Ministry of Higher Education
& Scientific Research
Tikrit University
College of Engineering
Civil Eng. Dept.

Class: Third
Subject: Soil Mechanics
Time: Three hours
Date: ١٥/ ٦ / ٢٠١٧

Final Exam/١st Attempt
٢٠١٦-٢٠١٧

Form (١)

Note : Attempt (٤) quations only

(Q١-A) An unconfined compression test has given unconfined compression strength of ١٢٦.٦ kN/m٢. In CD test the effective shear strength parameters are c′ = ٢٥ kN/m٢ and ϕ′ = ٣٠°. If the pore pressure parameter A = - ٠.٠٩. Calculate the initial pore pressure in the saturated sample. ***(١٥ marks)***

Solution

$\sigma'_{1f} = \sigma'_{3f} \tan^2(45+\phi/2) + 2c\tan(45+\phi/2)$

$\therefore \sigma'_{1f} = \sigma'_{3f} \tan^2(45+30/2) + 2*25\tan(45+30/2)$

$\sigma'_{1f} = 3\sigma'_{3f} + 86.6$ --- ①

From unconfined compression test

$\sigma'_1 - \sigma'_3 = (126.6 - 0) \Rightarrow \sigma'_{1f} = \sigma'_{3f} + 126.6$ --- ②

Solving the above equations

$\sigma'_{3f} + 126.6 = 3\sigma'_{3f} + 86.6 \Rightarrow \sigma'_{3f} = 20\ kN/m^2$

In unconfined compression test $\Delta\sigma_3$ = zero $\therefore u = -20\ kN/m^2$

and $\Delta u = B[\Delta\sigma_3 + A(\Delta\sigma_1 - \Delta\sigma_3)]$

for saturated soil $B = 1$

$\therefore A = \frac{\Delta u}{\sigma_1 - \sigma_3} = \frac{\Delta u}{\sigma'_1 - \sigma'_3}$

$\therefore -0.09 = \frac{\Delta u}{126.6} \Rightarrow \Delta u = -11.4\ kN/m^2$

The initial p.w.p is

$u_i = -20 - (-11.4) = \underline{\underline{-8.6}}\ kN/m^2$ Ans

(Q١-B) drive the equation of the one dimensional consolidation in soil ***(١٠ marks)***

Solution

The first assumption.The continuity equation is

$$k_z \frac{\partial^2 h}{\partial z^2} + k_x \frac{\partial^2 h}{\partial x^2} = \frac{1}{1+e}\left(e\frac{\partial S}{\partial t} + S\frac{\partial e}{\partial t}\right)$$

Where

z: coordinate in the vertical direction

x: coordinate in the horizontal direction

k_x, k_z: coefficient of permeability in x and z-direction

e: void ratio

h: total head

S: degree of saturation

t: time

due to the second assumption $S = 1$ and $\partial S/\partial t = 0$.

for the third assumption

$$k\frac{\partial^2 h}{\partial z^2} = \frac{1}{(1+e)}\frac{\partial e}{\partial t}$$ Continuity equation …(١)

$$\sigma_v = \gamma_t z + \text{surface stress}$$ Equilibrium equation …(٢)

$$\frac{\partial e}{\partial \bar{\sigma}_v} = -a_v$$ Stress – strain ……(٣)

Where a_v is coefficient of compressibility

Breaking the total head into its components

$$h = h_e + \frac{u}{\gamma_w} = h_e + \frac{1}{\gamma_w}(u_{ss} + u_e)$$

Where: h_e: elevation head

u_{ss}: steady state pore pressure

u_e: excess pore pressure

we have $\frac{\partial^2 h_e}{\partial z^2} = 0$ $\frac{\partial^2 u_{ss}}{\partial z^2} = 0$

so

$$\frac{k(1+e)}{\gamma_w a_v}\frac{\partial^2 u_e}{\partial z^2} = -\frac{\partial \bar{\sigma}_v}{\partial t}$$

if

$$c_v = \frac{k(1+e)}{\gamma_w a_v} = \frac{k}{\gamma_w m_v}$$

where m_v: is the coefficient of volume change

c_v : coefficient of consolidation

$$c_v \frac{\partial^2 u_e}{\partial z^2} = \frac{\partial u_e}{\partial t} - \frac{\partial \sigma_v}{\partial t}$$

