Ana Clara Keough
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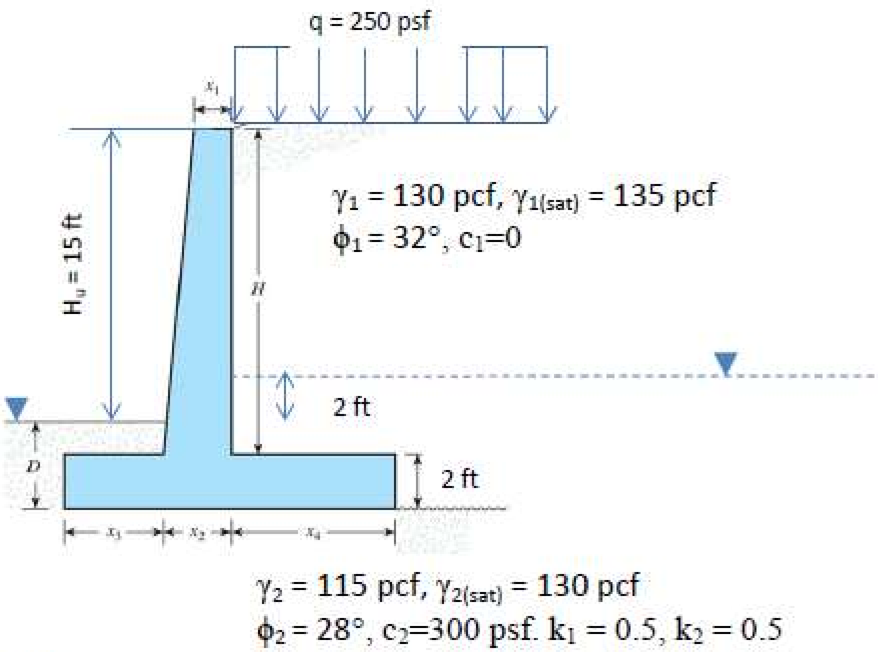
Given:

As foundation engineer, you are required to determine the preliminary dimensions of a reinforced concrete cantilever retaining wall, which will support a new roadway. The adjacent highway surcharge load is shown in the figure below. The unsupported height of the retaining wall (H_u) is 15 ft. and the foundation must be embedded a depth (D) of 5 ft. below the adjacent grade. Due to site flooding conditions, design flood level is at grade in front of the wall is expected to be two (2) feet higher behind the wall as shown in the figure below. Assume unit weight of concrete is 150 pcf. All soil properties are given in the figure. Use Rankine Active Earth Pressures and ignore passive earth pressure effects.



Find:

1. Using Figure 8.3b in your textbook, determine the preliminary unknown dimension of the retaining wall (x_1, x_2, x_3, and x_4) round to nearest 0.25 ft.. Using these preliminary dimensions and determine:
   a. Factor of Safety for Overturning Stability.
   b. Factor of Safety for Sliding Stability.
   c. Factor of Safety for Bearing Capacity.
2. What is the critical mode of failure for the preliminary design?

GIVEN

Wall dimensions

$\gamma c := 150$ pcf $\quad$ $Hu := 15$ ft $\quad$ $D := 5$ ft

$x5 := 2\,ft$ $\quad$ Surcharge $q := 250$ psf

Since horizontal granular backfill:

$\alpha := 0deg$

Soil properties

$\gamma 1 := 130$ pcf
$\gamma 1sat := 135$ pcf
$\phi'1 := 32deg$
$c'1 := 0$

$\gamma 2 := 115$ pcf
$\gamma 2sat := 130$ pcf
$\phi'2 := 28deg$
$c'2 := 300$ psf

$k1 := \frac{1}{2}$ $\quad$ $k2 := \frac{1}{2}$

$\gamma w := 62.4$ pcf

$H := Hu + D - x5 = 18$ ft

height of water behind the wall

$hwb := 7$ ft

METHOD 1 Use Figure 8.3b to determine initial proportioning

A) OVERTURNING STABILITY:

1. Determine the Rankine Active Force per unit length of Wall
 1.1 Determine Ka (active earth pressure coefficient) using EQ 7.1
 1.2 The force Pa can be obtained by adding stresses and the effects of hydrostatic pressure can be lumped into Pa
3. Determine the overturning moment
 3.2 Determine horizontal component of Pa and moment caused by it (Mo)
4. Determine the resisting forces and its corresponding moments
 4.1 For the areas of concrete below the water, a specific effective weight of concrete is used in order to represent the effect of water buoyancy on the structure
 4.2 The forces are tabled and vertical forces summed, as well as moments
4. Determine FSoverturning (Use EQN 8.5)

B) SLIDING Determine Kp (Use equation on page 385)
Sliding Factor of Safety can be calculated with EQ 8.11

