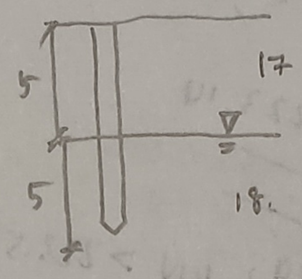
CV3013 PYP 2019/20

1) a) The purpose of site investigation in foundation engineering is to obtain sufficient information about the ground so as to enable safe and economic foundation design and avoid difficulties during construction.

b) There are four types of mechanisms of disturbance, the first one being a change in stresses as soil is being excavated, the vertical stress is reduce to zero. Besides that is mechanical disturbance due to the sampling techniques which may involve percussion acting in advancing the borehole. Also, changes in chemical content by contamination of drilling fluid is also a form of disturbance. Lastly, it is the changes of migration of moisture content / void ratio. This happens when water evaporates from the sample.

c) i) $q_t = 1.2 MPa$ $Q_t = \frac{q_t - \sigma_{vo}}{\sigma'_{vo}}$ $B_q = \frac{u_2 - u_o}{q_t - \sigma_{vo}}$

$u_2 = 460 kPa$



$\sigma_{vo} = 17(5) + 18(5) = 175 kPa$ ✓

$\sigma'_{vo} = 17(5) + (18-10)(5) = 125 kPa$

$u_o = 10 \times 5 = 50 kPa$ ✓

$Q_t = \frac{1.2 \times 10^6 - 175 \times 10^3}{125 \times 10^3} = 8.2$ ✓

$B_q = \frac{u_2 - u_o}{q_t - \sigma_{vo}} = \frac{400 - 50}{1.2 \times 10^3 - 175} = 0.4$ ✓

From the graph, the soil is classified as zone 3 where the soil behaviour is clays - clay to silty clay. //

ii) $\phi'_{max} \approx 29.5 (B_q)^{0.121} [0.256 + 0.366 B_q + \log (\frac{q_t - \sigma_{vo}}{\sigma'_{vo}})]$

$= 29.5 (0.4)^{0.121} [0.256 + 0.366(0.4) + \log (\frac{1.2 \times 10^3 - 175}{125})]$

$= 34.75° //$ ✓

iii) $N_{kt} = 14$

$C_u = \frac{q_t - \sigma_{vo}}{N_{kt}}$

$= \frac{1.2 \times 10^6 - 175 \times 10^3}{14}$

$= 73.21 kPa //$ ✓

iv) $k_o = 0.1 (\frac{q_t - \sigma_{vo}}{\sigma'_{vo}})$

$= 0.1 (\frac{1.2 \times 10^6 - 175 \times 10^3}{125 \times 10^3})$

$= 0.82 //$ ✓

2) a) characteristics value of a soil parameter refers to the derived values and results from laboratory and field tests, complemented by well established experience. The characteristic value serve as a cautious estimate of the soil parameter. It is also serve as a representative value ~~of average~~ of all the values of the measured soil parameter obtained and characteristic values are usually moderately conservative.

b) DA1C1

→ $\gamma_{\phi'} = 1.0$ $\gamma_d = \gamma_k / 1.0 = 17\ kN/m^3$ $Q = 110 \times 1.35 + 50 \times 1.5$

$\gamma_{cu} = 1.0$ $C_{uid} = C_{uik} / \gamma_{cu} = 35\ kPa$ $= 223.5\ kN.$

undrained

$q_D = (\pi+2) C_u s_c + q$

$s_c = 1 + 0.2\left(\frac{B}{L}\right) = 1 + 0.2\left(\frac{2}{2}\right)(17-9.81)(1)$

$= 1.2$ $\sigma q'$

$q_D = (\pi+2)(35)(1.2) + (17 \times 1)$ 223.14

$= \frac{232.95}{223.14}\ kPa.$ $R = q_D \times A = \frac{232.95}{223.14} \times 2 \times 2$

$= \frac{934.8}{892}\ kN.$ $> 223.5\ kN.$

DA1C2

→ $\gamma_\gamma = 1.0$ $\gamma_d = \gamma_k / 1.0 = 17\ kN/m^3$ $Q = 110 \times 1.0 + 50 \times 1.3$

