SVL

1. $U_0 = 30$ kPa

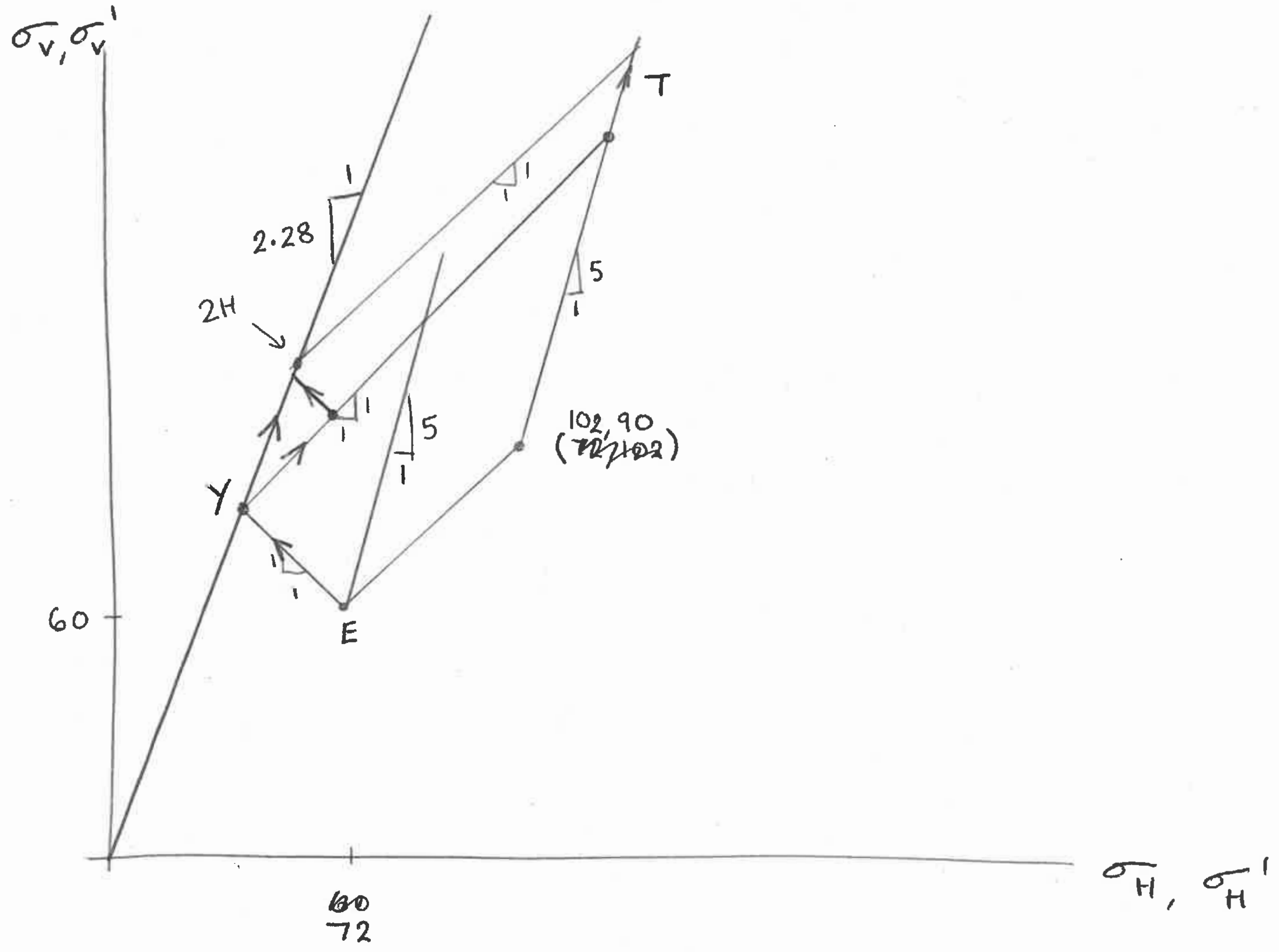
$\sigma_{VO} = 90$ kPa

$\sigma'_{VO} = 60$ kPa

$K_p = \frac{1+\sin 23}{1-\sin 23} = \underline{\underline{2.28}}$

$\sigma_{HO} = 102$ kPa.

$\sigma'_{HO} = 72$ kPa



At Y $\quad \sigma'_V = 2.28\,\sigma'_H \qquad \sigma'_V + \sigma'_H = 132$ kPa

$3.28\,\sigma'_H = 132 \qquad \sigma'_H = 40.2$ kPa $\qquad \sigma'_V = 91.7$ kPa

$$\frac{\sigma_V - 90}{5} = \sigma_H - 102$$

$$\frac{(91.7 + u) - 90}{5} = (40.2 + u) - 102$$

$$62.1 = \frac{4u}{5}$$

$u = \underline{\underline{77.7 \text{ kPa}}}$ $\qquad H = \underline{\underline{4.97\text{m}}}$

$\sigma_V = \underline{\underline{169.5 \text{ kPa}}}$

b) $\sigma_v = 169.5 + 79.5 = 249 \text{ kPa}$

$\sigma_H = \cancel{60}\ \cancel{72}\ 102 + 0.2 \times \cancel{8}159 = \cancel{91.8}\ 133.8 \text{ kPa}$

c) $2c_u \geq \cancel{157.2}\ 115 \text{ kPa}$

$c_u > \cancel{78.6}\ 57.5 \text{ kPa}$

$$\frac{249 - u}{133\ \cancel{91}.8 - u} = 2.28$$

$$249 - u = \cancel{209.3}\ 305.1 - 2.28u$$

$$1.28u = \cancel{-39.7}\ 56$$

$$u = \cancel{-31}\ 43.8 \text{ kPa}$$

~~c)~~ d) Plot height vs pore pressure. Kink in graph seen at yield.

