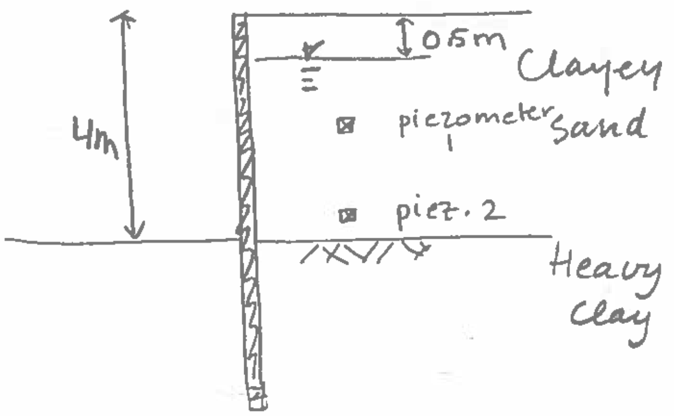
PROBLEM 1



$G_s = 2.68$

(a) (i) $d_{core} = 0.1\ m$

$l_{core} = 0.3\ m$

$V_T = \left(\frac{\pi d^2}{4}\right) l = \frac{\pi}{4}(0.1\ m)^2(0.3\ m) = 2.356 \times 10^{-3}\ m^3$

$M_T = 5.238\ kg$

$\rho_T = \frac{M_T}{V_T} = \frac{(5.238\ kg)}{(2.356 \times 10^{-3}\ m^3)} = 2,223\ kg/m^3$

Small specimen

$M_T = 57.34\ g$ $\quad M_s = 50.26\ g$ $\quad M_w = M_T - M_s = 7.08\ g$

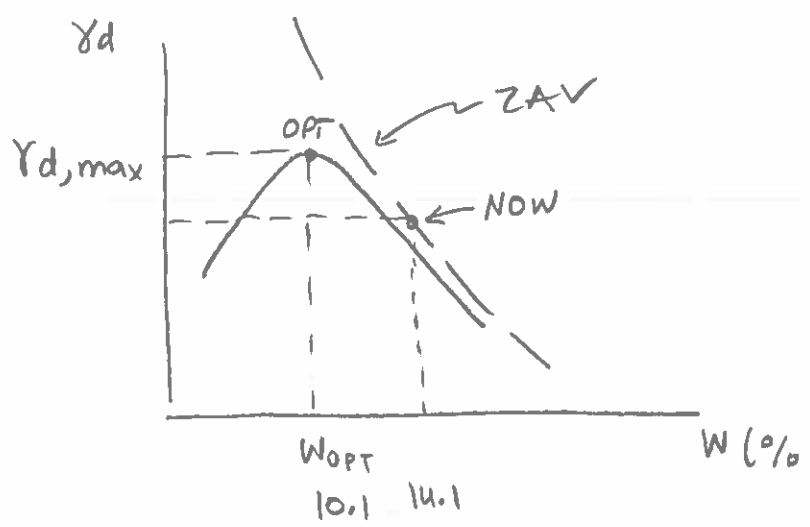
$w = \frac{M_w}{M_s} = \frac{7.08\ g}{50.26\ g} = 14.1\%$

(ii)

$\gamma_{d\,max} = 19.8\ \frac{kN}{m^3}$ @ $w_{opt} = 10.1\%$

$\gamma_T\ (now) = \rho_T g = 21.8\ \frac{kN}{m^3}$

$\gamma_d\ (now) = \frac{\gamma_T\ (now)}{(1+w)} = \frac{21.8\ kN/m^3}{(1+0.14)} = 19.1\ \frac{kN}{m^3}$



$$\gamma_d = \frac{G_s \gamma_w}{1 + \frac{G_s w}{S}}$$

We should check if the specimen at 3m depth is fully saturated after weeks of high water table

$S=1$

$$\gamma_d = \frac{(2.68)(9.81 kN/m^3)}{1+(2.68)(0.141)} = 19.08 \frac{kN}{m^3}$$ ✓ok

The specimen from the field is indeed fully saturated.

$$\text{Relative compaction} = \frac{\gamma_{d,now}}{\gamma_{d,max}} = \frac{19.1}{19.8} = 0.96$$