$\gamma_{cu} = 1.4$ $C_{uid} = 35/1.4 = 25\ kPa$ $= 175\ kN$

$q_D = (\pi+2) C_u s_c + q$ $s_c = 1.2$

$q_D = (\pi+2)(25)(1.2) + (17 \times 1)$ $\sigma q'$ → $(17-9.81) \times 1$

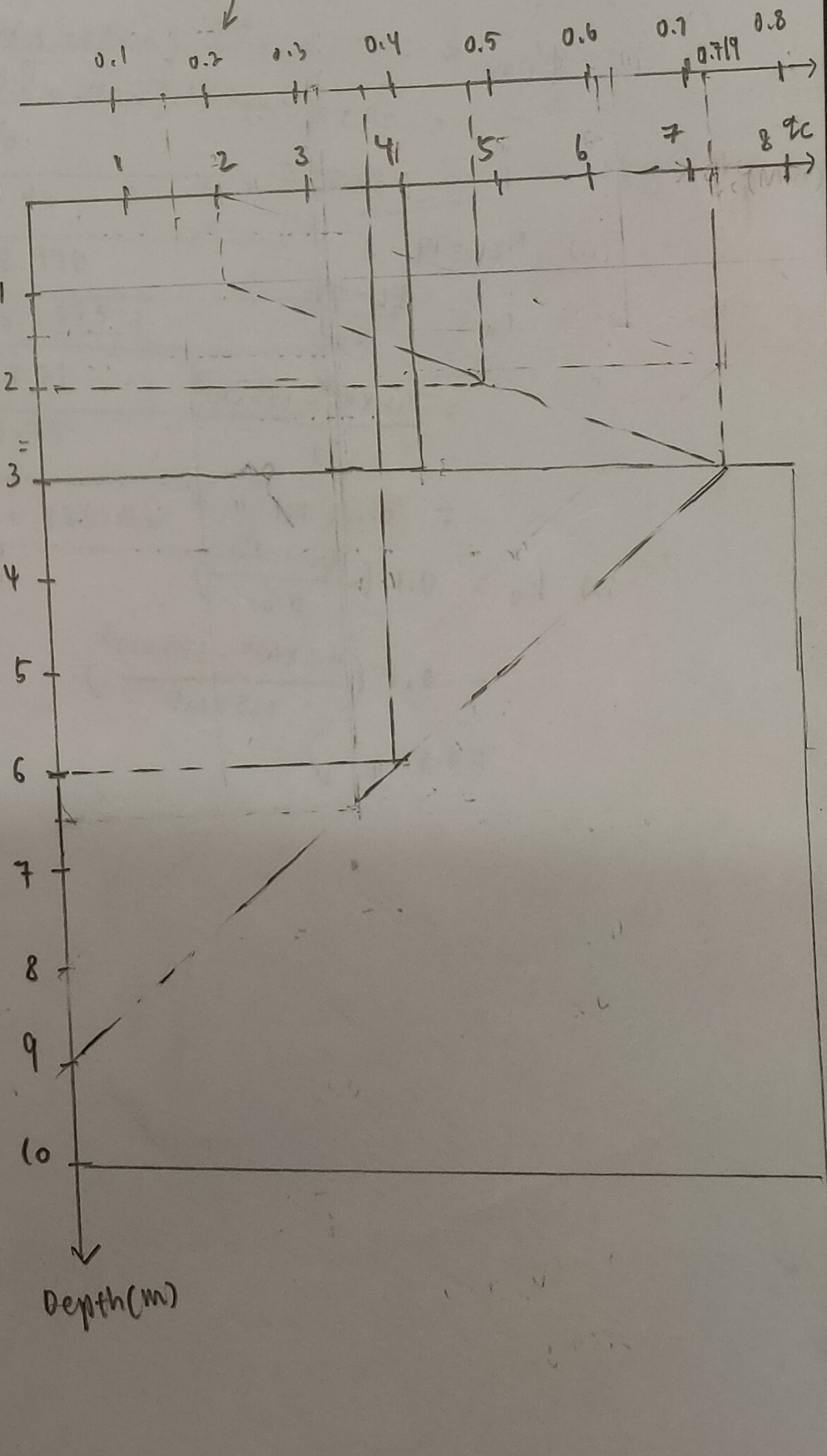
161.44

$= \frac{171.25}{161.44}\ kPa.$

$R = q_D \times A = \frac{171.25}{161.44} \times 2 \times 2$

$= \frac{685}{645.75}\ kN > 175\ kN$

for strip footing start at 0.2



c) WT at ground level, footing depth @ 1m ★

$q_n = 75\ kPa$

30 years after construction + immediately

Z_{fo} @ 4B

Z_{fp} @ B

① $L/B = \frac{25}{2} = 12.5 > 10$ (strip footing)

$Z_{fo} = 1 + 4B = 1 + 4(2) = 9$

$\sigma_p' = (15-9.81)(1+2) = 15.57\ kPa$

$Z_{fp} = 1 + B = 1 + 2 = 3$

$I_{Zp} = 0.5 + 0.1\left(\frac{q_n}{\sigma'_p}\right)^{0.5}$

$= 0.5 + 0.1\left(\frac{75}{15.57}\right)^{0.5}$

$= 0.719$ //

Use $E = 3.5 q_c$ ←

