STRUCTURAL CALCULATIONS

FOR

VACURA BULKHEAD

8439 87TH STREET

MERCER ISLAND, WA

FOR

ECCO DESIGNS

PROJECT NO. 2020-0040

January 22, 2020

CALCULATIONS

BY

KYLE NUNAN

REVIEWED AND STAMPED

BY

MICHAEL SZRAMEK, PE, SE

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STRUCTURAL CALCULATIONS

FOR

VACURA BULKHEAD
8439 87TH STREET,
MERCER ISLAND, WA

SITE SPECIFIC
LATERAL AND VERTICAL
ANALYSIS AND DESIGN
(DO NOT REUSE)

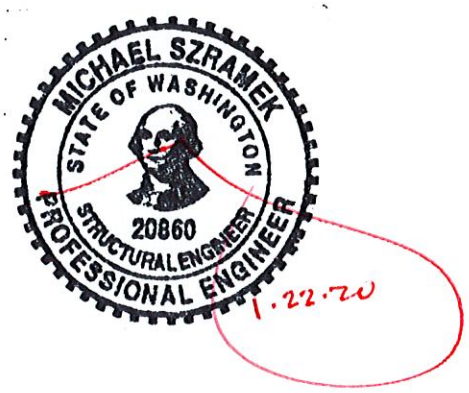
FOR
ECCO DESIGNS

PROJECT #2020-0040

BY
MC SQUARED, INC.

KYLE NUNAN

REVIEWED BY
MICHAEL SZRAMEK, PE, SE



SCOPE: CLIENT REQUESTED STRUCTURAL ENGINEERING TO PROVIDE LATERAL AND VERTICAL DESIGN FOR A REPLACEMENT BULKHEAD TO BE PUT ON THEIR WATERFRONT. THE WALL IS TO BE AROUND 8 FEET TALL AND RUN APPROXIMATELY 64 FEET.

BASIS OF DESIGN IS DRAWINGS PROVIDED BY CLIENT AND GEOTECHNICAL REPORT PROVIDED BY THE RILEY GROUP, INC.

LOADS:	2015 IBC/ASCE 7-10	
VERTICAL:	**WALL**	γ_{ROCKS} = 170 PCF VOID RATIO = 0.25 μ = 0.50
	SOIL	**BEARING = 1,500 PSF**
LATERAL:	**SOIL**	γ_{SOIL} = 120 PCF φ = 30° K_a = 0.33 K_p = 3.0

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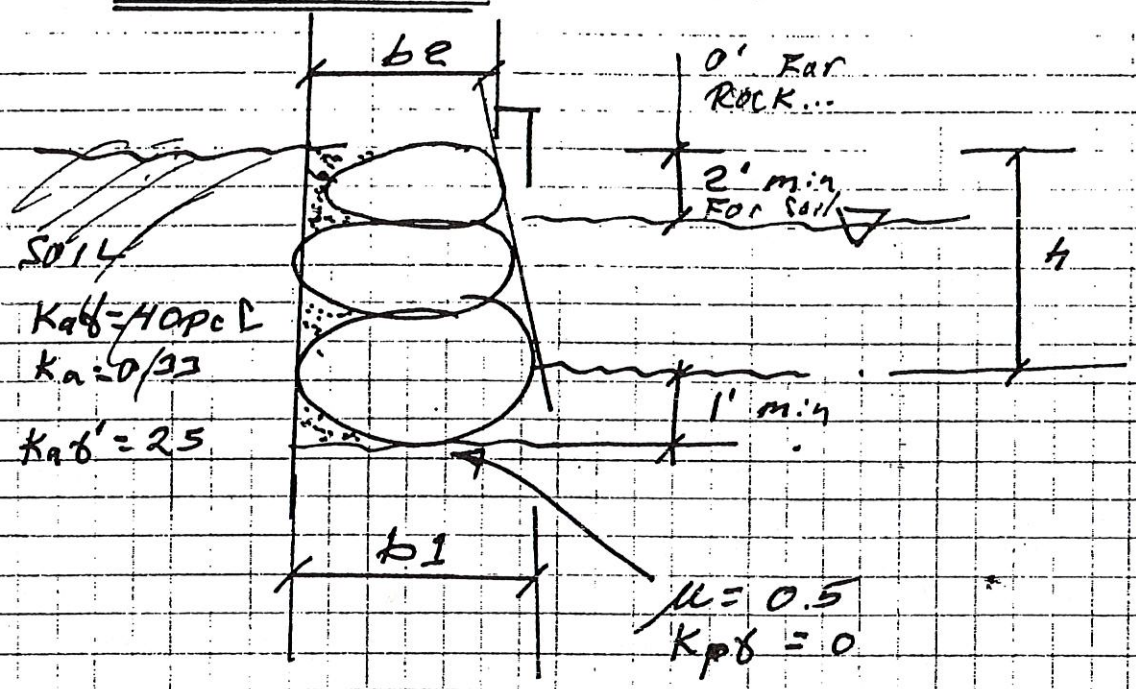
Rock wall