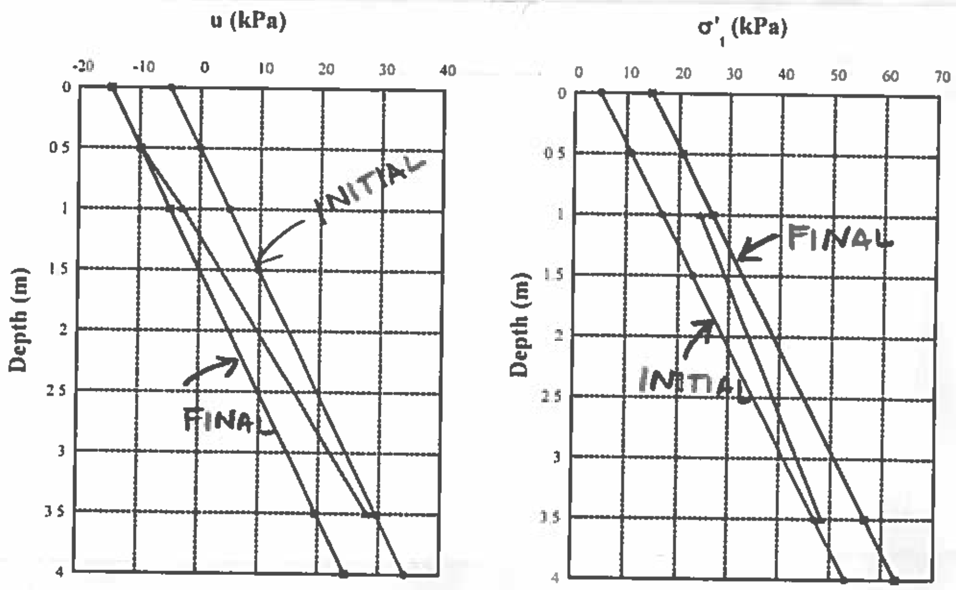
When the specimen became saturated it probably swelled a bit. Therefore current dry unit weight is a bit smaller than it was when the soil was first compacted. The compaction level is now above 95% of standard compaction ⇒ the soil was compacted well during construction and the contractor is not at fault for observed poor behaviour.

(c)

		HIGH LEVEL (-0.5m)		LOW LEVEL (-1.5m) LONG TERM	
z	σ_v (kPa)	u (kPa)	σ'_v (kPa)	u (kPa)	σ'_v (kPa)
0	0	-4.9	0	-14.7	14.7
0.5	10.9	0	10.9	-9.8	20.7
1	21.8	4.9	16.9	-4.9	26.7
1.5	32.7	9.8	22.9	0	32.7
3.5	76.3	29.4	46.9	19.6	56.7
4	87.2	34.3	52.9	24.5	62.7

at 4 days

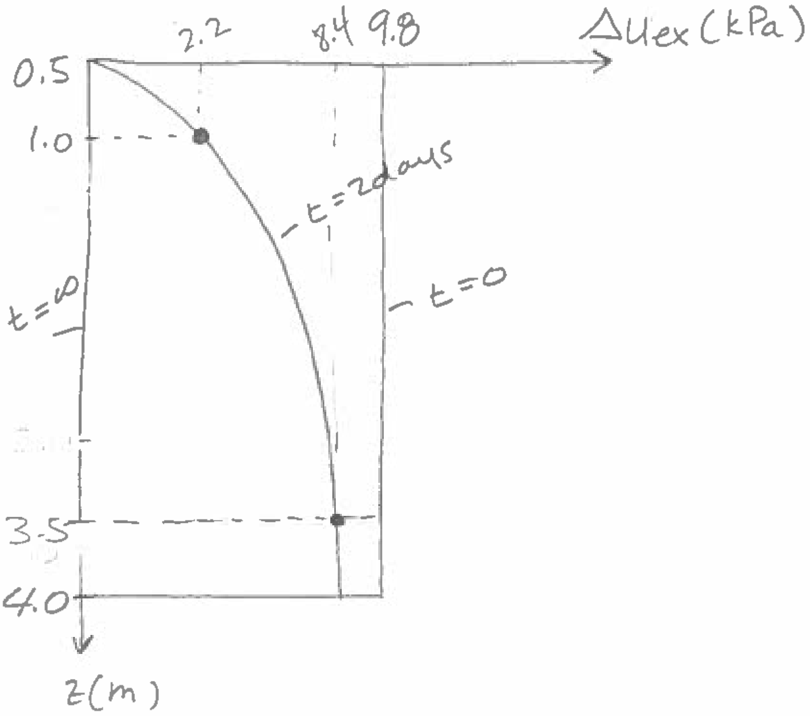
z	u (kPa)	σ'_{vo} (kPa)
0	0	0
0.5	-9.8	20.7
1	-2.7	24.4
3.5	28	48.3



Assumptions

- Water level drops instantaneously, creating an overpressure of 10 kPa, constant with depth
- The final condition is such that the pore pressure at 0.5 m becomes negative (−10 kPa)
- Dissipation of excess pore pressure is 1D

(d)



At 1m

$\Delta u_{ex} = -2.7-(-4.9) = 2.2 \text{ kPa}$

At 3.5m

$\Delta u_{ex} = 28 - 19.6 = 8.4 \text{ kPa}$

At $t = 2$ days $\quad R_v = \dfrac{\text{swept area}}{\text{total area}} = \dfrac{(10)(3.5) - 2/3(8.4)(3.5)}{(10)(3.5)} =$