Layer	ΔZ (m)	q_c (MPa)	E (MPa)	I_z	$I_z \Delta z / E$
1	2	4	14	0.48	0.0686
2	6	8	28	0.336	0.0771

terminate at Z_{fo}

$\Sigma I_z \Delta z / E = 0.1457$

$S = C_1 C_2 q_n \Sigma_1 \frac{I_z}{E} \Delta z$

$\sigma q' = (15-9.81)(1) = 5.19$ ← depth of footing

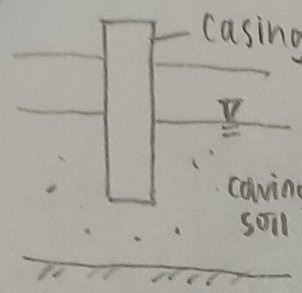
$C_1 = 1 - 0.5 \frac{\sigma'_q}{q_n} = 1 - 0.5 \frac{5.19}{75} = 0.9654$

$C_2 = 1 + 0.2 \log \frac{t}{0.1} = 1 + 0.2 \log \frac{30}{0.1} = 1.5$ (30 yrs)

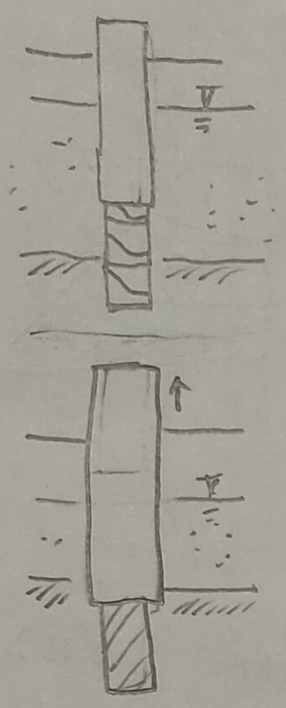
$= 1.0$ (immediate)

30 → $S = 0.9654(1.5)(75)(0.1457) = 15.77\ mm$ // ✓

imm → $S = 0.9654(1)(75)(0.1457) = 10.55\ mm$ // ✓



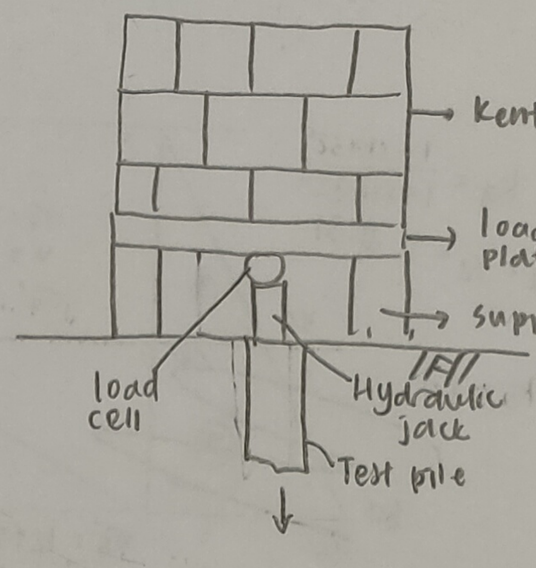
Install a casing into the soil using a vibrator driver



Drill through and ahead of the casing

Place the reinforcing steel and concrete, and remove the casing.

