ft

M_o = overturning moment = 552300 ft-lbs

where $P_w = 0$

$$F.S. = \frac{S_T}{Q} = \frac{S_T \times 2B}{3M} = \frac{(71270)(2)(35.6)}{(3)(552300)} = 3.0 \quad \underline{OK}$$

CASE I: Water = El 0

$K_a = 0.415$
$P_s = P_T = 115300$ (see diagram 6)
$S_T = 115300 \times \tan(40) + (0.3)(115300) = 131{,}300$ lbs/ft
M_o = overturning moment = 552300 ft-lbs
f = 0.3

$$F.S. = \frac{S_T}{Q} = \frac{S_T \times 2B}{3M} = \frac{(131300)(2)(35.6)}{(3)(552300)} = 5.6 \quad \underline{OK}$$

SLIPPING - SHEETING AND CELL FILL:

For simplicity, assume cell filled with shell down to bottom:

$$F.S. = \frac{B(P_w + P_a)\tan\delta + P_pH_p}{(P_wH/3 + P_aH_a)}$$

where tan = 0.25 (reference Pile Buck Design Manual, 1987)

$P_p = 47275$ lbs/ft
$P_a = 350$ lbs/ft
$P_w = P_{wR} - P_{wL} = 0$
$H_a = 15.9$ ft
$H_p = 11.8$ ft
$\delta = 2/3\emptyset = 26.7$ deg (NAVFAC 7.2)

$$F.S. = \frac{35.6[(0 + (350)(0.50)] + 47275(11.8)}{0 + (350)(15.9)} = 101 \quad \underline{OK}$$

HORIZONTAL SHEAR (CUMMINGS METHOD):

For simplicity, assume cell filled with shell down to bottom:

$$F.S. = \frac{M_r + M_i + P_p H_p}{P_w H/3 + P_a H_a}$$

where $M_r = \frac{ab^2}{2} + \frac{b^3}{3}$ = resisting moment from cell fill friction

$b = \tan\phi(B) = \tan(40)(35.6) = 30$ ft

$a = H - b = 84.4 - 30 = 54.4$ ft

so $M_r = \frac{(54.4)(30)^2(55)}{2} + \frac{30^3(55)}{3} = 1841400$ lb-ft

and $M_i = P_T(B)(f)$ = resisting moment from sheetpile friction

for High water = 17.4 -- P_T = 62570

for Low water = 0 ------ P_T = 115300

M_i (Low water) = (115300)(35.6)(0.3) = 1231400 lb-ft

M_i (High water) = (62570)(35.6)(0.3) = 668200 lb-ft

$P_w = P_{wR} - P_{wL} = 0$

P_p = 47275 lbs/ft

P_a = 350 lbs/ft

H_a = 15.9 ft

H_p = 11.8 ft

so F.S. (Low water) = $\frac{1841400 + 1231400 + (47275)(11.8)}{0 + (350)(15.9)} = 652$ **OK**

and F.S. (High water) = $\frac{1841400 + 668200 + (47275)(11.8)}{0 + (350)(15.9)} = 551$ **OK**

PULL-OUT OF OUTER SHEETING:

$$F.S. = \frac{Q_u}{Q_p} > 1.5$$

for clay, $Q_u = c_a$ x perimeter x embedded length

where c_a= 400 psf (avg)

perimeter = 35.6 x pi = 112 ft and embedded length = 29 ft

Q_u = 1300000 lbs

$$Q_p = \frac{P_a H_s - P_p H_B + P_w H}{3B(1 + B/4L)}$$

$P_w = 0$

P_p = 47275 lbs/ft and P_a = 350 lbs/ft

$H_s = H_B$ = 29 ft

$$Q_p = \frac{350(29) - 47275(29)}{3(35.6)[1 + (35.6/(4)(35.6)]} = -10200$$

F.S. = 1300000/10200 = 127 **OK**

PENETRATION OF INBOARD SHEETING:

$$F.S. = \frac{(P_p + P_s)\tan(\delta_o)}{P_d\tan(\delta_f)} = \frac{P_p\tan\delta + cL_s}{P_d\tan(\delta_f)}$$

where ~~deltaf~~ δ_f = angle of friction between sheetpile and cell fill
~~delta~~ δ_o = angle of friction between sheetpile and soil
P_d = cell fill pressure on inboard sheeting above dredgeline
P_s = soil pressure inside of inboard sheeting below dredgeline
P_p = soil pressure outside of inboard sheeting