~~d)~~ e) Half of excess p.p dissipated

$u_{ex} = \cancel{77.7}\ 43.8 - 30 = \cancel{47.7}\ 13.8 \text{ kPa}$

$\cancel{u_e}$ u @ restart $= \cancel{77.7}\ 30 + \cancel{23.85}\ 6.9$

$= \cancel{84.6}\ \cancel{53.85} \text{ kPa}\ 36.9$

$\sigma_v' = \cancel{91.7 + 23.85}\ 169.5 - 36.9 = \cancel{115.5 \text{ kPa}}\ 132.6$

$\sigma_H' = \cancel{40.2 + 23.85}\ 117.9 - 36.9 = \cancel{64}\ 81 \text{ kPa}$

$\sigma_v' + \sigma_H' = \cancel{179.5}\ 213.6 \text{ kPa}$

$\sigma_v' = 2.28\ \sigma_H'$

$3.28\ \sigma_H' = \cancel{179.5}\ 213.6$

$\sigma_H' = \cancel{54.72}\ 65.1 \text{ kPa}$

$\sigma_v' = \cancel{124.8}\ 148.5 \text{ kPa}$

$$\frac{\overset{148.5}{\cancel{124.8}} + u - \overset{169.5}{\cancel{102}}}{5} = \overset{65.1}{\cancel{54.7}} + u - \overset{117.9}{\cancel{90}}$$

$$4u = \cancel{199.3} \quad 31.8$$

$$u = \cancel{49.8}\ kPa \qquad \underline{7.95\ kPa}$$

$$\sigma_v = 174.6\ kPa$$

$$H = \underline{\underline{5.3m}}$$

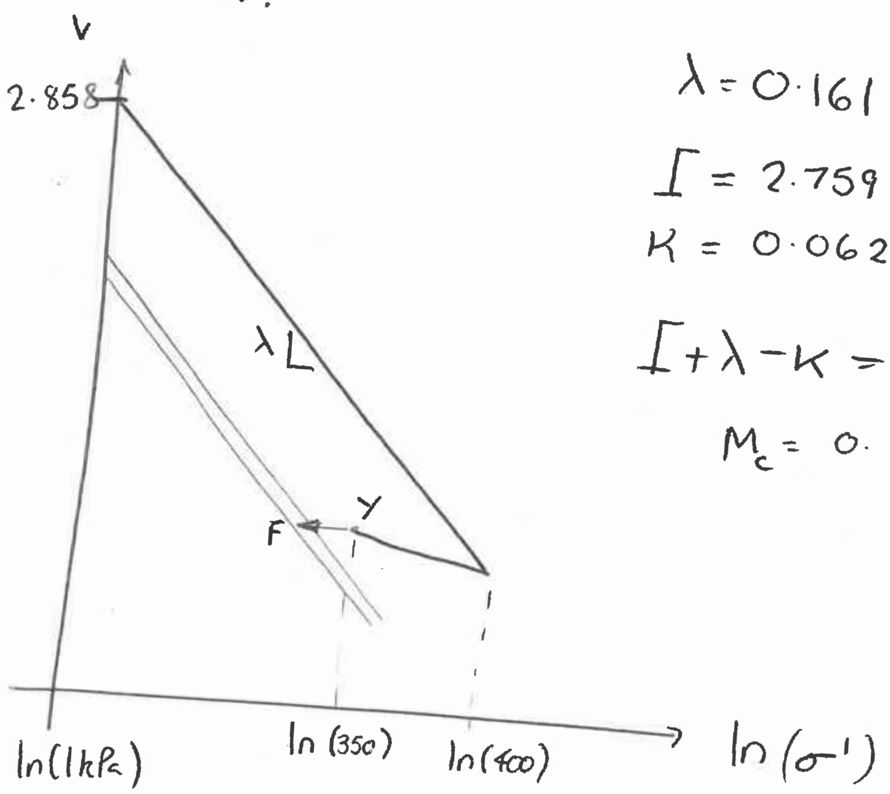
$$2C_u = 70.1$$

$$C_u = \underline{\underline{35\ kPa}}$$

3D2.

Q2)

a)