USE EFFECTIVE VALUES AS FOLLOWS

1. $\gamma_{rock} = 170$ pcf ($G_s = 2.72$ to 2.78)
   $\gamma_{sat\ wat} = 64$
2. Voids ratio = 0.25
3. $\mu_{rock-rock} = 0.6+$
4. $\therefore \gamma_{wall\ dry} = 170 \times 0.75 \sim 127.5$ pcf
5. $\gamma'_{wet} = ?$

   $\gamma' = (0.75 \times 170 + 0.25 \times 64) - 64 \approx 80$ pcf
6. $\gamma_{Dry\ soil} = 120$ $e = 0.28$
   $\gamma_{sat\ soil} = 138$
   $\gamma' = 74$
   $K_a = 0.33$
   $K_a\gamma = 40$
   $K_a\gamma' \sim 25$, w/ 30 min. -

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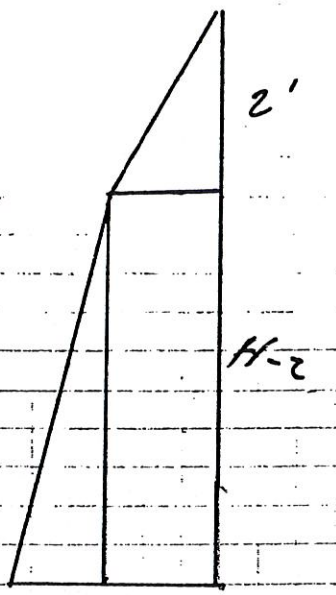
LOADS

SLIDING



$FH = \frac{1}{2} \times 40 \times 2^2 = 80$

$+ 40 \times 2 \times (H-2) = 80(H-2)$

$+ 30 \times \frac{(H-2)^2}{2} = 15(H-2)^2$

$\Sigma MOT = \left(\frac{1}{2} \times 40 \times 2^2\right)(H-2+0.67)$

$+ 40 \times 2 \times \frac{(H-2)^2}{2}$

$+ 30 \times \frac{(H-2)^3}{6}$

H	FH	MOT
4	300 ✓	414 ✓
6	640 ✓	1324 ✓
8	1100 ✓	3054 ✓

✓ = OK w/ computer output

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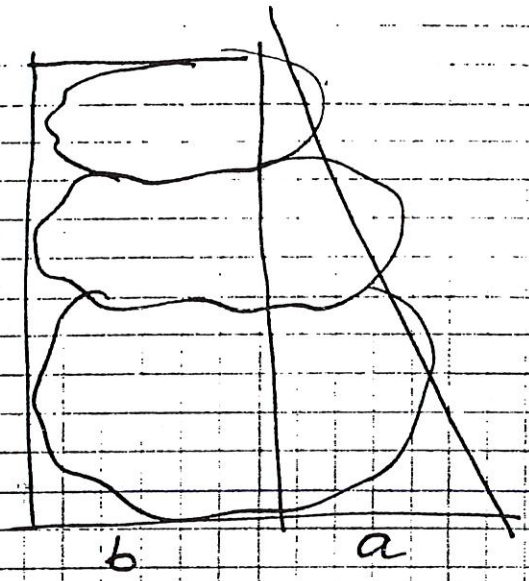

$W_{T,1} = b \times h \times \gamma'_{wall}$

$W_2 = \frac{a \times h}{2} \times \gamma'_{wall}$

$M_r = W_1 \times \frac{b}{2} + W_2 \times \left(b + \frac{a}{3}\right)$

$SFOT = M_r / M_{ot} \geq 3$

FOR "✓" = MATCHES COMPUTER RUN

h	b	a	W_1	W_2	M_r	SFOT
4'	3	0.75	960	120	1830	4.40 ✓
6'	3.5	1.25	1680	300	4115	3.09 ✓
8'	4.75	1.50	3040	480	9740	3.19 ✓