C) BEARING CAPACITY FAILURE

0. Determine eccentricity and maximum and minimum pressures (pressures at the toe and heel of wall) (EQNS 8.18 & 8.21)
1. Use Table 3.3 to determine Bearing Capacity Factors
2. Use Table 3.4 to determine Depth and Inclination Factors
3. Use Meyerhoff's Equation 8.22 to determine bearing capacity qu
4. Determine Bearing Capacity using EQ 8.23

SOLUTION Given the general dimensions we can obtain Ht: $Ht := Hu + D = 20 \ \text{ft}$

1 $x3 := 0.1 \cdot Ht = 2 \ \text{ft}$ $x2 := 0.1 \cdot Ht = 2 \ \text{ft}$ $B := 0.6 \cdot Ht = 12 \ \text{ft}$ $x4 := B - (x3 + x2) = 8 \ \text{ft}$

$x1 := 1.5 \ \text{ft}$ $\theta := \operatorname{atan}\left[\frac{(x2 - x1)}{18}\right] = 0.028$

DETERMINING RANKINE ACTIVE FORCE:

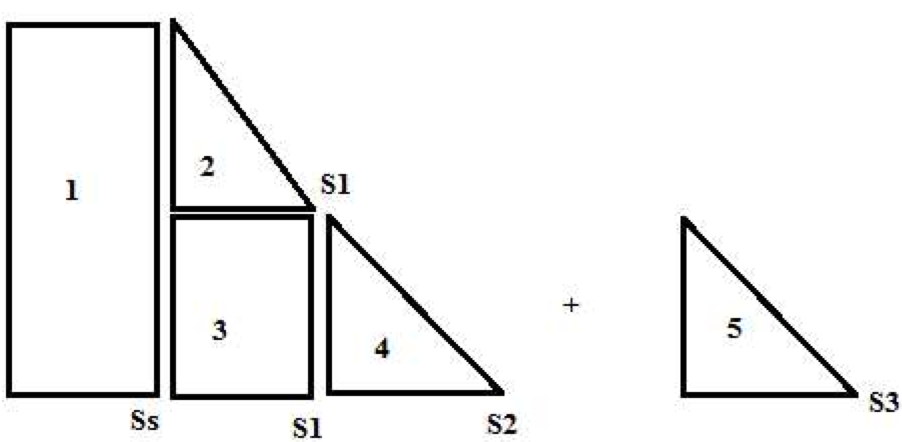
$$Ka := \tan\left(45 \cdot deg - \frac{\phi'1}{2}\right)^2 = 0.307$$

Stress Due to the surcharge: $Ss := q \cdot Ka = 76.815 \ \text{psf}$

Stress @ $z1 := Ht - hwb = 13 \ \text{ft}$ $S1 := Ka \cdot \gamma1 \cdot z1 = 519.267 \ \text{psf}$

Stress @ $z2 := Ht - z1 = 7 \ \text{ft}$ $S2 := Ka \cdot (\gamma1sat - \gamma w) \cdot z2 = 156.149 \ \text{psf}$

Hydrostatic Pressure $z2 = 7 \ \text{ft}$ $S3 := z2 \cdot \gamma w = 436.8 \ \text{psf}$



The stress areas in the picture are equal to:

$A1 := Ht \cdot Ss = 1.536 \times 10^3 \ \text{plf}$

$A2 := 0.5 \cdot z1 \cdot S1 = 3.375 \times 10^3 \ \text{plf}$

$A3 := z2 \cdot S1 = 3.635 \times 10^3$ $A4 := 0.5 \cdot z2 \cdot S2 = 546.521$

$A5 := 0.5 \cdot z2 \cdot S3 = 1.529 \times 1 \ \text{plf}$

$A5w := A5 = 1.529 \times 10^3$

Figure 3.1 - Stresses Areas and its Force Equivalents

The total rankine active pressure is equal to the sum of the areas above:

$$Pa := A1 + A2 + A3 + A4 + A5 = 1.062 \times 10^{4} \quad plf$$

The location of the force (to the bottom of the wall) is equal to:

$$H' := \frac{\left[A1\cdot\frac{Ht}{2} + A2\cdot\left(z2 + \frac{z1}{3}\right) + A3\cdot\frac{z2}{2} + (A4 + A5)\cdot\frac{z2}{3}\right]}{Pa} = 6.701\,ft$$

Overturning components:

$$Ph := Pa\cdot\cos(\alpha) = 1.062 \times 10^{4} \quad plf \qquad Mo := Ph\cdot(H') = 7.118 \times 10^{4} \quad lb - \frac{ft}{ft} \quad CCW$$

The hydrostatic pressure (and force Fbw) behind the wall also causes an overturning moment, however it has already been accounted within Pa.

