4D9 2024 Exam Solutions SAS229

Q.1. a. Soft fine-grained sediments of strength increasing roughly linearly with depth. This is because only the fine-grained deposits that end up in the water column due to depositional processes are likely to be carried out to such depths. Larger particles will fall out of suspension in shallower waters. [15%]

b. Sand ripples and waves in shallower water on the continental shelf. Canyons, gullies, slide deposits and debris flows on the slope of the continental shelf. Scour in shallower waters on the continental shelf. Pockmarks, mud volcanos and debris fields at the base of the escarpment. [Any 3 : 15%]

c. $\alpha = \frac{A_{shoulder}}{A_{shaft}} = \frac{4\pi D_s^2}{4\pi D^2} = \frac{30^2}{35.7^2} = 0.71$ [10%]

d. Place the cone in a calibration chamber and measure the cone resistance as the pressure is increased. Calculate the correction factor by dividing the measured cone resistance by the applied pressure. [10%]

e. Governing equations:

$$Q = \frac{q_{net}}{\sigma'_{vo}} = \frac{q_{net}}{\gamma' z} \qquad F = \frac{f_s}{q_{net}} \times 100 \qquad B_q = \frac{\Delta u_2}{q_{net}} = \frac{(u_2 - u_0)}{q_{net}}$$

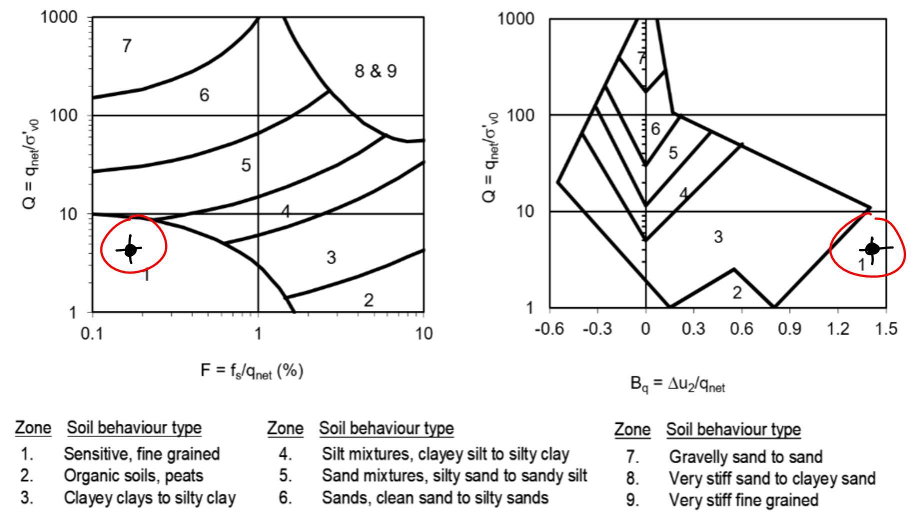
$$q_t = q_c + ((1-\alpha)u_2) = 600 + ((1-0.7)\times 1020) = 895.8 \text{ kPa}$$ [5%]

$$q_{net} = q_t - \sigma_v = q_t - \gamma z = 895.8 - (16 \times 20)$$
$$= 575.8 \text{ kPa.}$$ [5%]

$$Q = \frac{q_{net}}{\sigma'_{v0}} = \frac{575.8}{(16-10) \times 20} = 4.65$$ [5%]

$$F = \frac{f_s}{q_{net}} = \frac{1.0}{575.8} \times 100 = 0.17$$ [5%]

$$B_q = \frac{\Delta u_2}{q_{net}} = \frac{u_2 - u_0}{q_{net}} = \frac{1020 - (20 \times 9.81)}{575.8} = 1.43$$ [5%]



[5%]

Soil type 1: sensitive fine-grained, as expected.

f. Specify some element tests (e.g. simple shear or triaxial) at various depths and use the measurements to calibrate Nkt such that the cone analysis and element test measurements match. [10%]

g. The cone is influenced by the depth of the water column since the cone resistance measured will rise as the cone is lowered to the seabed. This limits the sensitivity of the cone which is problematic when trying to measure the undrained shear strength of weak sediments such as soft clays. [10%]