h	WT	F_h	SFS	
4	1.08	0.3	1.80	✓
6	1.98	0.64	1.55	✓
8	3.52	1.10	1.60	✓

results of rockery analysis

top	bot	fh	mot	wt	mr	sfs	sfot
3.00	3.75	0.30	0.41	1.08	1.83	1.80	4.43
3.00	4.00	0.45	0.79	1.40	2.47	1.54	3.13
3.50	4.75	0.64	1.33	1.98	4.11	1.55	3.09
4.25	5.50	0.85	2.08	2.73	6.69	1.60	3.22
4.75	6.25	1.10	3.05	3.52	9.74	1.60	3.19
5.25	7.00	1.38	4.29	4.41	13.60	1.60	3.17

```
ry quick and dirty program to design a rockery wall

SNG A-Z
INT I-J
te :      unit weight of rock = 170 pcf
          packing factor = 0.75 ... i.e.- void ratio=0.25
          submerged unit weight = 80 pcf
          assume that all of the rock is submerged
          assume that the top 2 feet of the soil is exerting 40pcf
          assume that all lower soil exerts 30 pcf when submerged...



y = 2!
ry = .04
ub = .03
all = .08
.min = 1.5
t.min = 3!
= .5
 = CHR$(12)
INT : LPRINT : LPRINT
INT "                    results of rockery analysis"
INT
INT "  ht      top      bot       fh       mot       wt       mr        sfs    sfot"
INT "=============================================================================

= "  ##     ##.##    ##.##    ##.##    ##.##     ##.##    ##.##     #.##    #.##"
nt:
 INPUT "  ht of wall top to bottom in feet "; h

 fh = .5 * kadry * hdry ^ 2 + kadry * hdry * (h - hdry)
 fh = fh + kasub * (h - hdry) ^ 2 / 2
 mot = .5 * kadry * hdry ^ 2 * (h - .6666 * hdry) + kadry * hdry * (h - hdry)
2 / 2
 mot = mot + kasub * (h - hdry) ^ 3 / 6

 'get triangular part of wall...
 a = INT(4! * h / 6 + 1!) / 4!
 w2 = w.wall * h * a / 2!

 'find the required minimum wall top width ... not to be less than 3 ft
 b = (sfs.min * fh - mu * w2) / (mu * w.wall * h)
 b = INT(4! * b + 1) / 4!
 IF b <= 3! THEN b = 3!
 w1 = w.wall * b * h
 mr = w1 * b / 2! + w2 * (b + a / 3!)
 sfot = mr / mot
 sfs = mu * (w1 + w2) / fh
cksfot:
 IF sfot < sfot.min THEN
     b = b + .25
     w1 = w.wall * b * h
     mr = w1 * b / 2! + w2 * (b + a / 3!)
     sfot = mr / mot
     sfs = mu * (w1 + w2) / fh
     GOTO checksfot
     END IF

 LPRINT USING a$; h; b; b + a; fh; mot; w1 + w2; mr; sfs; sfot
 INPUT "do you want a new wall ht (1=yes, 0=no) "; x
 IF x > 0 THEN GOTO newht
 LPRINT ff$
```

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ROCK BULKHEADS

DESIGN FOR 2 CONDITIONS : DRY
: TIDE IN @ .6H

ROCK PARAMETERS

γ_{ROCK} = 170 pcf 25% VOID RATIO
γ_{EFF} = 128 pcf DRY
γ_{WET} = (170 x .75 + .25 x 64) − 64 = 80 pcf
ROCK FRICTION +0.6

SOIL γ_{DRY} = 120 pcf ϕ = 30 K_A = .333
K_P = 3.00
γ_{WET} = 56 pcf

ACTIVE PRESSURE 40 pcf
ACTIVE WET 30 pcf MIN.

F.S. SLIDING ≥ 1.5
OT ≥ 3.0

DUE TO HIGH SILT CONTENT, USE SOIL BEARING OF 1500 PSF.

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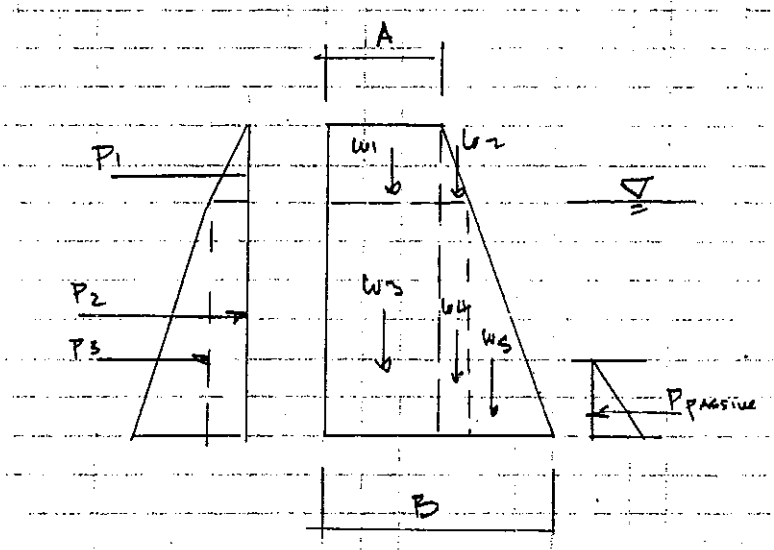