$\lambda = 0.161$

$\Gamma = 2.759$

$\kappa = 0.062$

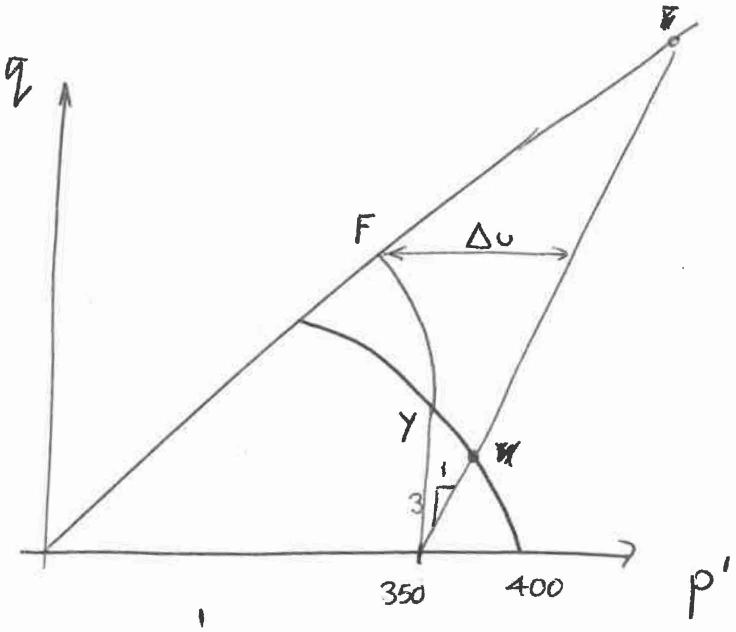
$\Gamma + \lambda - \kappa = 2.858$

$M_c = 0.89$

$$V_{400} = 2.858 - 0.161 \ln(400) = 1.893$$

$$V_{350} = V_{400} + 0.062 \ln\left(\frac{400}{350}\right) = \underline{\underline{1.902}}$$

b)



At yield $\frac{q}{p'} = M \ln \frac{p'_c}{p'}$

$p' = 350$

$p'_c = 400$

$$q_y = 0.89 \times 350 \times \ln\left(\frac{400}{350}\right) = \underline{\underline{41.6}} \text{ kPa}$$

$$u_{ex} = \frac{41.6}{3} = \underline{\underline{13.87}} \text{ kPa}$$

q_f Failure on CSL $v = 1.902$

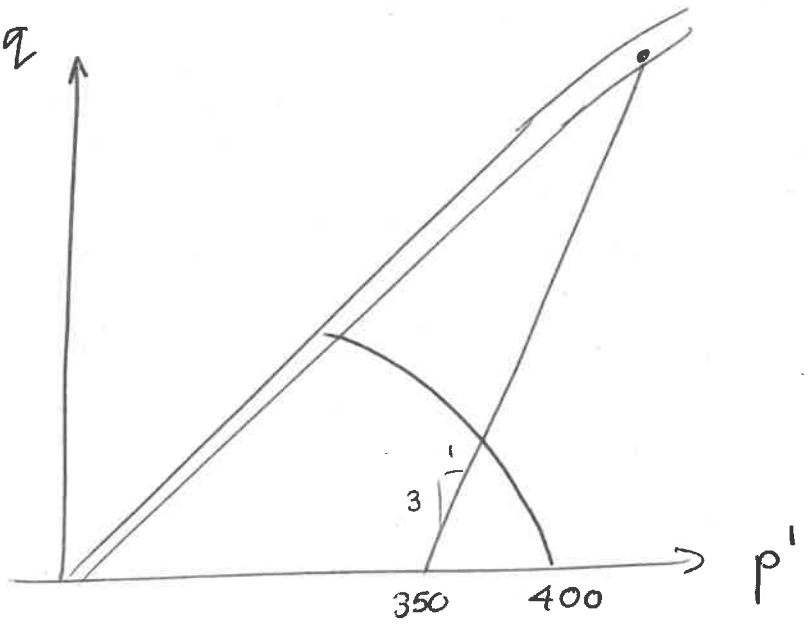
$$1.902 = 2.759 - 0.161 \ln p'$$

$p' = 205$ kPa

$q = Mp' = \underline{\underline{182.4 \text{ kPa}}}$

$u_{ex} = 350 + \frac{182.4}{3} - 205 = \underline{\underline{206 \text{ kPa}}}$

c) Drained



$$q = Mp' \ln\left(\frac{p'_c}{p'}\right) = 3(p' - 350)$$

Guess $p' = 380$ ~~RHS=~~ LHS= 17.35 RHS → $p' = 356$

LHS = 36.9 RHS $p' = 362$

LHS = 32.16 RHS $p' = 361$

LHS = 32.96 RHS $p' = 361$

$p' = 361$ kPa $q = \underline{\underline{33 \text{ kPa}}}$

On same K → $\Delta v = K \ln\left(\frac{361}{350}\right) = 0.0019$

$\epsilon_v = \underline{\underline{0.1\%}}$

contraction

At failure on CSL

$$q = Mp' = 3(p' - 350)$$

$$\cancel{(M-3)p} \quad (3 - M)p' = 1050$$

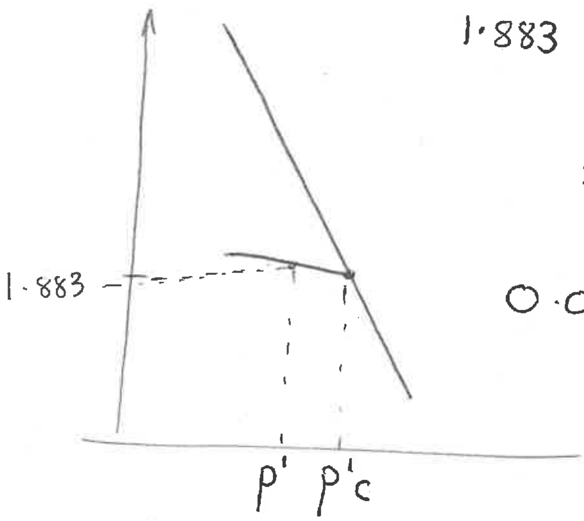
$$p' = \underline{497.6 \text{ kPa}}$$

$$q = \underline{\underline{442.1 \text{kPa}}}$$

$$V = 2.759 - 0.161 \ln(497.6) = 1.759$$

$$\epsilon_v = \frac{\Delta v}{v} = \frac{0.143}{1.902} = \underline{\underline{7.5\%}}$$