Q.2. $Q = \left(N_c s_u + \gamma' z\right) A_b + \alpha s_u A_s$

$A_s = A_i + A_e$

$A_e = \pi D L = \pi \times 4 \times 20 = 251.3 \ m^2$ [5%]

$D_i = D - 2t_w = 4 - (2 \times 0.05) = 3.9 \ m$ [5%]

$A_i = \pi D_i L = \pi \times 3.9 \times 20 = 245.0 \ m^2$ [5%]

$A_b = \frac{\pi}{4}\left(D^2 - D_i^2\right) = \frac{\pi}{4}\left(4^2 - 3.9^2\right) = 0.62 \ m^2$ [5%]

$S_{u\,rem} = \frac{16}{S_t} = \frac{16}{4} = 4 \ kPa.$ [5%]

$$\therefore Q = \underbrace{\left((7.5 \times 16) + (6 \times 20)\right) \times 0.62}_{\text{Base.}} + \underbrace{0.3 \times 16 \times 251.3}_{\text{Outer shaft}} + \underbrace{0.3 \times 4 \times 245.0}_{\text{Inner shaft.}}$$

$= 148.8 + 1206.24 + 301.56 = 1656.6 \ kN.$ [15%]

b. Factor of safety against plug failure.

$Q_{plug} = \frac{\pi D_i^2}{4} \times N_c \times S_u + \alpha \times S_{u\,rem} \times A_i$

$= \frac{\pi \times 3.9^2}{4} \times 9 \times 16 + 0.3 \times 4 \times 245.0 = 2014.2 \ kN$ [10%]

$F = \frac{Q_{plug}}{Q - W'} = \frac{2014.2}{1656.6 - 500} = 1.74 \ \therefore$ ok. [10%]

c. Solve for unknown z given $W' = Q$:

$Q = W' = \left(N_c S_u + \gamma' z\right) A_b + \alpha S_u \pi D + \alpha S_{u\,rem} \pi D_i$ [5%]

$\therefore 500 = \left(7.5 \times 16 + \gamma' z\right) 0.62 + 0.3 \times 16 \times \pi \times 4 \quad 0.3 \times 4 \times \pi \times 3.9$

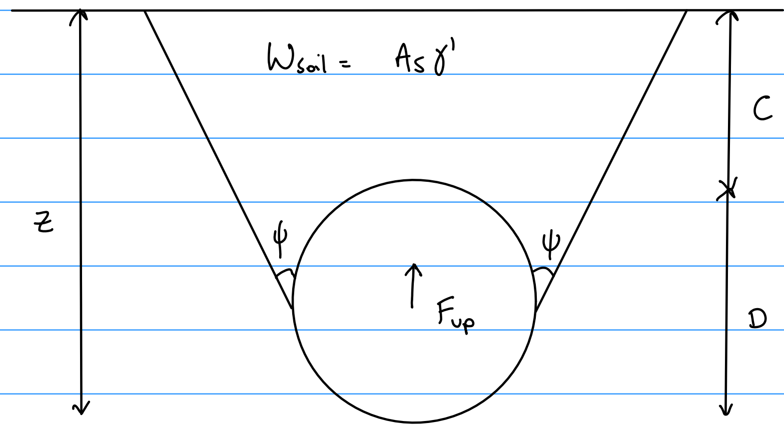
$= 74.4 + 3.72 z + 60.31 z + 14.7 z$ [10%]

$\therefore 425.6 = 78.73 z \rightarrow z = 5.41 \ m$ [5%]

d. The internal stiffeners may not cause complete remoulding of the soil, leading to an underestimate of Q. This is somewhat compensated for by Q_{plug} being overestimated for the same reasons, but this calculation is fairly sensitive to this assumption. [10%]

e. The anchor padeye should be positioned such that the resultant angle of pull at the padeye causes no rotation of the suction caisson upon loading. To ensure this one would need to solve for the optimal padeye depth using a "chain" solution such as provided by Neubecker and Randolph in order to determine the resultant pull angle on the mooring, whilst ensuring the restoring moments at the padeye are balanced. [10%]

