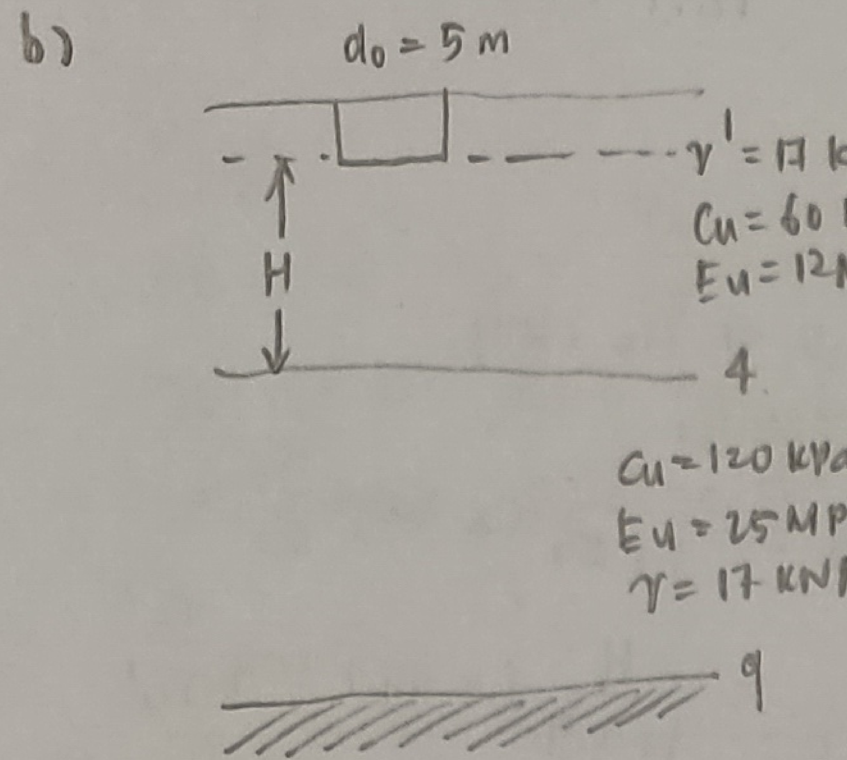
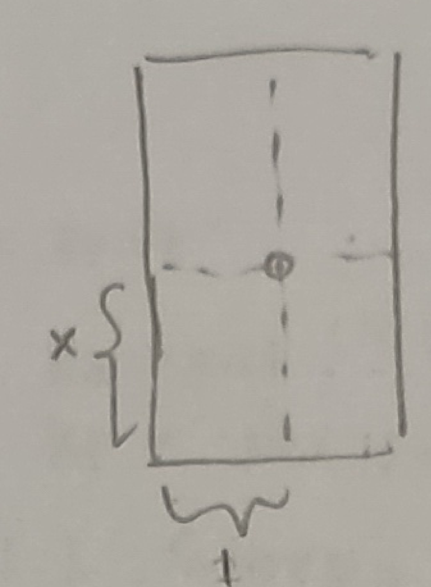
CV3013 2015/16

1) a) Ultimate Limit State (ULS) involves loss of overall stability and failure of the structure or its component and failure in the ground.

Serviceability Limit State (SLS) involves the excessive settlement & deformation and unacceptable vibrations, that causes damage or loss of function.

b)





i) $q_f = S_c N_c C_u + \sigma_q$

$N_c = (2+\pi)$

$S_c = 1 + 0.2 \frac{B}{L}$

* Two-layered soil

$C_{u1} / C_{u2} = 60/120 = 0.5$

H = 3 m

$H/B = 3/5 = 0.6$

From graph, $N_c = 5$

$S_c = 1.1$

$q_f = (1.1)(5)(C_{u1}) + 17(1)$

$= 347$ kPa //

$m = \frac{1}{5} = 0.2$

$n = \infty$

$I_{qr} = 0.06$

$\Delta\sigma = 4 I_{qr} q$

$= 24$

$\sigma_0' = 18(1) + (20-9.81)(1) + (18-9.81)(4)$

$= 60.95$

$\sigma_f' = 60.95 + 24 = 84.95$ kN

$S_{oed} = \frac{8}{1+0.9}\left[0.05 \log \frac{84.95}{60.95}\right]$

$= 0.03$

A = 0.5

$H/B = 8/2 = 4$

$\mu_c = 0.7$

$S_c = \mu_c S_{oed} = 0.7(0.03)$

$= 0.0212$

$=$

c) OCR = 1.0 ⇒ NC clay

$S_{oed} = \frac{H}{1+e_0}\left[C_c \log \frac{\sigma_f'}{\sigma_0'}\right]$

Use 2:1 Method to estimate $\Delta\sigma'$

$\Delta\sigma' = \frac{100}{(2+5)} = 14.286$ kPa

$\sigma_0' = (20-10)(1) + 4(18) + 18(1) = 100$ kPa

$\sigma_f' = \sigma_0' + \Delta\sigma' = 114.286$ kPa.

$S_{oed} = \frac{8}{1+0.9}\left[0.05 \log\left(\frac{114.286}{100}\right)\right]$

$= 0.0122$ m.

