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ثالث مدني
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Consolidation

Ex 1 Over a soil layer having an initial void ratio = 1.04 and thickness 9^m; a building is constructed and it is estimated that the final void ratio after construction shall be 0.98. What total settlement may be expected ultimately after sufficient time?

Solution: $e_o = 1.04$, $e_f = 0.98$, $H = 9^m$

$$S_{cf} = \frac{\Delta e}{1+e_o} H = \frac{e_o - e_f}{1+e_o} H$$

$$= \frac{1.04 - 0.98}{1+1.04} (9) = 0.2647^m = 26.47^{cm}$$

Ex 2 A 3^m depth of compacted sand ($\rho_{sand} = 1900 \frac{kg}{m^3}$) is placed over a soft clayey deposit 3.5^m thick. Calculate the final settlement of the clay layer if the coefficient of compressibility (m_v) equal to $0.007\ m^2/ton$.

Solution: $\rho_{sand}\ (fill) = 1900 \frac{kg}{m^3} * \frac{1\ KN}{100\ kg} = 19 \frac{KN}{m^3}$ ← γ_{fill}

$$\Delta P' = \Delta\sigma'_v\ (fill) = h_{fill} * \gamma_{fill}$$

$$= 3^m * 19 \frac{KN}{m^3} = 57 \frac{KN}{m^2}$$

$$S_{cf} = m_v * \Delta P * H$$

$$= 0.007 \frac{m^2}{ton} * \frac{1\ ton}{1000\ kg} * \frac{100\ kg}{1\ KN} * 57 \frac{KN}{m^2} * 3.5^m$$

$$= 0.1396^m \simeq 0.14^m = 14^{cm}.$$

Ex 3 On a Soft clay layer 2^m thick with L.L = 45%, the pressure was increased from 4 to 8 $\frac{kg}{cm^2}$ if the original Void ratio obtained by taking Samples from this soil and was found to be 0.67. Calculate the Settlement Caused by pressure increment.

Solution: $H = 2^m$, L.L. = 45% , $e_o = 0.67$

$$\left.\begin{array}{l} P'_o = 4\ kg/cm^2 \\ P'_f = 8\ kg/cm^2 \end{array}\right\} \rightarrow \Delta P' = 4\ kg/cm^2$$

$$C_c = 0.009\,(L.L. - 10) = 0.009\,(45 - 10)$$

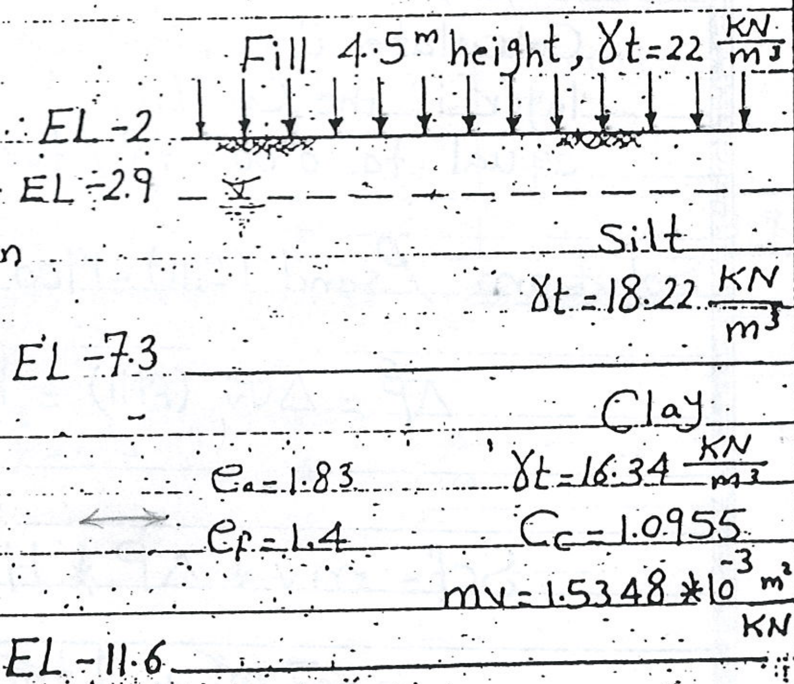
$$\rightarrow C_c = 0.315$$

$$S_{cf} = \frac{C_c}{1+e_o} H \log \frac{P'_o + \Delta P'}{P'_o}$$

$$= \frac{0.315}{1+0.67} (200\ cm) \log \frac{4+4}{4}$$

$$= 0.1135^m = 11.35\ cm$$

Ex 4 For the Soil profile shown; find the Final Consolidation Settlement of the Clay Layer by using three different approaches.



Solution: طلب السؤال ايجاد (Scf) بثلاث طرق أي من خلال تطبيق ثلاث قوانين وكالآتي.

① $\delta cf = \frac{\Delta e}{1+e_o} H = \frac{e_o - e_f}{1+e_o} H$

where $H = -7.3 - (-11.6) \rightarrow H = 4.3^m$

$\therefore Scf = \frac{1.83 - 1.4}{1+1.83} (4.3) = 0.653^m = 65.3^{cm}$

② $\delta cf = mv * \Delta P' * H$

where $\Delta P' = \Delta\sigma_v(fill) = h\,fill * \gamma fill = 4.5 * 22$

$\rightarrow \Delta P' = 99 \; KN/m^2$

$\therefore \delta cf = 1.5348 * 10^{-3} * 99 * 4.3 = 0.653^m = 65.3^{cm}$

③ $\delta cf = \frac{C_c}{1+e_o} H \log \frac{P'_o + \Delta P'}{P'_o}$

where $P'_o = \sigma'_v = \sigma - U$ لمنتصف طبقة الطين المنغمرة

$\sigma = 18.22(-2-(-7.3)) + 16.34 * \frac{4.3}{2} = 131.697 \; KN/m^2$

$U = \gamma_w . h_P = 9.81 \left(-2.9-(-7.3) + \frac{4.3}{2}\right) = 64.238 \; KN/m^2$

$\sigma' = P'_o = 131.697 - 64.238 = 67.641 \; KN/m^2$

$\therefore \delta cf = \frac{1.0955}{1+1.83} (4.3) \log \frac{67.641 + 99}{67.641} = 0.653^m = 65.3^{cm}$

Ex 5 The borehole records at a level site revealed the following details: $0 \rightarrow 0.25^m$ (top soil), $0.25 \rightarrow 3.5^m$ (Sand, with W.T. at 1.25^m), $3.5 \rightarrow 10^m$ (clay), $10 \rightarrow$ base of borehole (impervious shell). The bulk density of the top soil and Sand is $1920 \; Kg/m^3$. A building is supported on

a Raft of Dimensions 18 * 18 m, with its base at 2.25 m below ground Surface. The gross load from the raft and building is $2.7 * 10^4$ KN. Calculate the settlement of the structure due to consolidation of Clay layer, whose Coefficient of Volume Change (mv) decreases linearly from $4.2 * 10^{-4} \frac{m^2}{KN}$ at the top to $2.7 * 10^{-4} \frac{m^2}{KN}$ at its base. Use the pressure influnce Chart.

Solution: حسب المعطيات في السؤال نرسم رسم توضيحي للمنطقة (موقع المنشأ) ومقطع التربة مع الابعاد وكالاتي:

نجد شدة التحميل السطحي

$$\Delta q_s = \frac{\text{Wt. of building}}{\text{Area}}$$

$$= \frac{2.7 * 10^4 \ KN}{18 * 18 \ m}$$

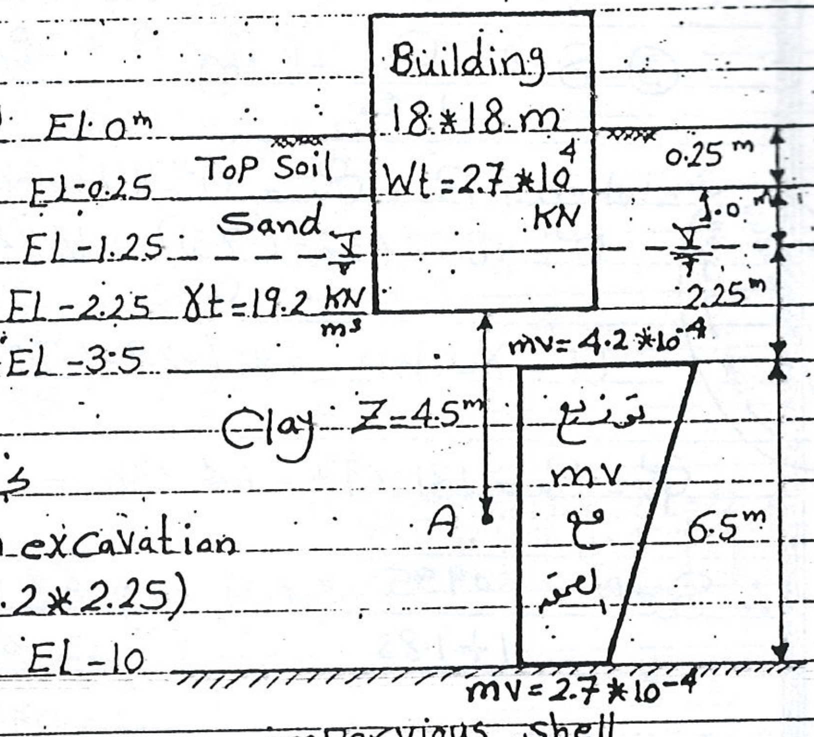
$$= 83.33 \ \frac{KN}{m^2}$$

نجد شدة التحميل السطحي الصافية

$$\Delta q_{s.net} = \Delta q_s - \gamma h_{excavation}$$

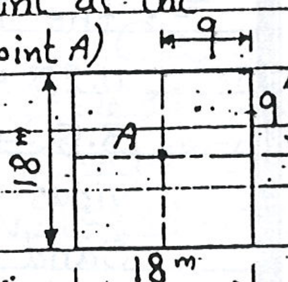
$$= 83.33 - (19.2 * 2.25)$$

$$= 40.133 \ \frac{KN}{m^2}$$



Using influence chart (Fig. 8.6) to determine ($\Delta\sigma_v$) at the middle of the clay layer. Choose the Point at the Centre of the building as worst case. (Point A)

$$m = n = \frac{9}{4.5} = 2 \ \xrightarrow{\text{Fig. 8.6}} \ f = 0.2325$$



$$\Delta\sigma_v = f * \Delta q_{s.net} = 4 * 0.2325 * 40.133$$

$$\Rightarrow \Delta\sigma_v = 37.324 \ KN/m^2 = \Delta P$$

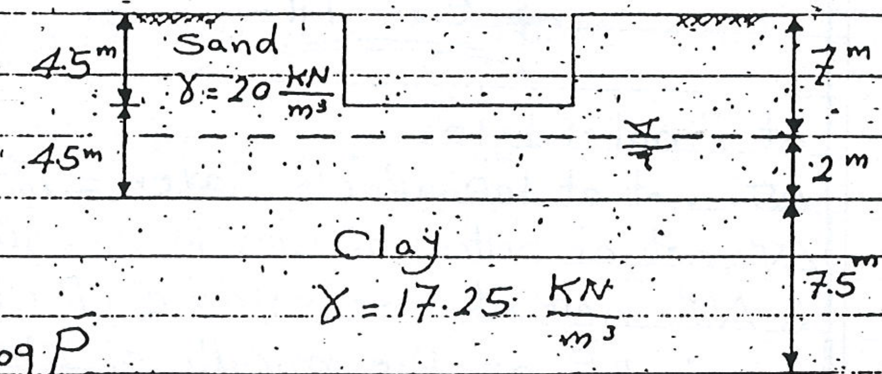
نجد الان قيمة mv في منتصف الطبقة الطينية المنضغطة (Point A)

(mv) at the middle of clay layer $= \dfrac{4.2 * 10^{-4} + 2.7 * 10^{-4}}{2}$

$\Rightarrow m_v = 3.45 * 10^{-4} \ \dfrac{m^2}{KN}$

$\therefore S_{cf} = m_v * \Delta \bar{P} * H$
$= 3.45 * 10^{-4} * 37.324 * 6.5 = 0.0837 \ m$
$= 8.37 \ cm$

Ex 6 For the Soil Profile Shown in figure:



$e = 1.2 - 0.044 \log \bar{P}$
(for the Clay layer.)

Estimate the amount of Settlement expected if the gross Pressure increase Caused by the load of the structure is 75 KN/m^2 at the top and 10 KN/m^2 at the bottom of the Clay stratum, and if the pressure release due to the excavation is 35 KN/m^2 and 10 $\frac{KN}{m^2}$ at the top and bottom of the Clay layer respectively.

