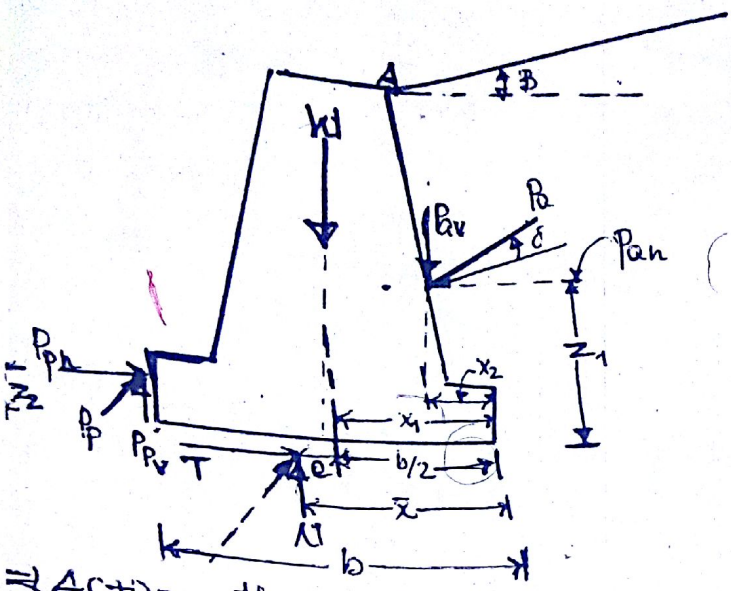
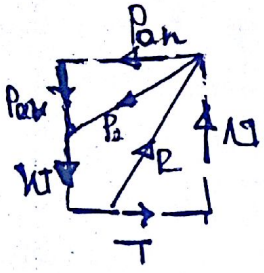
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Note Page 1

$W = W + P_{av} - P_{pv}$

$T = P_{ah} - P_{ph}$





A) Active thrust tends to overturn the wall around the toe; this is resisted by the weight of the wall & the vertical component of the active thrust (if any).
↳ Means the back surface is sloped

B) The active thrust also tends to push the wall outward; this is resisted by SLIDING OR SHEAR RESISTANCE at the base of the wall & the passive resistance (if any) of the soil lying above the toe of the wall.

∴ In gravity RW, the weight of the wall thus acts in two ways
↳ In resisting OVERTURNING at the toe.
↳ In resisting SLIDING at the base

⊛ DESIGN APPROACH FOR GRAVITY RW

i) tentative section is assumed.
ii) Active thrust & Passive resistance (if any) on the toe side are determined. (Assuming full mobilization).
iii) The resistance/stability to the tendencies of OVERTURNING, SLIDING, & BEARING PRESSURE are determined & compared with the actuating values of those tending to cause failure
↳ The margins of safety in each case are determined & checked for adequacy.
iv) If necessary, the tentative dimensions are revised & analyzed to ensure adequate safety, margin.

⊛ CRITERIA FOR A SATISFACTORY DESIGN

A) The base width must be full first ($\sigma_{max} \leq \sigma_{allow}$)
B) Tension shouldn't occur anywhere in the gravity RW.
C) The wall must be safe against SLIDING failure (Adequate)
D) The wall must be safe ...

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Note page 2

The eccentricity e of N may be computed by taking moments about the heel.