A = 0.5, $H/B = 8/2 = 4$

$\mu_c = 0.7$

$S_c = \mu_c S_{oed}$

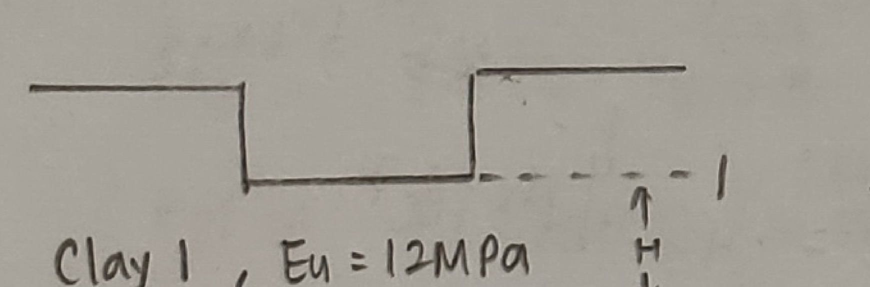
$= 0.7(0.0122)$

$= 0.0085$

$= 8.5$ mm //

ii) uniform load = 160 kPa (for μ_1 → refer to 'circle' graph)

* use principle of superposition: $\left(S_i = \mu_0 \mu_1 \frac{qB}{E}\right)$



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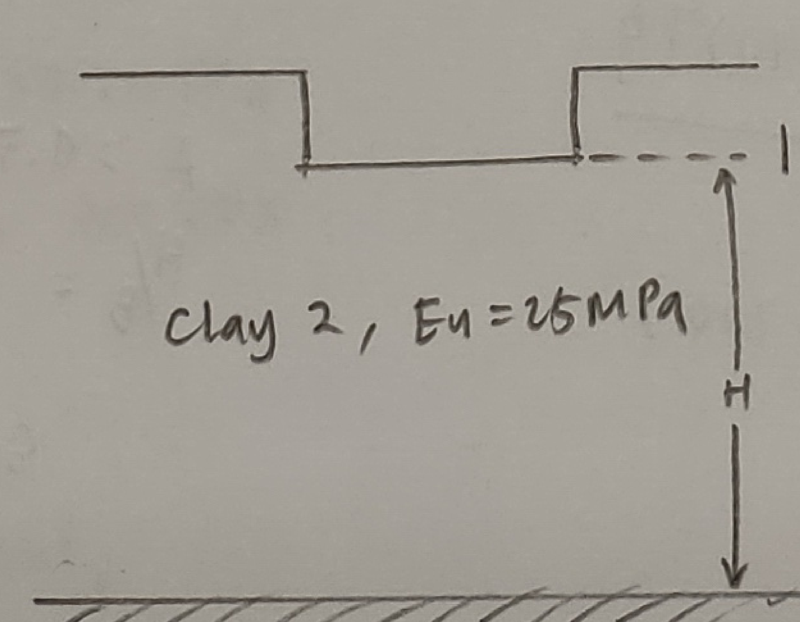

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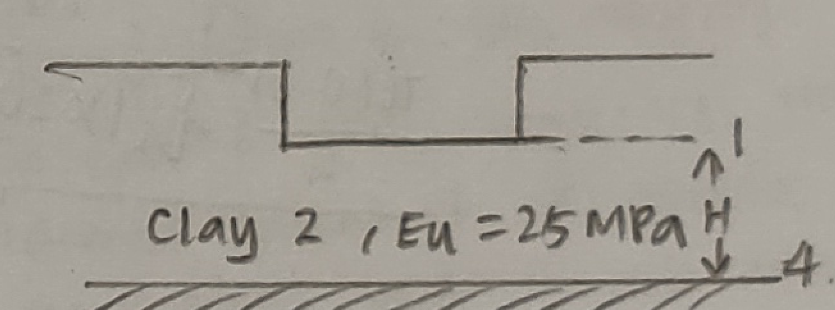