Solution: $e = 1.2 - 0.044 \log \bar{P}$ العلاقة المعطاة للتربة الطينية
والتي تربط بين (e) و ($\bar{P}$) يمكن من خلالها معرفة
نسبة الفجوات عند اي اجهاد فعال لأن (e) هي دالة
لـ ($\bar{P}$) $[e = f(\bar{P})]$. فاذا وجدنا ($\bar{P}_o$) قبل وضع الحمل سوف
نستطيع ان نجد (e_o) من العلاقة اعلاه . واذا وجدنا ($\bar{P}_f$)
من معلومات السؤال سوف نجد قيمة e_f من العلاقة اعلاه ايضاً ثم
نستطيع ايجاد S_{cf} من خلال المعادلة $S_{cf} = \dfrac{\Delta e}{1 + e_o} \cdot H$

at initial Stage :-

$P'_o = \sigma' = \sigma - U = \left[9 * 20 + \frac{7.5}{2} * 17.25\right] - \left[\left(2 + \frac{7.5}{2}\right) * 10\right]$

$\rightarrow P_o = 187.1875 \ KN/m^2$

$e_o = 1.2 - 0.044 \log P'_o = 1.2 - 0.044 \log 187.1875$

$\rightarrow e_o = 1.1$

at final Stage :-

$\Delta\sigma_v$ net at top of clay layer $= 75 - 35 = 40 \ KN/m^2$

$\Delta\sigma_v$ net at bottom of clay layer $= 10 - 10 = 0$

$\therefore \Delta\sigma_v$ net at the middle of clay layer $= \frac{40}{2} = 20 \ \frac{KN}{m^2}$

$\therefore \Delta P'$ at the middle of clay layer $= 20 \ KN/m^2$

$\therefore e_f = 1.2 - 0.044 \log (P_o + \Delta P')$

$= 1.2 - 0.044 \log (187.1875 + 20) \rightarrow e_f = 1.098$

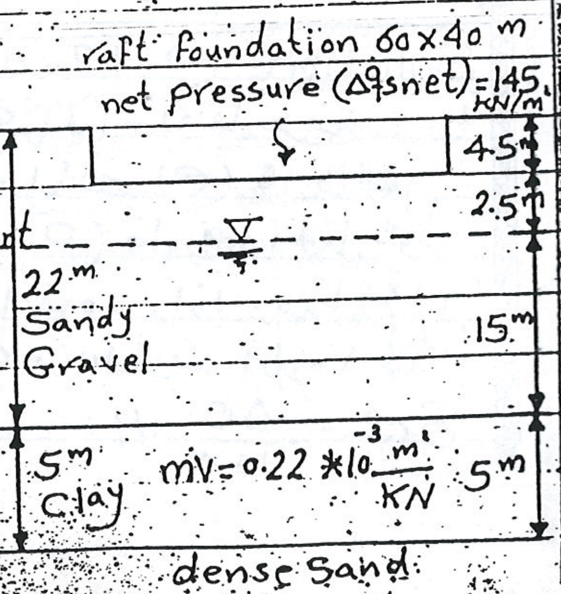
$\therefore S_{cf} = \frac{\Delta e}{1+e_o} H = \frac{e_o - e_f}{1+e_o} H$

$= \frac{1.1 - 1.098}{1 + 1.1} (7.5) = 7.1 * 10^{-3} \ m$

$= 7.1 \ mm$

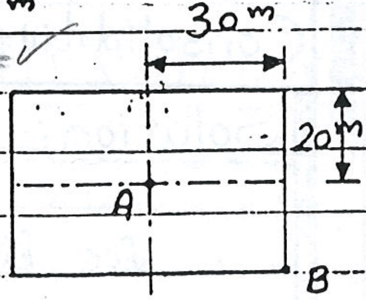
Ex 7 For the raft foundation shown in fig. find the final Consolidation Settlement at the centre and Corner of the raft given.

m	2	6	1.5
n	3	2	1
factor	0.2375	0.24	0.195



Solution: at Centre of the raft :- (Point A)

$B = 20^m$, $L = 30^m$, $Z = 20^m$



$m = \frac{20}{20} = 1$, $n = \frac{30}{20} = 1.5$ } → factor = 0.195

$\Delta\sigma_v = f * \Delta q_{s\,net}$

$= 4 * 0.195 * 145 = 113.1\ KN/m^2 = \Delta P$

$\delta_{cf} = m_v * \Delta P * H$

$= 0.22 * 10^{-3} * 113.1 * 5 = 0.1244^m = 12.44^{cm}$

at Corner of the raft :- (Point B)

$B = 40^m$, $L = 60^m$, $Z = 20^m$

$m = \frac{40}{20} = 2$, $n = \frac{60}{20} = 3$ } → factor = 0.2375

$\Delta\sigma_v = f * \Delta q_{s\,net}$

$= 0.2375 * 145 = 34.4375\ KN/m^2 = \Delta P$

$\delta_{cf} = m_v * \Delta P * H$

$= 0.22 * 10^{-3} * 34.4375 * 5 = 0.038^m = 3.8^{cm}$

Ex 8 A proposed building is to be constructed upon the surface of the soil profile shown imposes a vertical stress increment of 140 KPa at the middle of Clay layer. Estimate the Primary Consolidation Settlement of the Clay assuming that the soil above W.T. to be saturated.

N.G.L. — EL. 0

EL -3.0 W.T.

Fine Sand: $G_s = 2.76$, $e = 0.76$

EL -10.4

Clay: $G_s = 2.71$, $\omega = 42\%$, $C_c = 0.3$

EL -12.4

Coarse Sand

Solution: نجيب الكثافة المشبعة لكل من

fine sand and clay:

for fine sand: $\gamma_{sat} = \dfrac{G_s + e}{1+e}\gamma_w$

$= \dfrac{2.76 + 0.76}{1 + 0.76}(10) = 20 \dfrac{KN}{m^3}$

for clay: $\gamma_{sat} = \dfrac{G_s + e}{1+e}(\gamma_w)$

but $S * e = G_S * \omega$

$1 * e_o = 2.71 * 0.42 \rightarrow e_o = 1.1382$

$\therefore \gamma_{sat} = \dfrac{2.71 + 1.1382}{1 + 1.1382}(10) = 18 \dfrac{KN}{m^3}$

$P_o = \bar{\sigma} = \sigma - U = \gamma_{sat} * 10.4 + \gamma_{sat} * 1 - 9.4\,\gamma_w$

$= 20 * 10.4 + 18 * 1 - 8.4 * 10$

$\rightarrow P_o = 142 \dfrac{KN}{m^2}$

$\Delta\sigma_v$

$SCf = \dfrac{C_c}{1+e_o} H \log \dfrac{P_o + \Delta P}{P_o}$

$= \dfrac{0.3}{1 + 1.1382}(2) \log \dfrac{142 + 140}{142} = 0.0836^m = 8.36^{cm}$

Ex 9 for clay ①:

N.C.C, $\gamma_{sat} = 21 \dfrac{KN}{m^3}$,

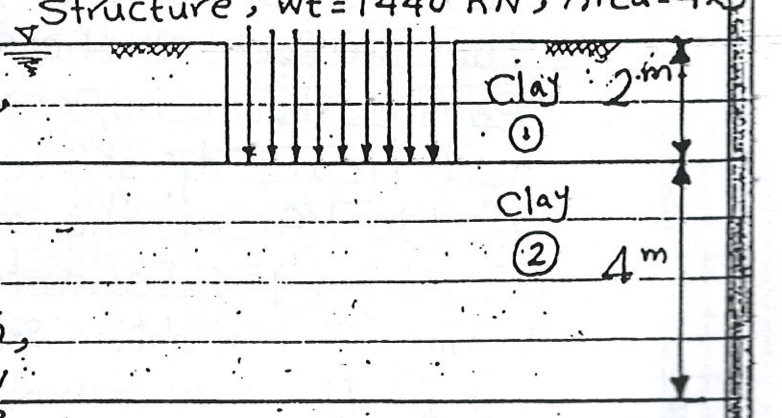
$e = 0.81$, $C_c = 0.3$

For clay ②:

O.C.C, O.C.R = 1.5,

$C_c = 0.2$, $C_r = 0.15$,

$e = 0.7$, $\gamma_{sat} = 22 \dfrac{KN}{m^3}$



Find SCf. Note: Use 2:1 method

Solution: يلاحظ في هذا السؤال وجود طبقتي Clay هما

Clay ① and ② ولكن Clay ① لا يحدث فيها عملية انضمام

لعدم وجود انضغاطية فيها وبذلك تحصل عملية الانضمام فقط

في تربة Clay ② مع ملاحظة ان هذه التربة من نوع O.C.C.

لذلك نحسب قيمة P_o لنقطة منتصف هذه التربة قبل وضع

الأحمال وكالآتي:

$$\bar{P_o} = \bar{\sigma} = \sigma - U$$

$$= 21 * 2 + 22 * 2 - 10 * 4 \rightarrow \bar{P_o} = 46 \frac{kN}{m^2}$$

نحسب الآن قيمة $\Delta \bar{P}$ وكالآتي:

$$\Delta q_s = \frac{\text{Wt. of building}}{\text{Area of building}} = \frac{1440\ kN}{3 * 4\ (m^2)} = 120 \frac{kN}{m^2}$$

$$\Delta q_{s\,net} = \Delta q_s - \gamma h \text{ of excavation}$$

$$= 120 - 21 * 2 = 78\ kN/m^2$$

$$\Delta \sigma_v = \frac{\Delta q_{s\,net} * B * L}{(B+Z)(L+Z)} = \frac{78 * 3 * 4}{(3+2)(4+2)} = 31.2 \frac{kN}{m^2} = \Delta \bar{P}$$

Since the soil is O.C.C. where $O.C.R = 1.5 = \frac{\bar{P_c}}{\bar{P_o}}$

$$1.5 = \frac{\bar{P_c}}{46} \rightarrow \bar{P_c} = 69\ kN/m^2$$

we must check $\bar{P_o} + \Delta \bar{P} \gtreqless \bar{P_c}$

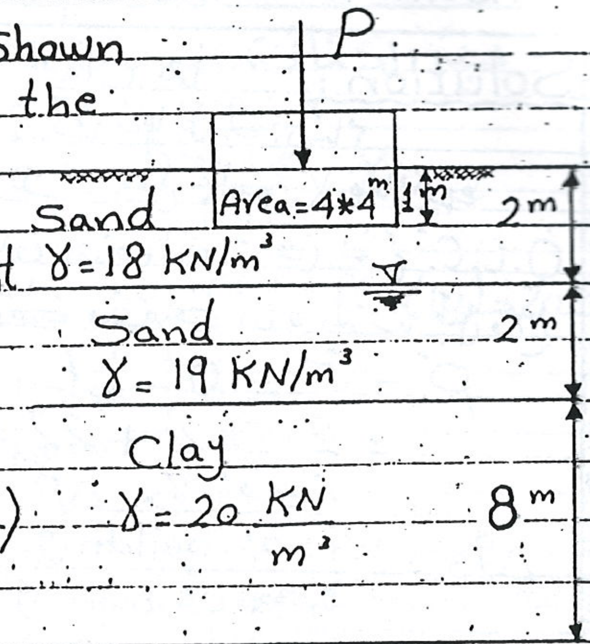
$$\underbrace{46 + 31.2}_{77.2} > 69$$

$$\therefore S_{cf} = \frac{C_r}{1+e_o} H \log \frac{\bar{P_c}}{\bar{P_o}} + \frac{C_c}{1+e_o} H \log \frac{\bar{P_o} + \Delta \bar{P}}{\bar{P_c}}$$

$$= \frac{0.15}{1+0.7} (4) \log \frac{69}{46} + \frac{0.2}{1+0.7} (4) \log \frac{46+31.2}{69}$$

$$= 0.0851^{m} = 8.51^{cm}$$

Ex 10 For the foundation shown in figure, determine the total applied load "P" that causes a Consolidation Settlement of 14 mm in the clay Layer. Given that



$$e = 0.72 - 0.18 \log\left(\frac{P}{100}\right)$$

Note: Use 2:1 method.