To determine the height of concrete that is submerged: $hb := 6 \quad ft \qquad hbs := 6 - x5 = 4$

RESISTING COMPONENTS

$$Pv := Pa\cdot\sin(\alpha) = 0$$

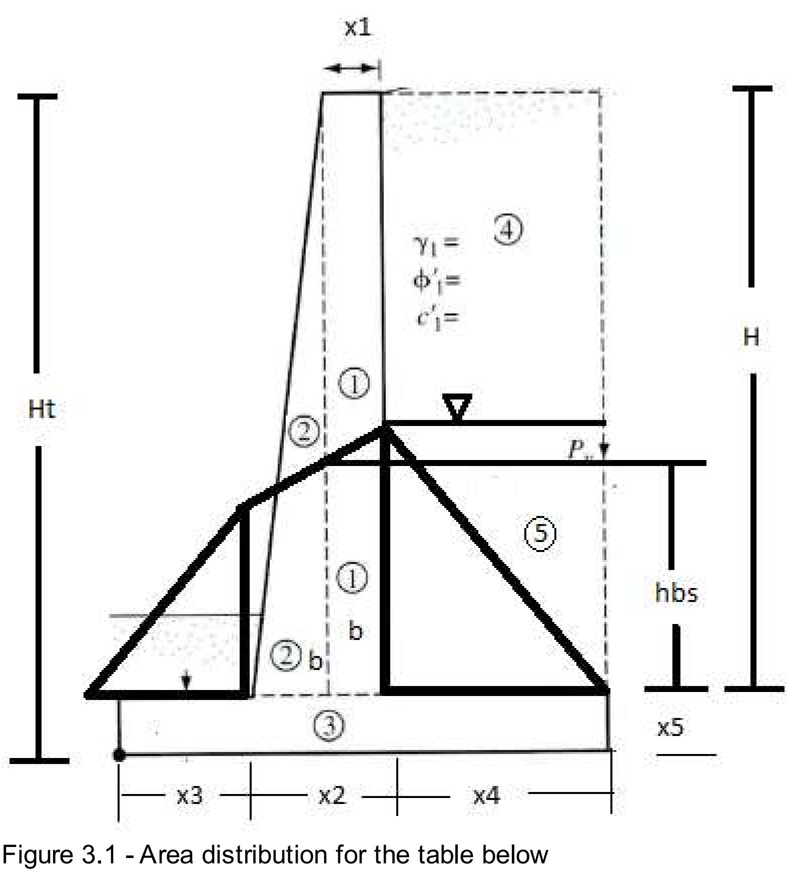


Figure 3.1 - Area distribution for the table below

Obs for the table below:
1. The suffix b (below) refers to areas submerged (below the water)
2. The vertical component of the surcharge is taken into consideration as a resisting force (See 7 below)
3. The vertical component of the hydrostatic pressure in the front of the wall causes a resisting moment (See 6 below)
4. Pp also causes a resisting moment, however, we'll assume it equal to zero for a conservative approach

Effective Concrete Weight

$$\gamma c' := \gamma c - \gamma w = 87.6$$

Effective Soil Weight

$$\gamma 1' := \gamma 1 - \gamma w = 67.6$$

Height above water table $Hw := Ht - 7 = 13 \quad ft$

SEC	AREA (ft^2)	W/unit length (plf)	M. Arm to C (ft)	Moment lb-ft/ft
1	$A1 := x1\cdot(H - hbs) = 21$	$w1 := \gamma c\cdot A1 = 3.15 \times 10^{3}$	$B1 := x3 + x2 - \frac{x1}{2} = 3.25$	$M1 := w1\cdot B1 = 1.024 \times 10^{4}$
	$A1b := x1\cdot hbs = 6$	$w1b := (\gamma c')\cdot A1b = 525.6$	$B1b := B1 = 3.25$	$M1b := w1b\cdot B1b = 1.708 \times 10^{3}$

2 $A2 := (x2 - x1)\cdot\frac{(H - hbs)^2}{2\cdot H} = 2.722$ $w2 := \gamma c\cdot A2 = 408.333$ $B2 := x3 + \frac{2}{3}\left(x2 - \frac{x1}{2}\right) = 2.833$ $M2 := w2\cdot B2 = 1.157\times 10^3$

$A2b := (x2 - x1)\cdot\frac{(H)}{2} - A2 = 1.778$ $w2b := \gamma c'\cdot A2b = 155.733$ $B2b := B2 = 2.833$ $M2b := w2b\cdot B2b = 441.244$

3 $A3 := x5\cdot B = 24$ $w3 := \gamma c'\cdot A3 = 2.102\times 10^3$ $B3 := \frac{B}{2} = 6$ $M3 := w3\cdot B3 = 1.261\times 10^4$

4 $A4 := x4\cdot(Hw) = 104$ $w4 := \gamma 1\cdot A4 = 1.352\times 10^4$ $B4 := B - \frac{x4}{2} = 8$ $M4 := w4\cdot B4 = 1.082\times 10^5$

5 $A5 := x4\cdot hbs = 32$ $w5 := \gamma 1'\cdot A5 = 2.163\times 10^3$ $B5 := B4 = 8$ $M5 := w5\cdot B5 = 1.731\times 10^4$

6 Hydrostatic Force Front $Ffw := 0.5\cdot\gamma w\cdot D^2 = 780$ plf $B6 := 0.333\cdot D = 1.665$ $M6 := Ffw\cdot B6 = 1.299\times 10^3$