$= 0.44$

$$T_v = \frac{1}{3}\left\{0.25 - \ln\left[\frac{3}{2}(1-R_v)\right]\right\} = 0.14$$

$$C_v = \frac{T_v d^2}{t} = \frac{(0.14)(3.5)^2}{(2 \text{ days})} = 0.85 \frac{m^2}{day}$$

For $R_v = 0.9 \quad T_v = 0.848$

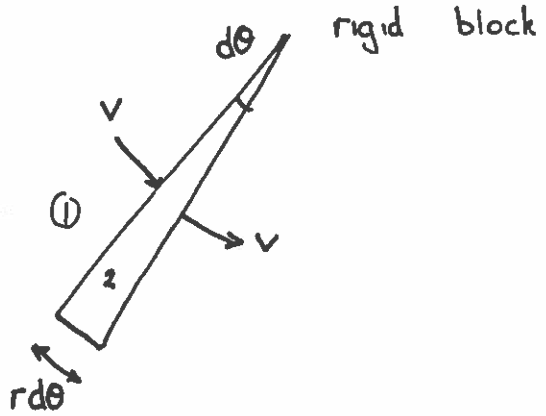
$$t = \frac{(0.848)(3.5)^2}{(0.85 \, m^2/day)} = 12.2 \text{ days}$$

(e) Right after drawdown the effective stress has not increased yet, but the pore pressure is high behind the wall. This extra force on the wall should be accounted for.

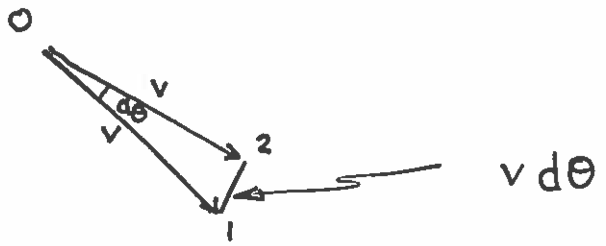
Q1 21 attempts

A large number of students attempted the question, but it proved too challenging. Very few were able to sketch all pore pressure and effective stress distributions, although at least initial and final profiles should have been straightforward. The idea of excess pore pressure being caused by a drop in water table level has proven to be quite confusing. If the students could not identify the intermediate isochrone it became difficult to answer the last part of the question.

2 a)



Holograph

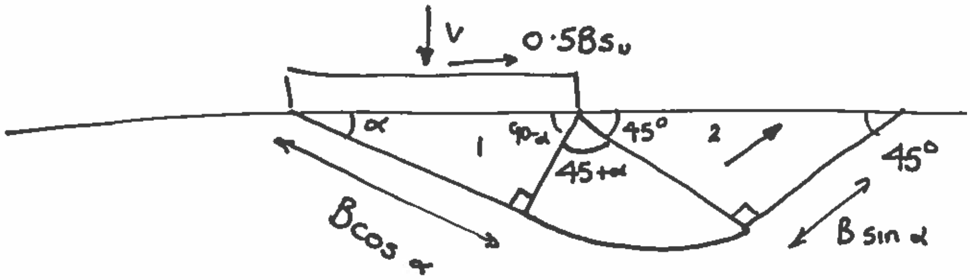


Work done in element $= s_u \left[\underbrace{v\,r\,d\theta}_{\text{outside fan}} + \underbrace{v\,d\theta\, r}_{\text{inside fan}} \right]$

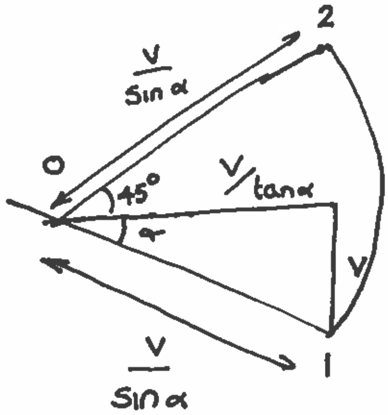
$= 2 v r \, d\theta \; s_u$

Work in fan $= 2 v r \theta \; s_u$.

b)