$$\bar{x} = \frac{\Sigma M}{\Sigma V}$$

$$\hookrightarrow e = \bar{x} - b/2$$

⇒ where

ΣM = Sum of moments of all the forces other than N about the heel

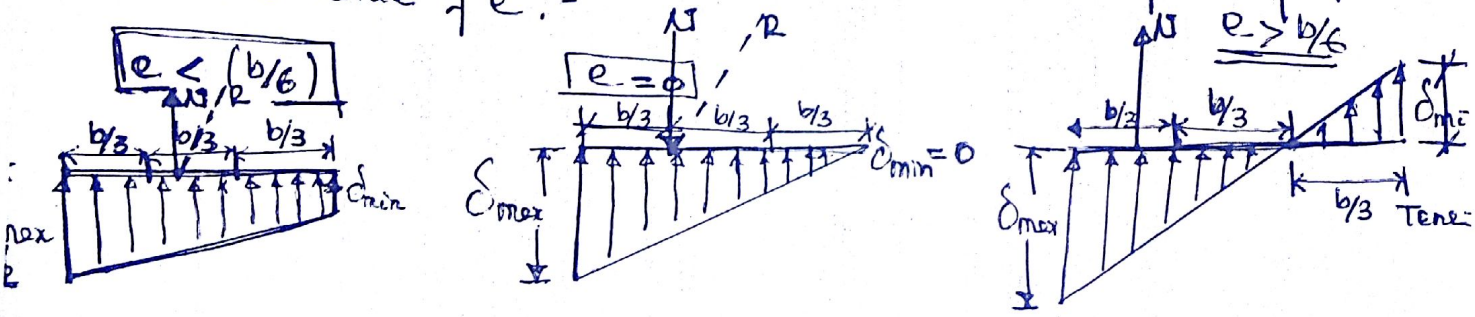
ΣV = Σ of all the vertical components of forces, other than T

⇒ The intensities of the pressure at the toe & the heel are given by,

$$\delta_{max} = \frac{N}{b}\left(1 + \frac{6e}{b}\right)$$

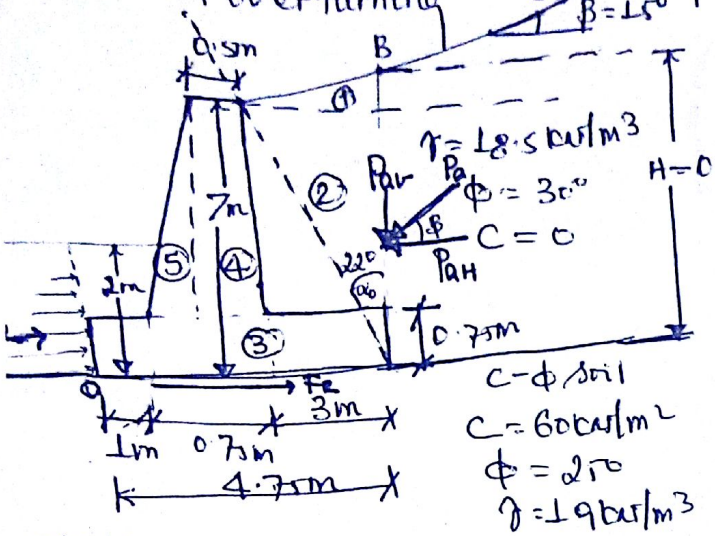
$$\delta_{min} = \frac{N}{b}\left(1 - \frac{6e}{b}\right)$$

⇒ The following three different cases arise depending upon the value of e:-



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The following Fig. shows a section of a [illegible] wall. Check the stability of the wall with respect to A| Overturning B| Sliding & c| Bearing capacity.



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SOL:

⇒ RANKINE ACTIVE PRESSURE

$\Rightarrow P_a = \frac{1}{2}\gamma K_a H^2$ — $H = 7.8m$

$= \frac{1}{2} * 18.5 * (1/3) * (7.8)^2$

$P_a = 187.6$ kN/m of wall. → $P_{aH} = P_a \cos\beta = 187.6 \cos 15° = 181.2$ kN/m

→ $P_{av} = P_a \sin\beta = 187.6 \sin 15° = 48.6$ kN/m

(A) CHECK FOR OVERTURNING

↳ The overturning & stabilizing moments may be calculated by taking moments about pt O.

$M_R = w_1 l_1 + w_2 l_2 + \dots w_5 l_5$ + Pav * 1.75m

↳ The overturning moment is

$M_O = P_{aH}(H/3)$

↳ The details of calculations are tabulated below.