Surcharge Vertical Component $Qq := q\cdot x4 = 2\times 10^3$ plf $Bq := B - \frac{x4}{2} = 8$ $M7 := Qq\cdot Bq = 1.6\times 10^4$

$$\Sigma V := w1 + w1b + w2b + Qq + w2 + w3 + w4 + w5 = 2.403\times 10^4\ \frac{lb}{ft}$$

$$\Sigma Mr := M1 + M1b + M2b + M2 + M3 + M4 + M5 + M6 + M7 = 1.689\times 10^5\ lb - \frac{ft}{ft}$$

$FSoverturning := \frac{\Sigma Mr}{Mo} = 2.373$ if(FSoverturning > 2,"OK!" ,"No Good") = "OK!"

FACTOR OF SAFETY AGAINST SLIDING:

We must obtain Kp $Kp := \tan\left(45\cdot deg + \frac{\phi'1}{2}\right)^2 = 3.255$ $Pp := 0.5\cdot Kp\cdot\gamma 2\cdot D^2 + 2\cdot c'2\cdot\sqrt{Kp}\cdot D = 1.009\times 10^4$

EQ 8.11 $FSsliding := \frac{(\Sigma V\cdot\tan(k1\cdot\phi'2) + B\cdot k2\cdot c'2 + Pp + Ffw)}{(Pa\cdot\cos(\alpha))} = 1.757$ if(FSsliding > 1.5,"okay" ,"not good") = "okay"

FACTOR OF SAFETY AGAINST BEARING CAPACITY FAILURE

$e := \frac{B}{2} - \frac{(\Sigma Mr - Mo)}{\Sigma V} = 1.932$ ft EQ 8.16, 8.17 and 8.18 $\text{if}\left(e < \frac{B}{6},\text{"okay"},\text{"not good"}\right) = \text{"okay"}$

$qtoe := \frac{\Sigma V}{B}\cdot\left(1 + 6\cdot\frac{e}{B}\right) = 3.936\times 10^3$ psf $qheel := \frac{\Sigma V}{B}\cdot\left(1 - 6\cdot\frac{e}{B}\right) = 68.395$ psf $qmax := \max(qtoe, qheel)$

Using Table 3.3 we have: $\phi'2 := 28\cdot deg$ $Nc := 25.8$ $Nq := 14.72$ $N\gamma := 16.72$ $B' := (B - 2e) = 8.137$ ft

$p := \frac{D}{B'} = 0.615$ $F\gamma d := 1$ $Fqd := 1 + 2\cdot\tan(\phi'2)\cdot(1 - \sin(\phi'2))^2\cdot\left(\frac{D}{B'}\right) = 1.184$ $Fcd := Fqd - \frac{(1 - Fqd)}{Nc\cdot\tan(\phi'2)} = 1.197$

$\psi := \text{atan}\left[\frac{(Pa\cdot\cos(\alpha))}{\Sigma V}\right] = 0.416$ $Fci := \left(1 - \frac{\psi}{90\cdot deg}\right)^2 = 0.54$ $Fqi := Fci = 0.54$ $F\gamma i := \left(1 - \frac{\psi}{\phi'2}\right)^2 = 0.022$

$q := (\gamma 2 - \gamma w)\cdot D = 263$

$qu := c'2\cdot Nc\cdot Fcd\cdot Fci + q\cdot Nq\cdot Fqd\cdot Fqi + .5\cdot\gamma 2\cdot B'\cdot N\gamma\cdot F\gamma d\cdot F\gamma i = 7.654\times 10^{3}$