d) If $\epsilon_v = 1\%$ $\quad V = 0.99 \times 1.902 = 1.883$



$$1.883 = \Gamma + \lambda - K - \lambda \ln p'_c + K \ln \frac{p'_c}{p'}$$

$$= 2.858 - \overset{0.161}{\cancel{\lambda}} \ln p'_c + 0.062 \ln \frac{p'_c}{p'}$$

$$0.062 \ln p'_c - 0.062 \ln p' - 0.161 \ln p'_c$$
$$= -0.975$$

$$\therefore \quad 0.099 \ln p'_c + 0.062 \ln p' = 0.975$$

Yield surface $\quad q = Mp' \ln \frac{p'_c}{p'}$

Load path $\quad q = 3(p' - 350)$

$$3p' - 1050 = 0.89\, p' \ln\left(\frac{p'_c}{p'}\right)$$

$$0.099 \ln(p'_c) + 0.062 \ln p' = 0.975$$

$$\ln(p'_c) = 9.848 - 0.626 \ln(p')$$

$$3p' - 1050 = 0.89 p' \ln(p'_c) - 0.89 p' \ln(p')$$

$$3p' - 1050 = 8.765 p' - 0.557 p' \ln p' - 0.89 p' \ln p'$$

$$5.765 p' + 1050 = 1.447 p' \ln p'$$

~~Try RHS p' = 400 - LHS p' = 419.4~~

~~LHS = 453.6~~

~~LHS = 514.3~~

LHS ~~623.7~~

Try values to approximate solution.

$p' = \underline{\underline{374}}$ kPa

$\Rightarrow q = 72$ kPa

$p'_c = 464$ kPa

~~Try RHS p' = 375~~

$\boxed{3D2}$

Problem 3

Part (a)

1. Sliding along base
2. Overturning about toe
3. Exceeding bearing capacity (sinking)
4. Sliding along blocks (above base)
5. Overturning within blocks (above toe)

Part (b)

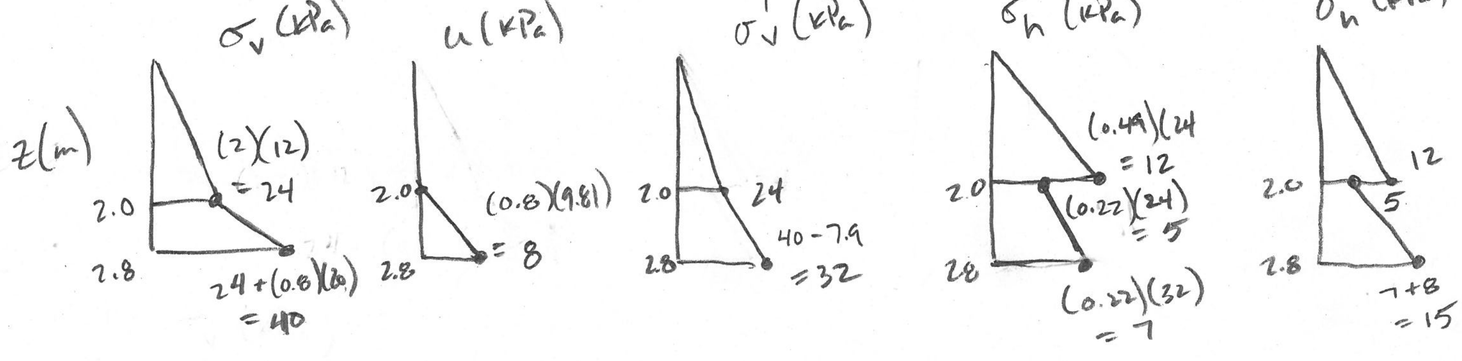
$$K_a = \frac{1-\sin\phi'}{1+\sin\phi'} \quad , \quad K_p = \frac{1}{K_a}$$

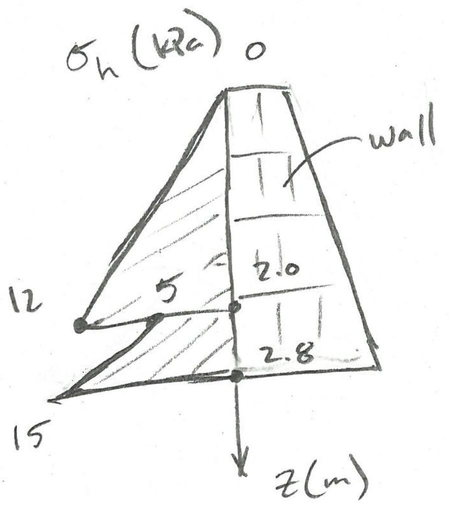
clay : $K_a = \dfrac{1-\sin 20^\circ}{1+\sin 20^\circ} = 0.490$