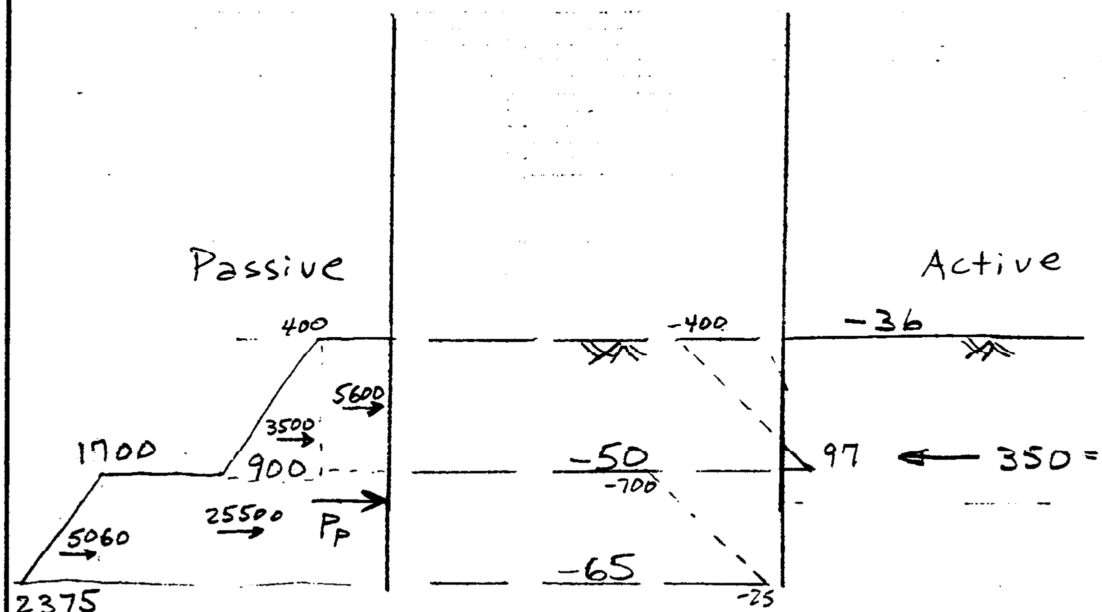
P_p = 47275 lbs/ft
P_s = 77700 lbs/ft
P_d = 37600 lbs/ft
δ_o = 0 for clay
δ_f = 26.7 deg

$$F.S. = \frac{400(29) + 400(29)}{37600\tan(26.7)} = 1.23$$

COMPUTATION SHEET

PROJECT IHNC Shiplock	PAGE OF	COMPUTED BY [initials]	DATE Sep 93
SUBJECT Mooring Cell, B = 79.3'		CHECKED BY	DATE

Active & Passive pressure on sheetpile walls from soil foundation.



$P_p = 35100$

$P_a = 97(2.7)^2/2 = 350$

distance from base

for p_a, $x = 15 + \frac{1}{3}(2.7) = 15.9'$

for P_p, $x = \dfrac{5600(22) + 3500(19.7) + 25500(7.5) + 5060(5)}{5600 + 3500 + 25500 + 5060}$

$x = 11.6$

Diagram 1

PROJECT IHNC Shiplock	PAGE OF	COMPUTED BY KF	DATE Sep 93
SUBJECT Mooring Cell, B = 79.3'		CHECKED BY	DATE

High Water = EL. 17.4

Active pressure inside of the cell wall. (For vert. shear)