Solution: $P_o' = \sigma' = \sigma - U = 18*2 + 19*2 + 20*4 - 6*10$

$$\Rightarrow P_o' = 94 \ KN/m^2$$

$$e_o = 0.72 - 0.18 \log\frac{94}{100} \Rightarrow e_o = 0.7248$$

$$S_{cf} = \frac{\Delta e}{1+e_o} H = \frac{e_o - e_f}{1+e_o} H$$

$$\frac{14}{1000} m = \frac{0.7248 - e_f}{1 + 0.7248}(8) \Rightarrow e_f = 0.7218$$

but $0.7218 = 0.72 - 0.18 \log \frac{P_f}{100} \Rightarrow P_f = 97.7 \ \frac{KN}{m^2}$

$\therefore \Delta P' = P_f' - P_o' = 97.7 - 94 = 3.7 \ KN/m^2 = \Delta\sigma_v$

but $\Delta\sigma_v = \frac{\Delta q_{s\,net} * B^2}{(B+Z)^2}$

$$3.7 = \frac{\Delta q_{s\,net} * 4^2}{(4+7)^2} \Rightarrow \Delta q_{s\,net} = 27.986 \ \frac{KN}{m^2}$$

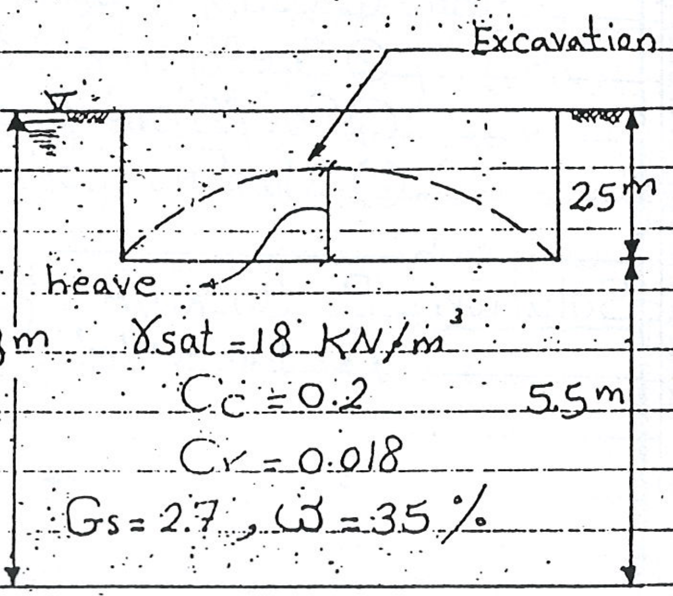
but $\Delta q_{s\,net} = \Delta q_s - \gamma h$ of excavation

$$27.986 = \Delta q_s - 18*1 \Rightarrow \Delta q_s = 45.986 \ \frac{KN}{m^2}$$

but $\Delta q_s = \frac{P}{A} \Rightarrow 45.986 = \frac{P}{16 \ m^2} \Rightarrow P = 735.77 \ KN$

($A = 4*4 \rightarrow 16 \ m^2$)

Ex 11 An excavation $3^m \times 6^m \times 2.5^m$ deep is made in a fully Saturated Clay layer Shown in the Figure. Find the expected heave of the bottom of the excavation use 2:1 method.



Solution: ① يتم أولاً حساب قيمة P_o في منتصف الطبقة الطينية المنضغطة قبل الحفر

$P_o = \bar{\sigma} = \sigma - u$

$= 18 * 5.25 - 10 * 5.25$

➡ $P_o = 42\ KN/m^2$

② حساب شدة التحميل السطحي الصافية Δq_s net حيث أن

$\Delta q_s\ net = \Delta q_s - \gamma h$ of excavation

$= 0 - 18 * 2.5$ ➡ $\Delta q_s\ net = -45\ \frac{KN}{m^2}$

③ حساب ΔP من النقطة المختارة في ①

$$\Delta P = \Delta\sigma_v = \frac{\Delta q_s net * B * L}{(B+Z)(L+Z)} = \frac{-45 * 3 * 6}{(3+2.75)(6+2.75)}$$

➡ $\Delta P = -16.1\ KN/m^2$

④ حساب قيمة e_o للطبقة الطينية Clay

$S e_o = G_s \omega$

$1 e_o = 2.7 * 0.35$ ➡ $e_o = 0.945$

⑤ حساب الانتفاخ heave من قانون SCf

$$SCf = \frac{C_c}{1+e_o} H \log \frac{P_o + \Delta P}{P_o}$$

$$= \frac{0.2}{1+0.945} (5.5) \log \frac{42 - 16.1}{42} = -0.119^m = -11.9^{cm}$$

الإشارة السالبة معناه انتفاخ وليس هبوط

Ex 12 A soil Sample with initial Conditions $\bar{P}_o = 80\ KN/m^2$ and $e_o = 0.8$ if the stress is increased to $140\ KN/m^2$ the void ratio is reduced to $e = 0.74$

Find: ① Compression index C_c.

② Coefficient of Compressibility a_v.

③ Coefficient of Volume change m_v.

④ Modulus of Elasticity E :

Solution: $\bar{P}_o = 80\ KN/m^2$, $\bar{P}_f = 140\ KN/m^2$ → $\Delta\bar{P} = \bar{P}_f - \bar{P}_o = 140 - 80$

$\Delta\bar{P} = 60\ KN/m^2$

$e_o = 0.8$, $e_f = 0.74$ → $\Delta e = e_o - e_f = 0.8 - 0.74 = 0.06$

① $C_c = \dfrac{\Delta e}{\Delta \log \bar{P}} = \dfrac{0.06}{\log \frac{140}{80}}$ → $C_c = 0.247$

② $a_v = \dfrac{\Delta e}{\Delta \bar{P}} = \dfrac{0.06}{60}$ → $a_v = 0.001\ \dfrac{m^2}{KN}$

③ $m_v = \dfrac{a_v}{1+e_o} = \dfrac{0.001}{1+0.8}$ → $m_v = 5.55 * 10^{-4}\ \dfrac{m^2}{KN}$

④ To Calculate Modulus of Elasticity E

since $m_v = \dfrac{\epsilon_{vol}}{\Delta\bar{P}}$ and $\Delta\bar{P} = E.\epsilon_{vol}$ (قانون هوك)

$\therefore m_v = \dfrac{\epsilon_{vol}}{E * \epsilon_{vol}}$ → $m_v = \dfrac{1}{E}$

$\therefore \boxed{E = \dfrac{1}{m_v}} = \dfrac{1}{5.55 * 10^{-4}} = 1800\ \dfrac{KN}{m^2}$

Ex [13] The Coordinates of two Points on a virgin Compression line are:

$e_1 = 1.78$ $P'_1 = 191.52\ KN/m^2$

$e_2 = 1.48$ $P'_2 = 383.04\ KN/m^2$

Find: ① Coefficient of Volume Change (mv)

② If $C_v = 0.23\ mm^2/sec$ within the pressure range. Find the Coeff. of Permeability

③ what is the void ratio Corresponding to $P' = 650\ KN/m^2$

Solution:

$e_1 = 1.78,\ e_2 = 1.48 \rightarrow \Delta e = 1.78 - 1.48 = 0.3$

$P'_1 = 191.52,\ P'_2 = 383.04 \rightarrow \Delta P' = 383.04 - 191.52$

$\Delta P' = 191.52\ KN/m^2$

① $mv = \frac{\Delta e}{1+e_0} * \frac{1}{\Delta P'}$

$= \frac{0.3}{1+1.78} * \frac{1}{191.52} \rightarrow mv = 5.6346 * 10^{-4}\ \frac{m^2}{KN}$

② $C_v = 0.23\ \frac{mm^2}{sec} * \frac{1^2\ m^2}{1000^2\ mm^2} * \frac{3600\ sec}{1\ hr} * \frac{24\ hr}{1\ day}$

$\rightarrow C_v = 0.019872\ \frac{m^2}{day}$

$C_v = \frac{K}{mv \cdot \gamma_w} \rightarrow K = C_v * mv * \gamma_w$

$= 0.019872\ \frac{m^2}{day} * 5.6346 * 10^{-4}\ \frac{m^2}{KN} * 10\ \frac{KN}{m^3}$

$\rightarrow K = 1.1197 * 10^{-4}\ m/day$

$C_c = \frac{\Delta e}{\Delta \log P'} = \frac{0.3}{\log \frac{383.04}{191.52}} \rightarrow C_c = 0.9966$

and $0.9966 = \frac{1.78 - e_{(P'=650)}}{\log \frac{650}{191.52}} \rightarrow (e\ at\ P' = 650) = 1.25$

Ex 14 The average value of (Cv) obtained by taking representative samples from clay layer 3^m thick was $5*10^{-4}$ cm²/sec. A structure was built over the clay layer which started settlement. How long did it take for half the ultimate settlement to obtain: (Estimated in days) and drained both side.

Solution: $H = 3^m$, $d = \frac{H}{2} = \frac{3}{2} = 1.5^m$; $U_{av} = 50\%$

$$C_v = 5*10^{-4}\frac{cm^2}{sec} * \frac{1^2\ m^2}{100^2\ cm^2} * \frac{3600\ sec}{1\ hr} * \frac{24\ hr}{1\ day}$$

$$\rightarrow C_v = 4.32*10^{-3}\ m^2/day$$

$$T_v = \frac{\pi}{4}(U_{av})^2 = \frac{\pi}{4}(0.5)^2 \rightarrow T_v = 0.196$$

but $T_v = \frac{C_v\,t}{d^2} \rightarrow t = \frac{T_v\,d^2}{C_v} = \frac{0.196*(1.5)^2}{4.32*10^{-3}}$

$$\rightarrow t = 102.26\ days \simeq 103\ days$$

Ex 15 Given the following data about a soil statum. Calculate the time required for 50% consolidation. Thickness $= 600^{cm}$, with double drainage, $K = 1.02*10^{-7}$ cm/sec; $e_o = 1.45$; $a_v = 0.00028\ \frac{cm^2}{gm}$, $T_v = 0.197$.

Solution: $m_v = \frac{a_v}{1+e_o} = \frac{0.00028}{1+1.45} = 1.14286*10^{-4}\ \frac{cm^2}{gm}$

$$C_v = \frac{K}{m_v\,\rho_w} = \frac{1.02*10^{-7}\frac{cm}{sec}}{1.14286*10^{-4}\frac{cm^2}{gm}*1\frac{gm}{cm^3}} = 8.925*10^{-4}\frac{cm^2}{sec}$$

$$t = \frac{T_v\,d^2}{C_v} = \frac{0.197*(300)^2\ cm^2}{8.925*10^{-4}\frac{cm^2}{sec}} = 19865546\ sec$$

$$\therefore t = 19865546\ sec * \frac{1\ hr}{3600\ sec} * \frac{1\ day}{24\ hr} = 229.9\ days \simeq 230\ days$$

Ex 16 A sample of Clay 3 cm thick, drained at top and bottom, Consolidated 50% in 10 min. In how much time shall a layer of the same clay 3 m thick, with double drainage Consolidates 50%

Solution: For Clay Sample :-

$H = 3^{cm}$ (double drainge) → $d = \frac{3}{2} = 1.5^{cm}$

$t = 10$ min

Casagrande's method: $C_v = \frac{0.197\, d^2}{t} = \frac{0.197\,(1.5)^2}{10} = 0.044325 \frac{cm^2}{min}$

For Clay Layer :-

$H = 3^m$ (double drainage) → $d = \frac{3}{2} = 1.5^m$

$t = \frac{0.197 * (1.5^m)^2 (100^2)}{0.044325}$ → $t = 100000$ min

$\therefore t = 100000 \text{ min} * \frac{1 \text{ hr}}{60 \text{ min}} * \frac{1 \text{ day}}{24 \text{ hr}} = 69.4$ days ~ 70 days

Ex 17 In a Consolidation test on a Soil, the void ratio of the sample decreases from 1.24 to 1.12 when the Pressure is increased from 20 T/m^2 to 40 T/m^2. Compute the Coeff. of Consolidation (C_v) in m^2/year given that the Coeff. of Permeability of the soil during the Pressure increment is $8.5 * 10^{-8} \frac{cm}{sec}$

Solution: $\Delta e = 1.24 - 1.12 = 0.12$, $\Delta P = 40 - 20 = 20 \frac{T}{m^2}$

$m_v = \frac{\Delta e}{1+e_o} * \frac{1}{\Delta P} = \frac{0.12}{1+1.24} * \frac{1}{20}$

→ $m_v = 2.68 * 10^{-3} \frac{m^2}{Ton}$

$C_v = \frac{K}{m_v \rho_w} = \frac{8.5 * 10^{-8} \frac{cm}{sec} * 3600 * 24 * 365 * \frac{1}{100}}{2.68 * 10^{-3} \frac{m^2}{ton} * 1 \frac{ton}{m^3}} = 10 \frac{m^2}{yr}$

Ex 18 Find out the time required for 5
in a soil having thickness 800 cm, and
at top and bottom. What will be the
Coeff of Consolidation if the Coeff. of Pe
Given; $e = 1.8$, $a_v = 0.0003 \frac{cm^2}{gm}$, $T_v = 0.3$

Solution: $m_v = \frac{a_v}{1+e_o} = \frac{0.0003}{1+1.8} = 1.0714 * 10$

$C_v = \frac{K}{m_v \rho_w} = \frac{10^{-7}\ cm/sec}{1.0714 * 10^{-4} * 1\ gm/c}$

$\rightarrow C_v = 80.64\ cm^2/day$

$\therefore t = \frac{T_v d^2}{C_v} = \frac{0.3 * (400)^2}{80.64} = 595.24$ day

Ex 19 A saturated soil stratum 5^m thick lies above
stratum and below a pervious stratum
Compression Index $C_c = 0.25$ and a Coe
Permeability $= 3.2 * 10^{-4}$ cm/sec, its void rai
of $1.5\ kg/cm^2$ is 1.9, Compute: ① The Ch
ratio due to increase of Stress to $2\ kg/cm$
of the soil stratum due to the above inc
③ Time (in min) for 50 % Consolidation

Solution: $C_c = \frac{\Delta e}{\Delta \log P} \rightarrow 0.25 = \frac{\Delta e}{\log \frac{2}{1.5}}$