$$K_p = \frac{1}{0.490} = 2.04$$

silty sand : $K_a = 0.22$, $K_p = 4.60$

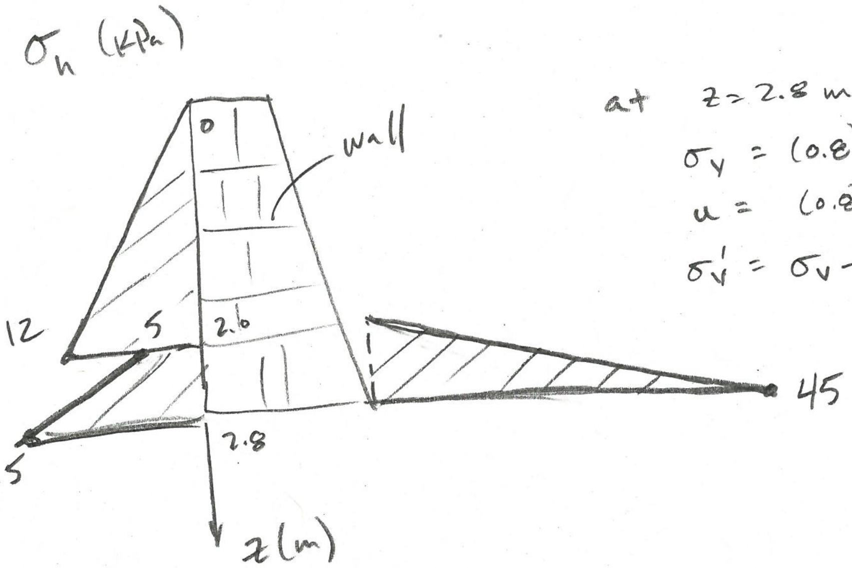
Active stress state behind wall :





Part (c)

Neglect influence of wall inclination
Assume failure along base - not given friction angle of blocks



at $z = 2.8$ m on front:

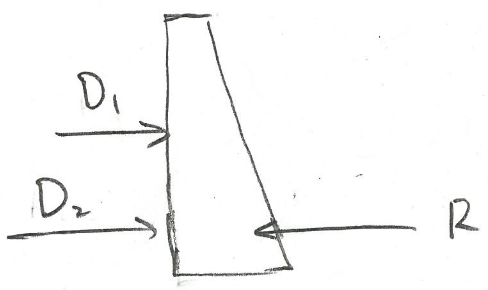
$\sigma_v = (0.8)(20) = 16$

$u = (0.8)(9.81) = 8$

$\sigma_v' = \sigma_v - u = 8$, $\sigma_h' = K_p \sigma_v' = (4.6)(8) = 37.5$

$\sigma_h = \sigma_h' + u = 38 + 37.5 = 45$

$$SF = \frac{F_{resisting}}{F_{driving}}$$



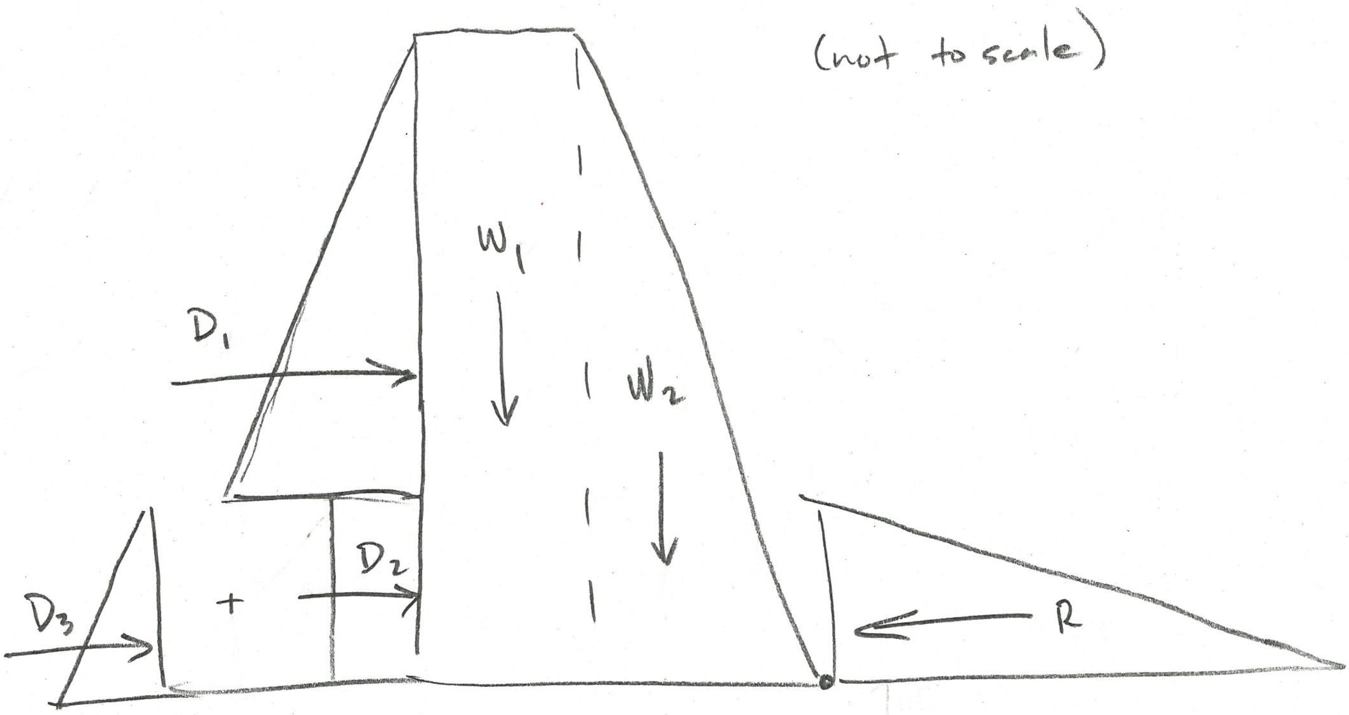
$$= \frac{R}{D_1 + D_2}$$

$$= \frac{\frac{1}{2}(0.8\ m)(45.3\ kPa)}{\frac{1}{2}(2.0\ m)(11.8\ kPa) + \frac{1}{2}(0.8\ m)(5.22\ kPa + 14.8\ kPa)} = \cancel{0.92}\ 0.91$$

$SF < 1 \Rightarrow$ FAIL

Part (d)