@ 17.4 $p = K_A \gamma' H - 2c$

$P_{17.4} = 0.415(90)(2) = 75$

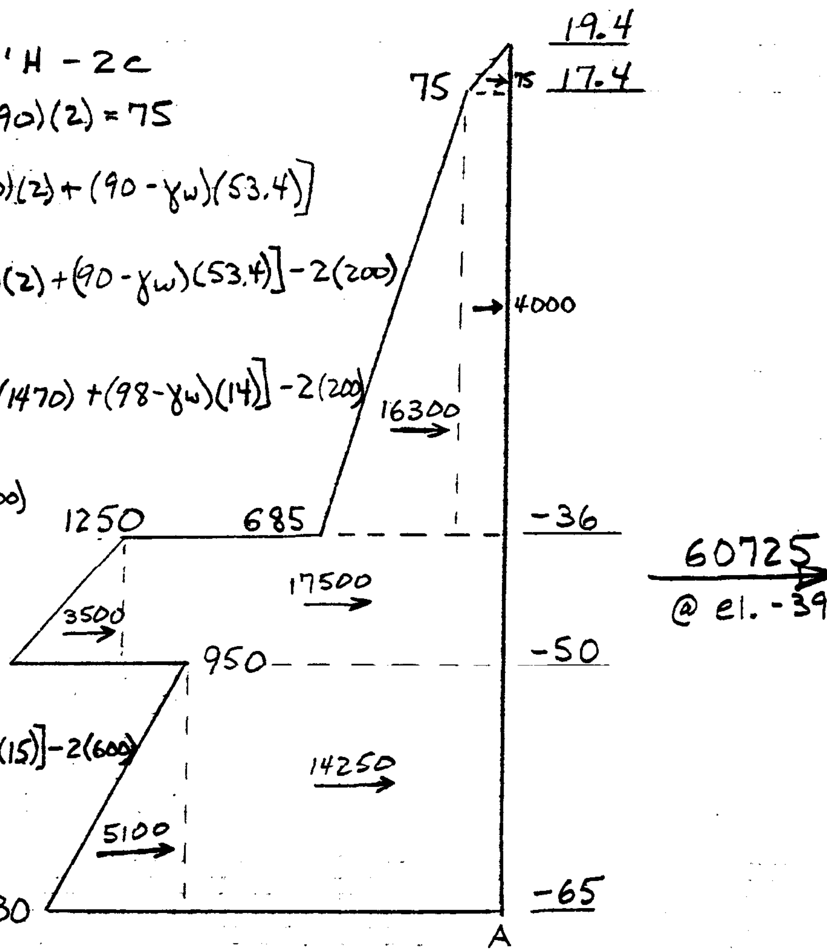
$P_{-36} = 0.415[(90)(2) + (90 - \gamma_w)(53.4)]$
$= 685$

$P_{-36} = (1)[(90)(2) + (90 - \gamma_w)(53.4)] - 2(200)$
$= 1250$

$P_{-50} = (1)[(180) + (1470) + (98 - \gamma_w)(14)] - 2(200)$
$= 1750$

$P_{-50} = (1)(2150) - 2(600)$
$= 950$

$P_{-65} = (1)[2150 + (108 - \gamma_w)(15)] - 2(600)$
$= 1630$



ΣResultants = 60725 p/f

distance "x" up from (pt A) is

$[75(83.1) + 4000(55.7) + 16300(46.8) + 17500(22) + 3500(19.7) + 14250(7.5) + 5100(5)] \div 60725$

$x = 26' = \text{elev.} -39$

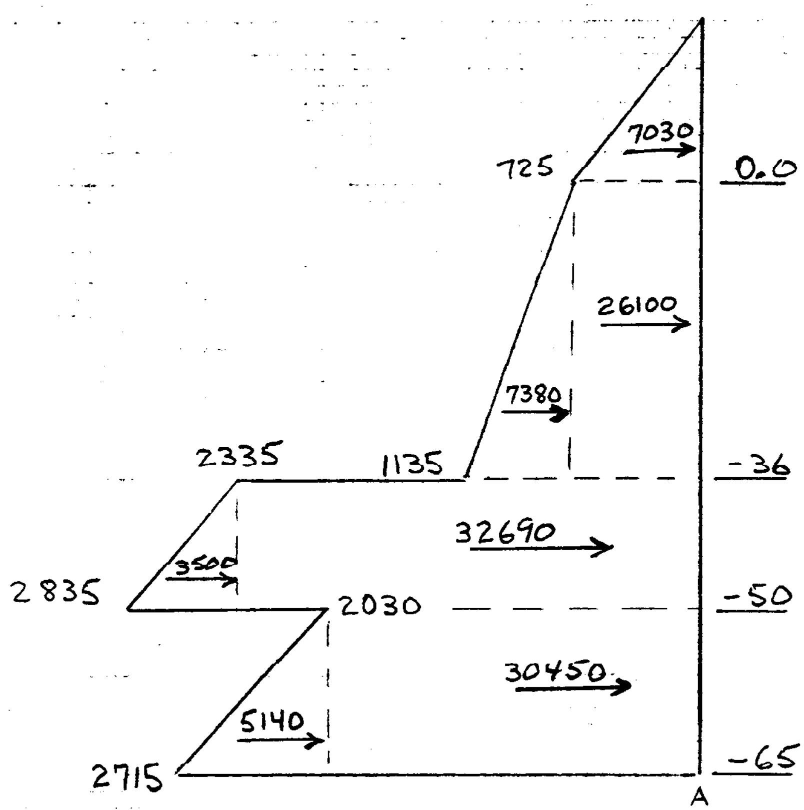
Diagram 2

COMPUTATION SHEET

PROJECT	PAGE OF	COMPUTED BY	DATE
SUBJECT		CHECKED BY	DATE

Low Water = EL 0.0

Active pressure inside of cell wall.
(For Vert. shear)