$S_{cf} = \frac{\Delta e}{1+e_o} H = \frac{0.031}{1+1.9} (5m) = 0.054^m =$

$m_v = \frac{\Delta e}{1+e_o} * \frac{1}{\Delta P} = \frac{0.031}{1+1.9} * \frac{1}{(2-1.5)} \rightarrow m_v =$

$C_v = \frac{K}{m_v \rho_w} = \frac{3.2 * 10^{-4}\ cm/sec}{0.0215 \frac{cm^2}{kg} * \frac{1\,kg}{1000\,gm} * \frac{1\,gm}{cm^3}} = 1$

$\therefore C_v = 14.85 \frac{cm^2}{sec} * \frac{60\,sec}{1\,min} = 891.317\ cm^2/min$

$$t = \frac{T_v\, d^2}{C_v} = \frac{0.2 * (500)^2\ cm^2}{891.317\ cm^2/min} = 56\ min$$

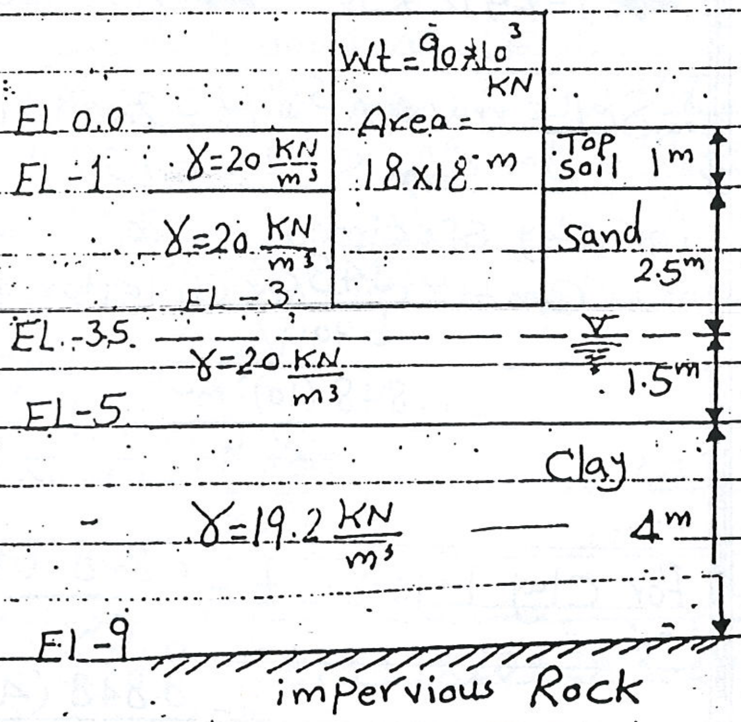
Ex 20 Boreholes at a building site show the following strata (levels in meters measured from ground surface): 0 → -1 (Top soil), -1 → -5 (Sand, and W.T at -3.5), -5 → -9 (clay). There is impervious rock below -9 m. The total unit weight of the Top soil and Sand is 20 KN/m³ and that of the Clay is 19.2 KN/m³. A building is Constructed on a Concrete raft 18*18 m at 3 m below Surface. The total load is $90 * 10^3$ KN. The Coefficient of Volume Compressibility varies linearly from $420 * 10^{-6} \frac{m^2}{KN}$ at $100 \frac{KN}{m^2}$ to $320 * 10^{-6} \frac{m^2}{KN}$ at $200 \frac{KN}{m^2}$. If a specimen of the clay reached 90% settelment in 4 hrs. when tested in a Consolidation test. The specimen was 20mm thick. Estimate the time in years for the building to reach 90% of its final Settelment. Also Calculate the final Settlement of the building. (use 2:1 method).

Solution: خذ اولاً

قيمة ال P_o في منتصف

الطبقة الطينية المنضغطة

قبل وضع الحمل



$P_o = \bar{\sigma} = \sigma - U$

$= 20*1 + 20*4 + 19.2*2 - 10*3.5$

→ $P_o = 103.4 \frac{KN}{m^2}$

خذ قيمة $\Delta\sigma_v$ لنفس النقطة

اعلاه وكالتالي :-

Consolidation of Soil	Page (18)	Ali Othman

$\Delta q_s = \dfrac{\text{Wt. of building}}{\text{Area of building}} = \dfrac{90*10^3 \text{ KN}}{18*18 \text{ m}^2} = 277.78 \dfrac{\text{KN}}{\text{m}^2}$

$\Delta q_{s\,net} = \Delta q_s - \gamma h_{excavation}$

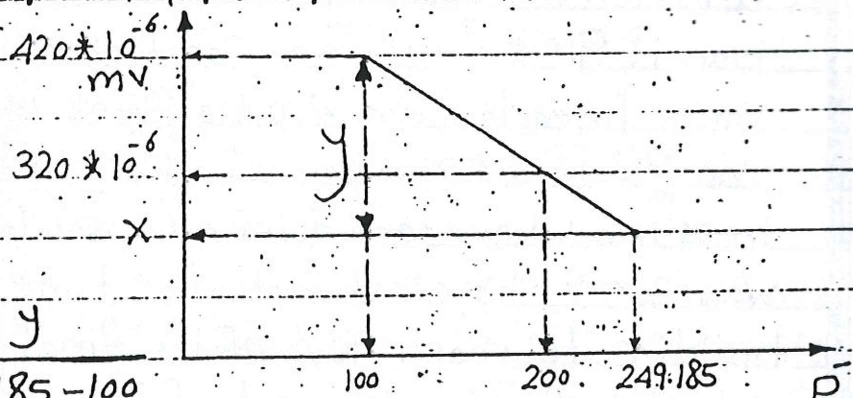
$= 277.78 - 20*3 \rightarrow \Delta q_{s\,net} = 217.78 \text{ KN/m}^2$

$\Delta \sigma_v = \dfrac{\Delta q_{s\,net} * B^2}{(B+Z)^2} = \dfrac{217.78*18^2}{(18+4)^2} = 145.785 \text{ KN/m}^2 = \Delta \bar{P}$

نحسب الآن قيمة (mv) المكافئة للإجهاد الكلي المؤثر على نقطة منتصف الطبقة الطينية المضغوطة ميدانيا

$\bar{P}_f = \bar{P}_o + \Delta \bar{P} = 103.4 + 145.785 = 249.185 \text{ KN/m}^2$

$\bar{P}$	mv
100	$420*10^{-6}$
200	$320*10^{-6}$
249.185	X



$\dfrac{420*10^{-6} - 320*10^{-6}}{200-100} = \dfrac{y}{249.185-100}$

$\rightarrow y = 1.492*10^{-4} \rightarrow X = 420*10^{-6} - y = 2.708*10^{-4} = mv$

في منتصف الطبقة الطينية

$\therefore S_{cf} = mv * \Delta\bar{P} * H = 2.708*10^{-4} * 145.785 * 4$

$\rightarrow S_{cf} = 0.158^{\,m} = 15.8^{\,cm}$

for clay specimen $H = 20^{mm} \rightarrow d = 10^{mm}$ (Two way drainage)

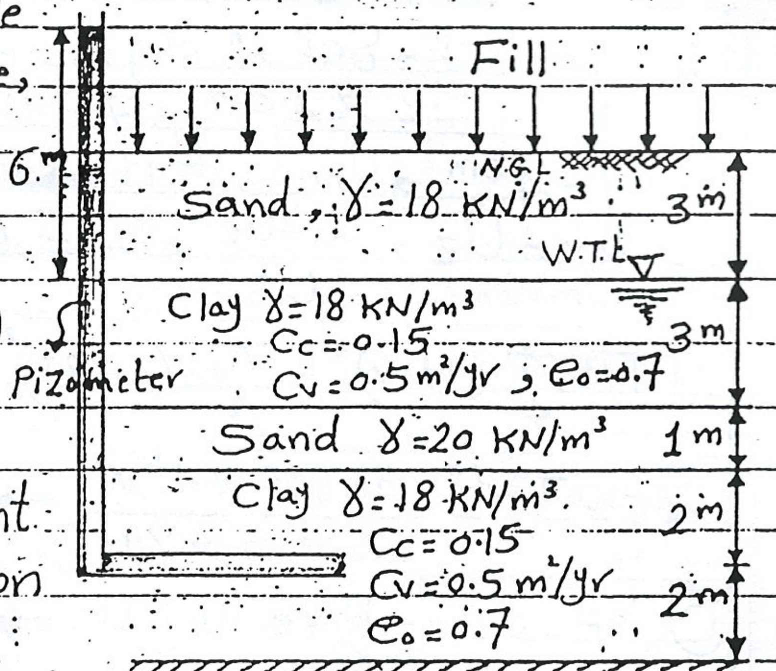
$C_v = \dfrac{0.848 d^2}{t_{90}}$ (Taylor's Method)

$= \dfrac{0.848 (10)^2 \text{ mm}^2 * \frac{1 \text{ m}^2}{1000^2 \text{ mm}^2}}{4 \text{ hr} * \frac{1 \text{ day}}{24 \text{ hr}} * \frac{1 \text{ yr}}{365 \text{ day}}} = 0.186 \text{ m}^2/\text{yr}$

For Clay Layer: $t = \dfrac{0.848 (d)^2}{C_v}$ ($H = d = 4^m$ one way Drainage)

$= \dfrac{0.848 (4)^2}{0.186} = 73.06$ year

Ex 21 For the soil profile shown in the figure, the pizometric reading immediately after applying the surface loading (fill) is 6 m above W.T.L.



Find.

(a) The total settlement due to Consolidation of Clay layers.

(b) The time required to have a reading of 4 m above W.T.L in the piezometer.

(c) The time required to have a reading of 0 m above W.T.L. in the piezometer.

(d) The value of piezometer reading after 15 years. (above W.T.L.)

Solution: $h_p = 6^m$ above W.T.L immediately after the applying of surface loading (Fill)

$\rightarrow U_i = h_p \gamma_w = 6 * 10 \rightarrow U_i = 60 \frac{KN}{m^2} = \Delta P = \Delta q_{s\,net} = \Delta \sigma_v$

(a) For Clay ①

$P_o' = \bar{\sigma} = \sigma - U = \underbrace{18*3 + 1.5*18}_{\sigma} - \underbrace{1.5*10}_{u} \rightarrow P_o = 66 \frac{KN}{m^2}$

$$S_{cf} = \frac{C_c}{1+e_o} H \log \frac{P_o' + \Delta P}{P_o'}$$

$$= \frac{0.15}{1+0.7}(3) \log \frac{66+60}{66} = 0.074^m = 7.4^{cm}$$

For Clay ②

$P_o' = \bar{\sigma} = \sigma - U = \underbrace{3*18 + 3*18 + 1*20*2*18}_{\sigma} - \underbrace{6*10}_{u}$

$\rightarrow P_o' = 104 \ KN/m^2$

$$S_{cf} = \frac{0.15}{1+0.7}(4) \log \frac{104+60}{104} = 0.0698^m = 6.98^{cm} = 7^{cm}$$

$\therefore$ total S_{cf} = S_{cf} of clay ① + S_{cf} of clay ②
$= 7.4^{cm} + 7^{cm} = 14.4^{cm}$

ⓑ $h_p = 4^{cm}$ above W.T.L → $U_e = 4 * 10 = 40\ KN/m^2$

$$U_{av} = U_z = \frac{U_i - U_e}{U_i} * 100 = \frac{60-40}{60} * 100 = 33.3\ \%$$

$$T_v = \frac{\pi}{4}(U_{av})^2 = \frac{\pi}{4}(0.333)^2 \rightarrow T_v = 0.0873$$

$$\therefore t = \frac{T_v d^2}{C_v} = \frac{0.0873 * 4^2\ m^2}{0.5\ m^2/yr} \rightarrow t = 2.79\ yrs$$

ⓒ $h_p = 0^m$ above W.T.L → $U_e = 0$

$$\rightarrow U_{av} = U_z = \frac{60-0}{60} * 100 \rightarrow U_{av} = 100\%$$

} → $T_v = 1$ always at end of Consolidation process

$$\therefore t = \frac{T_v d^2}{C_v} = \frac{1 * 4^2\ m^2}{0.5\ m^2/yr} \rightarrow t = 32\ yrs$$ زمن الانضمام الكلي

ⓓ at $t = 15$ yrs → $T_v = \frac{C_v t}{d^2} = \frac{0.5\ m^2/yr * 15\ yr}{4\ m^2} = 0.46875$

assume $U_{av} \leq 60\%$ → $T_v = \frac{\pi}{4}(U_{av})^2$

$$\rightarrow 0.46875 = \frac{\pi}{4}(U_{av})^2 \rightarrow U_{av} = 0.7725 > 60\ \%$$

∴ لا يجوز استخدام هذه المعادلة ونستعمل المعادلة البديلة أي ان

$U_{av} > 60\ \%$ → $T_v = 1.781 - 0.933 \log(100 - U_{av})$

$0.46875 = 1.781 - 0.933 \log(100 - U_{av})$

→ $U_{av} = 0.745 = 74.5\ \% > 60\ \%$ O.K.

$$U_{av} = \frac{U_i - U_e}{U_i} \rightarrow 0.745 = \frac{60 - U_e}{60} \rightarrow U_e = 15.3\ \frac{KN}{m^2}$$

$$\rightarrow h_p = \frac{U_e}{\gamma_w} = \frac{15.3\ KN/m^2}{10\ KN/m^3} \rightarrow h_p = 1.53^m$$ above W.T.L after 15 yrs.