Hodograph



$$V v + 0.5 B s_u \frac{v}{\tan\alpha} = s_u \left[\frac{v B \cos\alpha}{\sin\alpha} + \frac{v B \sin\alpha}{\sin\alpha} + \frac{2v}{\sin\alpha} B \sin\alpha \left(\frac{\pi}{4} + \alpha\right) \right]$$

$$V = B s_u \left[1 + \frac{\pi}{2} + 2\alpha + \frac{1}{2\tan\alpha} \right]$$

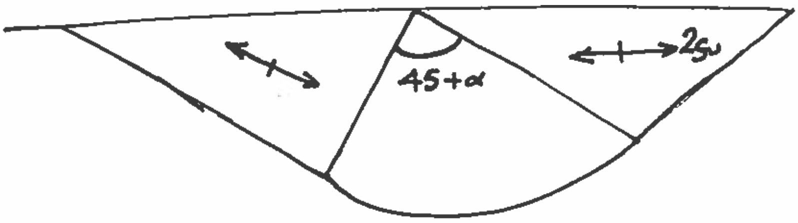
c) $$\frac{\partial V}{\partial \alpha} = B s_u \left[2 - \frac{1}{2} \operatorname{cosec}^2 \alpha \right] = 0$$

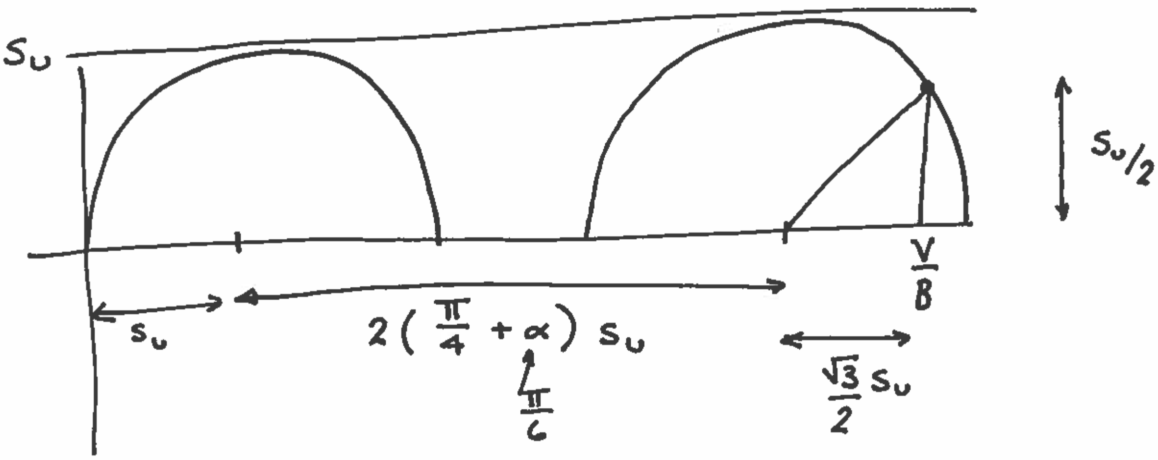
$$\operatorname{cosec} \alpha = \pm 2$$

$$\alpha = \underline{\underline{30^\circ}} = \frac{\pi}{6} \qquad \tan\alpha = \frac{1}{\sqrt{3}}$$

$$V = B s_u \underbrace{\left[1 + \frac{\pi}{2} + \frac{\pi}{3} + \frac{\sqrt{3}}{2} \right]}_{4.484}$$

d)



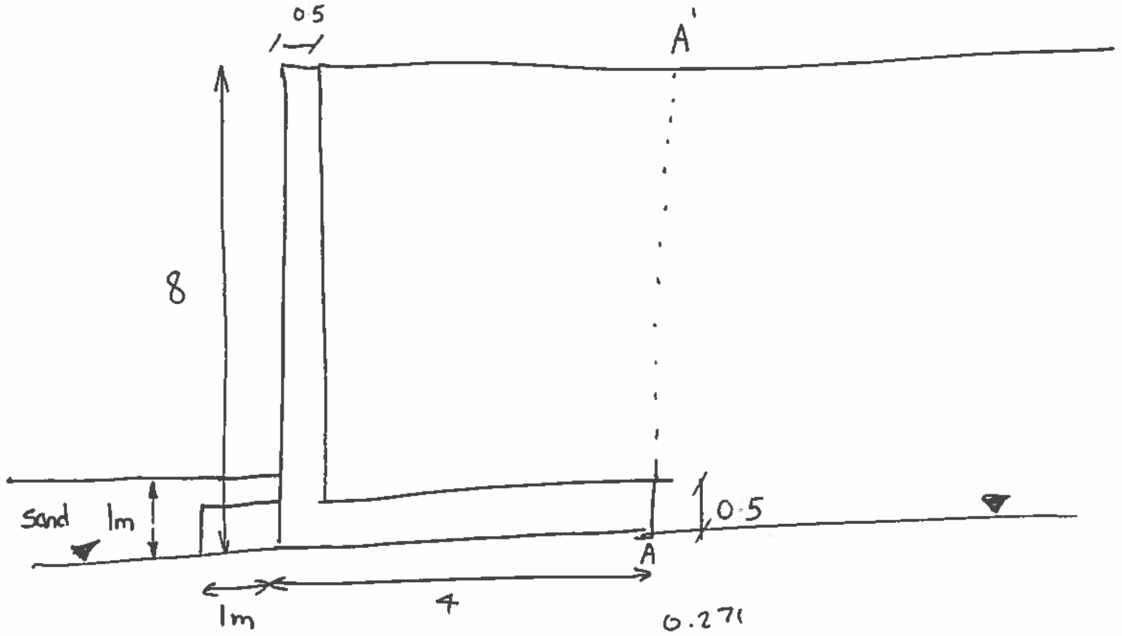


$$\frac{V}{B} = s_u\left(1 + \frac{\pi}{2} + \frac{\pi}{3} + \frac{\sqrt{3}}{2}\right) = \underline{\underline{4.484\,B\,s_u}}$$