$\frac{d}{B} = \frac{1}{5} = 0.2 \rightarrow \mu_0 = 0.96$

$\frac{H}{B} = \frac{3}{5} = 0.6 \rightarrow \mu_1 = 0.25$

$S_{i1} = \mu_0 \mu_1 \frac{qB}{E}$

$= 0.96(0.25)\frac{(160)(5)}{12 \times 10^3}$

$= 0.016$ m

$\frac{d}{B} = \frac{1}{5} = 0.2 \rightarrow \mu_0 = 0.96$

$\frac{H}{B} = \frac{8}{5} = 1.6 \rightarrow \mu_1 = 0.4$

$S_{i2} = \mu_0 \mu_1 \frac{qB}{E}$

$= 0.96(0.4)\frac{(160)(5)}{25 \times 10^3}$

$= 0.0123$ m

$\frac{d}{B} = \frac{1}{5} = 0.2 \rightarrow \mu_0 = 0.96$

$\frac{H}{B} = \frac{3}{5} = 0.6 \rightarrow \mu_1 = 0.25$

$S_{i3} = \mu_0 \mu_1 \frac{qB}{E}$

$= 0.96(0.25)\frac{160(5)}{25 \times 10^3}$

$= 0.00768$ m

By superposition ⇒ $S_{i1} + S_{i2} - S_{i3} = 0.02062$ m

$= 20.62$ mm //

Assumptions: The clay layer are fully undrained and $\nu = 0.5$

Average settlement is calculated

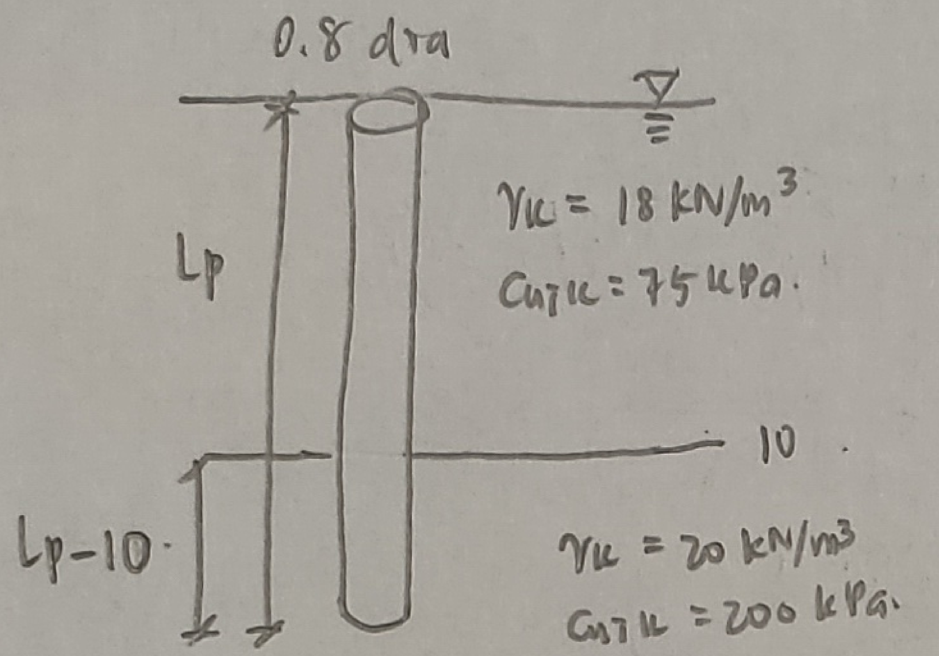
The area is flexible

2) a) - When actions applied to foundation are large
- When near surface soil have low strength and /or low stiffness (low resistance)
- When large structure are situated on very heterogenous deposits, or when soil layers are inclined.
- For settlement sensitive structures where displacement must be keep small.
- In marine environment where tidal, wave or flow actions may erode material from around a foundation near the ground surface (scour)

c) η_g is dependent on :
- load transfer mode (side friction vs [illegible]
- soil type
- sequence of pile installation
- Elapsed time since the pile were driven
- Direction of applied load.
- Interaction between pile cap & soil

$\gamma_{cu} = 1.0$
$\gamma_\gamma = 1.0$

b) Bored concrete pile ⇒ non-displacement.



DA1b A2+M1+R4

$C_{u1d} = \frac{C_{u1k}}{\gamma_{cu}} = \frac{75}{1.0} = 75$ kPa

$\gamma_{1d} = \frac{\gamma_k}{\gamma_\gamma} = \frac{18}{1.0} = 18$ kN/m³

$C_{u2d} = \frac{C_{u2k}}{\gamma_{cu}} = \frac{200}{1.0} = 200$ kPa

$\gamma_{2d} = \frac{\gamma_k}{\gamma_\gamma} = \frac{20}{1.0} = 20$ kN/m³

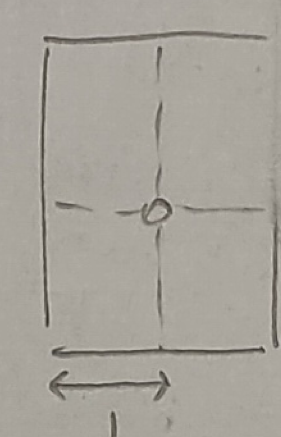
$Q_A \leq R_d$

DA1b ↘

$\gamma_A (Q_k + \gamma_{conc} A_p L_p) \leq R_d$

$1.0 \left(2000 + 24 \frac{\pi (0.8)^2}{4} L_p\right) \leq R_d$

$2000 + 12.06 L_p \leq R_d$



$Q_{bu} = A_p (N_c C_u + \sigma_q)$

$N_c = (2+\pi)\left(1 + 0.27\sqrt{\frac{d}{B}}\right) \leq 9.0$

Assume large d/B ⇒ $N_c = 9.0$, Assume model factor, $\xi = 1.55$

$Q_{buik} = \frac{A_p (N_c C_u + \sigma_q)}{\xi}$ (C_{u2d})

$= \frac{\frac{\pi (0.8)^2}{4} \{(9 \times 200) + [18(10) + 20(L_p - 10)]\}}{1.55}$

$= 0.324 (1800 + 180 + 20 L_p - 200)$

$= 576.72 + 6.48 L_p$

For non-displacement piles

$\alpha = 1.16 - \left(\frac{C_u}{185}\right)$ for $30 \leq C_u \leq 150$ kPa

$\alpha = 0.35$ for $C_u > 150$ kPa

For clay 1, $\alpha = 1.16 - \frac{75}{185} = 0.755$

Clay 2, $\alpha = 0.35$

$Q_{suik} = \frac{\pi D_0 L_p \tau_{int}}{\xi}$ ($= \alpha C_u$) $= \frac{\pi D_0 [10(0.755)(75) + (L_p - 10)(0.35)(200)]}{1.55}$

$= \frac{\pi (0.8) [566.25 + 70 L_p - 700]}{1.55}$

$= 113.5 L_p - 216.87$

$R_d = \frac{Q_{buik} + Q_{suik}}{2} = 179.925 + 60 L_p$

$2000 + 12.06 L_p \leq 179.925 + 60 L_p$

$1820.075 \leq 47.94 L_p$

$L_p \geq 38$ m

* check $d/B = \frac{38 - 10}{0.8}$

$= 35$

∴ $S_c N_c = 9.0$ is ok!