1. Assume rotation about toe
2. Ignore inclination again to evalute pressure (passive) on front
3. Assume wall drains freely
4. Neglect buoyancy of submerged part of wall (small volume)



TOE

	moment arm (m)	force (kN)	moment (kN·m)
W_1	0.4	$(18)(0.4)(2.8) = \cancel{7.2}$ 20.1	$\cancel{2.9}$ 8.1
W_2	$(2/3)(0.2) = 0.133$	$\frac{1}{2}(18)(0.2)(2.8) = \cancel{1.8}$ 5.0	$\cancel{0.2}$ 0.67
D_1	$0.8 + \frac{1}{3}(2) = 1.47$	$\frac{1}{2}(2)(11.8) = 11.8$	−17
D_2	$\frac{1}{2}(0.8) = 0.4$	$(0.8)(5.22) = 4.2$	−1.7
D_3	$\frac{1}{3}(0.8) = 0.27$	$\frac{1}{2}(0.8)(15-5) = 3.9$	−1.0
R	$\frac{1}{3}(0.8) = 0.27$	$\frac{1}{2}(0.8)(45) = 18$	4.8

$$M_{resist} = \overset{8.1}{\cancel{2.9}} + \overset{0.67}{\cancel{0.2}} + 4.8 = \overset{13.6}{\cancel{8}} \text{ kN·m}$$

$$M_{driving} = 17 + 1.7 + 1 = 20 \text{ kN·m}$$

$$SF = \frac{M_{resist}}{M_{driving}} = \frac{\overset{13.6}{\cancel{8}} \text{ kN·m}}{20 \text{ kN·m}} = \overset{0.68}{\cancel{0.4}}$$

$$SF = \overset{0.68}{\cancel{0.4}} < 1 \Rightarrow \text{FAIL}$$

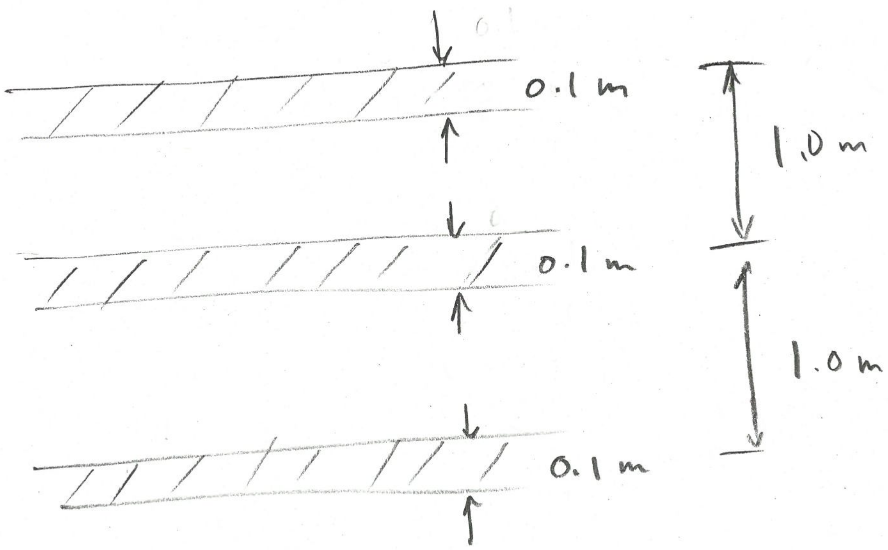
Part (e)

Overturning critical ; need $SF = 1$

$$\Rightarrow SF = 1 = \frac{(\overset{13.6}{\cancel{8}} \text{ kN·m}) + (1.8 \text{ m}) F_{anchor}}{(20 \text{ kN·m})}$$

$$F_{anchor} = \frac{20 - \overset{13.6}{\cancel{8}}}{1.8} = \overset{3.5}{\cancel{6.7}} \text{ kN/m}$$

From above :



$F^{*}_{anchor} = F_{anchor}\,(1\text{ m})$ ... total force along 1 m width

$F^{*}_{anchor} = 2\,\tau_f\, b\, L^{*}$

$\tau_f = \sigma_v \tan\delta$ ... shear stress at failure

$b = 0.1\text{ m}$ ... strip width

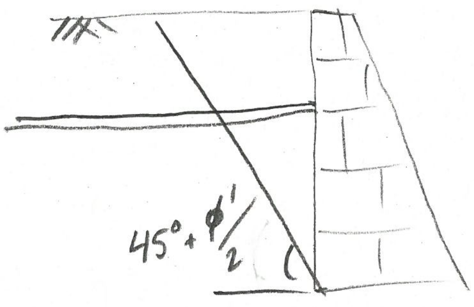
L^{*} ... required length

$$\tau_f = \underbrace{(12\text{ kN/m}^3)(1\text{ m})}_{\sigma_v} \tan 20^\circ = 4.4\text{ kPa}$$

$$L^{*} = \frac{F_{anchor}\,(1\text{ m})}{2\,\tau_f\, b} = \frac{(\cancel{6.1}\ 3.5\text{ kN/m})(1\text{ m})}{2\,(4.4\text{ kN/m}^2)(0.1\text{ m})}$$