Q2 16 attempts,

The question was the least popular with great difference in success. The answers were mostly either correct or blank, with very little in between. The most difficulty was given by the upper bound approach. Some students did not have any answers on the exam sheet.

3.



$$K_a = \frac{1-\sin\phi}{1+\sin\phi} = 0.271$$

$$K_p = 3.69$$

$$P_A = \frac{0.271 \times 18 \times 8 \times 8}{2} = 156 \text{ kN/m}$$

b) Resistance :

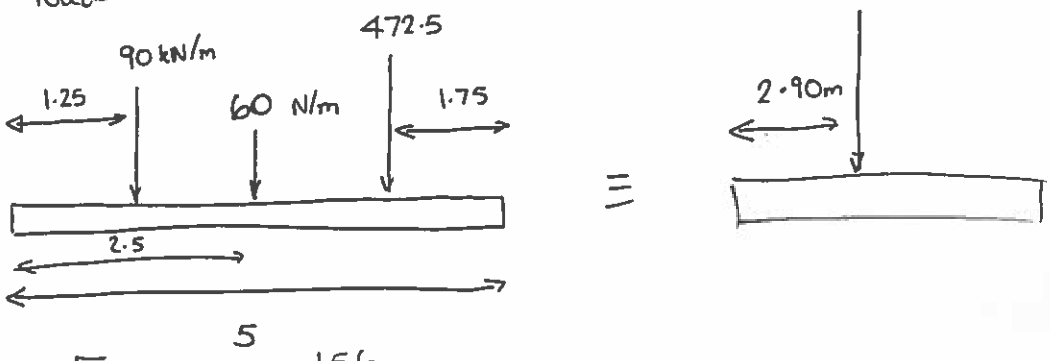
Shear in clay = 5 s_u = 200 kN/m

Passive resistance from sand = $3.61 \times 18 \times \frac{1}{2}$ = 32.5 kN/m

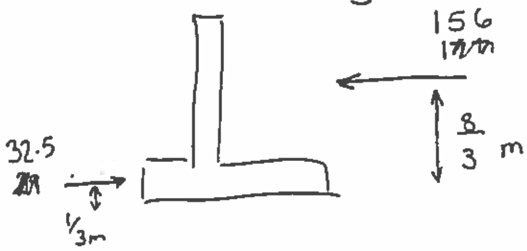
$$FoS_{sliding} = \frac{232.5}{156} = 1.49$$