1) c) OCR = 1.0 ⇒ NC clay

For NC clay,

$S_{oed} = \frac{H}{1+e_0} C_c \log \frac{\sigma_f'}{\sigma_0'}$

$= \frac{H}{1+0.9} (0.05) \log \frac{\sigma_f'}{\sigma_0'}$

$= 0.0263 H \log \frac{\sigma_f'}{\sigma_0'}$

$4 \times I_{qr} \times q$

* All H = 2

Layer	Z (m)	m, n	I_{qr}	$\Delta\sigma'$	σ_0'	σ_f'	S_{oed}
1	2	0.5	0.138	55.2	36.38	91.58	0.0212
2	3	0.333	0.10	40	52.76	92.76	0.0131
3	4	0.25	0.08	32	60.95	92.95	0.0097
4	5	0.2	0.06	24	69.14	93.14	0.0683

$\Sigma = 0.0513$

① $(18 \times 1) + (20 - 9.81) \times 1 + (18 - 9.81) \times 1 = 36.38$

② $(18 \times 1) + (20 - 9.81) \times 1 + (18 - 9.81) \times 3 = 52.76$

" $\times 4 = 60.95$

" $\times 5 = 69.14$

A = 0.5
H/B = 8/2 = 4 } $\mu_c = 0.7$

$S_c = \mu_c S_{oed} = 0.7 \times 0.051$
$= 0.0355$
$= 35.5$ mm

i) DA1b   * GWT well below excavation

A2 + M2 + R1

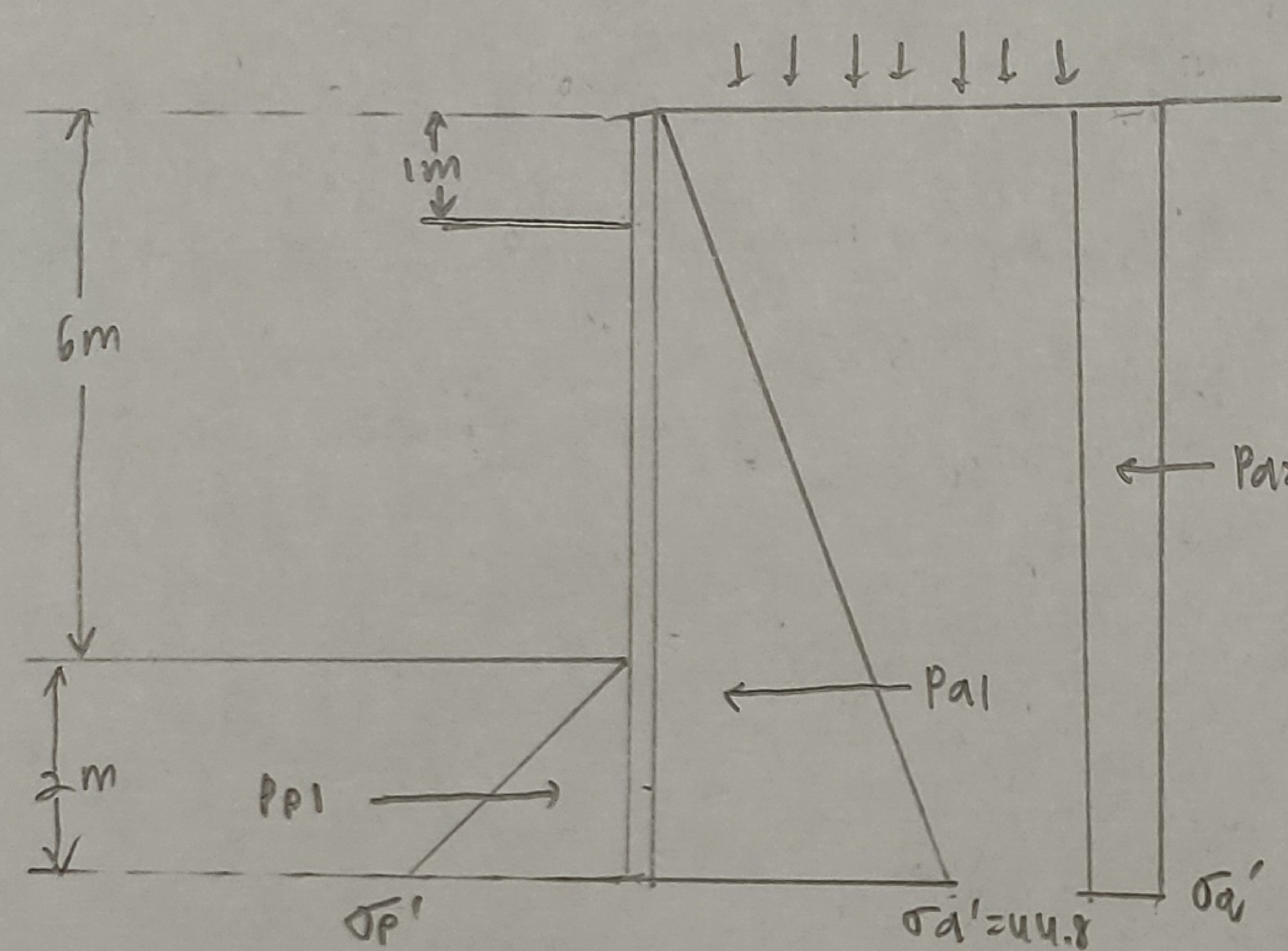
$\gamma_{\phi'} = 1.25$
$\gamma_{c'} = 1.25$
$\gamma_{cu} = 1.4$
$\gamma_\gamma = 1.0$