If total stress is constant with time $\frac{\partial \sigma_v}{\partial t} = 0$

The initial excess pore pressure is uniform with depth

There is a drainage at both top and bottom of the consolidation stratum

Let H_{dr} is length of maximum drainage bath and $T = \frac{c_v t}{H^2}$ where T is time factor

$\frac{\partial^2 u_e}{\partial Z^2} = \frac{\partial u_e}{\partial T}$ Solving this equation satisfying the following condition

Initail condition at t = ٠ , $u_e = u_o$ for ٠ ≤ ≤ ٢, u_o = initial $\frac{z}{H_{dr}}$ excess p.w.p

Boundary condition at all t

u_e = ٠ for $\frac{z}{H_{dr}}$ =٠ and ٢, the solution of this equation is

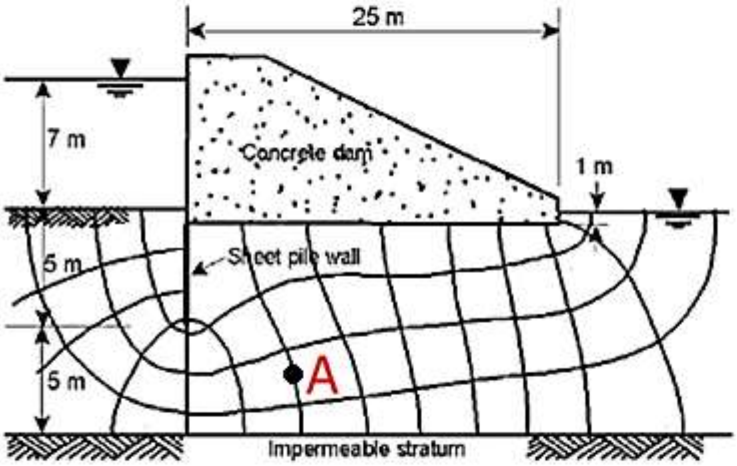
$$u_e = \sum_{m=0}^{m=\infty} \frac{2u_0}{M}(\sin MZ)e^{-M^2T} \quad \text{where} \quad M = \frac{\pi}{2}(2m+1)$$

m: is dummy variable taking on values ١, ٢, ٣, ٤ .....

The solution is conveniently portrayed in the graph (Isochrones) as shown

$$U_z = 1 - \frac{u_e}{u_0}$$

(Q٢-A) The concrete dam ٢٥ m long shown in Figure is embedded ١ m into the ground surface and has a sheet pile wall ٥ m deep at its heel. The headwater is ٧ m deep and the tail water is at ground surface. The permeability of the soil is k=٢٠x١٠-٤ cm/sec both vertically and horizontally. Calculate the seepage under the dam and the Pore Water pressure at A; A is ٢m above the impervious layer. ***(١٢ marks)***



Solution

$h = 7^m$, $N_f = 4$, $N_d = 13$; $H = 10$

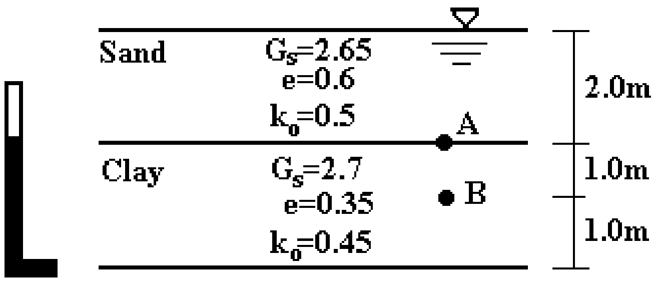
Pressure head per net $= 7/13 = 0.54$

Pressure head at $A = h + H - ($No. of potential at $A *$ Pressure head per net$) - z$

$= 7 + 10 - (6.5 * 0.54) - 2 = 11.49^m$

Pore Water pressure at $A = 11.49 * 9.81 = \underline{112.717}\ kN/m^2$

(Q٢-B) Compute the vertical and horizontal effective and total stresses at A and B for the profile shown ***(١٣ marks)***