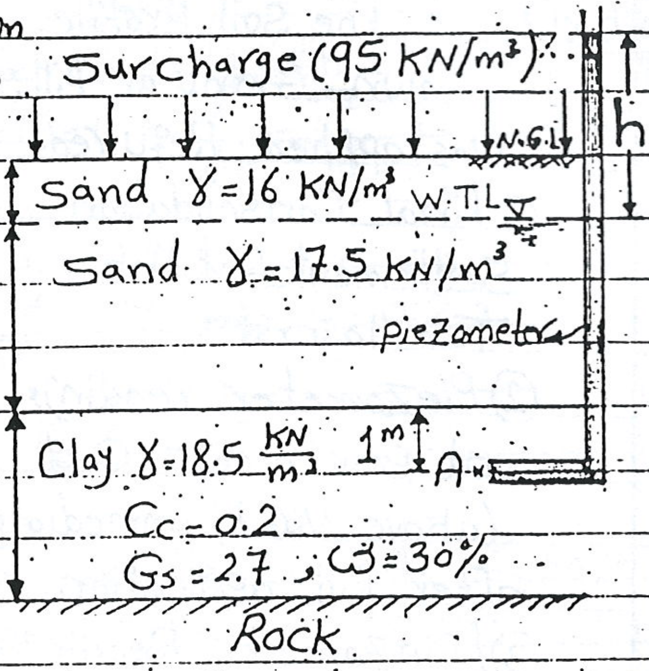
Ex 22 For the soil profile shown in the figure. A surcharge load is applied on the ground surface; Determine:

① hight of water in the Piezometer immediately after the application of load.

② Degree of Consolidation when $h = 7^m$ at (A).

③ (h) when the degree of Consolidation at A = 50 %.

④ Final Consolidation Settlement.



Solution: $\Delta q_{s\,net}\,(\text{Fill}) = 95\ KN/m^2 = \Delta\sigma_v = \Delta P = U_i$

① but $U_i = h\,\gamma_w \rightarrow 95 = h\,(10) \rightarrow h = 9.5^m$ (above W.T.L.)

② $h = 7^m \rightarrow U_e = 7 * 10 = 70\ KN/m^2$

$$U_{av} = U_z = \frac{U_i - U_e}{U_i} = \frac{95 - 70}{95} = 0.263 = 26.3\ \%$$

③ When $U_{av} = 50\% = \dfrac{95 - U_e}{95} \rightarrow U_e = 47.5\ KN/m^2$

$U_e = h\,\gamma_w \rightarrow 47.5 = h\,(10) \rightarrow h = 4.75^m$

④ $S * e_o = G_s\,\omega \rightarrow 1\,e_o = 2.7\,(0.3) \rightarrow e_o = 0.81$

$$P_o = \bar{\sigma} = \sigma - U = \underbrace{16 * 2 + 17.5 * 4 + 18.5 * 1.5}_{\sigma} - \underbrace{10 * 5.5}_{U}$$

$\rightarrow P_o = 74.75\ KN/m^2$

$$S_{cf} = \frac{C_c}{1+e_o} H \log \frac{P_o + \Delta P}{P_o} = \frac{0.2}{1+0.81}(3) \log \frac{74.75 + 95}{74.75}$$

$\rightarrow S_{cf} = 0.118^m = 11.8\ cm$

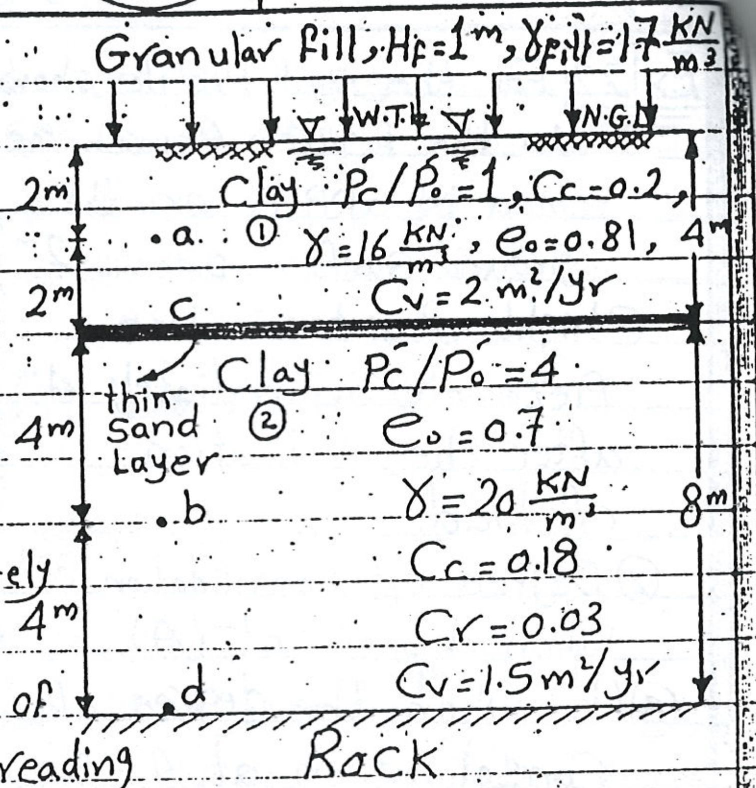
Ex 23 For the soil profile shown, Granular fill was applied; Required.

① Final Consolidation Settlement for the Two layers.

② Piezometer readings at points a, b, c, d (above N.G.L) immediately after fill application.

③ [Piezometer Reading of Point (a) / Piezometer reading of Point (b)] above N.G.L., 6 months after fill application.

④ [Settlement of layer ① / Settlement of layer ②] 6 months after fill application.



Solution: for clay layer ① :- Since $\frac{P_c'}{P_o'} = 1 \rightarrow$ N.C.C.

$$\Delta P' = \Delta\sigma_v = \Delta q_{s\,net\,(fill)} = h_{fill} * \gamma_{fill} = 17 * 1 = 17\ \frac{KN}{m^2}$$

$$P_o' = \sigma' = \sigma - U = 2*16 - 10*2 = 12\ KN/m^2$$

$$Sc_{f_①} = \frac{C_c}{1+e_o} H \log \frac{P_o' + \Delta P'}{P_o'} = \frac{0.2}{1+0.81} (4) \log \frac{12+17}{12}$$

$$\rightarrow Sc_{f_①} = 0.17^m = 17^{cm}$$

for clay layer ② : Since $\frac{P_c'}{P_o'} = 4 \rightarrow$ O.C.C.

$$\Delta P' = 17\ KN/m^2$$

$$P_o' = \sigma' = \sigma - U = 16*4 + 20*4 - 8*10 \rightarrow P_o' = 64\ \frac{KN}{m^2}$$

We must check since $\frac{P_c'}{P_o'} = 4 \rightarrow P_c' = 4*64 = 256\ \frac{KN}{m^2}$

$$P_o' + \Delta P' = 64 + 17 = 81\ KN/m^2 < P_c' = 256\ \frac{KN}{m^2}$$

$$\therefore Sc_{f_②} = \frac{C_r}{1+e_o} H \log \frac{P_o' + \Delta P'}{P_o'} = \frac{0.03}{1+0.7} (8) \log \frac{64+17}{64} = 0.014^m = 1.4$$

$\therefore$ total $S_{cf} = S_{cf①} + S_{cf②} = 17^{cm} + 1.4^{cm} = 18.4^{cm}$ ① الـ

② $\Delta\sigma_v' = \Delta P = U_i = 17\ KN/m^2$ immediately after fill application

→ Piezometer readings at $a = b = c = d = \frac{U_i}{\gamma_w} = \frac{17}{10} = 1.7^m$ above (W.T.L.)

③ for clay layer ①: $t = 6$ months $= 0.5$ yr

$$T_v = \frac{C_v t}{d^2} = \frac{2 m^2/yr * 0.5 yr}{2^2} \rightarrow T_v = 0.25$$

assume $U_{av} \leq 60\% \rightarrow T_v = \frac{\pi}{4}(U_{av})^2$

$$\rightarrow 0.25 = \frac{\pi}{4}(U_{av})^2 \rightarrow U_{av} = 0.5642 \leq 60\%$$

$\therefore$ O.K.

Since $U_{av} = \frac{U_i - U_e}{U_i} \rightarrow 0.5642 = \frac{17 - U_e}{17}$

→ $U_e = 7.408\ KN/m^2$ → $h_{①}$ (above W.T.L.) $= \frac{U_e}{\gamma_w} = \frac{7.408}{10} = 0.7408^m$

for clay layer ②: $t = 6$ months $= 0.5$ yr

$$T_v = \frac{C_v t}{d^2} = \frac{1.5 * 0.5}{8^2} \rightarrow T_v = 0.01172$$

assume $U_{av} \leq 60\% \rightarrow T_v = \frac{\pi}{4}(U_{av})^2 \rightarrow 0.01172 = \frac{\pi}{4}(U_{av})^2$

→ $U_{av} = 0.12215 < 60\%$ o.k, Since $U_{av} = \frac{U_i - U_e}{U_i}$

→ $0.12215 = \frac{17 - U_e}{17}$ → $U_e = 14.923\ KN/m^2$

→ $h_{②}$ (above W.T.L) $= \frac{U_e}{\gamma_w} = \frac{14.923}{10} = 1.4923^m$

$\therefore \frac{h \text{ of clay ①}}{h \text{ of clay ②}} = \frac{0.7408}{1.4923} = 0.496 \simeq 0.5$

④ for clay layer ①: $t = 6$ months $= 0.5$ yr → $T_v = 0.25$ → $U_{av} = 0.5642$

$\therefore S_{ct①} = U_{av} * S_{cf①} = 0.5642 * 17^{cm} = 9.59\ cm$

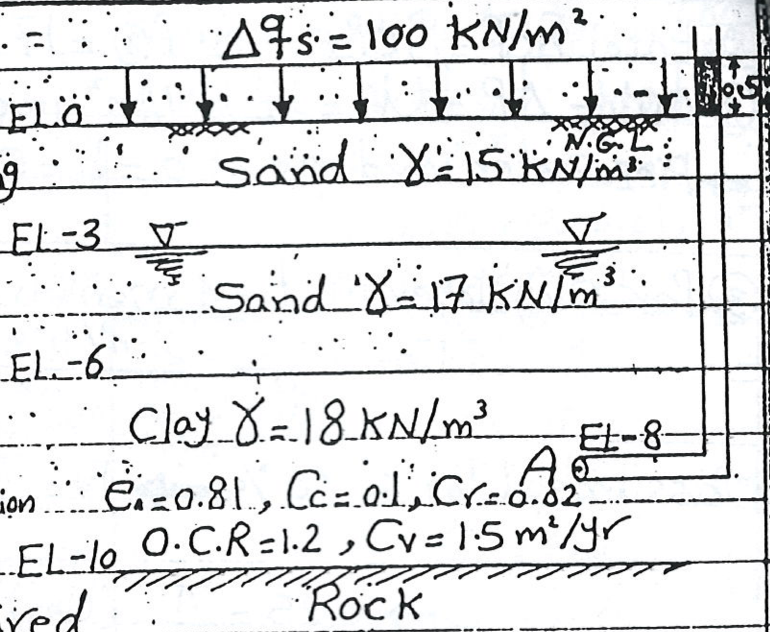
for clay layer ②: $t = 6$ months $= 0.5$ yr → $T_v = 0.01172$

→ $U_{av} = 0.12215$

and $S_{ct②} = U_{av} * S_{cf①} = 0.12215 * 1.4^{cm} = 0.171^{cm}$

$$\therefore \frac{S_{ct①}}{S_{ct②}} = \frac{9.59^{cm}}{0.171\ cm} = 56$$

Ex 24 For the soil profile shown in figure: the piezometric reading at point (A) at time (t) after fill application is 0.5^m above ground surface. Find:



① The degree of consolidation at time (t).

② Time (in years) required to record this reading.

③ The final consolidation settlement.

④ Time (in years) required for the increase in the effective stress and to be equal to 130 KN/m².