A 5'-3"
B 7'-0"
H 8

.21

		Wt	Arm Ot	Arm Br.	M Ot	M Br.
W_1	5.25 (2) 128	1344	4.375	-.875	5880	-1176
W_2	.44 (2) ½ 128	56	1.60	1.89	90	106
W_3	5.25 (6) 80	2520	4.375	-.875	11025	-2205
W_4	.44 (6) 80	211	1.53	1.97	323	416
W_5	1.31 (6) ½ (80)	314	.87	2.63	274	824
		4445			17592	-2035

.47

P_1	$2^2 (1/2) 40$	80	6.67	533
P_2	80 (6)	480	3.0	1440
P_3	$30 (6)^2 \cdot \frac{1}{2}$	540	2	1080
		[1100]		3053

P_p —

SLIDING $\frac{4445 \times .5}{1100} = 2.02 \geq 1.50$ OK

OVER-TURNING $\frac{17592}{3053} = 5.76 \geq 3.0$ OK

EARTH PRESSURE $\frac{4445}{7} \pm \frac{1018}{8.17} = 635 \pm 125$

760 psf
510 psf OK

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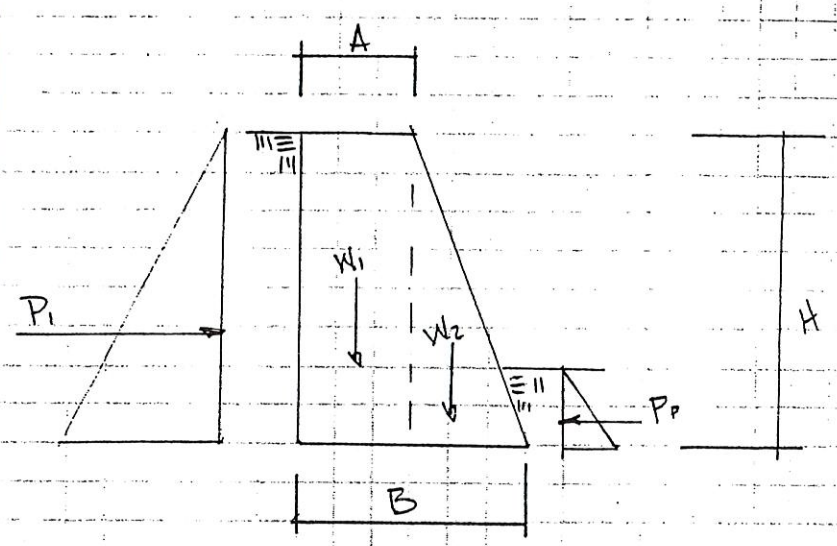
.32

.140 = $6^2(\frac{1}{2})AL$



A	5.25
B	7.0
H	0

		Wt	ARM OT	ARM BRG	M OT	M BRG.
W_1	5.25 (8) 128	5376	4.375	-.875	23520	-4704
W_2	1.75 (8) $\frac{1}{2}$ (128)	896	1.17	2.33	1045	2087
		6272			24565	-2617
P_1	40 (8)^2 $\frac{1}{2}$	[12900]		2.67		3413
P_P		[ ]				

SLIDING $\frac{6272\,(.5)}{12900} = 2.45 \geq 1.5$ OK

OVER TURNING $\frac{24565}{3413} = 7.20 \geq 3.0$ OK

EARTH PRESSURE $\frac{6272}{7} \pm \frac{766}{8.17} = 896 \pm 97$

933 PSF
799 PSF OK

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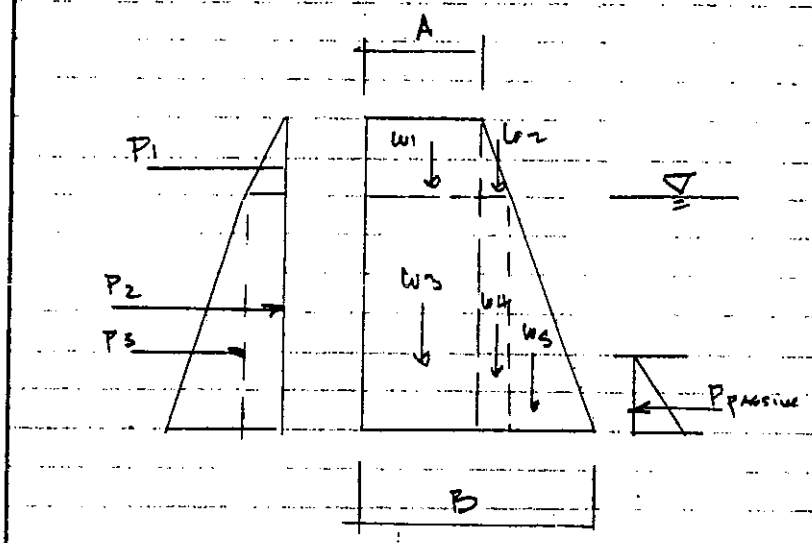