SECTION No.	~~AREA~~ Area (m²)	Unit wt (kN/m³)	Weight kN/m	Leverarm (m)	Moment (kN·m)
2	$= (1/2 * 3 * 0.8)$	18.5	$= 1.2 * 18.5 = 22.20$	⇒ 3.75	= 83.25
1	18.75 =	18.5	$= 18.75 * 18.5 = 346.90$	⇒ 3.25	= 1,127.40
3	3.56 =	24.0	$= 3.56 * 24 = 85.60$	⇒ 2.38	= 203.25
4	3.13 =	24.0	$= 3.13 * 24 = 75.10$	⇒ 1.50	= 112.65
5	0.78 =	24.0	$= 0.78 * 24 = 18.70$	⇒ 1.17	= 21.88
			$\sum P_{av} = 48.6$	⇒ 4.75	= 230.85
			$\sum R_v = 596.90$		$\sum M = M_R = 1,779.3$

$M_O = (P_{aH})(H/3) = 181.2 * (7.8/3) = 471.12$ kN·m.

$\Rightarrow F_O = \frac{M_R}{M_O} = \frac{1,779.3}{471.12} = 3.78 > 1.5$ OK, Safe against overturning. (1)

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↳ the force that resists the moment is

$$F_R = C_a B + R \tan\delta + P_p$$

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$$F_R = (60 * 4.75) + 596.9 \tan 25^\circ + 470$$

$$F_R = 1,033 \text{ kN/m}$$

$$P_{ah} = 181.2 \text{ kN/m}$$

$$F_s = \frac{F_R}{P_{ah}} = \frac{1,033}{181.2} = 5.7 > 1.5 \quad \text{OK!}$$

Normally the passive earth pressure P_p is not considered in the analysis.

↳ By neglecting P_p, the factor of safety is

$$F_s = \frac{F_R - P_p}{P_{ah}} = \frac{1,033 - 470}{181.2} = 3.1 > 1.5 - \text{OK!}$$

* Check for B.C failure.

↳ the pressures at the toe & heel of the RW may be

$$q_t = \frac{R}{B}\left(1 + \frac{6e}{B}\right)$$

$$= \frac{596.9}{4.75}\left(1 + \frac{6 * 0.183}{4.75}\right)$$

$$q_t = 154.7 \text{ kN/m}^2$$

$$\rightarrow e = \frac{B}{2} - \frac{(M_R - M_O)}{R}$$

$$= \frac{4.75}{2} - \frac{(1,779.3 - 471.2)}{596.9}$$

$$e = 0.183 \text{ m}$$

$$\Rightarrow q_h = \frac{R}{B}\left(1 - \frac{6e}{B}\right) = \frac{596.9}{4.75}\left(1 - \frac{6 * 0.183}{4.75}\right)$$

$$q_h = 96.6 \text{ kN/m}^2$$

↳ the ultimate B.C, q_u here to be

$$q_t \le \frac{q_u}{F_s}$$

where $F_s = 3$

$K_p = 2.46$

$\Rightarrow C_a = \alpha C_u$

α = adhesion factor

$\Rightarrow R$ = total vertical force

$= \Sigma R_v$

$R = 596.9 \text{ kN}$

$\Rightarrow \delta$ = angle of wall friction

$\delta = \phi = 25^\circ$

$$\Rightarrow P_p = \frac{1}{2}\gamma H_p^2 K_p + 2C H_p \sqrt{K_p}$$

$$= \left(\frac{1}{2} * 19 * (2)^2 * 2.46\right) + 2 * 60 * 2\sqrt{2.46}$$

$$P_p = 470 \text{ kN/m}$$

(2)

, safe against

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A Cantilever Retaining wall retains dry sand to a depth of 5.5m as shown on the fig. Check the stability of the retaining wall against sliding and overturning.

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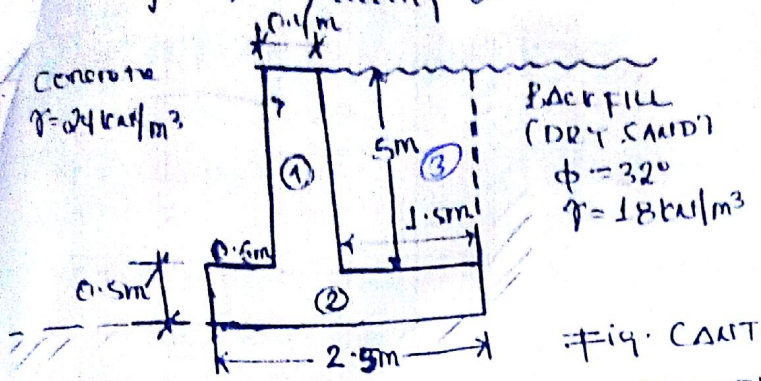


Fig. CANTILEVER RETAINING WALL.

$$K_a = \frac{1-\sin\phi}{1+\sin\phi} = \frac{1-\sin 32^\circ}{1+\sin 32^\circ}$$

$$K_a = 0.3072$$

FOUNDATION SOIL SAME AS BACKFILL.