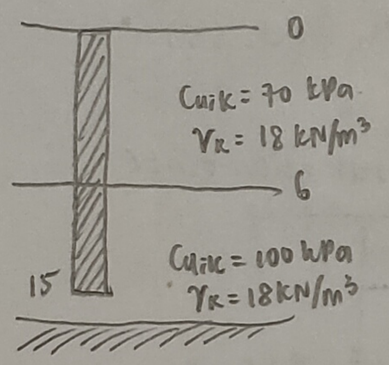
c) Kentledge pile load test is a type of static load test and it is most similar to the loading regime in the completed foundation.



The weight added must be at least equal to the maximum load, though it is normally increased by 20% to account for variability in the predicted capacity

The use of a hydraulic jack reacting against dead weight to develop the test load in a static load test.

b)



DA1b A2 + M1 + R4

$\gamma_\gamma = 1.0$ $\quad \gamma_d = \frac{18}{1.0} = 18\ kN/m^3$

$\gamma_{cu} = 1.0$ $\quad Cuiid = \frac{70}{1.0} = 70\ kPa$

$Cuzid = \frac{100}{1.0} = 100\ kPa$

$$Q_{bu} = \frac{A_p(S_c N_c Cuzid + \gamma_d L_p)}{\xi_1}$$

appendix $d/B = 9/1 = 9$

↳ $N_c = (2+\pi)\left(1 + 0.27\sqrt{\frac{d}{B}}\right) = 9.31$

$\therefore S_c N_c = 9.0$

$$Q_{buik} = \frac{\frac{\pi(1.0)^2}{4}[9.0(100.03) + 18(15)]}{1.55(1.0)}$$

$= 592.85\ kN$ ← bored concrete pile

For non-displacement piles, $\alpha = 1.16 - \left(\frac{Cu}{185}\right)$ for $30 \leq Cu \leq 150$

For 1st layer (0-6m), $Cu = 50\ kPa$, $\alpha = 1.16 - \left(\frac{70}{185}\right) = 0.782$

2nd layer (6-15m), $Cu = 71.43\ kPa$, $\alpha = 1.16\left(\frac{100}{185}\right) = 0.619$