A 5' 9"
B 7' 9"
H 9

		Wt	Arm Ot	Arm Res	Mot	Mres.
W1	2 (5.75) 128	1472	4.875	-1	7176	-1472
W2	.44 (2) ½ 128	57	1.85	1.94	105	111
W3	5.75 (7) 80	3220	4.875	-1	15698	-3220
W4	.44 (7) 80	246	1.89	2.09	464	515
W5	1.54 (7) ½ (80)	431	1.02	2.82	442	1219
		5246			23885	-2847

.22

P1	2² (40) ½	80	X 7.67	613
P2	7 (80)	560	3.5	1960
P3	7² (½) 30	735	2.33	1715
		[1375]		4288

Pp

SLIDING $\frac{5246\,(.5)}{1375} = 1.91 \geq 1.5$ OK

OVER-TURNING $\frac{23885}{4288} = 5.56 \geq 3.0$ OK

EARTH PRESSURE $\frac{5246}{7.75} \pm \frac{1441}{10} = 700 \pm 144$ 844 556

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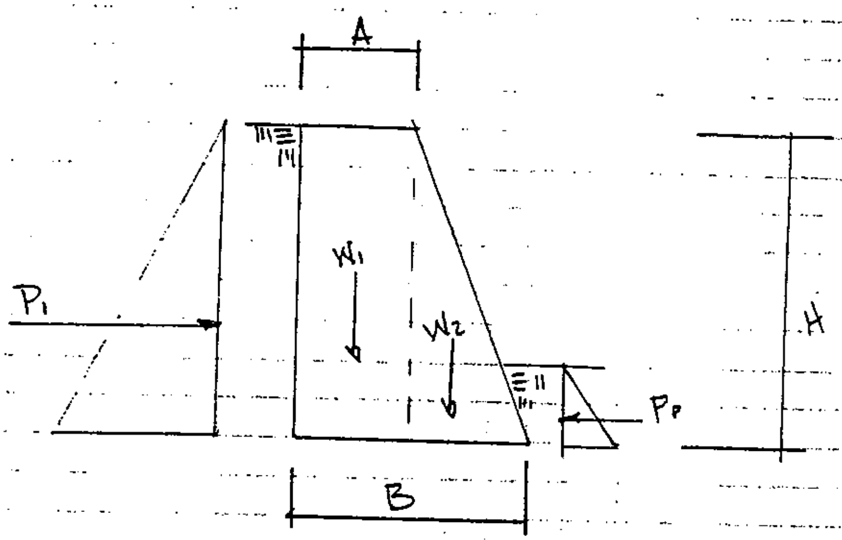

A	5.75
B	7.75
H	9

		Wt	ARM OT	ARM BRG	M OT	M BRG
W_1	5.75 (9) 128	6624	4.875	−1	32292	−6624
W_2	2 (9) ½ 128	1152	1.33	2.54	1536	2928
		7776			30756	−3696
P_1	9^2 (1/2) 40	[1620]	3		4860	
P_P		[ ]				