Given: $T_v = (\pi/4)\, U_{av}^2$ for $U_{av} \leq 60\%$

$T_v = -0.933 \log(1 - U_{av}) - 0.085$ for $U_{av} > 60\%$

Solution: $h = 0.5^m$ above N.G.L after time = t

→ $h = 0.5 + 3 = 3.5^m$ above W.T.L after time = t → $U_e = 3.5 * 10 = 35 \ KN/m^2$

Since $U_i = \Delta P = \Delta q_s \text{ (Fill)} = 100 \ KN/m^2$

① ∴ $U_{av} = \frac{U_i - U_e}{U_i} * 100\% = \frac{100 - 35}{100} * 100 = 65\% > 60\%$

∴ $T_v = -0.933 \log(1 - 0.65) - 0.085$ → $T_v = 0.34$

② $t = \frac{T_v d^2}{C_v} = \frac{0.34 * 4^2}{1.5}$ → $t = 3.63$ yrs

③ To Calculate S_{cf}: since O.C.R = 1.2 → O.C.C

$\bar{P_o} = \bar{\sigma} = \sigma - U = 15*3 + 17*3 + 18*2 - 10*5 = 82 \ \frac{KN}{m^2}$

$O.C.R = 1.2 = \frac{\bar{P_c}}{\bar{P_o} = 82}$ → $\bar{P_c} = 98.4 \ KN/m^2$

Now we must check $\bar{P_o} + \Delta \bar{P} \gtreqless \bar{P_c}$

$82+100 > 98.4 \rightarrow S_{cf} = \frac{C_r}{1+e_o} H \log \frac{P_c'}{P_o'} + \frac{C_c}{1+e_o} H \log \frac{P_o' + \Delta P}{P_c'}$

$\rightarrow S_{cf} = \frac{0.02}{1+0.81}(4) \log \frac{98.4}{82} + \frac{0.1}{1+0.81}(4) \log \frac{82+100}{98.4}$

$= 0.0625\ m = 6.25\ cm$

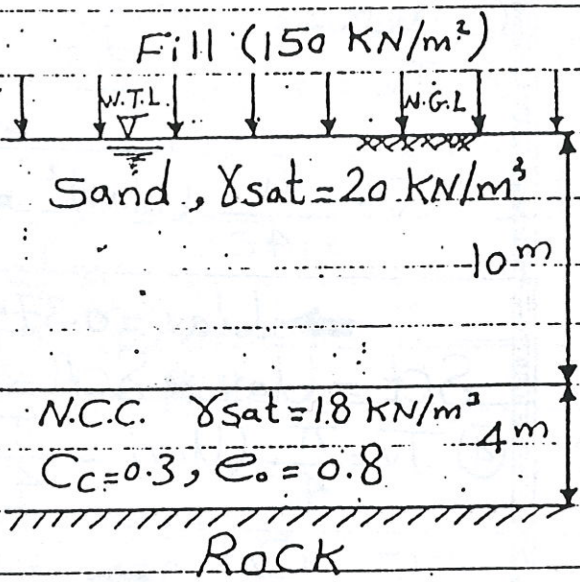
④ $P_t' = 130\ KN/m^2$; $P_o' = 82\ KN/m^2$, $P_f' = 82+100 = 182\ KN/m^2$

$U_{av} = \frac{P_t' - P_o'}{P_f' - P_o'} * 100 = \frac{130-82}{182-82} * 100 \rightarrow U_{av} = 48\% < 60\%$

$\therefore T_v = \frac{\pi}{4}(U_{av})^2 = \frac{\pi}{4}(0.48)^2 \rightarrow T_v = 0.181$

$\rightarrow t = \frac{T_v d^2}{C_v} = \frac{0.181 * 4^2}{1.5} \rightarrow t = 1.93\ yr$

Ex 25 The following results were obtained from a Consolidation test Carried out on a Sample obtained from the middle of the Clay layer shown. Initial thickness of the Sample = 25 mm and $t_{50} = 4.6$ min



If a fill of 150 KN/m² was placed on the ground surface. Determine: ① The Coeff. of Consolidation "Cv". ② Total Settlement of Clay layer. ③ The Settlement at the end of (6) months. ④ Time required for 40% Consolidation of the Clay layer. ⑤ The time required for 4 cm Settlement. ⑥ The Pore water Pressure immediately after loading, and at the end of Consolidation for a Point in the middle of the Clay Layer.

Solution: thickness of Sample = 25 mm → d = 12.5 mm
(Two way Drainage), $t_{50} = 4.6$ min

① $C_v = \frac{0.197\, d^2}{t_{50}}$ (Casagrande's Method)

$= \frac{0.197 (12.5)^2 \, mm^2}{4.6 \, min} * \frac{1^2 \, m^2}{1000^2 \, mm^2} * \frac{60 \, min}{1 \, hr} * \frac{24 \, hr}{1 \, day} * \frac{365 \, day}{1 \, yr}$

→ $C_v = 3.517 \, m^2/yr$

②
$\Delta q_s = 150 \, KN/m^2 = \Delta\sigma_v = U_i = \Delta \bar{P}$

$\bar{P}_o = \bar{\sigma} = \sigma - U = 20 * 10 + 2 * 18 - 10 * 12$ → $\bar{P}_o = 116 \frac{KN}{m^2}$

$S_{cf} = \frac{C_c}{1+e_o} H \log \frac{\bar{P}_o + \Delta\bar{P}}{\bar{P}_o}$

$= \frac{0.3}{1+0.8} (4) \log \frac{116+50}{116}$ → $S_{cf} = 0.24^{m} = 24^{cm}$

③ at t = 6 months = 0.5 yr

$T_v = \frac{C_v t}{d^2} = \frac{3.517 \frac{m^2}{yr} * 0.5 \, yr}{4^2 \, m^2}$ → $T_v = 0.11$

$T_v = \frac{\pi}{4} (U_{av})^2$ → $0.11 = \frac{\pi}{4} (U_{av})^2$

→ $U_{av} = 0.374 = 37.4\% < 60\%$ o.K

$S_{ct} = U_{av} * S_{cf} = 0.374 * 24^{cm} \simeq 9$ cm

④ $T_v = \frac{\pi}{4} (U_{av})^2 = \frac{\pi}{4} (0.4)^2$ → $T_v = 0.125$

$T_v = \frac{C_v t}{d^2}$ → $0.125 = \frac{3.517 * t}{4^2}$ → $t = 0.57$ yr

⑤ $S_{ct} = 4^{cm}$, $S_{cf} = 24^{cm}$, Since $U_{av} = \frac{S_{ct}}{S_{cf}}$

$U_{av} = \frac{4}{24}$ → $U_{av} = 0.167 = 16.7\% < 60\%$ o.K

→ $T_v = \frac{\pi}{4} (U_{av})^2 = \frac{\pi}{4} (0.167)^2 = 0.022$

$T_v = \frac{C_v t}{d^2}$

$0.022 = \frac{3.517 * t}{4^2}$ → $t = 0.1$ yr

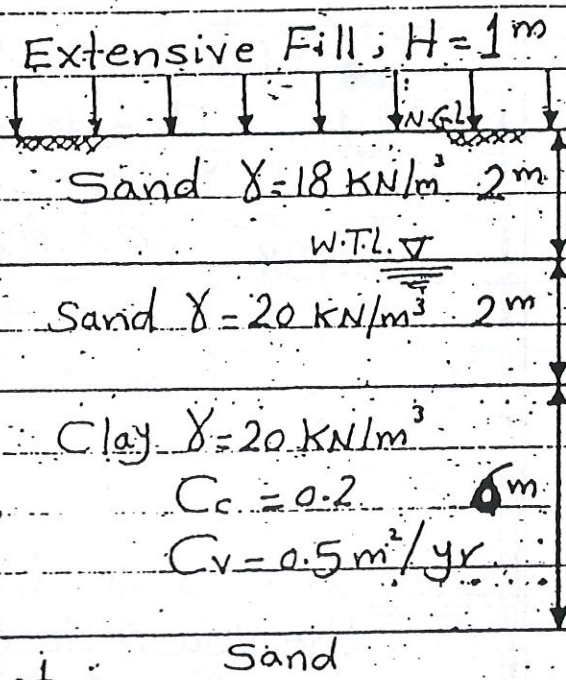
⑥ immediately after applying loading (at $t = 0$):
Pore water Pressure $= U_o + U_i = h_p \gamma_w + U_i$
$= 12 * 10 + 150 = 270 \ KN/m^2$

at end of Consolidation process (at $t = \infty$):
Pore water Pressure $= U_o + U_e^{\,0} = h_p \gamma_w$
$= 12 * 10 = 120 \ KN/m^2$

Ex 26 For the soil profile shown in the figure. The final Settlement of the clay layer is found to be 60 mm due to the application of the 1 m fill. Find:

① The unit weight of fill, if the void ratio at the end of Consolidation is (0.5)

② The Piezometer reading at a mid-Point in the clay layer (6) months after the application of the fill.



Solution: $S_{cf} = 60 \ mm = 0.06 \ m$, $e_f = 0.5$

$$S_{cf} = \frac{\Delta e}{1+e_o} H = \frac{e_o - e_f}{1+e_o} H$$

$$0.06 \ m = \frac{e_o - 0.5}{1+e_o} (6 \ m) \rightarrow e_o = 0.515$$

$$S_{cf} = \frac{C_c}{1+e_o} H \log \frac{P_o' + \Delta P}{P_o'}$$

Since $P_o' = \bar{\sigma} = \sigma - U = 2*18 + 2*20 + 3*20 - 5*10$

$\rightarrow S_{cf} = 86 \ KN/m^2$

$$0.06 \ m = \frac{0.2}{1+0.515} (6) \log \frac{86 + \Delta P}{86} \rightarrow \Delta P = 16.4 \ KN/m^2$$

Since $\Delta P = \Delta \sigma_v = \Delta q_s (fill) = h_{fill} * \gamma_{fill}$

① ∴ $16.4 = 1^m * \gamma_{fill}$ → $\gamma_{fill} = 16.4\ KN/m^3$

② $t = 6$ months $= 0.5\ yr$

$T_v = \frac{C_v t}{d^2} = \frac{0.5 * 0.5}{3^2}$ → $T_v = 0.0277$

$T_v = \frac{\pi}{4} (U_{av})^2$ → $0.0277 = \frac{\pi}{4} (U_{av})^2$

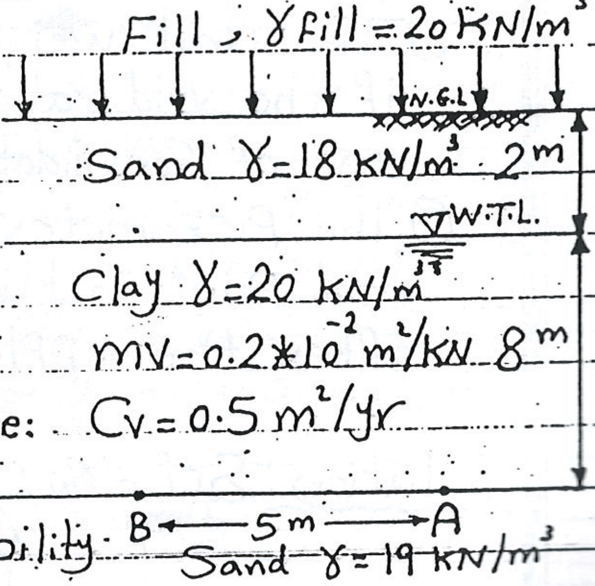
→ $U_{av} = 0.188 = 18.8\% < 60\%$ o.k

$U_{av} = \frac{U_i - U_e}{U_i} * 100\%$

$0.188 = \frac{16.4 - U_e}{16.4}$ → $U_e = 13.3\ KN/m^2$

$(h\ \text{above W.T.L}) = \frac{U_e}{\gamma_w} = \frac{13.3}{10} = 1.33^m$ above W.T.L

Ex 27 It is required to decrease the void ratio of the clay layer from (1.2) to (0.98) by applying fill on the N.G.L for the soil profile shown in figure, Determine:



① Height of fill required.

② The Coeff. of Compressibility of Soil « a_v »

③ Time required to reach half the final Consolidation Settlement.

④ Degree of Consolidation for Point (A) and (B), 1 year after fill application.

