)

$G_s = 2.61 \qquad \gamma_b = 16.6 \ kN/m^3$

$\frac{G_s + e}{1+e} = 1.66 \qquad e = 1.44 \qquad v = 2.44$

$\sigma' = 99.5 \ kPa.$

$\Gamma + \lambda - \kappa - \lambda \ln \sigma_{max} + \kappa \ln \frac{\sigma_{max}}{\sigma} = 2.44$

$\rightarrow \sigma_{max} = 504 \ kPa$

b) $\sigma = 2.5 \times 6.6 = 16.5 \ kPa$

$\Delta v = \kappa \ln \frac{99.5}{16.5} = 0.090 \qquad V = 2.541$

$\epsilon_v = \frac{0.090}{2.44} = 0.0368 \rightarrow \rho_v = 184 mm$

c) $\sigma = 613.2 \ kPa > \sigma_{max} \Rightarrow$ n.c.l

$v = \Gamma + \lambda - \kappa - \lambda \ln(613.2)$

$= 2.308 \qquad \Delta v = 0.233$

$\epsilon_v = \frac{0.233}{2.541} = 0.0909$

$\rho = 0.455 \ m$

d) $C_{v_\kappa} = 1 m^2/yr$ so $C_{v_\lambda} = \frac{\kappa}{\lambda} = 0.19 \ m^2/yr$

$12\% \rightarrow \kappa \rightarrow T_v = 0.01 \quad R_v = 0.12 \quad t = 23$ days

$89\% \rightarrow \lambda \rightarrow T_v = 0.8 \quad R_v = 0.89 \quad t = 26$ yrs.

A popular question that was generally reasonably well handled, but many students assumed that the initial soil was normally consolidated and thus could not find a preconsolidation pressure. The data in the question and databook would allow the previous stress path to be found.

2.

ω =	2	4	6	8	10	12	14	16
ρ_b	1783	1857	1921	1974	2009	2020	2004	1982
ρ_d	1748	1786	1812	1828	1826	1804	1758	1709

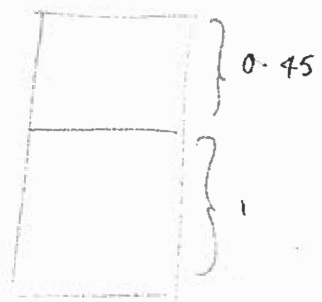
$\omega_{opt} \approx 9\%$ max dry density ~ 1830 kg/m^3

b) $G_s \sim 2.65$

$$\frac{2.65 \times 10}{1+e} = 1830 \qquad e = \underline{\underline{0.45}}$$

$$\omega G_s = 0.2385$$

$$S_r = \frac{0.2385}{0.45} = \underline{\underline{0.53}}$$



A popular question which was generally very well handled. Students showed a good understanding of the techniques involved. The only repeated mistake was optimizing for bulk density rather than dry density.

c) @ 4% dry of optimum. Strong + stiff, compacts fairly well but susceptible to wetting collapse when water rises

@ 14% decent dry density and will compact but fairly well saturated + soft. Plastic material is good if it can carry weight of construction plant.

Take 4% material + add water to $\underline{\sim 9\%}$

d) Quite big particle size so permeability a bit high for flood embankment. $k \sim 0.01 D_{10}^2 = \underline{\underline{10^{-5}}}$ m/s

Capillary rise $\frac{3\times10^{-5}}{3\times10^{-5}} = 1$m.

Top of embankment will dry out!