$$Q_{suik} = \frac{\pi D_o L_p \alpha Cu_{id}}{\xi_1}$$

$$= \frac{\pi(1.0)(6)(0.782)(70) + \pi(1.0)(9)(0.619)(100)}{1.55}$$

$= 2782.$

$= \frac{2782.}{1.55}$

$= 1794.84$

$$R_d = \frac{Q_{buik} + Q_{suik}}{2} = \frac{2387.69}{2} = 1193.85\ kN$$

d) $R_{avg} = \frac{950 + 1020 + 990 + 1060}{4}$

$= 1005\ kN$

$R_{min} = 950\ kN$

$$R_k = \min\left[\frac{R_{avg}}{\xi_1}, \frac{R_{min}}{\xi_2}\right]$$

For $n = 4$,

$\xi_1 = 1.38$, $\xi_2 = 1.15$

$$R_k = \min\left[\frac{1005}{1.38}, \frac{956}{1.15}\right]$$

$= [728.26, 826.09]$

$= 728.26\ kN$ //

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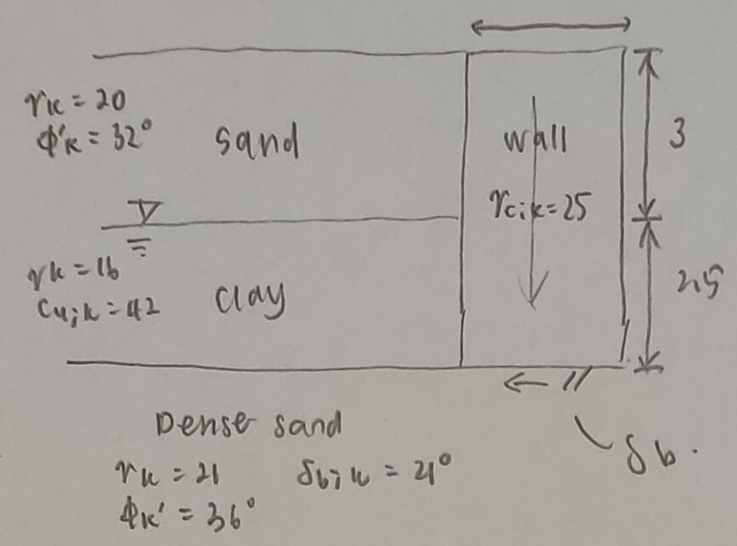
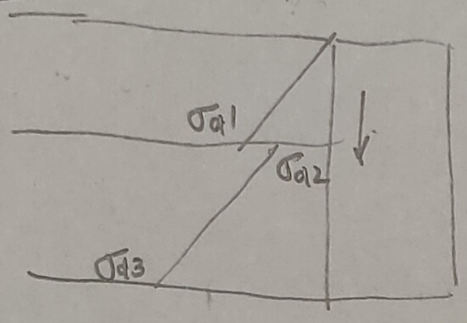
4) a)



Rankine ✓

i) DA1b - GEO ✓



Sand Fill

Material factor, $\gamma_{\phi'} = 1.25$

design $\phi'_d = \tan^{-1}[\tan \phi'_k / \gamma_{\phi'}]$
$= \tan^{-1}[\tan 32° / 1.25]$
$= 26.56°$

$K_a = K_{ah} = \dfrac{1 - \sin\phi'_d}{1 + \sin\phi'_d} = 0.382$

Clay

$\gamma_{cu} = 1.4$
design $c_{u;d} = 42/1.4$
$= 30$ kPa

Dense sand

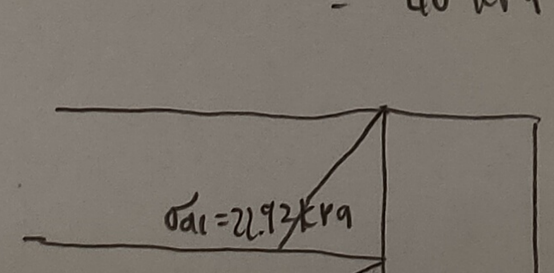
$\gamma_{\phi'} = 1.25$
$\phi'_d = \tan^{-1}[\tan(36°)/1.25]$
$= 30.17°$

$K_a = K_{ah} = \dfrac{1 - \sin\phi'}{1 + \sin\phi'} = 0.331$

$\sigma_{a1} = K_{ah}\gamma H = 0.382 \times 20 \times 3$
$= 22.92$ kPa ✓

$\sigma_{a2} = \cancel{K_a}\ \sigma_v - 2c_u = 3(20) - 2(30)$
$= 0$ ✓

$\sigma_{a3} = \sigma_v - 2c_u = [3(20) + 2.5 \times 16] - 2(30)$
$= 40$ kPa ✓



ii) ODF = 1.2 (Sliding Failure) ✓

Destabilising force

$P_{ah;1} = \cancel{K_{ah}\gamma H \gamma_{G,dst}}$ $0.5(22.92)(3)\underline{(1.0)}$ ($\gamma_{G,dst}$)
$= 34.38$kN ✓

$P_{ah;2} = 0.5(40)(2.5)\underline{(1.0)}$ ($\gamma_{G,dst}$)
$= 50$kN ✓

Total $= 84.38$ kN. ✓

Stabilising

self weight $= 5.5 \times B \times 25$
$= 137.5B$ kN/m.