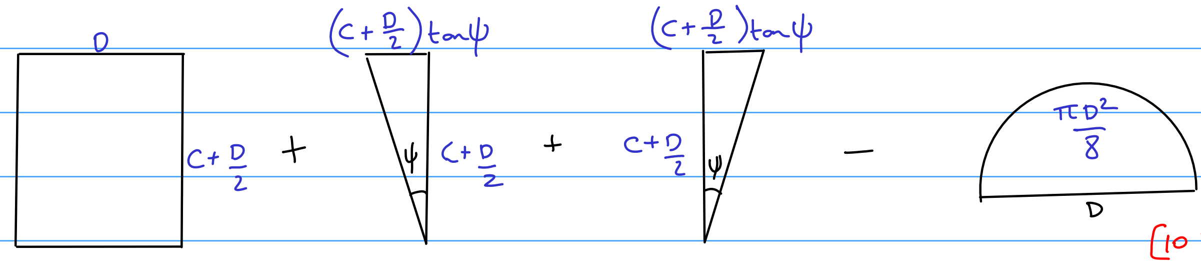
3.



[10%]

Lower bound : $F_{up} = W_{soil} = A_s \gamma' + (SG-1)\dfrac{\pi D^2}{4}\gamma_w$ (1)

$A_s =$



[10%]

$$A_s = \left(C+\frac{D}{2}\right)D + \left(C+\frac{D}{2}\right)\left(C+\frac{D}{2}\right)\tan\psi - \frac{\pi D^2}{8}$$

$$= CD + \frac{D^2}{2} + \left(C+\frac{D}{2}\right)^2 \tan\psi - \frac{\pi D^2}{8}$$

$$= CD + \frac{D^2}{2}\left(1-\frac{\pi}{4}\right) + \left(C+\frac{D}{2}\right)^2\tan\psi$$ → sub into (1) Q.E.D.

[10%]

b. (1) $p' \approx \gamma' z = 10 \times \left(C+\frac{D}{2}\right) = 10 \times 0.75 = 7.5$ kPa

[5%]

(2) $p' \approx \dfrac{(1+K_0)}{2}\gamma' z$ where $K_0 = 1-\sin(\phi_{cs})$

$= 0.455$

$\approx \dfrac{(1+0.455)}{2}\gamma' z = 5.45$ kPa.

$I_R = \min\left(I_D(Q - \ln p') - 1,\ 4\right)$ and $\psi = \dfrac{5 I_R}{0.8}$

$$\left.\begin{array}{l} I_R \text{ (1)} = 3.79 \rightarrow \psi = 23.7^\circ \\ I_R \text{ (2)} = 3.98 \rightarrow \psi = 24.9^\circ \end{array}\right\} \text{Either acceptable}$$

[5%]

$$A_s = CD + \frac{D^2}{2}\left(1 - \frac{\pi}{4}\right) + \left(C + \frac{D}{2}\right)^2 \tan\psi$$

$$= 1 \times 0.5 + \frac{0.5^2}{2}\left(1 - \frac{\pi}{4}\right) + \left(1 + \frac{0.5}{2}\right)^2 \tan\psi$$

$$= 0.5 + 0.026 + 1.5625 \tan\psi$$ [10 %]

① $A_s = 1.21 \ m^2$

$\therefore F_{up} = 1.21 \times 10 + (3-1)\frac{\pi\, 0.25^2}{4} 10$

$= 13.08 \ kN/m$

Either ① or ②

② $A_s = 1.25 \ m^2$

$\therefore F_{up} = 1.25 \times 10 + (3-1)\frac{\pi\, 0.25^2}{4} 10$

$= 13.57 \ kN/m$ [10 %]

c. The mean effective stress p' is taken as that at rest (either vertical ① or K_0 approximated ②). This is very likely to be an under-estimate of p' at failure, which will lead to a corresponding over-estimation of ψ and thus A_s and eventually F_{up}. [10 %]

Measurement of Q and I_D are also likely to be subject to significant errors in practice and the calculation of I_R and thus ψ will be very sensitive to those issues at such low effective stress levels. [10 %]

Finally, the assumption that no shear is done within the shear bands that emanate from the cable to the soil surface is highly questionable and will lead to a significant underestimate of F_{up}. [10 %]

d. ① Rock dumping above the cable pathway [5 %]

② Concrete mattresses laid over the cable pathway [5 %]

4. a. $s_u = s_{um} + kz = 2 + 20 \times 1 = 22\ kPa.$ [5%]

$A_f = 5 \times 5 = 25\ m^2$ [5%]

$N_c = 12$ [5%]

$T_a = N_c A_f s_{u\,mob} = 12 \times 25 \times 22 = 6{,}600\ kN$ [5%]

b. $\frac{T_a}{2}\left(\theta_a^2 - \theta_m^2\right) = z_a Q_{av}$ – Governing eqn.