Given: $T_v = \frac{\pi}{4} (U_{av})^2$ for $U < 60\%$

$T_v = -0.933 \log (1 - U_{av}) - 0.085$

Solution: $e_o = 1.2$, $e_f = 0.98$, Since $S_{cf} = \frac{\Delta e}{1+e_o} H$

$\therefore S_{cf} = \frac{1.2 - 0.98}{1+1.2}(8) \rightarrow S_{cf} = 0.8^m = 80^{cm}$

$S_{cf} = m_v * \Delta P' * H$

$0.8^m = 0.2 * 10^{-2} * \Delta P' * 8 \rightarrow \Delta P' = 50\ KN/m^2$

Since $\Delta P' = \Delta \sigma_v = \Delta q_s (fill) = h_{fill} * \gamma_{fill}$

① $\therefore h_{fill} = \frac{50}{20} = 2.5^m$

② $m_v = \frac{a_v}{1+e_o} \rightarrow a_v = m_v(1+e_o) = 0.2*10^{-2}(1+1.2)$

$\rightarrow a_v = 4.4 * 10^{-3}\ m^2/KN$

③ $T_v = \frac{\pi}{4}(U_{av})^2 = \frac{\pi}{4}(0.5)^2 \rightarrow T_v = 0.197$

$t = \frac{T_v * d^2}{C_v} = \frac{0.197 * 4^2}{0.5} \rightarrow t = 6.28\ yrs$

④ U_{av} at A and B after one year = 100 % Because

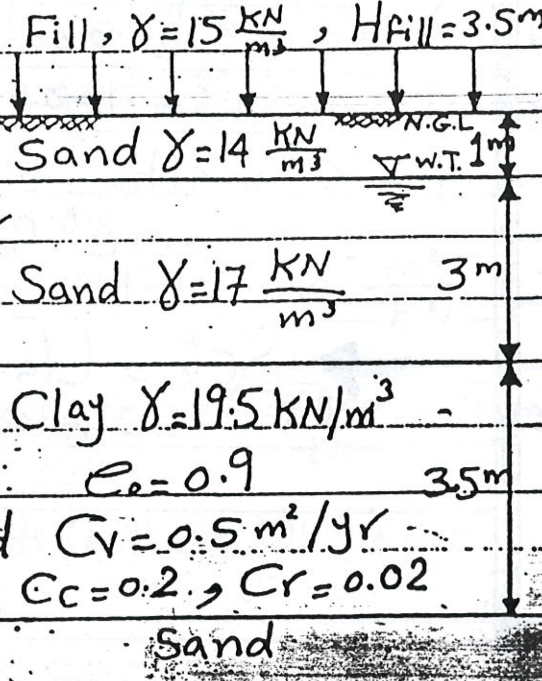
$U_e = 0\ \% \rightarrow U_{av} = 100\ \%$

وذلك لأن النقاط الطينية القريبة من الرمل هي اول النقاط التي
يتسرب ضغط الماء الزائد منها ، وبذلك فإنه بعد مرور فترة قصيرة
من تسليط الحمل فأن درجة الانضمام في النقاط الطينية القريبة من منطقة
منفذة تكون مساوية = 100% لتسرب جميع ضغط الماء الزائد منها .

Ex 28 For the soil profile shown in figure, find :-

① The Settlement 6 months after fill application if the Clay is normally Consolidated.

② The settlement 6 months after fill application if the Clay had been preconsolidated to an average Pressure = 300 $\frac{KN}{m^2}$



Solution: ① For N.C.C. $S_{cf} = \frac{C_c}{1+e_o} H \log \frac{P_o' + \Delta P'}{P_o'}$

$P_o' = \bar{\sigma} = \sigma - U = 14*1 + 17*3 + 19.5*1.75 - 10*4.75$

→ $P_o' = 51.625\ KN/m^2$

$\Delta P' = \Delta\sigma_v = \Delta q_s\ (fill) = h_{fill} * \gamma_{fill} = 3.5 * 15 = 52.5\ KN/m^2$

∴ $S_{cf} = \frac{0.2}{1+0.9} (3.5) \log \frac{51.625 + 52.5}{51.625} = 0.1123\ m = 11.23\ cm$

at $t = 6$ months $= 0.5$ year ; $T_v = \frac{C_v t}{d^2} = \frac{0.5 * 0.5}{1.75^2}$

→ $T_v = 0.082$; and since $T_v = \frac{\pi}{4}(U_{av})^2$ [$U_{av} \le 60\%$]

$0.082 = \frac{\pi}{4}(U_{av})^2$ → $U_{av} = 0.3224 = 32.24\% < 60\%$ o.k

→ $S_{ct} = U_{av} * S_{cf} = 0.3224 * 0.1123 = 0.0362^{m} = 3.62^{cm}$

② When the Clay had been Preconsolidated to an average Pressure $P_c' = 300\ kN/m^2$ → O.C.C
then we must check $P_o' + \Delta P' \gtreqless P_c'$

$P_o' + \Delta P' = 51.625 + 52.5 = 104.125\ kN/m^2 < P_c' = 300\ \frac{KN}{m^2}$

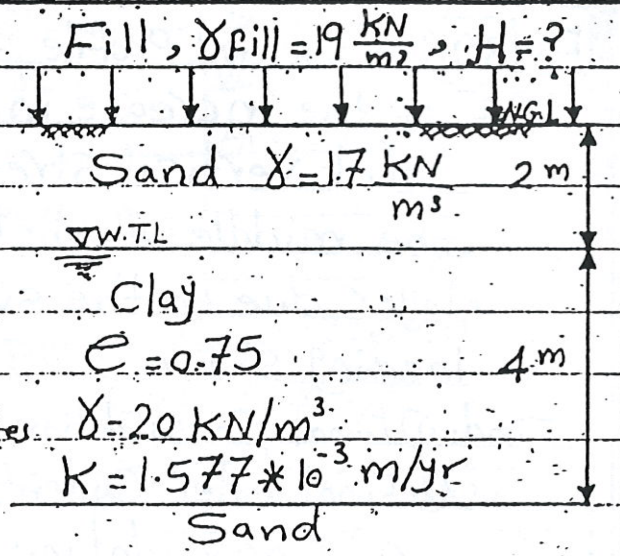
∴ $S_{cf} = \frac{C_r}{1+e_o} H \log \frac{P_o' + \Delta P'}{P_o'}$

$= \frac{0.02}{1+0.9}(3.5) \log \frac{51.625 + 52.5}{51.625} = 0.01123^{m} = 1.123\ cm$

$t = 6$ months $= 0.5$ yr → $T_v = 0.082$ → $U_{av} = 32.24\%$
(Same for this Part like Part ①)

→ $S_{ct} = U_{av} * S_{cf}$
$= 0.3224 * 0.01123 = 0.00362^{m} = 0.362^{cm}$

Ex 29 Find the height of fill which would result in 3 cm Settlement after 1.5 year of Service, if a Sample of the same clay layer when tested in the Lab. gave: $H = 19\,mm$, Consolidates (30%) in 11 minutes.



Solution: for clay sample: $H = 19\,mm \rightarrow d = \frac{H}{2} = \frac{19}{2} = 9.5\,mm$

$U_{av} = 30\%$, $t = 11\,min$ (Two way drainage)

$\therefore T_v = \frac{\pi}{4}(U_{av})^2 = \frac{\pi}{4}(0.3)^2 \rightarrow T_v = 0.0707$

$$C_v = \frac{T_v d^2}{t} = \frac{0.0707 * (9.5)^2\ mm^2}{11\ min} * \frac{1^2\ m^2}{1000^2\ mm^2} * \frac{60\ min}{1\ hr} * \frac{24\ hr}{1\ day} * \frac{365\ day}{1\ yr}$$

$\rightarrow C_v = 0.3048\ m^2/yr$

Now; for Clay Layer 4 m thick, $d = 2\,m$, at $t = 1.5\,yr$

$$T_v = \frac{C_v t}{d^2} = \frac{0.3048 * 1.5}{2^2} \rightarrow T_v = 0.1143$$

assume $U_{av} \le 60\% \rightarrow T_v = \frac{\pi}{4}(U_{av})^2$

$\rightarrow 0.1143 = \frac{\pi}{4}(U_{av})^2 \rightarrow U_{av} = 0.3815 < 60\%$ o.k

Since $\delta_{ct} = U_{av} * \delta_{cf} \rightarrow 3\,cm = 0.3815 * \delta_{cf} \rightarrow \delta_{cf} = 7.864\,cm$

Since $C_v = \frac{K}{m_v \gamma_w} \rightarrow m_v = \frac{K}{C_v \gamma_w}$

$$\rightarrow m_v = \frac{1.577 * 10^{-3}}{0.3048 * 10} \rightarrow m_v = 5.17356 * 10^{-4}\ \frac{m^2}{KN}$$

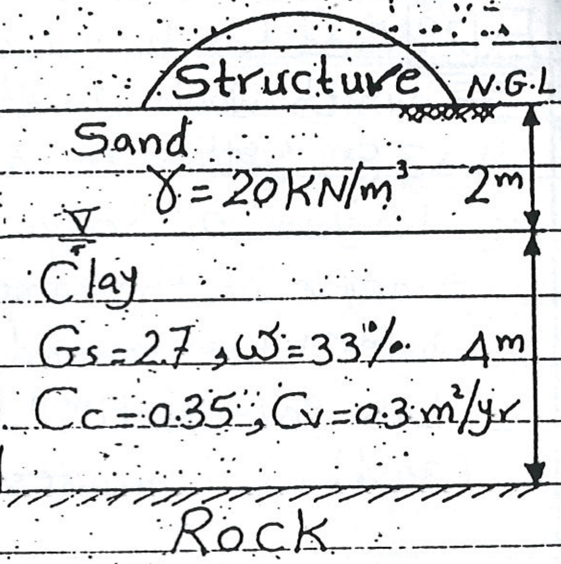
Since $\delta_{cf} = m_v * \Delta P' * H$ where $\delta_{cf} = \frac{7.864}{100} = 0.07864\,m$

$0.07864\,m = 5.17356 * 10^{-4} * \Delta P' * 4$

$\rightarrow \Delta P' = 38\ KN/m^2 = \Delta q_s\ (\text{Fill}) = h_{fill} * \gamma_{fill}$

$\therefore h_{fill} = \frac{38}{19} = 2\,m$

Ex 30 For the soil profile shown, If the increase in the total vertical stress at the middle of the clay layer due to the surface loading shown is 25 kN/m². Find: ① Final Consolidation Settlement. ② Final Water Content (at end of Consolidation). ③ Time required for 40% Consolidation.



Solution: For clay layer: $S * e_o = G_s * \omega$

$1 e_o = 2.7 * 0.33 \rightarrow e_o = 0.891$

$\gamma_{sat} = \frac{G_s + e}{1+e}\gamma_w = \frac{2.7+0.891}{1+0.891}(10) \rightarrow \gamma_{sat} = 19 \text{ kN/m}^3$

$P_o' = \sigma' = \sigma - u = 20*2 + 19*2 - 10*2 \rightarrow P_o' = 58 \text{ kN/m}^2$

Since $\Delta P = 25 \text{ kN/m}^2 \rightarrow \delta_{cf} = \frac{C_c}{1+e_o} H \log \frac{P_o' + \Delta P}{P_o'}$

① $\rightarrow \delta_{cf} = \frac{0.35}{1+0.891}(4)\log\frac{58+25}{58} \rightarrow \delta_{cf} = 0.115^m = 11.5^{cm}$

and $\delta_{cf} = \frac{e_o - e_f}{1+e_o} H \rightarrow 0.115^m = \frac{0.891 - e_f}{1+0.891}(4)$

$\rightarrow e_f = 0.836$ and Since $S * e_f = G_s\, \omega_f$

② $\rightarrow 1 * 0.836 = 2.7 * \omega_f \rightarrow \omega_f = 0.31 = 31\%$

③ at $U_{av} = 40\% \rightarrow T_v = \frac{\pi}{4}(U_{av})^2 = \frac{\pi}{4}(0.4)^2$

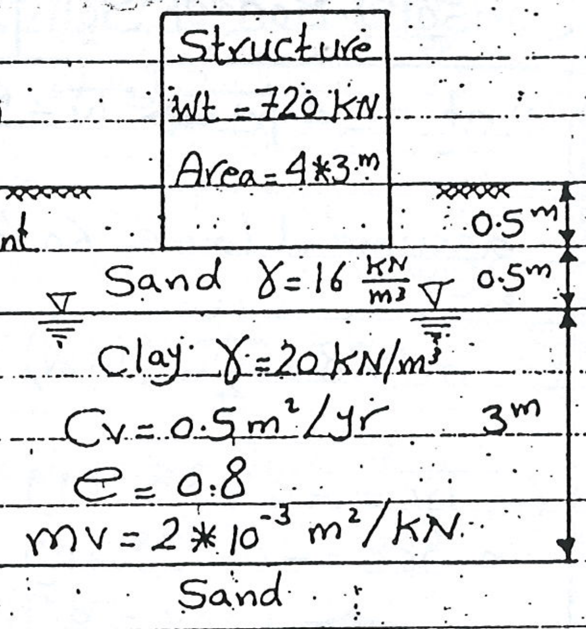
$\rightarrow T_v = 0.1256$ and Since $t = \frac{T_v d^2}{C_v}$

$= \frac{0.1256 * 4^2}{0.3}$

$\rightarrow t = 6.7 \text{ yrs}$

Ex 31 For the soil profile and loading condition shown in figure Find:

1. Final Consolidation Settlement
2. Settlement after 3 months.
3. Time (in days) to have a Settlement of 6 cm.
4. Degree of Consolidation after 4 years.
5. Time to end of Consolidation Process.