* Rankine ⇒ no P_{av}

$P_{av;1d} = 0.5(22.92)(3)\tan 26.56$ (1.0) ($\tan^{-1}(\tan 21/1.25) = 17.07$)
$= 10.56$

$P_{av;2d} = 0.5(40)(2.5)\tan 17.07$ (1.0)
$= 15.35$

$R_{v;d} = 137.5B$ kN/m. $R_{v;d} = 25.91 + 137.5B$.

$R_{h;d} = 137.5B \tan\delta_{b;d} + c_a B'$ / $\gamma_{R;h}$
$= 42.25B$

$R_{h;d} = F_{v;d}\tan\delta'_{base} / \gamma_{R;h}$
$= (25.91 + 137.5)\tan 17.07$

Wall base friction $\delta_{b;d}$

$\delta_{b;d} = \tan^{-1}[\tan(\delta_{b;d})/1.25]$
$= \tan^{-1}[\tan 21°/1.25]$
$= 17.07°$

ODF $= 1.2$

$(25.91 + 137.5B)\tan 17.07 = 101.256$
$25.91 + 137.5B = 329.752$
$B = 2.21$m.

$\dfrac{(137.5B \tan 17.07)}{84.38} = 1.2$

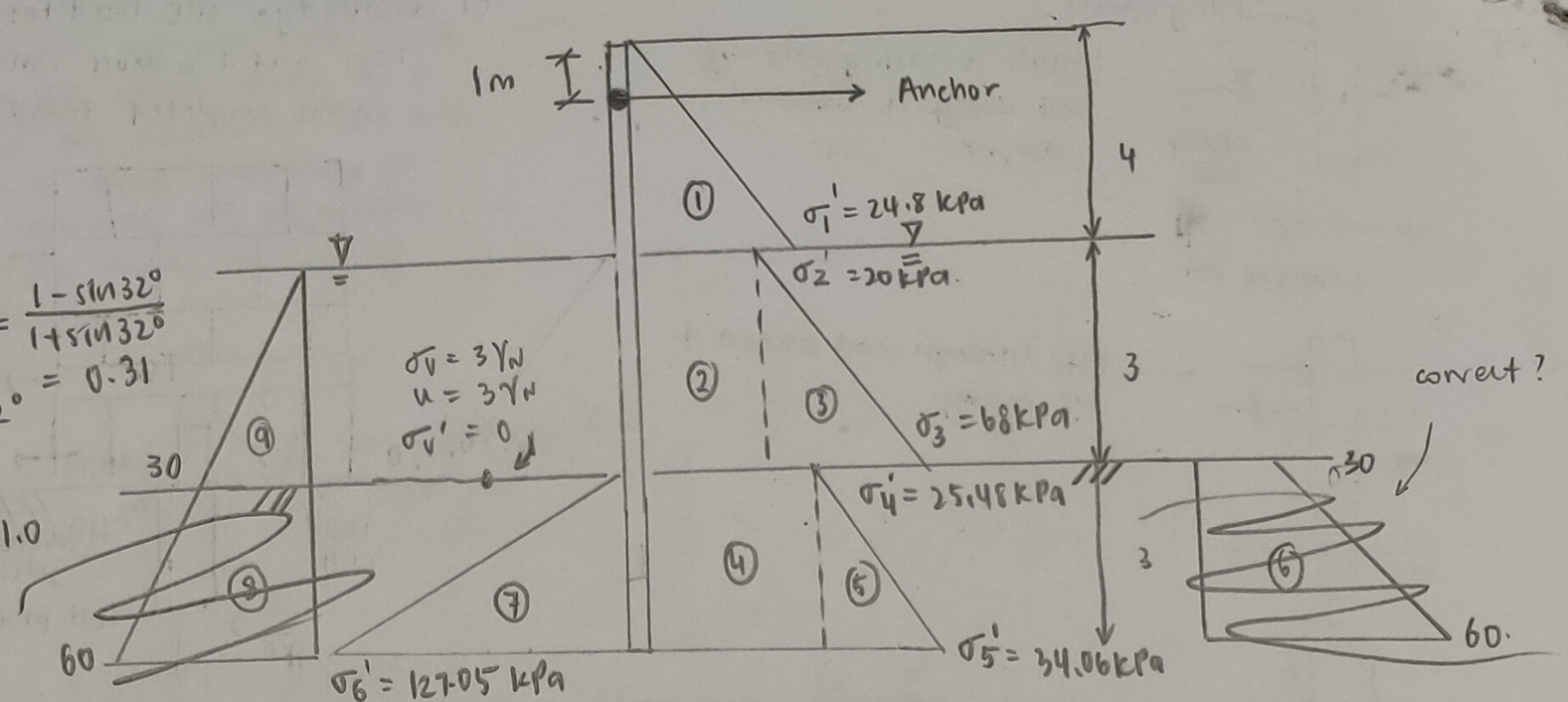
$137.5B \tan 17.07 = 101.256$
$137.5B = 329.752$
$B = 2.398 \approx 2.4$m ✓