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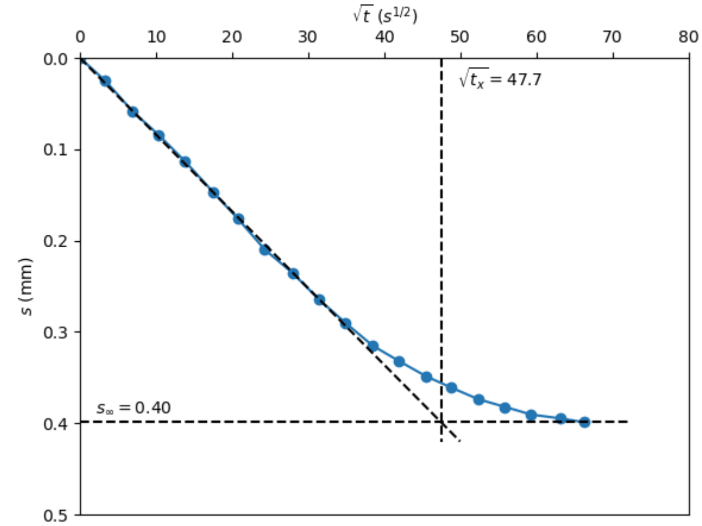
Q.3. Solved graphically:



[5%]

[5%]

$s_\infty = 0.40$ mm ; $\Delta\sigma' = 50$ kPa. ; $\sqrt{t_x} = 47.7$ s^{-1}

$h_i = 15.2$ m $\rightarrow$ $\bar{h} = 15.2 - \left(\frac{0.4}{2}\right) = 15.0$ mm [5%]

$\therefore L = 7.5$ mm (Double drained)

$$E_o = \frac{\Delta\sigma' 2L}{s_\infty} = \frac{50 \times 2 \times 7.5}{0.4} = 1875 \text{ kPa.}$$ [5%]

$$c_v = \frac{3L^2}{4t_x} = \frac{3 \times 7.5^2}{4 \times 2275 \times 1\times10^{-6}} = 1.85 \times 10^{-8} \text{ m}^2/\text{s}$$

$= 0.58$ m^2/yr [5%]

$$k = \frac{\gamma_w c_v}{E_o} = \frac{9.81 \times 1.85 \times 10^{-8}}{1875} = 9.7 \times 10^{-11} \text{ m/s}$$ [5%]

b. $$s_\infty = \frac{\Delta\sigma' h}{E_o} = \frac{100 \times 5}{1875} = 0.53 \text{ m}$$ [5%]

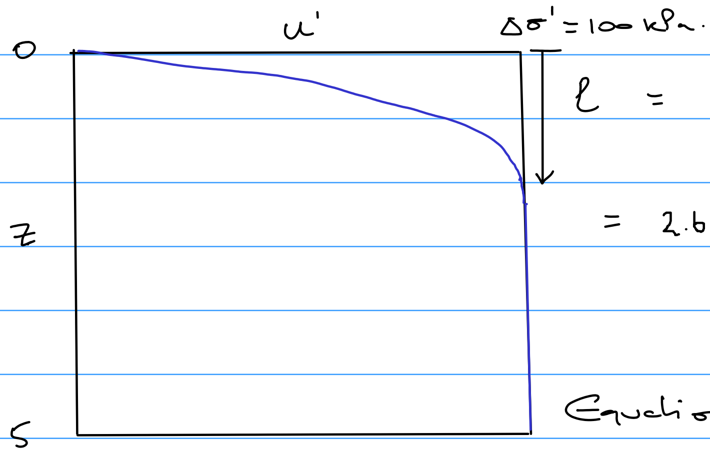
c. Problem could be single or double drained, therefore calculate both to create bounds on settlement at 1 year post - construction.

$$\tilde{T} = \frac{c_v t}{L^2} \rightarrow \begin{cases} \tilde{T} \leq 1/12 \rightarrow \text{Stage 1 (Penetrating isochrone)} \\ \tilde{T} \geq 1/12 \rightarrow \text{Stage 2 (Refracting isochrone)} \end{cases}$$

Single drained (surface): $\tilde{T} = \frac{0.58 \times 1}{5^2} = 0.023 \quad \therefore$ Stage 1 [5%]

$\tilde{S} = \frac{S}{S_\infty} = \sqrt{\frac{4\tilde{T}}{3}} = 0.176 \quad \therefore S = 0.046$ m [5%]