3 Let k sand = k clay

$q_{soil\,sand} = q_{soil\,clay}$

$kAi_{sand} = kAi_{clay}$

$\frac{\Delta h}{l}_{sand} = \frac{\Delta h}{l}_{clay} \Rightarrow \frac{4 - h_{tA}}{2} = \frac{h_{tA} - 2}{2}$

$2h_{tA} = 6 \therefore h_{tA} = 3^m$

h_p @ $A = 3 - 2 = 1^m$

h_p @ $B = 2.5 - 1 = 1.5^m$

$\gamma_{t\,sand} = \frac{G + Se}{1 + e}\gamma_w = \frac{2.65 + 0.6}{1 + 0.6} * 9.81 = 19.927\ kN/m^3$

$\gamma_{sat\,clay} = \frac{2.7 + 0.35}{1 + 0.35} * 9.81 = 22.163\ kN/m^3$

$\sigma_{vA} = 19.927 * 2 = 39.854\ kN/m^2$ $\sigma'_{vA} = 39.854 - 9.81 = 30.044\ kN/m^2$

$\sigma'_{hA} = 30.044 * 0.5 = 15.022\ kN/m^2$ $\sigma_{hA} = 15.022 + 9.81 = 24.832\ kN/m^2$

$\sigma_{vB} = 39.854 + 1 * 22.163 = 62.017\ kN/m^2$

$\sigma'_{vB} = 62.017 - 1.5 * 9.81 = 47.302\ kN/m^2$

$\sigma'_{hB} = 47.302 * 0.45 = 21.286\ kN/m^2$

$\sigma_{hB} = 21.286 + 1.5 * 9.81 = 36.009\ kN/m^2$

(Q٣-A) A direct shear box test was conducted on a sample of sand , gave the following observations at the time of failure , normal stress = ٨٠kN/m٢; shear stress = ٤٨kN/m٢ . Determine :

(a) the angle of internal friction;
(b) the magnitude and direction of principle stress in the zone of failure;
(c) the magnitude of maximum deviator stress if a sample of the same sand with the same void ratio were tested in the UU test with an all round pressure of ٥٨ kN/m٢. ***(١٥ marks)***

Solution

(a) $\phi = \tan^{-1}\left(\frac{\tau}{\sigma_n}\right) = \tan^{-1}\left(\frac{48}{80}\right) = 31^\circ$

(b) $\theta = 45 + \phi/2 = 45 + \frac{31}{2} = 60.5^\circ$

$\sigma_n = \frac{\sigma_1 + \sigma_3}{2} + \frac{\sigma_1 - \sigma_3}{2} \cos(121)$

$80 = \frac{\sigma_1 + \sigma_3}{2} + \frac{\sigma_1 - \sigma_3}{2}(-0.515)$ --- ①

$\tau = \frac{\sigma_1 - \sigma_3}{2} \sin 2\theta \Rightarrow 48 = \frac{\sigma_1 - \sigma_3}{2}(0.857)$

$\therefore 112 + \sigma_3 = \sigma_1$

$\therefore 80 = \frac{112 + \sigma_3 + \sigma_3}{2} + \frac{112 + \sigma_3 - \sigma_3}{2}(-0.515)$

$80 = 56 + \sigma_3 - 28.84$

$\therefore \sigma_3 = 52.8$ kN/m²

$\sigma_1 = 112 + 52.84 = 164.84$ kN/m²

(c) $\sigma_1 = \sigma_3\left(\frac{1+\sin\phi}{1-\sin\phi}\right)$

$\sigma_1 = \sigma_3\left[\frac{1+\sin 31}{1-\sin 31}\right] = 58 * 3.124 = 181.19$ kN/m²

$\therefore \sigma_d = \sigma_1 - \sigma_3 = 123.194$ kN/m²

(Q٣-B) Dry soil with G_S = ٢.٧١ is mixed with ١٦٪ by weight of water and compacted to produce a cylinder samples of ٣٨ mm diameter and ٧٦ mm long with ٦٪ air content. Calculate the mass of the mixed soil that will be required and the void ratio of the sample. ***(١٠ marks)***