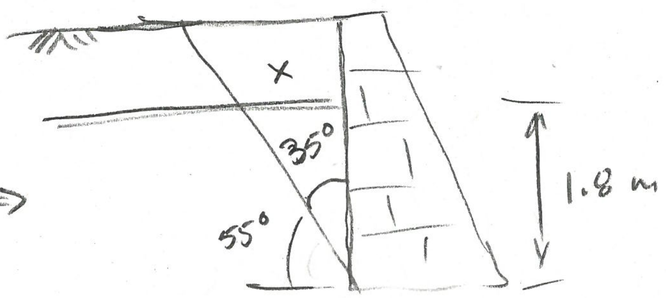
$$= \cancel{7.6}\ 4.1\text{ m}$$

Need to consider active zone:



assume $\phi' = 20^\circ$

$\Rightarrow$



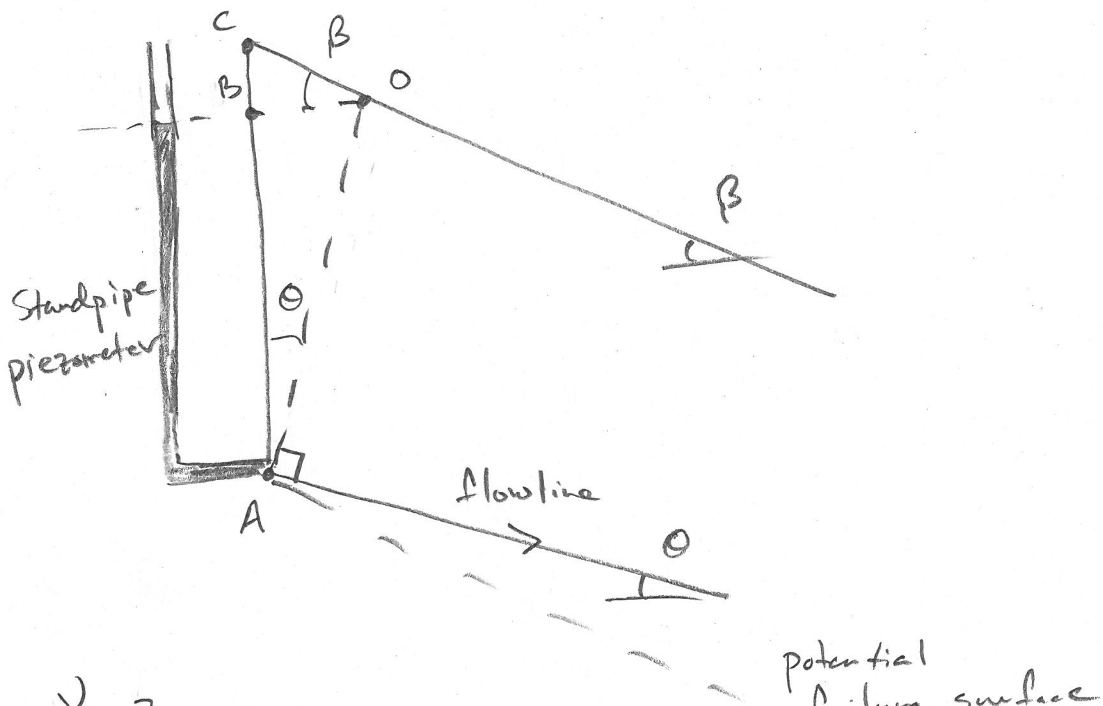
$x = (1.8\text{ m}) \tan 35^\circ$
$= 1.3\text{ m}$

$\Rightarrow L = L^{*} + x = \cancel{9}\ 5.3\text{ m}$

3D2

Problem 4

Part (a)



$u_A = \gamma_w z_{AB}$

z_{AB} ... height (head) measured from A to B

From triangle OAB : $\overline{OB} = \overline{AB} \tan \theta$

From triangle OBC : $\overline{BC} = \overline{OB} \tan \beta$

$\overline{BC} = \overline{AB} \tan\theta \tan\beta$

$AB + BC = z$ ... depth to potential failure surface

$z - \overline{AB} = \overline{AB} \tan\theta \tan\beta$

Solve : $\overline{AB} = \dfrac{z}{1 + \tan\theta \tan\beta}$

$\overline{AB} = z_{AB} = \dfrac{u_A}{\gamma_w} \Rightarrow u = \dfrac{\gamma_w z}{1 + \tan\theta \tan\beta}$

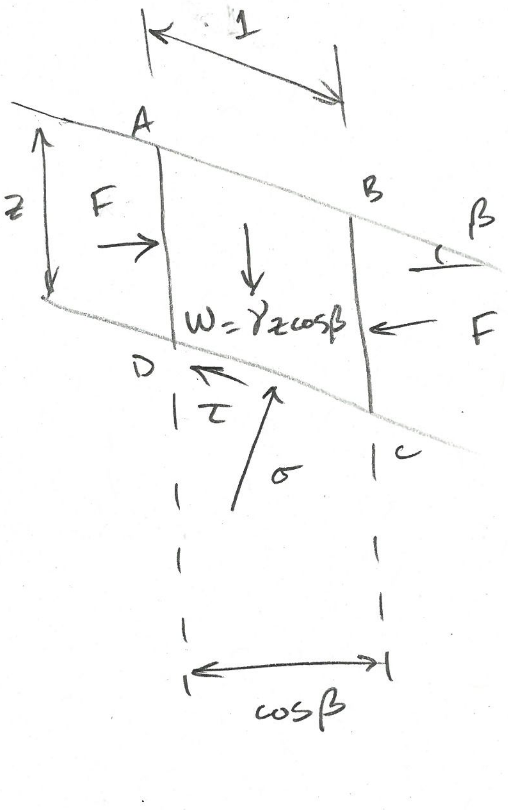
Drop "A" & "AB" since points could be anywhere

$$= \frac{\gamma_w z \cos\theta \cos\beta}{\cos\theta \cos\beta + \sin\theta \sin\beta}$$

$$= \frac{\gamma_w z \cos\theta \cos\beta}{\cos(\theta - \beta)}$$

$$= \frac{\gamma_w z \cos\theta \cos\beta}{\cos(\beta - \theta)}$$

Part (b)