$\Sigma R = 112300$

distance "x" up from pt. A is

$[7030(71.5) + 26100(47) + 7380(41) + 32690(22) + 3500(19.7) + 30450(7.5) + 5140(5)] \div 112300$

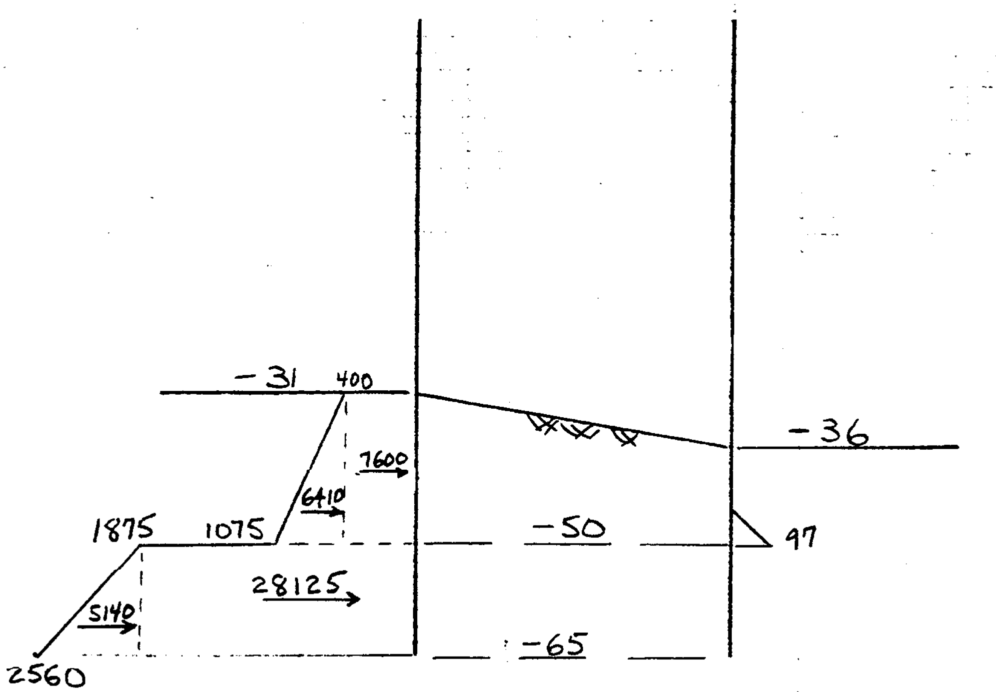
$x = 27.4$ = elev. 37.6

Diagram 3

COMPUTATION SHEET

PROJECT IHNC Shiplock	PAGE OF	COMPUTED BY [initials]	DATE Sep 93
SUBJECT Guidewall Dolphin		CHECKED BY	DATE

Active & Passive pressures on sheetpile walls from foundation soils.



$P_p = 47275$ $P_a = 350$

distance from base for Resultant P_p

$$X = \frac{7600(24.5) + 6410(21.3) + 28125(7.5) + 5140(5)}{47275} = 11.8$$

Diagram 4

COMPUTATION SHEET

PROJECT IHNC Shiplock	PAGE OF	COMPUTED BY LT	DATE Sep 93
SUBJECT Guidewall Dolphin		CHECKED BY	DATE