4) b) i) DA1a – Rankine

$\gamma_r = 1.0$

$\gamma_d = 1.0$

$\gamma_{cu} = 1.0$



Sand fill

$\gamma_d = \frac{20}{1.0} = 20\ kN/m^3$

$\phi'_d = \tan^{-1}[\tan(32)/1.0] = 32°$

$K_a = \frac{1-\sin 32°}{1+\sin 32°} = 0.31$

Soft clay

$\gamma_d = \frac{16}{1.0} = 16\ kN/m^3$

$K_a = 1.0$

$C_{uid} = \frac{30}{1.0} = 30$ kPa

Dense sand

$\gamma_d = \frac{21}{1.0} = 21\ kN/m^3$

$\phi'_d = \tan^{-1}[\tan(36)/1.0] = 36°$

$K_a = \frac{1+\sin 36°}{1+\sin 36°} = 0.26$

$K_p = \frac{1+\sin 36°}{1-\sin 36°} = 3.85$

$\sigma_1' = K_a\gamma H = 0.307 \times 4 \times 20 = 24.8$ kPa.

$\sigma_2 = \sigma_{v0} - 2C_u = 20(4) - 2(30) = 20$ kPa

$\sigma_3 = \sigma_{v0} - 2C_u = [20(4) + 16(3)] - 2(30) = 68$ kPa

$\sigma_4' = K_a\gamma H = 0.26[20(4) + (16-10)(3)] = 25.48$ kPa (33.28).

$\sigma_5' = K_a\gamma H = 0.26[20(4) + (16-10)(3) + (21-10)(3)] = 34.06$ kPa (41.86)

$\sigma_6' = K_p\gamma H = 3.85(21-10)(3) = 127.05$ kPa (242.55).

ii) Take moments about anchor (use single source principle). (Area 6 & 8 cancel out each other

Area	Force (kN/m)	Lever arm (m)	Moments (kNm/m)
①	$\frac{1}{2} \times 24.8 \times 4 \times 1.35 = 66.96$	$(2/3)(4) - 1 = 1.67$	111.6
②	$20 \times 3 \times 1.35 = 81$	$3 + 3/2 = 4.5$	364.5
③	$\frac{1}{2}(68-20)(3) \times 1.35 = 97.2$	$(2/3)(3) + 3 = 5$	486
④	$25.48(3) \times 1.35 = 103.19$	$(3/2) + 6 = 7.5$	773.96
⑤	$\frac{1}{2}(34.06-25.48)(3)(1.35) = 17.37$	$(2/3)(3) + 6 = 8$	138.996
⑥	$\Sigma P_{aid} = 365.72$		$\Sigma M_{oid} = 1875.1$
⑦	$\frac{1}{2}(127.05)(3)(1.35) = 257.28$	$(2/3)(3) + 6 = 8$	2058.21
⑨	$\frac{1}{2}(30)(3)(1.35) = 60.75$	$(2/3)(3) + 3 = 5$	303.75
	$\Sigma P_{pid} = 318.03$		$\Sigma M_{rid} = 2361.96$

$ODF = \frac{M_{rid}}{M_{oid}} = 1.26$ //

Anchor force $T = 365.72 - 318.03$

$= 47.69 \times 2.5$

$= 119.2$ kN per anchor