$= 46$ mm



$\ell = \sqrt{12 c_v t}$

$= 2.61$ m $\gg 1.0$ m $\therefore u' \ll 100$ kPa

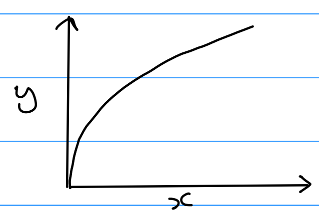
[5%]

Equation of parabola: $y^2 = 4ax$

$\rightarrow y = |L - z| \qquad x = u'_L - u'$

(Translate parabola direction)

[5%]



$\rightarrow (|L - z|)^2 = 4a(u'_L - u')$

Solve for a : @ z = 0

$\rightarrow 2.61^2 = 4a(u'_L - 0) \rightarrow 2.61^2 = 4a100$

$\therefore a = 0.017$ [5%]

Solve @ 1.0 m depth:

$(|L - 1|)^2 = 4 \times 0.017 \times (100 - u')$

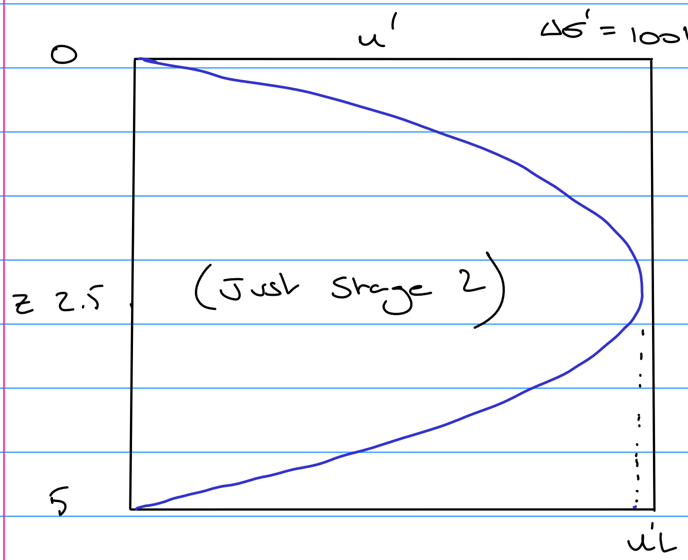
$\therefore u' = 62$ kPa. [5%]

Double drained (surface and base) : $\hat{T} = \dfrac{0.58 \times 1}{2.5^2} = 0.0928$ ∴ Stage 2

$$\tilde{S} = \frac{S}{S_\infty} = \sqrt{\frac{4\tilde{T}}{3}} = 0.353 \quad \therefore \; S = 0.094 \text{ m}$$

$$= 94 \text{ mm.}$$

[5%]



At mid-depth :

$$\tilde{u}_L = \exp\left[-3\left(\hat{T} - 1/12\right)\right]$$

$$= \exp\left[-3\left(0.09 - 1/12\right)\right]$$

$$= 0.98$$

$$\therefore \; u'_L = 0.98 \times 100$$

$$= 98 \text{ kPa.}$$

[5%]

Solve for a : @ $z = 0$

$$\rightarrow 2.5^2 = 4a\left(u'_L - 0\right) \rightarrow 2.5^2 = 4a98$$

$$\therefore \; a = 0.016$$

[5%]

Solve

@ 1.0 m depth :

$$\left(L - 1\right)^2 = 4 \times 0.016 \times \left(98 - u'\right)$$

$$\therefore \; u' = 63 \text{ kPa.}$$

[5%]

Total Settlement : $46 \text{ mm} \leq S \leq 94 \text{ mm}$

(Excess) Pore pressure : $63 \text{ kPa} \leq u' \leq 63 \text{ kPa}$

d. The drainage conditions (single vs. double drained) are a significant uncertainty. The depth from which the oedometer sample was taken raises questions about whether it is representative of the full 5m layer depth. Effects of creep and loading increment duration in the oedometer test provides a further source of uncertainty. Finally, the parabolic isochrone solution used above is an approximation. Any three [15%]

This was the most difficult question on the paper, mainly because students found it difficult to estimate the excess pore pressure at 1m depth after 1 year. Many attempted to use linear approximation whereas manipulation of a parabola was what was being sought.