SLIDING $\frac{7776(.5)}{1620} = 2.40 \geq 1.5$ OK

OVERTURNING $\frac{30756}{4860} = 6.32 \geq 3.0$ OK

EARTH PRESSURE $\frac{7776}{7.75} \pm \frac{1164}{10} = 1003 \pm 116$

1119
887 OK

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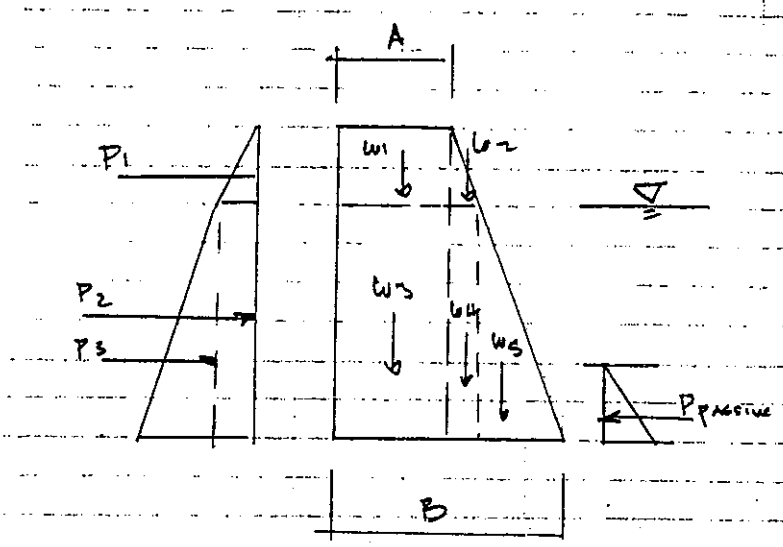

A 6'-3"
B 8'-6"
H 10

.225

6.48

		Wt	ARM OT	ARM BRG	M OT	M BRG.
W_1	2(6.25) 128	1600	5.37	-1.125	8600	-1800
W_2	.45 (2) 128 (1/2)	58	2.10	2.15	122	125
W_3	6.25 (8) 80	4000	5.37	-1.125	21480	-4500
W_4	.45 (8) 800	288	2.02	1.01	582	291
W_5	1.900 (8) 1/2 (900)	576	1.20	3.05	691	1756
		6522			31535	-4128
P_1	$2^2(60)\cdot\frac{1}{2}$	80	8.67		694	
P_2	80 (8)	640	4		2560	
P_3	$8^2(1/2)30$	960	2.67		2560	
		[1680]			5814	

P_P

SLIDING $\frac{6522\ (.50)}{1680} = 1.94 \geq 1.5$ OK

OVER-TURNING $\frac{31535}{5814} = 5.42 \geq 3.0$ OK

EARTH PRESSURE $\frac{6522}{8.5} + \frac{1680}{12.04} = 767 \quad 140$

907 psf
627 psf

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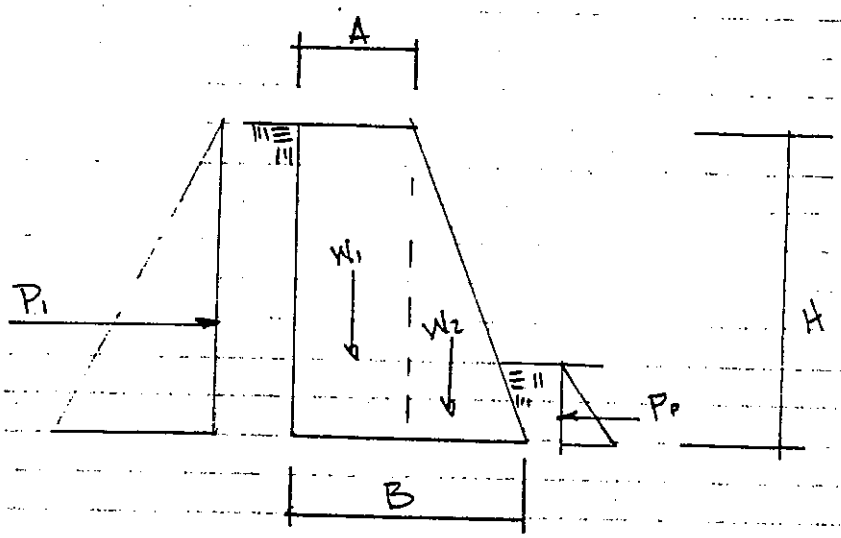
$= b^2\left(\frac{1}{2}\right)Hc$



A 6'-3"
B 8'-6"
H 10'

		Wt	ARM_{OT}	ARM_{RES}	M_{OT}	M_{RES}
W_1	6.25 (10) 128	8000	5.375	-1.125	43000	-9000
W_2	2.25 (10) $\frac{1}{2}$ (128)	1440	1.5	1.5	2160	2160
		9440			45160	-6840
P_1	$10^2\left(\frac{1}{2}\right)40$	[2000]	10/3		6666	
P_P		[-]				