$V = 7.6 * \frac{\pi (3.8)^2}{4} = 86.19\ cm^3$ $\quad \gamma_s = G_s \gamma_w = 2.71 * 9.81 = 26.585\ kN/m^3$

$V_s = V_w + V_a = 86.19\ cm^3 = 8.619 * 10^{-5}\ m^3$

$\frac{W_s}{26.585} + \frac{0.16 W_s}{9.81} + 0.06 * 8.619 * 10^{-5} = 8.619 * 10^{-5}$

$\therefore W_s = 0.0015014\ kN,$

$W_s = V_s * \gamma_s = V_s * G * \gamma_w$

$0.0015014 = V_s * 2.71 * 9.81$

$\therefore V_s = \underline{\underline{5.648 * 10^{-5}\ m^3}}$

$V_v = V - V_s = 8.619 * 10^{-5} - 5.648 * 10^{-5}$

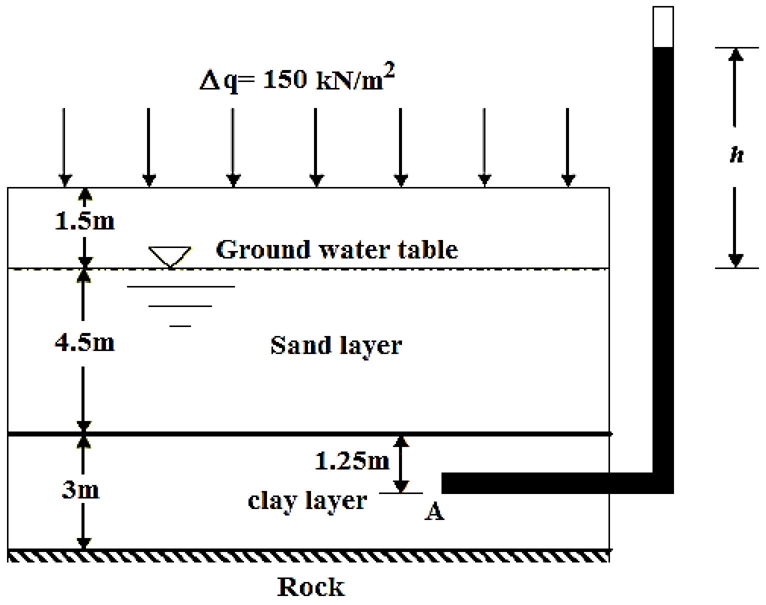
$= 2.971 * 10^{-5}$

$e = V_v / V_s = \frac{2.971 * 10^{-5}}{5.648 * 10^{-5}} = \underline{\underline{0.526}}$

(Q٤-A) For the profile shown :

(a) How high (h) will the water rise in the piezometer immediately after the application of the surface load of ١٥٠ kN/m٢.

(b) Find the increment of effective stress in point (A) due to application of ١٥٠ kN/m٢ after ٤ months, c_v = ٨.٦٨*١٠-٤ cm٢/sec



(١٥ marks)

Solution

(a) The hight in pezometer is
(١٥٠/٩.٨١) – ٤.٥ – ١.٢٥ = ٩.٥٤m
(b)

$T = \frac{C_v t}{H^2}$, $C_v = 8.68 * 10^{-4}\ cm^2/sec$
$t = 4 * 30 * 60 * 60 = 10368000\ sec$
$H = 1.25 * 100 = 125\ cm$

$T = \frac{8.68 * 10^{-4} * 10368000}{(125)^2} = 0.576$

$\frac{z}{H_{dr}} = \frac{1.25}{3} = 0.4167$

From chart $U = 0.78$

incrment in stress $= 150 * (1 - 0.78) = 33\ kN/m^2$

(Q٤-B) Defined: liquid limit, pressure head, consistency, Residual soils, equipotential lines ***(١٠ marks)***

liquid limit: is the moisture content in percent at which the soil changes from liquid to plastic state

Pressure head: is the height of the vertical column of water in the piezometer installed at that point

Consistency: Soil consistency is the strength with which soil materials are held together or the resistance of soils to deformation and rupture.. Soil consistency may be estimated in the field using simple tests or may be measured more accurately in the laboratory.