$\tau = W \sin\beta = \gamma_z \cos\beta \sin\beta$

$\sigma = W \cos\beta = \gamma_z \cos^2\beta$

$\sigma' = \sigma - u$

$$\frac{\tau}{\sigma'} = \tan\phi' = \frac{\gamma_z \cos\beta \sin\beta}{\gamma_z \cos^2\beta - u} = \frac{\tan\beta}{\left(1 - \dfrac{u}{\gamma_z \cos^2\beta}\right)} \quad (\#)$$

Substitute using result from (a)

$$\frac{u}{\gamma z \cos^2\beta} = \frac{\gamma_w}{\gamma} \frac{\sec^2\beta}{1 + \tan\theta \tan\beta}$$

$$\sec^2\beta = 1 + \tan^2\beta$$

$$\frac{u}{\gamma z \cos^2\beta} = \frac{\gamma_w}{\gamma} \frac{1 + \tan^2\beta}{1 + \tan\theta \tan\beta}$$

Substitute into (#) :

$$\tan\phi' = \frac{\tan\beta}{\left[1 - \frac{\gamma_w}{\gamma}\frac{(1+\tan^2\beta)}{(1+\tan\theta\tan\beta)}\right]}$$

Part (c)

$\theta = 90°$: $\tan\theta \to \infty$ $\Rightarrow$ $\tan\phi' = \tan\beta$

$\theta = 0$: $\tan\phi' = \dfrac{\tan\beta}{\left[1 - \frac{\gamma_w}{\gamma}(1+\tan^2\beta)\right]}$

$\theta = 90°$ is case of freely draining slope, for which $\beta = \phi'$ at failure

$\Theta = 0$ is the case of horizontal flow, which may occur when downward flow is impeded.

$$\tan\phi' = \underbrace{\left[\frac{1}{1 - \frac{\gamma_w}{\gamma}(1 + \tan^2\beta)} \right]}_{\text{always greater than } 1} \tan\beta$$

$\Rightarrow$ slope destabilsed compared with $\Theta = 90°$

Part (d)

Assume $\Theta = 0$ since the lower boundary is impermeable (flow roughly horizontal).

This will give safer estimate.

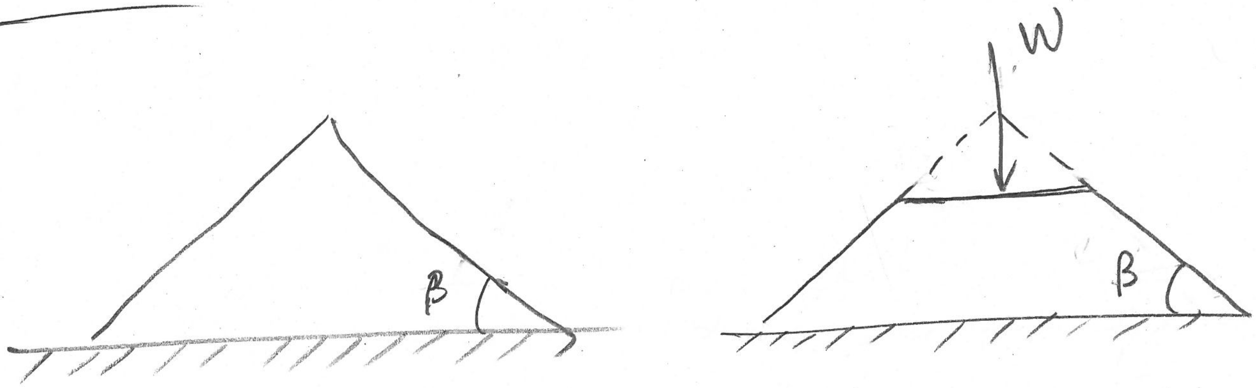
$$\tan 35° = \frac{\tan\beta}{1 - \frac{9.81}{18}(1 - \tan^2\beta)}$$

Solve : $\beta = 16°$

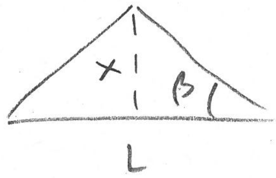
Flow is in fact complex, and locally θ could take on a range of values $\rightarrow$ which should be checked.

To be more rigorous, need to compute distribution of pore pressures (e.g., using <u>flow net</u>) and consider <u>finite</u> slope failure (e.g., using limit equilibrium or FE solver).

<u>Part (e)</u>



<u>Stable</u> $\Longrightarrow$ <u>also stable</u>



$$x = \frac{L}{2}\tan\beta$$

$$\Rightarrow \quad W = \frac{1}{2} L \left(\frac{L}{2}\tan\beta\right)\gamma$$

$$= \frac{1}{4}\gamma L^2 \tan\beta$$

Some distribution of surcharge that produces

$W = \frac{1}{4}\gamma L^2 \tan\beta$ will be stable, but

a uniform distribution is not necessarily

stable.

Hence, $q = \frac{W}{L} = \frac{1}{4}\gamma L \tan\beta$ will

provide a dubious (potentially unsafe)

estimate of the maximum surcharge that

can be applied.

A safe estimate of q could be assessed

using limit equilibrium, limit theorems, or

finite element calculations.