High Water = 17.4

Active pressures inside cell wall from cell fill

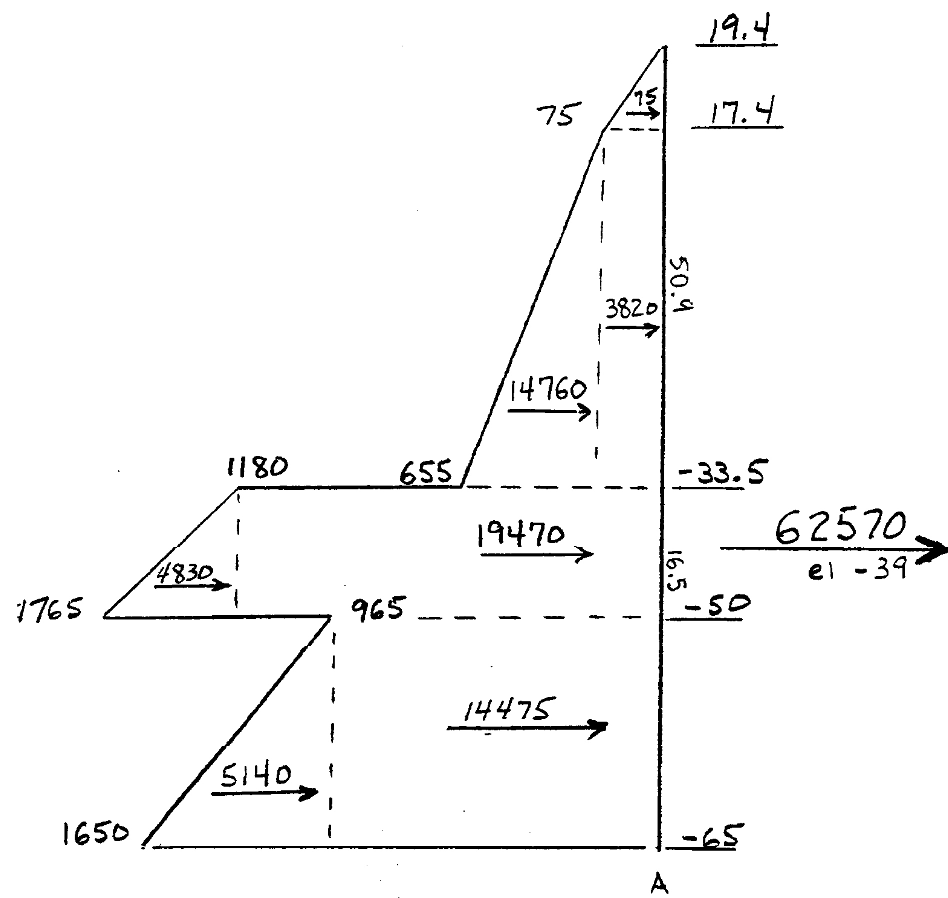


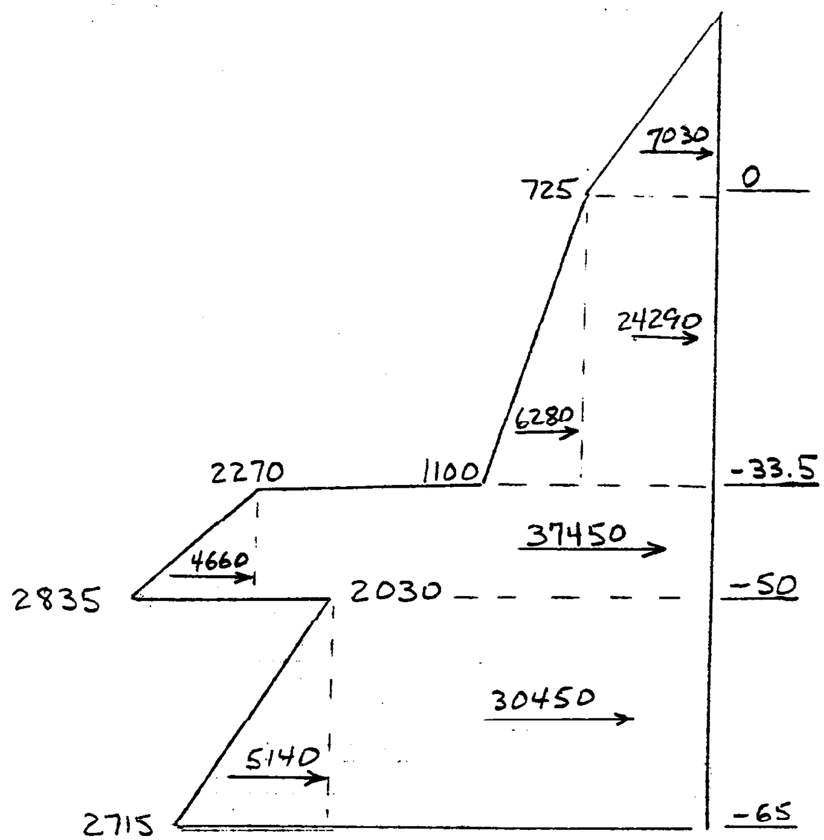
Diagram 5

COMPUTATION SHEET

PROJECT IHNC Shiplock	PAGE OF	COMPUTED BY KT	DATE Sep 93
SUBJECT Guidewall Dolphin		CHECKED BY	DATE

Low Water = EL 0.0

Active pressure inside cell wall from cell fill.



$\Sigma R = 115300$ @ EL -39

Diagram 6