No	DESCRIPTION	FORCE (kN) VERTICAL	FORCE (kN) HORIZ.	Δ (m) (lever arm)	MOMENTS ABOUT TOE (kN·m) CLOCKWISE	MOMENTS ABOUT TOE (kN·m) COUNTERWISE
1-	$W_1 = (5 \times 0.4 \times 24)$	48	–	0.8	$= 48 \times 0.8$ (38.4)	–
2-	$W_2 = (2.5 \times 0.5 \times 24)$	30	–	$\frac{1}{2} \times 2.5 = 1.25$	$= 1.25 \times 30 = 37.5$	–
3-	$W_3 = (5 \times 1.5 \times 18)$	135	–	$= 0.4 + 0.6 + (\frac{1}{2} \times 1.5) \Rightarrow (1.75)$	$\Rightarrow 135 \times 1.75 =$ 236.25	–
4-	$P_a = (\frac{1}{2} \times 0.3072 \times 18 \times 5.5^2)$ $P_a = 83.64$	–	83.64	$= \frac{1}{3} \times 5.5$ (1.833)	–	$\Rightarrow 83.64 \times 1.833$ (153.34).
	Sum = Σ	213	83.64		312.15	$\Rightarrow$ 153.06
		↑ $R_V = \Sigma V$	↑ $R_H = \Sigma H$		↳ $\Sigma M_{stabilizing}$	↳ $\Sigma M_{overturning}$

⇒ Let the angle of friction bln the concrete & the foundation material would be $\delta = 20^\circ$

$$M = \tan\delta = \tan 20^\circ = 0.364.$$

Sliding resistance

$$\hookrightarrow F_s = \frac{M R_V}{R_H} = \frac{0.364 \times 213}{83.64} = 0.93$$

(Since the factor of safety against sliding is less than 1.5, so it is not safe.)

resistance overturning

$$\hookrightarrow F_o = \frac{\Sigma M_R}{\Sigma M_o} = \frac{312.15}{153.06} = 2.04$$

(Since the factor of safety against overturning is greater than 1.5, it is safe.)

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A RETAINING WALL WITH A VERTICAL SMOOTH BACK WAS DESIGNATE FOR THE CONDITIONS:- THE DRY COHESIONLESS BACKFILL HEIGHT IS 6m, AN ANGLE OF SHEARING RESISTANCE IS 35°, THE DRY UNIT WEIGHT IS 17 kN/m³, AND ITS FACTOR OF SAFETY AGAINST OVERTURNING & SLIDING IS 1.5. HOWEVER, IT IS FOUND THAT THE WATER TABLE MAY RISE TO THE TOP OF THE BACKFILL. WHAT WILL BE THE FACTOR OF SAFETY AGAINST SLIDING AND OVERTURNING IN THIS CASE?

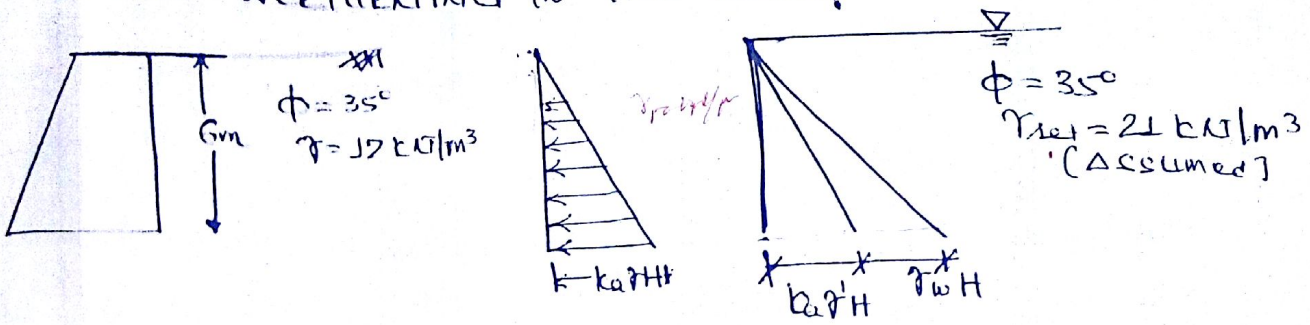


Fig. Retaining walls & pressure Distribution.