SLIDING $\frac{9440\ (.5)}{2000} = 2.36 \geq 1.5$ OK

OVERTURNING $\frac{45160}{6666} = 6.78 \geq 3.0$ OK

EARTH PRESSURE $\frac{9440}{8.5} \pm \frac{-174}{12.04} = 1111 \pm 14$ 1125 1093

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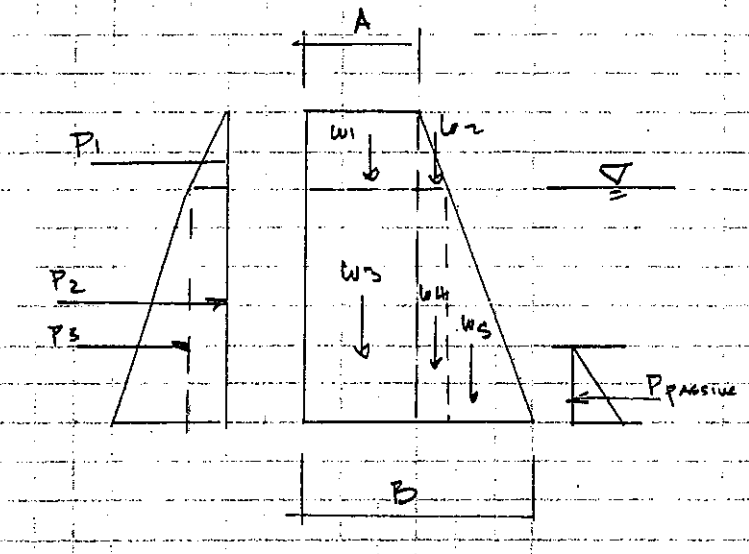

A 6'-6"
B 9'-3"
H 11'-0"

		Wt	ARMOT	ARMBRG	MOT	MBRG.
W1	2.20 (6.5) 120	1830	6	-1.37	10982	-2516
W2	2.20 (.55) 128 (1/2)	77	2.56	2.06	198	159
W3	8.80 (6.5) 80	4576	6	-1.37	27456	-6269
W4	.55 (8.8) 80	387	2.47	2.15	958	832
W5	8.80 (2.2) 80 (1/2)	774	1.47	3.15	1135	2441
		7644			40729	-5354
P1	2.2²(40) 1/2	97		9.53	923	
P2	88(8.8)	774		4.40	3407	
P3	8.8² (1/2) 30	1161		2.93	3407	
		[2032]			7737	

PP

SLIDING $\frac{7644 \times .5}{2032} = 1.88 \geq 1.5$ OK

OVER-TURNING $\frac{40729}{7737} = 5.26 \geq 3.0$ OK

EARTH PRESSURE $\frac{7644}{9.25} + \frac{2383}{14.26} = 826 \pm 167$ 993 / 659

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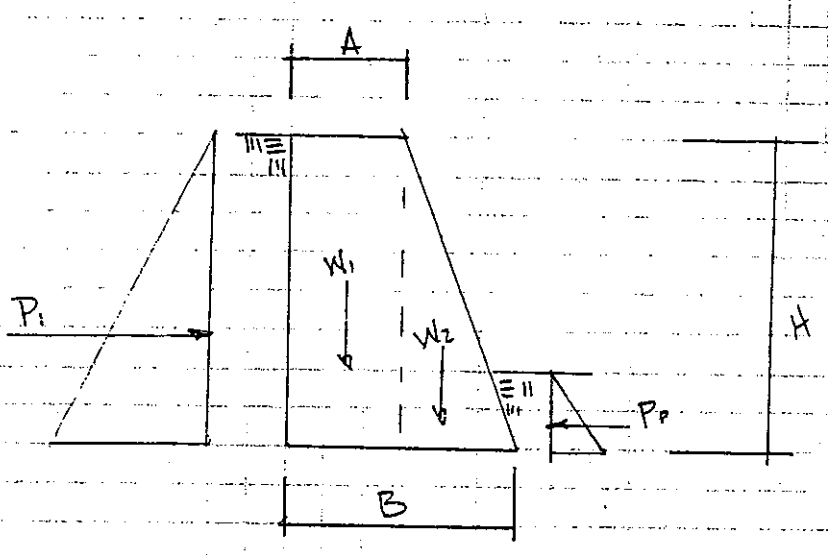
240 = 6²(½)Hc



A 6'-6"
B 91.3"
H 11

		Wt	ARM OT	ARM BRG	M OT	M BRG
W1	11 (6.5) 120	9152	6	-1.37	54912	-12538
W2	11 (2.75) 120 (½)	1936	1.93	2.79	3549	5405
		11088			58461	-7133
P1	11² (½) 40	[2420]	3.66		8873	
PP		[ ]				

SLIDING $\frac{11088\ (.5)}{2420} = 2.30 \geq 1.5$ OK

OVER TURNING $\frac{58461}{8873} = 6.59 \geq 3.0$ OK

EARTH PRESSURE $\frac{11088}{8.25} \pm \frac{1740}{14.26} = 1199 \pm 122$ 1320 1077