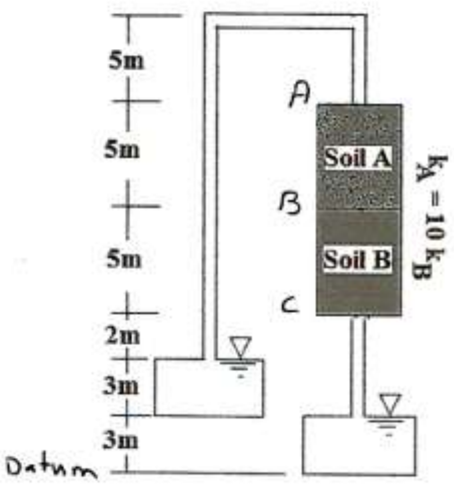
Residual soils: the soils formed by the weathered products at their place of origin

Equipotential lines: is a line along which the potential (total) head at all points is the same

(Q٥-A) For the setup shown, Find total head (h_t), Elevation head (h_e) and Pressure head (h_p) for the soil the setup shown

(١٥ marks)

Solution



$q_A = q_B$

$k\,a\,i)_A = k\,a\,i)_B$

$k_A * \cancel{a} * \frac{\Delta h_{tA}}{\cancel{L}} = k_B * \cancel{a} * \frac{\Delta h_{tB}}{\cancel{L}}$

$10\,\cancel{k_B}\,\Delta h_{tA} = \cancel{k_B}\,\Delta h_{tB}$

$10 * \left(6 - h_{tB}\right) = \left(h_{tB} - 3\right)$

$-10 h_{tB} + 60 = h_{tB} - 3$

$11 h_{tB} = 63 \quad \therefore h_{tB} = 5.73^{m}$

	h_e	h_p	h_t
A	18	-12	+6
C	8	-5	+3
B	13	-7.27	5.73

(Q٥-B) A soil element is subjected to an initial stresses P_o = ٤٠٠ kN/m٢ and q =٠. Compute the value of σ_h at σ_v = ٦٠٠ kN/m٢ for the following:

(A) If the stresses increased such that $\Delta\sigma_v$ = ٣$\Delta\sigma_h$

(B) $\Delta\sigma_v$ = ٠ ***(١٠ Marks)***

$T = \frac{C_v t}{H^2}$, $C_v = 8.68 * 10^{-4}$ cm²/sec
$t = 4 * 30 * 60 * 60 = 10368000$ sec
$H = 1.25 * 100 = 125$ cm

$T = \frac{8.68 * 10^{-4} * 10368000}{(125)^2} = 0.576$

$\frac{z}{H_{dr}} = \frac{1.25}{3} = 0.4167$

From chart $U = 0.78$

increment in stress $= 150 * (1 - 0.78) = 33$ kN/m²

(A) $\Delta p = \frac{\Delta\sigma_v + \Delta\sigma_h}{2} = \frac{3\Delta\sigma_h + \Delta\sigma_h}{2} = 2\Delta\sigma_h$

$\Delta q = \frac{\Delta\sigma_v - \Delta\sigma_h}{2} = \frac{3\Delta\sigma_h - \Delta\sigma_h}{2} = \Delta\sigma_h$

$\therefore \frac{\Delta q}{\Delta p} = \frac{1}{2}$

$\frac{q - 0}{p - 400} = \frac{1}{2} \Rightarrow q = 0.5p - 200$

$\therefore \frac{600 - \sigma_h}{2} = 0.5 \frac{600 - \sigma_h}{2} - 200$

$\therefore \sigma_h = 1350$

(B)

$\Delta\sigma_v = 0$

$\Delta p = \frac{0 + \Delta h}{2}$, $\Delta q = \frac{0 - \Delta h}{2}$

$\frac{\Delta q}{\Delta p} = -1$

$\therefore \Delta q = -\Delta p$

$\frac{600 - \sigma_h}{2} = -\frac{600 - \sigma_h}{2}$

$300 - \frac{\Delta\sigma_h}{2} = -300 + \frac{\Delta\sigma_h}{2}$

$\sigma_h = \infty$