Soln:

$$k_a = \frac{1-\sin\phi}{1+\sin\phi} = \frac{1-\sin 35^\circ}{1+\sin 35^\circ} = 0.2702$$

$$P_a = \frac{1}{2} k_a \gamma_{dry} H^2 = \frac{1}{2} * (0.2702) * 17 \frac{kN}{m^3} * (6m)^2 = 82.80 kN/m$$ acting at the $\frac{1}{3}H = \frac{1}{3}(6m) = 2m$ from the base.

$$\Rightarrow F_S = \frac{M R_v}{P_H} = \frac{\tan 20^\circ * R_v}{82.80} = 1.5$$ (Sliding) [$\delta = 20^\circ$ is assumed].

$$R_v = \frac{1.5 * 82.80 kN/m}{0.364} = 341.21 kN/m$$

341.21

$$\Rightarrow F_O = \frac{\Sigma M_R}{\Sigma M_O} = \frac{\Sigma M_R}{82.80 * 2m} = 1.5$$

$$\Sigma M_R = 82.80 * 2 * 1.5 = 248.4 kN/m$$

* DETERMINATION OF FACTOR OF SAFETY WHEN THE WATER TABLE RAISED TO THE TOP OF THE BACKFILL?

$$P_a = \left[\frac{1}{2} k_a \gamma' H^2 + \frac{1}{2} \gamma_w H^2\right]$$

$$= \left(\frac{1}{2} * 0.2706 * (21 - 9.81) * 6^2\right) + \left(\frac{1}{2} * 9.81 * 6^2\right) \Rightarrow (\gamma_{sat} = 21 \frac{kN}{m^3})$$ [Assumed]

$$= 54.30 + 176.58$$

$$P_a = 231.08 kN/m$$

$\Rightarrow$ The active earth pressure is 231.08 kN/m acting at a height of 2m above the base.

$$F_S = \frac{M R_v}{231.08} = \frac{0.364 * 341.21}{231.08} = 0.54 < 1.5$$ (Not safe)

(4)

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$\Rightarrow F_s = \frac{M_{Rv}}{R_H} = \frac{0.364 * 341.21}{231.08} = 0.54 < 1.5$

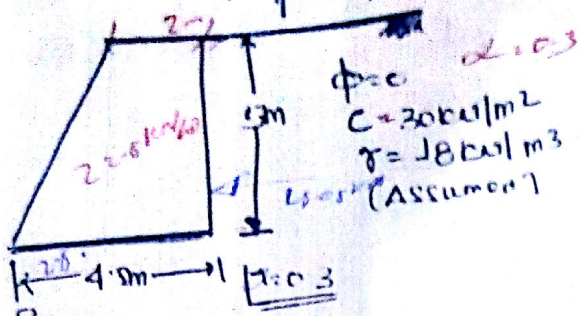
Since the factor of safety against sliding in less than 1.5, it is not safe.

$\Rightarrow F_o = \frac{\Sigma M_R}{\Sigma M_O} = \frac{248.4}{231.08 * 2} = 0.54 < 2$ NOT safe!

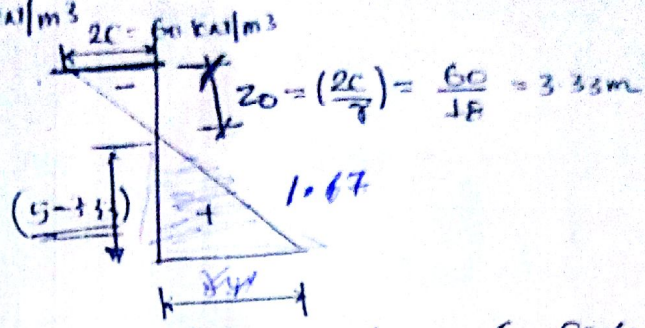
Since the factor of safety against overturning is less than 2, it is not safe.