Sand

$\gamma_\gamma = 1.0 \quad \gamma_d = \frac{\gamma_k}{\gamma_\gamma} = \frac{20}{1.0} = 20\ kN/m^3$

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

$\delta/\phi' = 0.66$, $\phi'_d = 30.17°$ from graph, $K_a = 0.28$, $K_p = 5.0$



$\sigma_a' = K_a \gamma H = 0.28(20 \times 8) = 44.8\ kPa$

$\sigma_q' = K_a q = 0.28(20) = 5.6\ kPa$

$\sigma_p' = K_p \gamma H = 5.0(20)(2) = 200\ kPa$

$P_{a1} = \frac{1}{2}(8)(44.8)\gamma_{G,dst}^{(1.0)} = 179.2\ kPa$

$P_{a2} = 5.6(8)\gamma_{Q,dst}^{(1.3)} = 58.24\ kPa$

$P_{p1} = \frac{1}{2}(2)(200)\gamma_{G,stb}^{(1.0)} = 200\ kPa$

ii) Free earth support method

Taking moment abt anchor / strut,

Active pressure (kPa)	Lever arm (m)	Moment (kNm)
179.2	2/3 (8) − 1 = 13/3	776.53
58.24	8/2 − 1 = 3	174.72
	ΣMo;d	951.25
Passive pressure (kPa)		
200	(2/2) + (6−1) = 6	1200
	ΣMr;d	1200/$\gamma_{R;e}$

$ODF = \frac{1200}{951.25} = 1.26$

→ wrs is satisfactory !

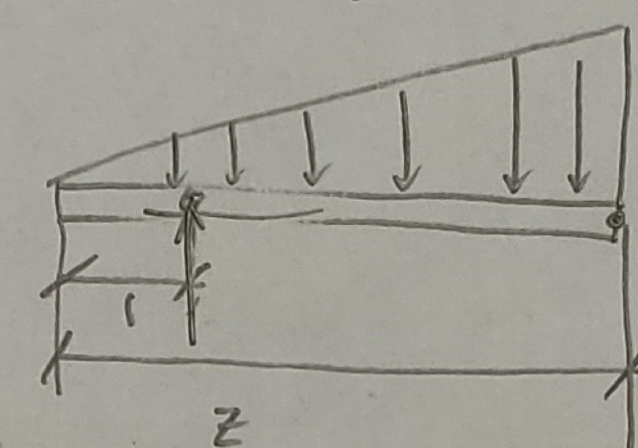
iii) sum force horizontally

$T + P_p = P_a$

$T + 200 = 179.2 + 58.24$

$T = 37.44$ kN per metre run.

iv) Find location z where shear force is zero.



$T - 0.5 K_a \gamma H^2 = 0$

$T - 0.5(0.28)(20)(z)^2 = 0$

$37.44 = 2.8z^2$

$z = 3.66\ m$

b) i) The primary objectives for a soil investigation is to obtain sufficient amount of information about the soil / ground so as to enable a safe & economical foundation design & avoid any difficulties during construction.

The essential tasks includes :

- check for ground contamination
- Determine location of ground water and artesian condition
- perform in-situ testing to access ground / soil characteristics in the field.
- obtain soil samples for identification, classification & lab testing.
- Determine the sequence, thickness, lateral extent of soil strata and if applicable, bedrock elevation.

ii) For a clay soil ↗ FVT to get cu

→ undisturbed samples (using thin wall sampler / stationary piston sampler) to carry out lab test for permeability & consolidation of soil, UU, CD, CU Test also.

→ disturbed samples (open drive sampler) for lab test for atterberg limits, density or water content.

→ SPT to get undrained shear strength but value obtain is correlated with the results from the lab test / support other test data.

→ PMT to get cu

→ CPT to obtained cu (calibrated against UU triaxial) & in-situ horizontal stresses & OCR value

For a sandy soil

→ undisturbed samples for lab test to find out fine content & grain distribution

→ SPT to get relative density I_D & peak friction angle ϕ'

→ CPT to get same thing

→ PMT to get strength parameters like ϕ' and ψ

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3) a) We should use the low tide river water level for calculation against sliding & bearing ULS because if we consider a high tide level, there will be a water flow from in front of wall to back of the wall. An upward flow at the back of wall causes an increase in water pressure & decrease in effective stress of soil, thus decreasing the active pressure. Hence, design shld be done using low tide level as it is more dangerous.

b) i) Coulomb, DA1b.

sand,

$\gamma_k = 20 kN/m^3$

$c'_k = 0$

$\phi'_k = 38°$.