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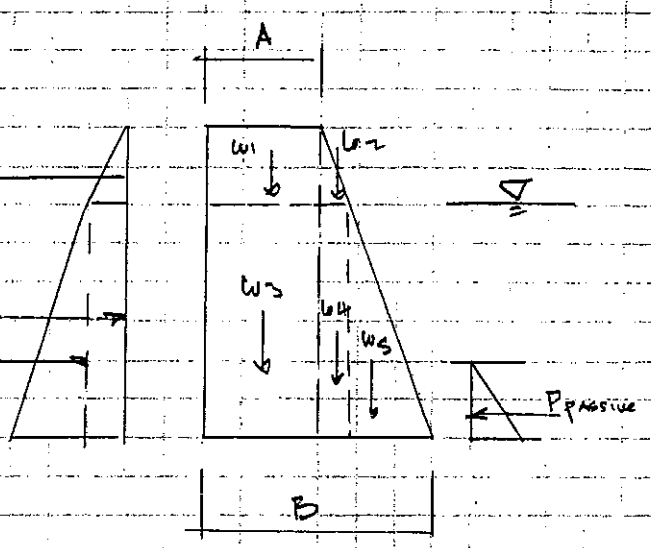

A	6'-9"
B	9'-9"
H	12'

6.95

		Wt	ARM OT	ARM BR	MOT	MBR.
W_1	2.4 (6.75) 120	2073	6.38	-1.50	13229	-3110
W_2	2.4 (.60) 120	184	2.8	2.07	515	381
W_3	9.6 (6.75) 80	5184	6.38	-1.50	33048	-7776
W_4	0.60 (9.6) 80	461	2.7	2.17	1245	459
W_5	9.6 (2.4) 80 (1/2)	921	1.6	3.27	1473	3016
		8823			49510	-7031
P_1	$2.4^2 \cdot \frac{1}{2}$ (40)	115	10.4		1198	
P_2	9.6 (96)	922	4.8		4424	
P_3	9.6^2 (1/2) 30	1382	3.2		4424	
		[2419]			10046	

P_P

SLIDING $\frac{8823\ (.5)}{2419} = 1.82 \geq 1.5$ OK

OVER-TURNING $\frac{49510}{10046} = 4.93$

EARTH PRESSURE $\frac{8823}{9.75} + \frac{3015}{15.84} = 905 \pm 100$ 1095 / 1714

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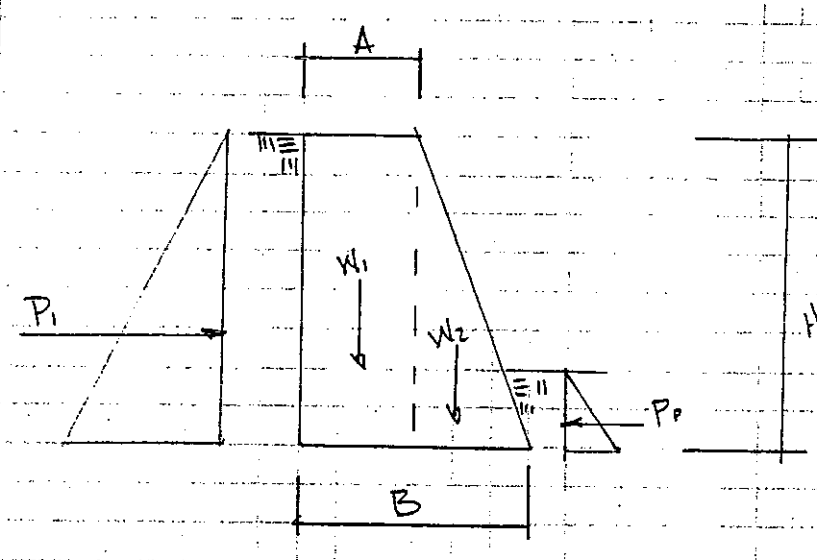
$640 = 6^2(\frac{1}{2})Hc$



A 6.75'
B 91.5"
H 12

		Wt	ARM_{OT}	ARM_{BRG}	M_{OT}	M_{BRG}
W_1	6.75(12) 128	10368	6.38	-1.5	66148	-15552
W_2	3(12) 1/2 (128)	2304	2	2.88	4608	6624
		12672			70756	
P_1	$12^2(\frac{1}{2})$ 40	[2880]	4			11520
P_P		[ ]				

SLIDING $\frac{12672(.5)}{2880} = 2.20 \geq 1.5$ OK

OVER TURNING $\frac{70756}{11520} = 6.14 \geq 3.0$ OK

EARTH PRESSURE $\frac{12672}{9.75} \pm \frac{2592}{15.84} = 1300 \pm 163$ 1463, 1136