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masonry retaining wall has a top width of 2m, bottom width of 4.5m and a height of 5m. Its face retaining a soil ($C = 30 kN/m^2$) is vertical. Given that the coefficient of friction between its concrete base and the soil below is 0.3, investigate the stability of the wall against possible sliding failure. Given that the density of masonry is 22.5 kN/m³



$\phi = 0$
$C = 30 kN/m^2$
$\gamma = 18 kN/m^3$
Loose (Assumed)



$(\gamma H - 2C) = 18 \times 5 - 60 = 90 - 60 = 30 kN/m^3$

Soln

By having $\gamma = 18 kN/m^3$, we have

$$z_0 = \left(\frac{2c}{\gamma}\right) = \frac{2 \times 30}{18} = 3.33m.$$

$$\gamma H - 2C = (18 \times 5) - 2 \times 30 = 90 - 60 = 30 kN/m^3$$

$$P_a = \frac{1}{2}(\gamma H - 2C) * (5 - 3.33)$$

$$= \frac{1}{2} \times 30 * 1.67 = 25.05 kN/m$$

For cohesive soil, the compression zone will be reduced to a depth of $\frac{2C}{\gamma}$

$\sigma_{max} = \gamma H - 2C$

Total active pressure is 25.05 kN/m & it acts a height of

$$\bar{y} = (5 - 3.33) * \frac{1}{3} = 0.56m \text{ from the base.}$$

$\Rightarrow$ Weight of wall = $W = \frac{1}{2} \times (4.5 + 2) \times 5 \times 22.5 kN/m^3$

$$W = 365.63 kN/m = R_v$$

$$F_s = \frac{\mu R_v}{P_H} = \frac{0.3 * (365.63)}{25.05} = 4.38 > 2.0 \quad \text{Ok!}$$

Since the factor of safety for sliding is greater than 2 (for cohesive backfill), it is safe.

- To check Stability

Overturning moment =

- Safety F.S = $F_S > 2.0$

Masonry Construction = > 1.5

25.05.

OK.

$2.5 \times 5 \times 22.5$

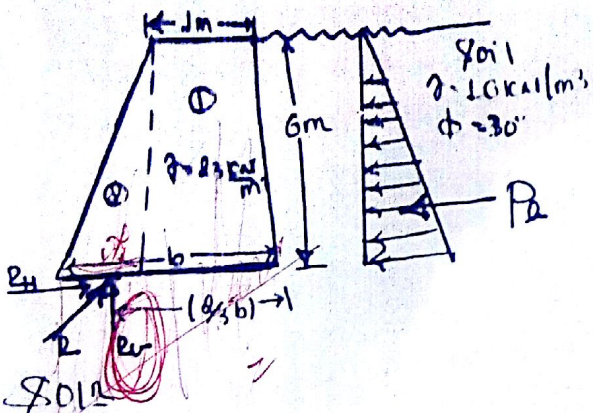
$= 104.$

$140.625 + 225$

$0.3 \times (365.625)$

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A masonry retaining wall of a trapezoidal section is 6m high & 1m wide at the top, retaining soil level with its top. Find the minimum width of the wall at base in order that tension may not be induced at the base. Masonry & soil weigh 23.6 kN/m³, respectively. The angle of repose of the soil is 30°. The back face of the wall is vertical.



Given $\phi = 30°$

$k_a = \frac{1-\sin 30}{1+\sin 30} = \frac{1}{3}$

$\sum F_x = 0 \Rightarrow P_a = R_H$

$\sum F_y = 0 \Rightarrow \sum W = R_V$

$\rightarrow W_1 = (1m) * (6m) * 23 \frac{kN}{m^3} = 138 \frac{kN}{m}$

$\rightarrow W_2 = \frac{1}{2}(b-1) \times 6 \times 23 = 69(b-1)$.