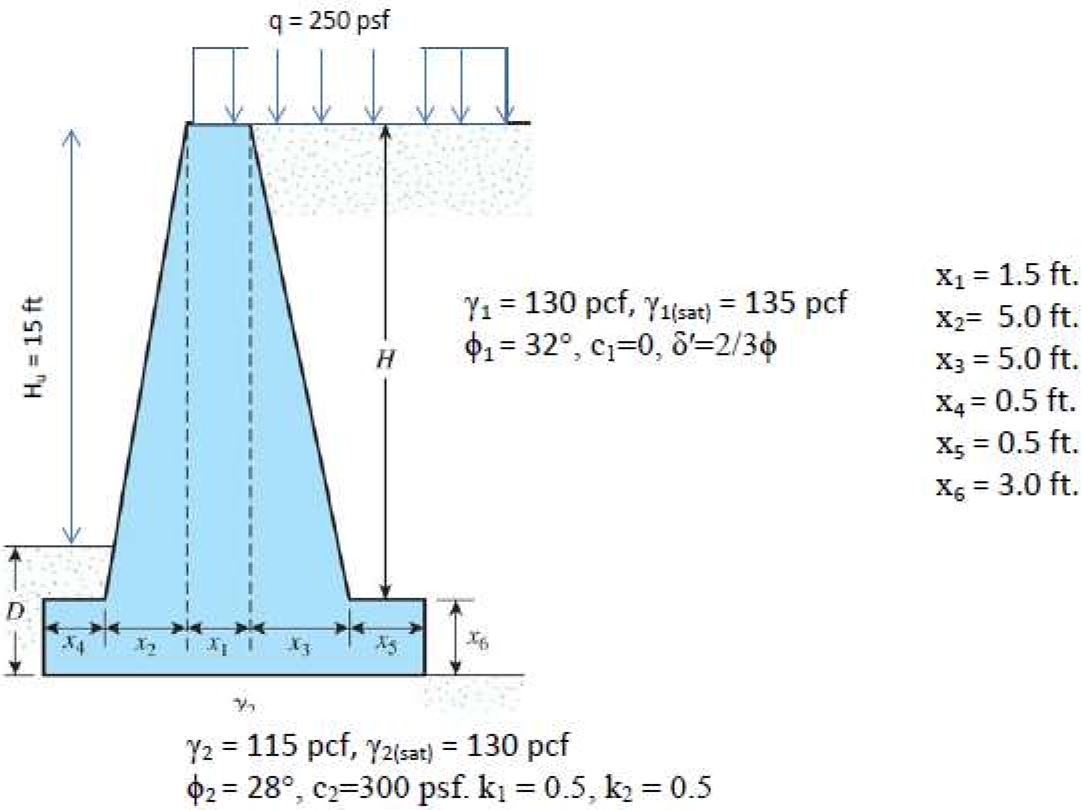
$FSbearing := \frac{qu}{qmax} = 1.945$

if(FSbearing > 3, "okay", "not good") = "not good"

PART B In the preliminary design Bearing Capacity is the critical mode of failure.

Given:

You are requested evaluate a massive gravity wall option using dimensions shown in the figure below for the same site conditions described in Problem 3. Use Coulomb Active Earth Pressures and ignore passive earth pressure effects.



Find:

1. Using these preliminary dimensions determine:
   a. Factor of Safety for Overturning Stability.
   b. Factor of Safety for Sliding Stability.
   c. Factor of Safety for Bearing Capacity.
2. What is the critical mode of failure for the massive gravity wall option?
3. Which option would you recommend for the final design? **Cantilever/Massive Gravity**
   a. Explain your preferred choice and discuss how you would improve the design to achieve the following minimum requirements:
      i. Factor of Safety for Overturning Stability = 2.0
      ii. Factor of Safety for Sliding Stability = 1.5
      iii. Factor of Safety for Bearing Capacity = 3.0

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GIVEN

Wall dimensions

$\gamma c := 150 \text{ pcf}$ $\quad Hu := 15 \text{ ft}$ $\quad D := 5 \text{ ft}$

$x5 := 2\text{ ft}$ $\quad$ Surcharge $q := 250 \text{ psf}$

Since horizontal granular backfill:

$\alpha := 0\text{deg}$

$x1 := 1.5 \text{ ft}$ $\quad x2 := 5 \text{ ft}$ $\quad x3 := 5 \text{ ft}$ $\quad x4 := 0.5 \text{ ft}$ $\quad x5 := 0.5 \text{ ft}$ $\quad x6 := 3.0 \text{ ft}$ $\quad B := x4 + x2 + x1 + x3 + x5 = 12.5$

Soil properties

$\gamma 1 := 130 \text{ pcf}$ $\quad \gamma 2 := 115 \text{ pcf}$ $\quad k1 := \frac{1}{2}$ $\quad k2 := \frac{1}{2}$

height of water behind the wall

$\gamma 1sat := 135 \text{ pcf}$ $\quad \gamma 2sat := 130 \text{ pcf}$ $\quad hwb := 7 \text{ ft}$

$\phi'1 := 32\text{deg}$ $\quad \phi'2 := 28\text{deg}$ $\quad \gamma w := 62.4 \text{ pcf}$

$c'1 := 0$ $\quad c'2 := 300 \text{ psf}$ $\quad H := Hu + D - x6 = 17 \text{ ft}$

$\delta' := \frac{2}{3}\cdot\phi'1 = 0.372$

METHOD

A) OVERTURNING STABILITY:

1. Determine the Coulomb Active Force per unit length of Wall using Equation 7.27
   1.1 Determine Ka using EQ 7.26
      The angles can be obtained through the geometry of the wall
   1.2 Determine the γeq due to the surcharge using EQN 7.28
      This equation will take in consideration the effects due to the surcharge into Pa
2. Determine the location of the Coulomb Active force (a) using statics concepts
3. Determine the overturning moment
   3.1 Determine angle that the force Pa is applied to the wall using geometry
   3.2 Determine horizontal component and moment caused by
   3.3 Determine the horizontal hydrostatic force caused by the water in the soil, and the corresponding overturning moment it causes
   3.4 The total overturning moment will be equal to the sum of the two moments calculated in 3.2 and 3.3
4. Determine the resisting forces and its corresponding moments
   4.1 For the areas of concrete below the water, an specific effective weight of concrete is used in order to represent the effect of water buyoncy on the structure
   4.2 The forces are tabled and vertical forces summed, as well as moments
4. Determine FSoverturning (Use EQN 8.5)