c) Foundation loads

V



H



Total load on foundation base,

$V = 622.5$ kN/m

$H = 123.5$ kN/m

$M = 163.5$ kNm/m

equivalent to

$V = 622.5$ kN/m

$H = 123.5$ kN/m

$e = 0.262$ m

$\Rightarrow$ $V = 610.5$

$H = 148$

$B = 5 - 2(0.262) = \underline{4.476}$ m

$V_{ult} = (2+\pi) s_u B = 205.6 \times 4.476 = 920.3$ kN/m

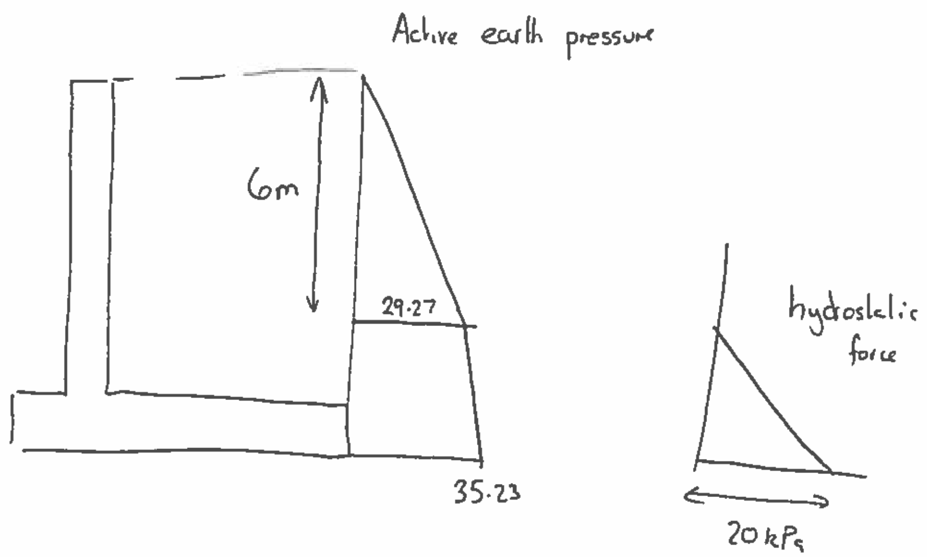
$H_{ult} = B s_u = 179$ kN/m

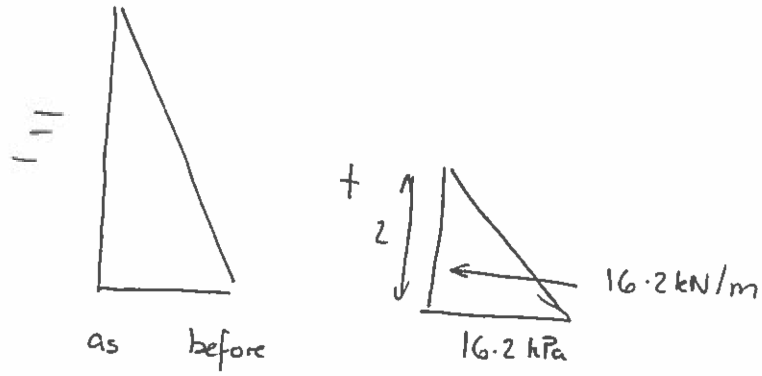
$\frac{V}{V_{ult}} = 0.676$ $\frac{H}{H_{ult}} = 0.690$

failure @ $\frac{H}{H_{ult}} = 0.876$

stable.

H changes





V changes self-weight of soil increases by

$1.5 \times 3.5 \times 3 = 15.75$ kN/m

now $V = 638.3$ kN/m

$H = 139.8$ kN/m

$M = 163.3 - 16.2 \times 2/3 + 15.75 \times 0.75$

$= 164.3$ kNm/m

$V_{ult} = 922.3$ kN

$H_{ult} = 179.4$ kN

$e = 0.257$ m $B = 4.486$m

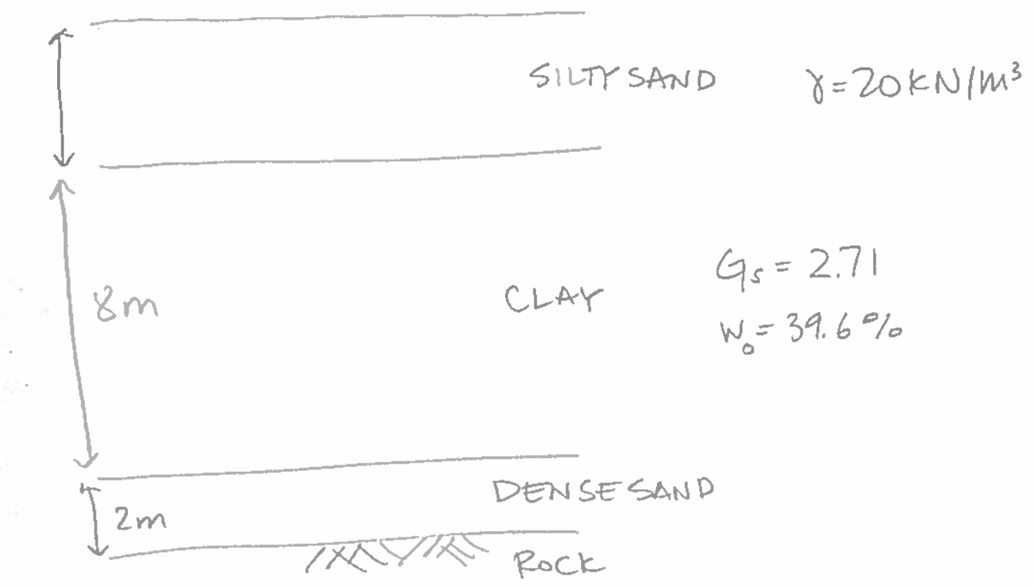
$\frac{V}{V_{ult}} = 0.692$ $\frac{H}{H_{ult}} = 0.852$ @ failure

but $\frac{H}{H_{ult}} = 0.778$ still ok

Q3 25 attempts

This was also a popular question. Generally students could identify the forces involved, but there was confusion on how to calculate the eccentricity and effective width of the foundation. The need to assess interaction between horizontal and vertical loads was not recognised by a good number of the students. In the final part, most students assessed the change in stresses, but did not add the extra horizontal force caused by the water.