$\delta/\phi = 2/3$.

$\gamma_{\phi'} = 1.25$

$\phi'_d = \tan^{-1}[\tan 38°/1.25]$

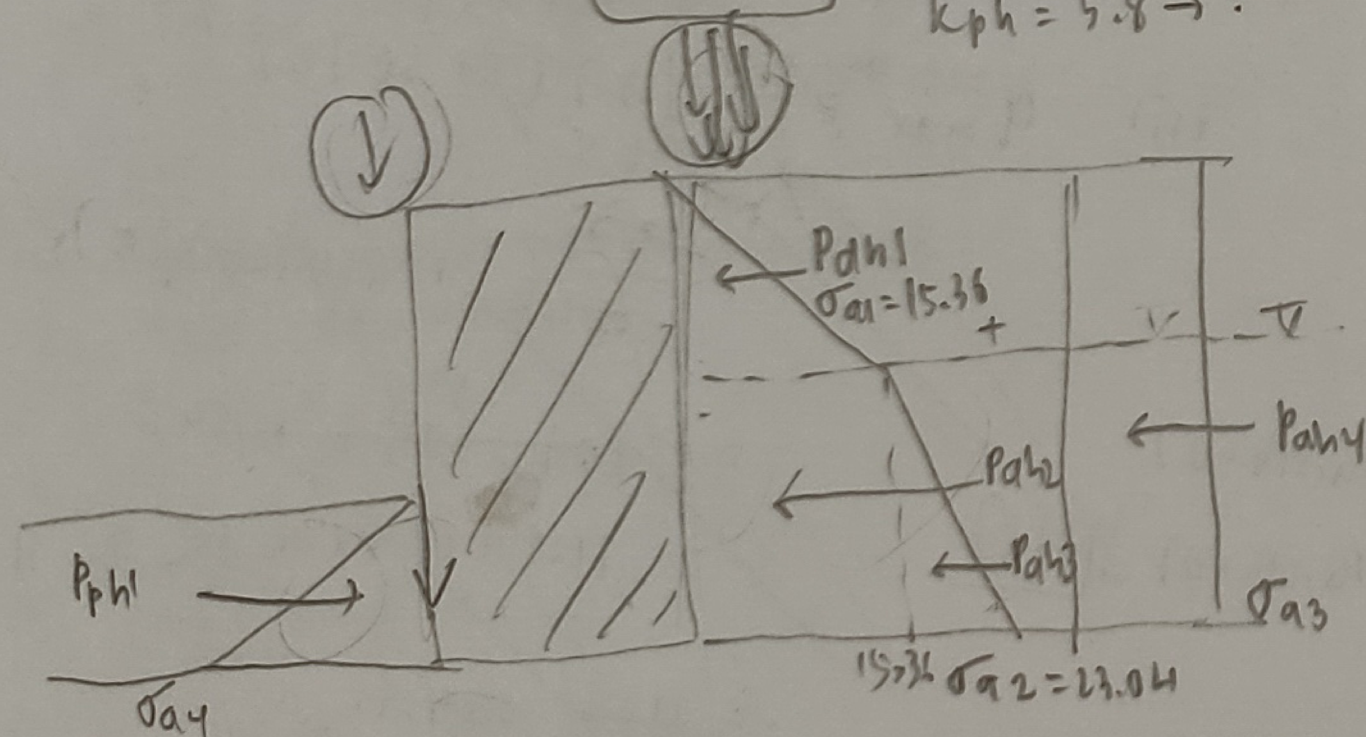
$= 32°$ ✓

From chart, $\phi'_d = 32°$, $\delta/\phi = 2/3 \rightarrow$

$K_{ah} = 0.256 \rightarrow ?$

For clay layer, $\phi'_d = 32°$, $\delta/\phi = 2/3$

$K_{ph} = 5.8 \rightarrow ?$



$\sigma_{a1} = K_{ah}\gamma H = 0.256 \times 3 \times 20 = 15.36 kPa$

$\sigma_{a2} = K_{ah}\gamma' H = 0.256 \times [20(6) - 10(3)] = 23.04 kPa$

$\sigma_{a3} = K_a q = 0.256 (10) = 2.56 kPa$.

$\sigma_{a4} = K_{ph}\gamma H = 5.8 \times 18 \times 1 = 104.4 kPa$

$\delta/\phi = 2/3$

$\delta = 21.3°$

$P_{ah1;d} = 0.5(3)(15.36)\gamma_{G;dst}^{1.0} = 23.04 kN/m$

$P_{ah2;d} = 3(15.36)\gamma_{G;dst} = 46.08 kN/m$

$P_{ah3;d} = 0.5(23.04 - 15.36)(3)\gamma_{G;dst} = 11.52 kN/m$

$P_{ah4;d} = 6 \times 2.56 \times \gamma_{Q;dst}^{1.3} = 19.968 kN/m$

$P_{ph1;d} = 0.5(104.4)(1)\gamma_{G;stb}^{1.0} = 52.2 kN/m$

$P_{av1;d} = 0.5(3)(15.36)\tan 21.3°\,\gamma_{G;stb}^{1.0} = 8.98 kN/m$

$P_{av2;d} = 3(15.36)\tan 21.3°\,\gamma_{G;stb} = 17.97 kN/m$

$P_{av3;d} = 0.5(7.68)(3)\tan 21.3\,\gamma_{G;stb} = 4.49 kN/m$

$P_{av4;d} = 6(2.56)\tan 21.3\,\gamma_{Q;stb} =$ ~~5.99 kN/m~~ 0

$P_{pv1;d} = 0.5(104.4)\tan 21.3\,\gamma_{G;stb}^{1.0} = 20.35 kN/m$.