$\rightarrow P_a = 96 kN/m$

$\Rightarrow R_V = \frac{1}{2}(b+1) \times 6 \times 23 = 69(b+1)$

Soil

$\hookrightarrow P_a = \frac{1}{2} k_a \gamma H^2 = \frac{1}{2}(\frac{1}{3}) * 16 \frac{kN}{m^3} * (6m)^2$

$P_a = 96 kN/m$

$\hookrightarrow P_a$ acts horizontally at $H/3 = 6/3 = 2m$ from the base.

$R_H = P_a$ & $R_V = W$

$\hookrightarrow$ For no tension to develop, R_V must act at a distance $(2/3)b$ from the heel.

$\hookrightarrow$ Taking moments of all the forces about the heel, we have

$R_V (2b/3) = (W_1 \times \frac{1}{2}) + W_2 \left(1 + \frac{1}{3}(b-1)\right) + P_a \times (6/3)$

$= \frac{W_1}{2} + W_2 + W_2 \frac{(b-1)}{3} + P_a \times 2$

$= \frac{138}{2} + 69(b-1) + \frac{69(b-1)^2}{3} + 96 \times 2$

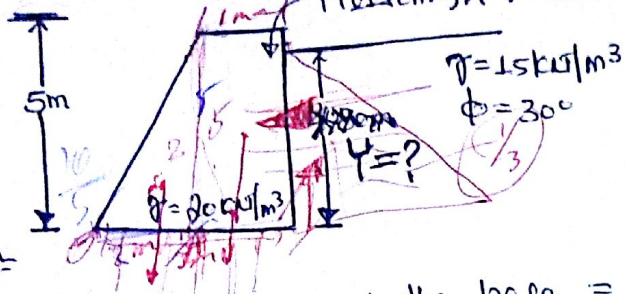
$46(b+1) = 69 + 69(b-1) + 23(b-1)^2 + 192$

$b^2 + b - 9.35 = 0$

$b = 2.60 m$

The min. base width of the wall that can be adopted is 2.60m.

A masonry retaining wall ... Its width at the top is 1m & at its base is 3m. The unit weight of masonry is 20kN/m³. Upto what height can a soil weighing 15kN/m³ be retained by this wall so that the maximum Pressure at the base will be 1.2 times the min. Pressure at the base? The angle of repose of the soil is 30°.



$\sigma_{max} = \frac{R_v}{b}\left(1 + \frac{6e}{b}\right)$

$\sigma_{min} = \frac{R_v}{b}\left(1 - \frac{6e}{b}\right)$

↳ b = 3m
↳ H = 5m

Soln:-

⟹ Max. pressure at the base = 1.2 * (min. pressure at the base)

⟹ $\sigma_{max} = 1.2\,\sigma_{min}$.

$\frac{R_v}{b}\left(1 + \frac{6e}{b}\right) = 1.2\,\frac{R_v}{b}\left(1 - \frac{6e}{b}\right)$

$b + 6e = 1.2b - 7.2e$

$0.2b = 13.2e$ ⟹ $e = \frac{0.2 \times b}{13.2} = \frac{0.2 \times 3}{13.2} = 0.045m$

$e = 0.045m$

↳ Therefore, $\bar{x} = e + b/2$

$\bar{x} = 0.045 + 3/2 = 0.045 + 1.5$

$\bar{x} = 1.545m$

↳ $k_a = \frac{1 - \sin 30}{1 + \sin 30} = \frac{1 - 1/2}{1 + 1/2} = \frac{1/2}{3/2} = \frac{1}{3}$ ⟹ $k_a = 1/3$

↳ $P_a = \frac{1}{2} k_a \gamma H^2 = \frac{1}{2} * \frac{1}{3} * 15\,\frac{kN}{m^3} * H^2$

$P_a = 2.5H^2$ (Acting at a height of H/3 from the base of the retaining wall)

⟹ Taking moments of all forces about the heel of the wall, we have

$(R_v)1.545 = \left(2.5H^2 * \frac{H}{3}\right) + (1 * 5 * 20 * 0.5) + (1/2 * 2 * 5 * 20) * 1.67$

$H = 4.8m$

388.3 kN

$P_a = \frac{1}{2} \gamma H^2 K_a$