PROBLEM 4



Assume $S=1$

(a) $e_o = (0.396)(2.71) = 1.073$ $\quad v_o = 2.073$

$\frac{\Delta h}{h_o} = \frac{\Delta v}{v_o}$ $\quad v = v_o - \frac{\Delta h}{h_o} v_o$

σ'_v (kPa)	1	12.5	25	50	100	200	400
h (mm)	25	24.9	24.8	24.5	23.9	23.1	21.8
Δh (mm)	0	0.1	0.2	0.5	1.1	1.9	3.2
v	2.073	2.065	2.056	2.032	1.981	1.916	1.808

σ'_v (kPa)	100	25
h (mm)	22.1	22.5
Δh (mm)	2.9	2.5
v	1.833	1.866

} unload

$k = \frac{1.866 - 1.833}{\ln\left(\frac{100}{25}\right)} = 0.024$

$\sigma'_{v,max} \approx 90 kPa$

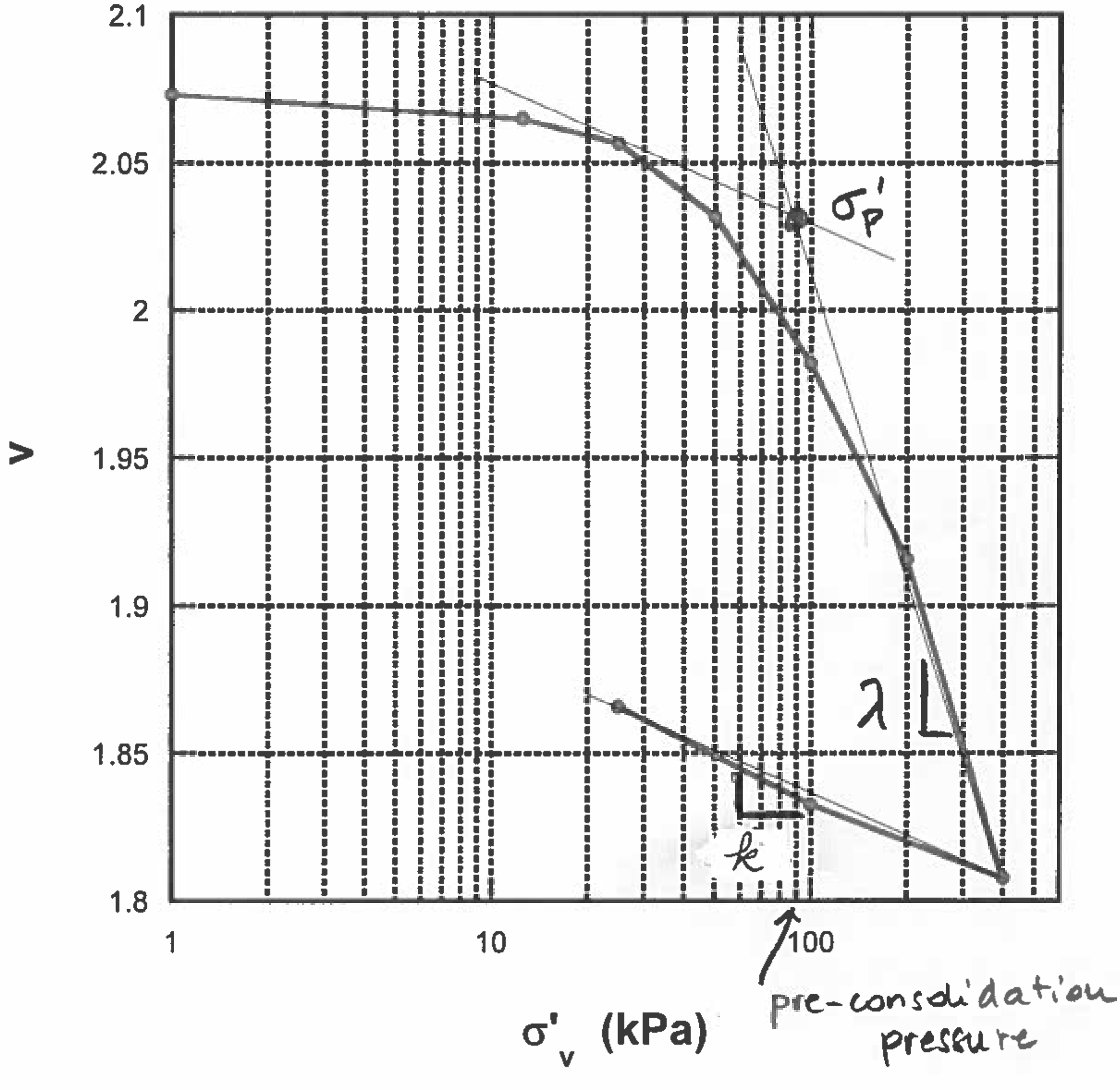
Estimate λ from increment from 200 kPa to 400 kPa