$z_a Q_{av} = b N_c \int_0^{z_a} s_u \, dz$ → $b = 2.5d = 0.25$, $N_c = 7.6$

$= b N_c \int_0^{z_a} s_{um} + kz \, dz$

$= 0.25 \times 7.6 \times 240$

$= 456\ kNm$ [10%]

$\theta_m = 0$ hence. $\frac{T_a}{2} \theta_a^2 = z_a Q_{av.} - w$ (chain weight)

$\therefore \theta_a = \sqrt{\frac{2 \times 454}{6{,}600}} = 0.37\ (21.2°)$ [5%]

$\frac{T_m}{T_a} = e^{\mu(\theta_a)}$

$A_b = 2.5\ d_{bar}$ and $A_s = 8.0\ d_{bar}$ [5%]

$\mu = \frac{F}{Q} = \frac{A_s \alpha s_u}{A_b N_c s_u} = \frac{8.0\alpha}{2.5 N_c} = \frac{8 \times 0.3}{2.5 \times 7.6} = 0.12$ [5%]

$\therefore T_m = 6{,}600\, e^{0.12(0.37)} = 6{,}899\ kN$ [5%]

c. $z^* = e^{x^* \theta_a}$ where $z^* = \dfrac{z}{z_a}$ and $x^* = \dfrac{x}{z_a}$ [5%]

Solve for x taking $z \simeq 2.5\,d_{bar}$ (Chain just breaking through mudline...)

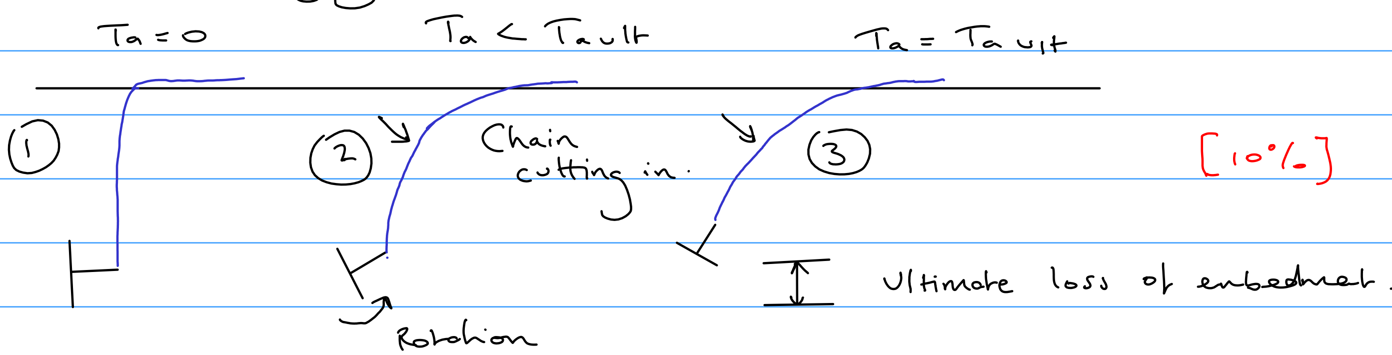
$$\frac{0.25}{20} = e^{\frac{x}{z_a}\theta_a}$$

$$\ln\left(\frac{0.25}{20}\right) = \frac{x}{z_a}\theta_a \quad \therefore \quad |x| = \left|\ln\left(\frac{0.25}{20}\right)\frac{z_a}{\theta_a}\right|$$

$$= 236.8 \text{ m}$$ [5%]

Chain breaks through mudline ~237 m from anchor padeye.

d. Anchor keying process:



[10%]

At stage ① the anchor is not loaded and the mooring chain exits near vertically. [5%]

At stage ② increased mooring line loads cause the chain to "cut" into the seabed. The anchor begins to be loaded and rotates due to the shank offset. [5%]

At stage ③ the line of action of mooring loads is inline with the shank. Some "loss of embedment" has occurred. [5%]

The "loss of embedment" on keying reduces S_u and thus T_a, therefore reducing the overall capacity of the system. [5%]