Q.4 a. $\gamma' = 10\ kN/m^3$; $\phi' = 33°$

$B = 10m$; $L = 20m \longrightarrow \frac{B}{L} = \frac{1}{2}$ [5%]

$h = 1m$

$\sigma'_{vo} = h\gamma' = 10\ kPa.$ [5%]

Shape Factors

$s_q = 1 + \frac{B}{L}\sin\phi' = 1 + \frac{1}{2}\sin\phi' = 1.272$ [5%]

$s_\gamma = 1 - 0.3\frac{B}{L} = 1 - 0.3 \times \frac{1}{2} = 0.85$ [5%]

Bearing Capacity Factors.

$N_q = \tan^2\left(\pi/4 + \phi'/2\right)\exp\left(\pi\tan\phi'\right)$ [5%]

$= 26.09$

For EC7 : $N_\gamma = 2\left(N_q - 1\right)\tan\phi'$ [5%]

$= 32.59$

Bearing Capacity

$q_f = s_q N_q \sigma'_{vo} + s_\gamma N_\gamma \frac{\gamma' B}{2}$

$= 1.272 \times 26.09 \times 10 + 0.85 \times 32.59 \times \frac{10 \times 10}{2}$

$= 1716.9\ kPa$ [10%]

b. Corner settlement for a flexible foundation:

$$w_{corner} = \frac{(1-\nu)}{G} q \frac{B}{2} I_{rect}. \qquad [5\%]$$

Centre settlement for a flexible foundation by superposition.

Centre / corner settlement for a rigid foundation:

$$w_{rgd} = \frac{(1-\nu)}{G} \bar{q} \frac{\sqrt{BL}}{2} I_{rgd}. \qquad [5\%]$$

$$G = \frac{E}{2(1+\nu)} = \frac{5{,}000}{2(1+0.25)} = 2{,}000 \text{ kPa}. \qquad [5\%]$$

$\frac{L}{B} = \frac{20}{10} = 2$ → $I_{rect} = 0.766$ } databook [5%]

→ $I_{rgd} \approx 0.9$ [5%]

Flexible: $w_{corner} = \frac{(1-0.25)}{2{,}000} \frac{100 \times 10}{2} \times 0.766$

$= 0.142 \text{ m} = 142 \text{ mm}$ [5%]

$w_{center} = 4 \times \frac{(1-0.25)}{2{,}000} \frac{100 \times 5}{2} \times 0.766$

$= 0.28 \text{ m} = 280 \text{ mm}$ [5%]

Rigid: $w_{rgd} = \frac{(1-0.25)}{2{,}000} \frac{100 \times \sqrt{10 \times 20}}{2} \times 0.9$

$= 0.24 \text{ m} = 240 \text{ mm}$ [5%]

$\therefore \Delta w_{min} = 142 \text{ mm}$ and $\Delta w_{max} = 280 \text{ mm}$

c. Settlement greater than 75mm can be problematic for foundations on sand (Poulos et al. 2001) with respect to the connection of services (eg. water), hence not even the flexible assumption satisfies this general guidance by some distance! [5%] However, even such a flexible foundation will suffer from differential settlement, which may cause structural damage: [5%]

$$\Delta w = \Delta w_{centre} - \Delta w_{corner}$$

$$= 280 - 142 = 138 \text{ mm} \quad [5\%]$$

$$138 \text{ mm} \gg \frac{B}{150} \; (= 66 \text{ mm}) \quad [5\%]$$

Students found this question straightforward in spite of the fact it was selected by less than half of the candidates. The most significant issue was in understanding the influence and problems associated with excessive building settlement where some quantitative comparisons were desired whereas most students only provided qualitative analyses.