B) SLIDING

Determine Kp (Use equation on page 385)
Sliding Factor of Safety can be calculated with EQ 8.11
The values that represent the hydrostatic pressure vertically resisting sliding and contributing to it are added to the equation

C) BEARING CAPACITY FAILURE

0. Determine eccentricity and maximum and minimum pressures (pressures at the toe and heel of wall) (EQNS 8.18 & 8.21)
1. Use Table 3.3 to determine Bearing Capacity Factors
2. Use Table 3.4 to determine Depth and Inclination Factors
3. Use Meyerhoff's Equation 8.22 do determine bearing capacity qu
4. Determine Bearing Capacity using EQ 8.23

SOLUTION Given the general dimensions we can obtain Ht: $\quad Ht := Hu + D = 20 \text{ ft}$

$\beta := \text{atan}\left(\frac{H}{x3}\right) = 1.285$ $\quad$ Angle of the backfill: $\quad \alpha := 0\cdot\text{deg}$

$$Ka := \frac{\left(\sin(\beta + \phi'1)^2\right)}{\sin(\beta)^2\cdot\sin(\beta - \delta')\cdot\left[1 + \sqrt{\frac{(\sin(\phi'1 + \delta')\cdot\sin(\phi'1 - \alpha))}{\sin(\beta - \delta')\cdot\sin(\alpha + \beta)}}\right]^2} = 0.417$$

Eqn 7.26

$$\gamma eq := \gamma 1 + \left(\frac{\sin(\beta)}{\sin(\beta+\alpha)}\right)\cdot\left(2\cdot\frac{q}{H}\right) = 159.412$$

$$Pa := .5\cdot\gamma eq\cdot Ht^2\cdot Ka = 1.329\times 10^4 \quad \text{plf}$$ EQ 7.27

Location of the line of action of the resultant:

from the bottom of the wall

$$z := \frac{\left[0.5\cdot Ka\cdot\gamma 1\cdot\frac{Ht^3}{6} + Ka\cdot\frac{Ht^2}{2}\cdot q\cdot\left(\frac{\sin(\beta)}{\sin(\beta+\alpha)}\right)\right]}{Pa} = 4.287 \quad \text{ft}$$

AS SEEN IN EXAMPLE 7.7 page 347

Angle for the force Pa

$$\alpha 2 := 90 - \frac{\beta}{deg} + \frac{\delta'}{deg} = 37.723 \qquad \alpha := 37.723\cdot deg = 0.658$$

Overturning components:

$$Ph := Pa\cdot\cos(\alpha 2) = 1.328\times 10^4 \ \text{plf} \qquad Mo1 := Ph\cdot(z) = 5.695\times 10^4 \ \ lb - \frac{ft}{ft} \quad \text{CCW}$$

The hydrostatic pressure (and force Fbw) behind the wall also causes an overturning moment:

$$Fbw := A5w = 1.529\times 1 \ \text{plf} \qquad Mo2 := Fbw\cdot\frac{z2}{3} = 3.567\times 10^3 \quad \text{CCW}$$

$$Mo := Mo1 + Mo2 = 6.051\times 10^4 \quad \text{plf} \quad \text{CCW}$$

Resisting Components:

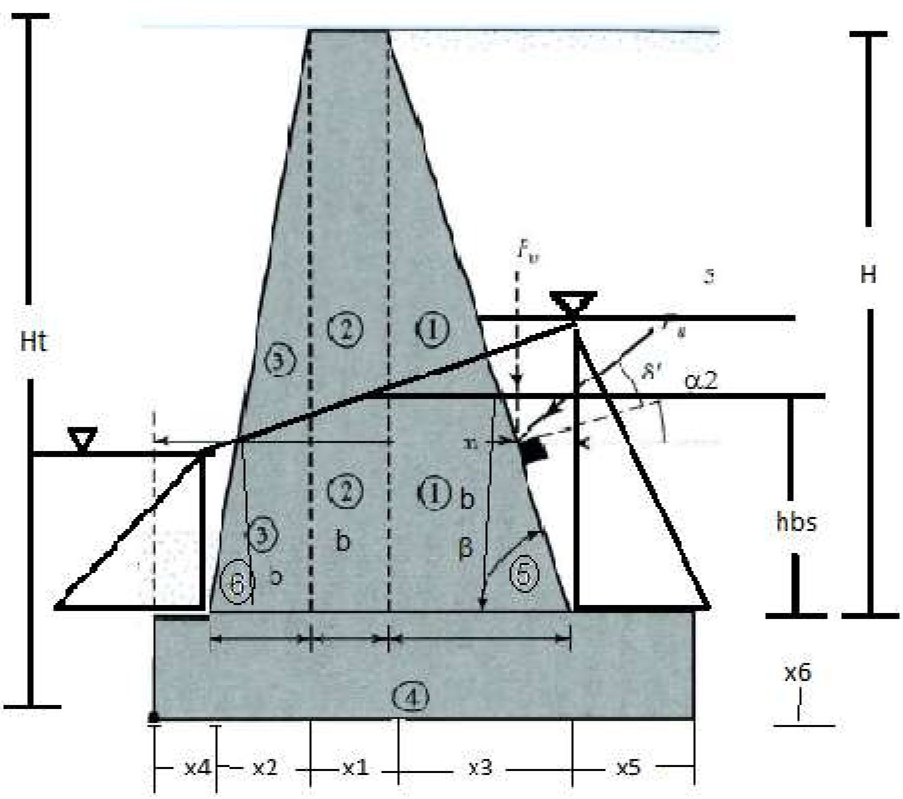

Figure 4.1 - Area distribution and location of important geometrical variables for table 4.1 below

To determine the height of concrete that is submerged:

$$hb := 6 \ \ \text{ft} \qquad hbs := 6 - x6 = 3$$

Obs for the table below:
1. The suffix b (below) refers to areas submerged (below the water)
2. The vertical component of the surcharge is taken into consideration as a resisting force (See 7 below)
3. The vertical component of the hydrostatic pressure in the front of the wall causes a resisting moment (See 6 below)
4. Pp also causes a resisting moment, however, we'll assume it equal to zero for a conservative approach
5. Although the moments below are shown as positive they are in fact clockwise (thus negative)

Effective Concrete Weight

$$\gamma c' := \gamma c - \gamma w = 87.6$$

At z=13 x for the triangle (A1 & A3)

$$xin := x3\cdot\frac{(H - hbs)}{H}$$

Effective Soil Weight

$$\gamma 1' := \gamma 1 - \gamma w = 67.6$$

Height above water table $Hw := Ht - 7 = 13$ ft

SEC	AREA (ft^2)	W/unit length (plf)	M. Arm to C (ft)	Moment lb-ft/ft
1	$A1 := xin\cdot\frac{(H-hbs)}{2} = 28.824$	$w1 := \gamma c\cdot A1 = 4.324\times10^{3}$	$B1 := x4 + x2 + x1 + .667\cdot xin = 9.746$	$M1 := w1\cdot B1 = 4.214\times10^{4}$
	$A1b := (xin)\cdot hbs = 12.353$	$w1b := \gamma c'\cdot A1b = 525.6$	$B1b := x4 + x2 + x1 + .5\cdot xin = 9.059$	$M1b := w1b\cdot B1b = 4.761\times10^{3}$
2	$A2 := (x1)\cdot(H-hbs) = 21$	$w2 := \gamma c\cdot A2 = 3.15\times10^{3}$	$B2 := x3 + x2 + .5x1 = 10.75$	$M2 := w2\cdot B2 = 4.39\times10^{3}$
	$A2b := (x1)\cdot(hbs) = 4.5$	$w2b := \gamma c'\cdot A2b = 394.2$	$B2b := B2 = 10.75$	$M2b := w2b\cdot B2b = 4.238\times10^{3}$
3	$A3 := xin\cdot\frac{(H-hbs)}{2} = 28.824$	$w3 := (\gamma c)\cdot A3 = 4.324\times10^{3}$	$B3 := x4 + x2 - .667\cdot x3 = 2.165$	$M3 := w3\cdot B3 = 9.36\times10^{3}$
	$A3b := (xin)\cdot hbs = 12.353$	$w3b := \gamma c'\cdot A3b = 1.082\times10^{3}$	$B3b := x4 + x2 - .5x3 = 3$	$M3b := w3b\cdot B3b = 3.246\times10^{3}$
4	$A4 := x6\cdot B = 37.5$	$w4 := \gamma c'\cdot A4 = 3.285\times10^{3}$	$B4 := 0.5\cdot B = 6.25$	$M4 := w4\cdot B4 = 2.053\times10^{4}$
5	$A5 := (x3 - xin)\cdot\frac{hbs}{2} = 1.324$	$w5 := \gamma c'\cdot A5 = 115.941$	$B5 := x4 + x2 + x1 + \frac{2}{3}x3 + \frac{1}{3}\cdot xin = 11.706$	$M5 := w5\cdot B5 = 1.357\times10^{3}$
6	$A6 := (x3 - xin)\cdot\frac{hbs}{2} = 1.324$	$w6 := \gamma c'\cdot A6 = 115.941$	$B6 := x4 + .333\cdot(x2 - xin) = 0.794$	$M6 := w6\cdot B6 = 92.037$
7	Hydrostatic Force Front	$Ffw := 0.5\cdot\gamma w\cdot D^{2} = 780\ plf$	$B7 := 0.333\cdot D = 1.665$	$M7 := Ffw\cdot B6 = 619.182$
		$Pv := Pa\cdot\sin(\alpha2) = 315.729$	$B8 := B - \frac{(z - x6)}{\tan(\beta)} - x5 = 11.622$	$M8 := Pv\cdot B8 = 3.669\times10^{3}$

$$\Sigma V := w1 + w1b + w2b + w2 + w3 + w3b + w4 + w5 + w6 + Pv = 1.763\times10^{4}\ \frac{lb}{ft}$$

$$\Sigma Mr := M1 + M1b + M2b + M2 + M3 + M3b + M4 + M5 + M6 + M7 + M8 = 9.44\times10^{4}\quad lb - \frac{ft}{ft}$$

$$FSoverturning := \frac{\Sigma Mr}{Mo} = 1.56$$

if(FSoverturning > 2,"OK!" ,"No Good") = "No Good"