Weight of wall $= 4 \times 6 \times 24 \times \gamma_{G;stb}^{1.0} = 576 kN/m$.

$P_{ah;d} = 100.608 kN/m$.

$R_{v;d} = 627.79$

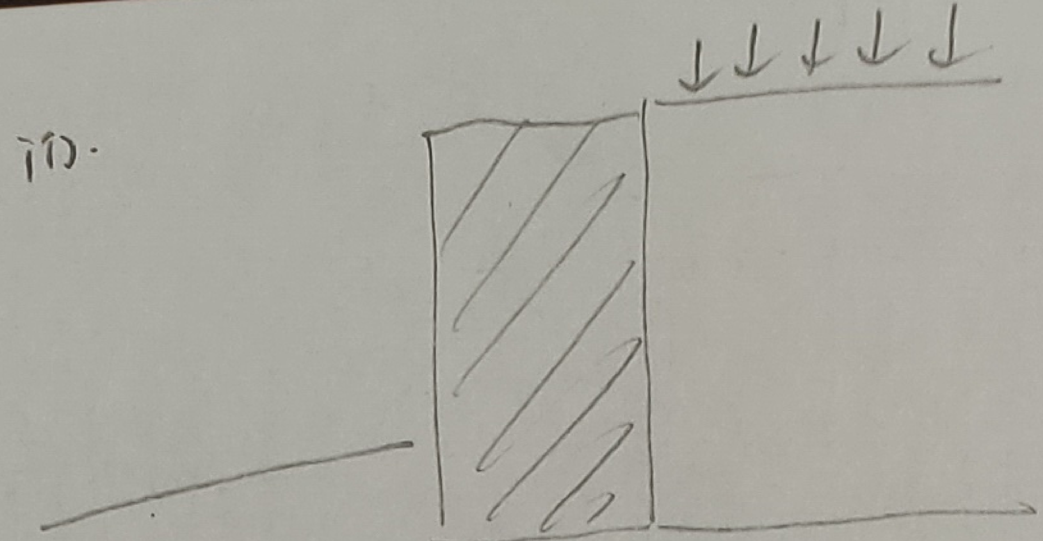
$R_{h;d} = F_{v;d}\tan\delta_{base} / \gamma_{R;h} + C_{b;d}A + P_{ph1;d}$

$= 0 + \frac{70}{1.4}(4) + 52.2 = 252.2 kPa$

$ODF = \frac{100.608}{252.2}$

$= 2.51$

ii)



$G_{wall;d} = 4 \times 6 \times 24 \times \gamma_{G;dst}^{1.0} = 576 kN/m$.

⋮

~~$F_{v;d} = 627.79$~~

$\Sigma M_{o;d} = 23.04(1+3) + 46.08(1.5) + 11.52(1) + 19.968(3) + 20.35(0)$.

$= 232.704 kNm/m$.

$\Sigma M_{r;d} = 576(2) + 52.2(\frac{1}{3}) + 31.44(4)$

$= 1295.16 kNm/m$

$x^* = \frac{\Sigma M_{r;d} - M_{o;d}}{F_{v;d}} = \frac{1062.456}{627.456}$

$= 1.693 m$

$e = B/2 - 1.693 = 0.307 < B/6 = 0.666$.

$q_{max} = (R_v/B)(1 + 6e/B)$

$= 229.2 kPa >$

$q_{f;d} = 200$

∴ not satisfied.

$q_{min} = (R_v/B)(1 - 6e/B)$

$= 84.67 kPa$.

4 (a) A strutted steel sheet pile wall supports a 6 m deep excavation in uniform sand with a 2 m embedment below the excavation (Figure Q4). The strut is located at 1 m below the top of the wall. The *characteristic* values of the sand are: unit weight γ_k = 20 kN/m³ and friction angle, ϕ'_k = 36°. The wall roughness is δ = 2/3 ϕ'. The groundwater table is located far below the excavation. A surcharge q_k of 20 kPa acts behind the wall.

Adopting EC7 Design Approach 1 Combination 2 (DA1b) for the GEO ultimate limit state (ULS) of rotational failure of the wall about the strut location:

(i) Calculate and plot the active and passive earth pressure distributions on the wall that correspond to this ULS. (5 Marks)

(ii) Using the free earth support method, determine if the wall meets the requirement of this ULS. (4 Marks)

(iii) Calculate the design strut load per meter run of the wall. (3 Marks)

(iv) Find the location of maximum moment in the sheet pile wall. (3 Marks)

(b) (i) State the primary objectives of a soil investigation programme for any major civil engineering project. Describe the essential tasks that constitute a well conceptualized soil investigation programme. (5 Marks)

(ii) Soil strength parameters are fundamental to foundation design. Describe briefly an appropriate combination of a sampling technique and laboratory tests, or suitable in-situ testing methods, that could be used to obtain the strength parameters for:

- a clay soil; and
- a sandy soil.