$\lambda = \frac{1.916 - 1.808}{\ln\left(\frac{400}{200}\right)} = 0.156$

$v_\lambda = v_{400} + \lambda \ln\left(\frac{400}{1}\right) = 1.808 + (0.156)\ln\left(\frac{400}{1}\right) = 2.743$

$\Gamma = v_\lambda - \lambda + k = 2.743 - 0.156 + 0.024 = 2.611$

11b/13


2.1
2.05
2
1.95
1.9
1.85
1.8
v
1
10
100
σ'v (kPa)
σp'
λ
k
pre-consolidation pressure

12/13

(b) $\gamma_T = \frac{G_s + Se}{1+e} \gamma_w = \frac{2.71 + 1.073}{2.073} (9.8 kN/m^3) = 17.9 kN/m^3$

$\sigma_v = (17.9 kN/m^3)(4m) + (9.8 kN/m^3)(0.5) = 76.5 kPa$

$u = (9.8 kN/m^3)(4.5m) = 44.1 kPa$

$\sigma'_v = 32.4 kPa$

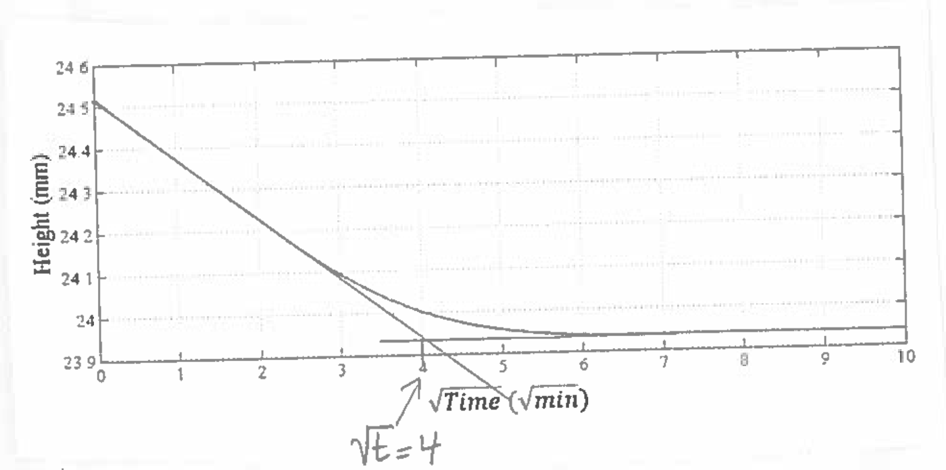
(c) $q = (20 kN/m^3)(5m) - (0.5)(9.8 kN/m^3) = 95.1$

$\sigma'_{vf} = 132.4 kPa$

$\Delta v = k \ln\left(\frac{90}{32.4}\right) + \lambda \ln\left(\frac{127.5}{90}\right) = 0.025 + 0.054 = 0.079$

$\Delta h = \frac{\Delta v}{v_0} h_0 = 0.31 \ m$

(d)



$C_v = \frac{3}{4}\frac{d^2}{t} = \frac{3}{4}\frac{(24.5 mm/2)^2}{16 min} = 7.03 \frac{mm^2}{min} \left(\frac{10^{-3}}{1mm}\right)^2 \left(\frac{60min}{1hr}\right)\left(\frac{24hr}{1day}\right) =$

$= 0.010 \frac{m^2}{day} = 3.7 \frac{m^2}{yr}$

$T = 0.848$ when $R_v = 0.9$

$t = \frac{(0.848)(4m)^2}{(3.7 m^2/yr)} = 3.67 yrs$

4yrs maybe too long to wait for starting construction. 13/13

It is possible to speed up construction by installing vertical drains, or by using a larger pre-load. Quite often estimates of cv are lower than in the field. A two-stage plan may be developed to monitor settlement in the first 6 months and assess whether the extra pre-load will be needed.

Q4 31 attempts,

This was the most popular question, with all students attempting it, and generally good results. The questions were the most similar to example papers and followed a pattern seen in other exams. Well prepared students were able to answer all the questions well. Some students struggled with basic concepts which are described in the data book.

ANSWERS

1. (a)(i) 2223 kg/m3, 14.1%; (a)(ii) 19.1 kN/m3; (c) 12.2 days.
2. (b) V = BSu(1+π/2+2α+1/(2 tan α)); (c) V/B = 4.484 BSu.
3. (a) FS = 1.49; (b) e = 0.262 m; (c) V = 638.3 kN/m, H = 139.8 kN/m.
4. (a) λ=0.156, κ=0.024, σ'p=90 kPa; (b) σ'v=32.4 kPa; (c) ρ=31 cm; (d) 3.67 years.