Factor of Safety against Sliding

We must obtain Kp

$$Kp := \tan\left(45\cdot deg + \frac{\phi'1}{2}\right)^{2} = 3.255 \qquad Pp := 0.5\cdot Kp\cdot\gamma2\cdot D^{2} + 2\cdot c'2\cdot\sqrt{Kp}\cdot D = 1.009\times10^{4}$$

EQ 8.11 $$FSsliding := \frac{(\Sigma V\cdot\tan(k1\cdot\phi'2) + B\cdot k2\cdot c'2 + Pp + Ffw)}{(Pa\cdot\cos(\alpha) + Fbw)} = 1.424$$

if(FSsliding > 1.5,"okay" ,"not good") = "not good"

FACTOR OF SAFETY AGAINST BEARING CAPACITY FAILURE

$e := \frac{B}{2} - \frac{(\Sigma Mr - Mo)}{\Sigma V} = 4.328 \quad ft$ EQ 8.16, 8.17 and 8.18 $\text{if}\left(e < \frac{B}{6}, \text{"okay"}, \text{"not good"}\right) = \text{"not good"}$

$qtoe := \frac{\Sigma V}{B}\cdot\left(1 + 6\cdot\frac{e}{B}\right) = 4.341 \times 10^{3} \quad psf$ $qheel := \frac{\Sigma V}{B}\cdot\left(1 - 6\cdot\frac{e}{B}\right) = -1.52 \times 1 \, psf$ $qmax := \max(qtoe, qheel)$

Using Table 3.3 we have: $\phi'2 := 28\cdot deg$ $Nc := 25.8$ $Nq := 14.72$ $N\gamma := 16.72$ $B' := (B - 2e) = 3.844 \quad ft$

$p := \frac{D}{B'} = 1.301$ $F\gamma d := 1$ $Fqd := 1 + 2\cdot\tan(\phi'2)\cdot(1 - \sin(\phi'2))^{2}\cdot\left(\frac{D}{B'}\right) = 1.389$ $Fcd := Fqd - \frac{(1 - Fqd)}{Nc\cdot\tan(\phi'2)} = 1.418$

$\psi := \frac{180}{\pi}\,\text{atan}\left[\frac{(Pa\cdot\cos(\alpha) + Fbw)}{\Sigma V}\right] = 34.327$ $\psi := 23.119 deg$ $Fci := \left(1 - \frac{\psi}{90\cdot deg}\right)^{2} = 0.552$ $Fqi := Fci = 0.552$

$F\gamma i := \left(1 - \frac{\psi}{\phi'2}\right)^{2} = 0.03$ $q := (\gamma 2 - \gamma w)\cdot D = 263$

$qu := c'2\cdot Nc\cdot Fcd\cdot Fci + q\cdot Nq\cdot Fqd\cdot Fqi + .5\cdot\gamma 2\cdot B'\cdot N\gamma\cdot F\gamma d\cdot F\gamma i = 9.142 \times 10^{3}$

$FSbearing := \frac{qu}{qmax} = 2.106$ $\text{if}(FSbearing > 3, \text{"okay"}, \text{"not good"}) = \text{"not good"}$

PART B In the analysis of the gravity wall, it is conservative to not account for the resisting moment given the soil behind the wall. In this case, however, the design becomes unsafe and fails in overturning and bearing capacity.

PART C I would recommend the cantilever as a prefered design. I am more confident in its design calculations, I believe it is likely easier to be constructed (instead of sloping walls) which would likely reduce in construction time and cost. The simplicity also shows that it will likely require less material while maitaining satisfactory levels of safety, which also represent a reduced value in cost.

The current design already satisfies overturning and sliding, thus, to improve and achieve final factor of safety of design I would recomend to increase the value of qu and/or decrease the value of qmax.

To increase the value of qu, one possible modification is to add soil to the front of the retaining wall. By increasing the dimension D we increase the value of qu. That, however, has costs included to it.

Another option is to increase the width of the base B. By increasing B, we reduce eccentricity e, increase effective width B', which increases the final value of qu. At the same time, this increase in B, also reduces the value of qmax, probably being more effective in reaching the factor of safety sought. It is necessary to take into account that the increase in B, will also increase in costs.

Thus a cost-analysis is necessary in order to obtain which one of the methods would be more effective and desired.

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