State clearly the shear strength parameters that can be derived from such tests. (5 Marks)

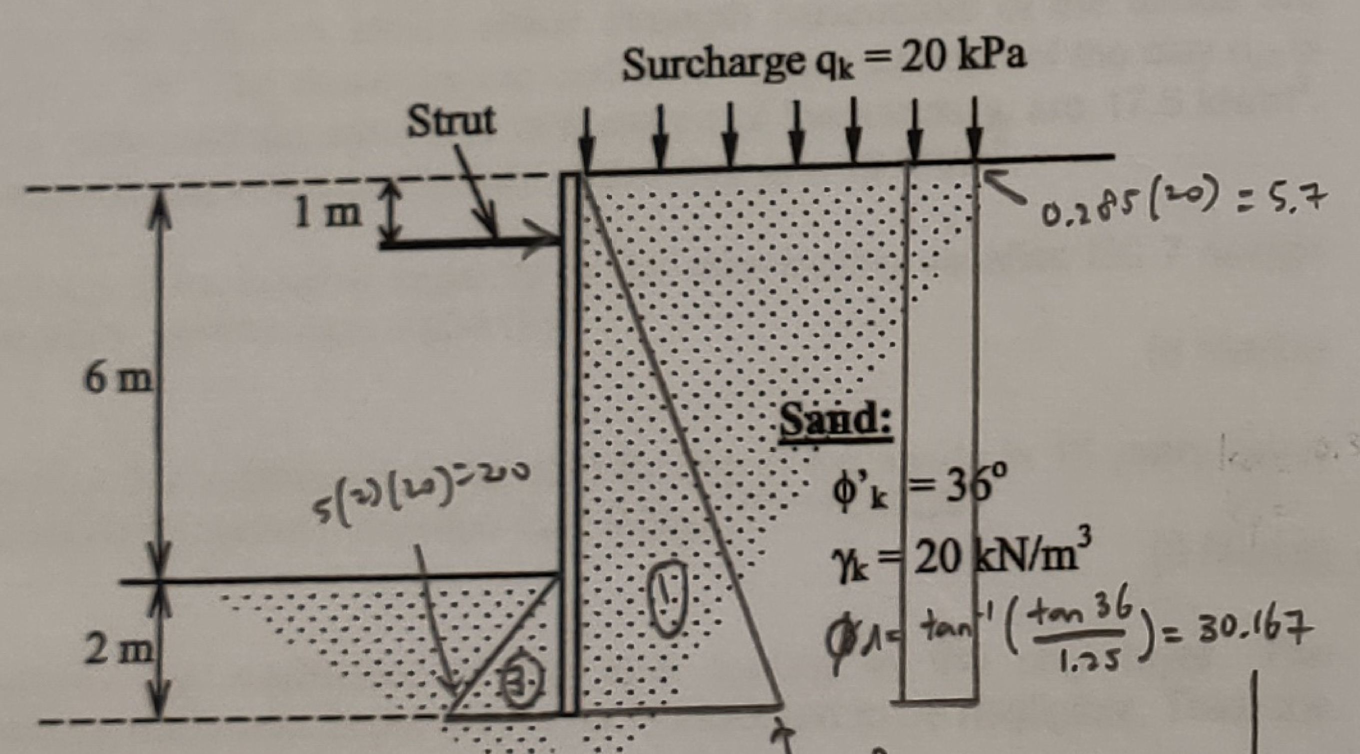


Figure Q4

0.285(8)(20) = 45.6

$\delta_{wall,d}$ = 20.111

$\delta = \frac{2}{3}\phi'$

Graph: k_{ah} = 0.285

k_{ph} = 5.0

END OF PAPER

γ_{dq} = 1
$\gamma_{G,A}$ = 1
$\gamma_{Q,dst}$ = 1.3
$\gamma_{G,stb}$ = 0

4)(a)

Σ M strut Force (kN/m)	Arm (m)	Moment (kNm/m)
① ½(45.6)(8) $\gamma_{G,dst}$ = 182.4	$\frac{2}{3}$(8) − 1 = 4.333	790.4
② 5.7(8) $\gamma_{Q,dst}$ (1.3) = 59.28	½(8) − 1 = 3	177.84
241.68		$M_{o,d}$ = 968.24
③ ½(2)(200) $\gamma_{G,stb}$ = 200 kN	$\frac{2}{3}$(2) + 5 = 6.333	1266.67
		$M_{r,d}$ = 1266.67

Overturning ODF = 1266.67 / 968.24 = 1.31 > 1 (ok)

(iii) T + 200 = 241.68

T = 41.68 kN/m

(iv) Location where V = 0

41.68 − [1.3(5.7x) + ½x(2.0x)(0.285)] = 0

2.85x² + 7.41x − 41.68 = 0

x = 2.74 m

(b)(i) − To obtain sufficient info. about the ground so as to enable safe & economic foundation design, avoid difficulty during construction.

- Determine the thickness, sequence, lateral extent of soil profile, bed rock elevation
- obtain soil sample for identification, classification, lab testing
- perform in-situ test to access ground or soil characteristic in field
- Determine location of ground water lvl & artesian condition
- check for ground contamination

(ii) Clay: FVT → C_u

SPT → C_u

CPT → C_u

Sand: SPT/CPT → ϕ', ϕ