Solution: $\Delta q_s = \frac{\text{Wt. of building}}{\text{Area of building}} = \frac{720\ KN}{3*4\ m} = 60\ KN/m^2$

$\Delta q_{s\,net} = \Delta q_s - \gamma h_{excavation} = 60 - 16*0.5$

$\rightarrow \Delta q_{s\,net} = 52\ KN/m^2$

$\Delta P = \frac{\Delta q_{s\,net} * B * L}{(B+Z)(L+Z)} = \frac{52*3*4}{(3+2)(4+2)} \rightarrow \Delta P = 20.8\ \frac{KN}{m^2}$

① $S_{cf} = m_v * \Delta P * H = 2*10^{-3} * 20.8 * 3 \rightarrow S_{cf} = 0.1248\ m = 12.48\ cm$

② at $t = 3\ months = \frac{3}{12}\ yr = 0.25\ yr$

$T_v = \frac{C_v t}{d^2} = \frac{0.5*0.25}{1.5^2} \rightarrow T_v = 0.055$

assume $U_{av} \leq 60\% \rightarrow T_v = \frac{\pi}{4}(U_{av})^2$

$\rightarrow 0.055 = \frac{\pi}{4}(U_{av})^2 \rightarrow U_{av} = 0.266 = 26.6\% \leq 60\%$ o.k

$S_{ct} = U_{av} * S_{cf} = 0.266 * 0.1248 = 0.0332\ m = 3.32\ cm$

③ when $S_{ct} = 6\ cm = 0.06\ m$, Since $U_{av} = \frac{S_{ct}}{S_{cf}} = \frac{0.06}{0.1248}$

$\rightarrow U_{av} = 0.48 = 48\% < 60\%$

$\therefore T_v = \frac{\pi}{4}(U_{av})^2 = \frac{\pi}{4}(0.48)^2 \rightarrow T_v = 0.1815$

$t = \frac{T_v d^2}{C_v} = \frac{0.1815 * 1.5^2}{0.5} \rightarrow t = 0.817\ yr * 365 = 298\ days$

④ at $t = 4yr \rightarrow T_v = \frac{C_v t}{d^2} = \frac{0.5 * 4}{1.5^2} \rightarrow T_v = 0.888$

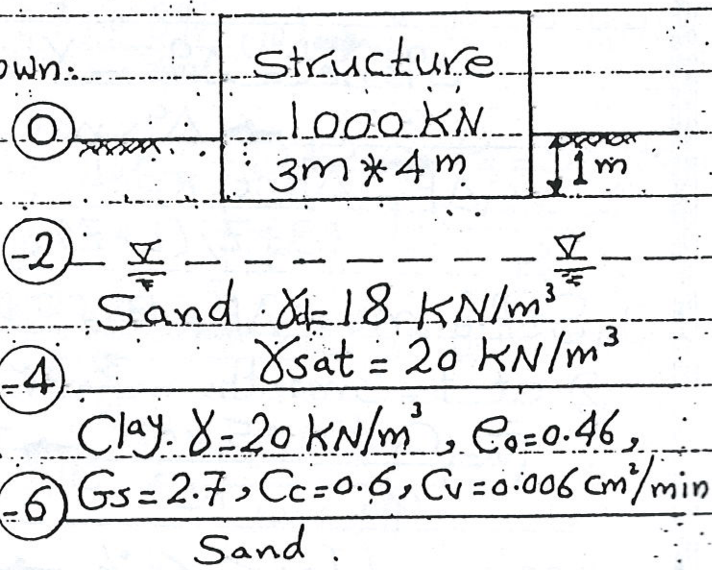
assume $U_{av} \leq 60\% \rightarrow T_v = \frac{\pi}{4}(U_{av})^2$

$0.888 = \frac{\pi}{4}(U_{av})^2 \rightarrow U_{av} = 1.06\% = 106\% > 60\%$
$\therefore$ Not O.K

$\therefore T_v = -0.933 \log(1 - U_{av}) - 0.085$
$0.888 = -0.933 \log(1 - U_{av}) - 0.085$
$\rightarrow U_{av} = 0.91 = 91\% > 60\%$ O.K

⑤ at end of Consolidation Process $T_v = 1$
$\therefore t = \frac{T_v d^2}{C_v} = \frac{1 * 1.5^2}{0.5} \rightarrow t = 4.5$ yrs زمن عملية الانضغام الكلية

Ex 32 For the soil profile shown:
Find: ① How much total Settlement will occur.
② When will Consolidation Process ends (in days).
③ When will half the Settlement occur (in days).
④ What's the Settlement after 6 mon. of loading.
⑤ Final water Content (at end of the Consolidation).



Solution: $P_o = \bar{\sigma} = \sigma - U = 18*2 + 20*2 + 20*1 - 10*3 = 66$ kN/m²

$\Delta q_s = \frac{Wt.}{Area} = \frac{1000}{(3*4)\ m^2} \rightarrow \Delta q_s = 83.33$ kN/m²

$\Delta q_{s\,net} = \Delta q_s - \gamma h_{excavation} = 83.33 - 18*1 = 65.33$ kN/m²

$\Delta P = \Delta\sigma_v = \frac{\Delta q_{s\,net} * B * L}{(B+Z)(L+Z)} = \frac{65.33*3*4}{(3+4)(4+4)} = 14$ kN/m²

$$S_{cf} = \frac{C_c}{1+e_o} H \log \frac{P_o + \Delta P}{P_o} = \frac{0.6}{1+0.46} (2) \log \frac{66+14}{66}$$

① → $S_{cf} = 0.069^{m} = 6.9\ cm$

② at end of Consolidation Process $T_v = 1$ always

$$C_v = 0.006 \frac{cm^2}{min} * \frac{1^2\ m^2}{100^2\ cm^2} * \frac{60\ min}{1\ hr} * \frac{24\ hr}{1\ day} = 8.64*10^{-4} \frac{m^2}{day}$$

$$t = \frac{T_v d^2}{C_v} = \frac{1*1^2\ m^2}{8.64*10^{-4}\ m^2/day} = 1157.4 \simeq 1158\ days$$

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③ $U_{av} = 50\% < 60\%$ → $T_v = \frac{\pi}{4}(U_{av})^2 = \frac{\pi}{4}(0.5)^2$

→ $T_v = 0.197$

$$\therefore t = \frac{T_v d^2}{C_v} = \frac{0.197*1^2\ m^2}{8.64*10^{-4}\ m^2/day} \rightarrow t = 228\ days$$

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④ at $t = 6$ months $= 0.5\ yr$

$$C_v = 8.64*10^{-4} \frac{m^2}{day} * \frac{365\ day}{1\ yr} \rightarrow C_v = 0.3154\ m^2/yr$$

$$T_v = \frac{C_v t}{d^2} = \frac{0.3154*0.5}{1^2} \rightarrow T_v = 0.1577$$

assume $U_{av} \le 60\%$ → $T_v = \frac{\pi}{4}(U_{av})^2$ → $0.1577 = \frac{\pi}{4}(U_{av})^2$

→ $U_{av} = 0.448 = 44.8\% < 60\%$ O.K

$\therefore S_{ct} = U_{av} * S_{cf} = 0.448 * 0.069 = 0.03^{m} = 3^{cm}$

⑤ $S_{cf} = 0.069^{m} = \frac{e_o - e_f}{1+e_o}(H) = \frac{0.46 - e_f}{1+0.46}(2)$

→ $e_f = 0.41$

$S * e_f = G_s * \omega_f$

$1*0.41 = 2.7*\omega_f$ → $\omega_f = 0.1518$

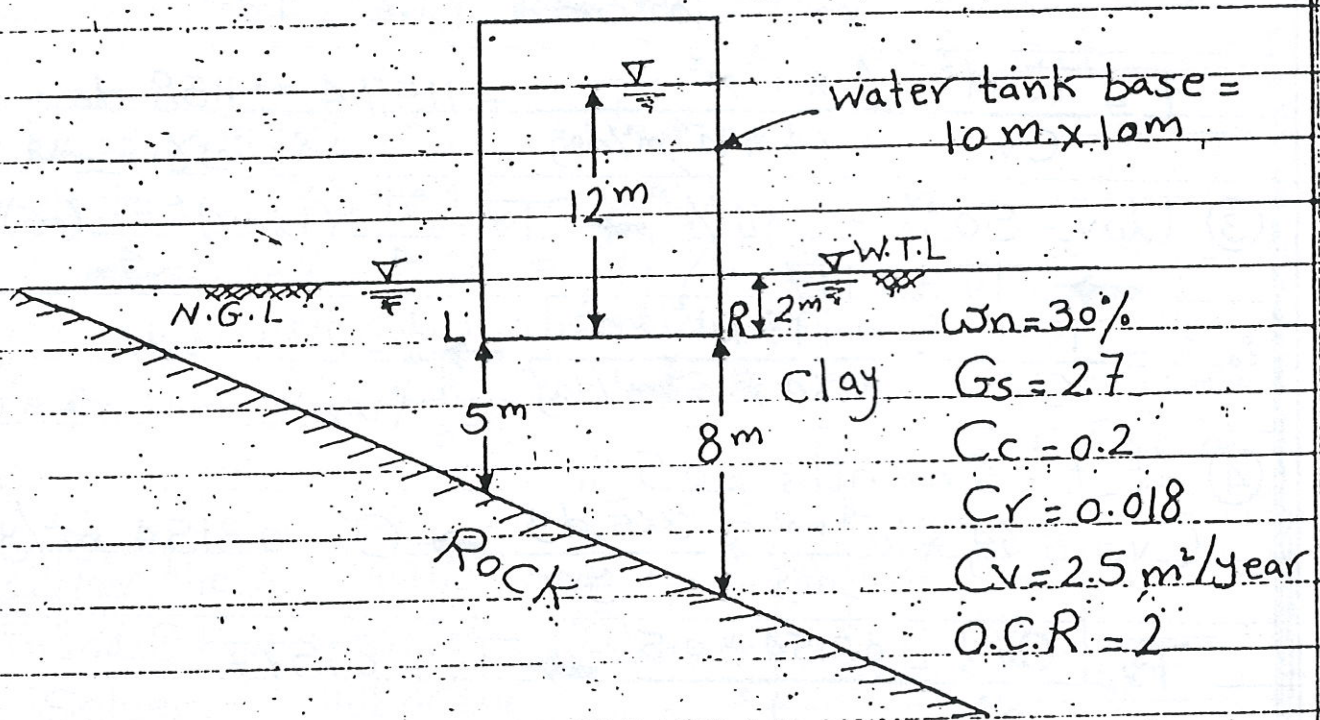
$= 15.18\%$

Ex 33 For the water tank shown in figure below. Find:

① Final Consolidation Settlement of the Right (R) and left (L) sides.

② The Average Final Consolidation Settlement.

③ Time Required for 40% Consolidation.



Solution: At the Right side (R)

$S * e_o = G_s\, \omega \rightarrow 1\, e_o = 2.7 * 0.3 \rightarrow e_o = 0.81$

$\gamma_{sat} = \frac{G_s + e}{1+e}(\gamma_w) = \frac{2.7+0.81}{1+0.81}(10) \rightarrow \gamma_{sat} = 19.4\ \frac{KN}{m^3}$

$P_o' = \bar{\sigma} = \sigma - U = 19.4 * 6 - 10 * 6 \rightarrow P_o = 56.4\ KN/m^2$

$O.C.R = \frac{P_c}{P_o} \rightarrow 2 = \frac{P_c}{56.4} \rightarrow P_c = 112.8\ KN/m^2$

$\Delta q_s = \frac{Wt.\ of\ tank}{Area} = \frac{Volume * \gamma_w}{Area} = \frac{Area * h * \gamma_w}{Area}$

$\therefore \Delta q_s = h * \gamma_w = 12 * 10 \rightarrow \Delta q_s = 120\ KN/m^2$

$\Delta q_{s\,net} = \Delta q_s - \gamma\, h_{excavation}$

$= 120 - 19.4 * 2 \rightarrow \Delta q_{s\,net} = 81.2\ KN/m^2$

$\Delta P' = \frac{\Delta q_{s\,net} * B^2}{(B+Z)^2} = \frac{81.2 * 10^2}{(10+4)^2} \rightarrow \Delta P' = 41.43\ KN/m^2$

$\therefore \bar{P_o} + \Delta \bar{P} = 56.4 + 41.43 = 97.83 < \bar{P_c} = 112.8$ (the soil is o.c.c.)

$\therefore S_{cf} = \frac{C_r}{1+e_o} H \log \frac{\bar{P_o} + \Delta \bar{P}}{\bar{P_o}}$

$= \frac{0.018}{1+0.81} (8) \log \frac{56.4 + 41.43}{56.4}$ ➡ $S_{cf} = 0.02^m = 2^{cm}$

at left side (L) :-

$e_o = 0.81$, $\gamma_{sat} = 19.4 \ KN/m^3$, $\Delta q_{s\,net} = 81.2 \ KN/m^2$

$\bar{P_o} = 19.4 (4.5) - 10 (4.5)$ ➡ $\bar{P_o} = 42.3 \ KN/m^2$

$O.C.R = 2 = \frac{\bar{P_c}}{42.3}$ ➡ $\bar{P_c} = 84.6 \ KN/m^2$

$\Delta \bar{P} = \frac{\Delta q_{s\,net} * B^2}{(B+Z)^2} = \frac{81.2 * 10^2}{(10+2.5)^2}$ ➡ $\Delta \bar{P} = 51.97 \frac{KN}{m^2}$

$\bar{P_o} + \Delta \bar{P} = 42.3 + 51.97 = 94.27 > \bar{P_c} = 84.6 \frac{KN}{m^2}$ (the soil is o.c.c)

$\therefore S_{cf} = \frac{C_r}{1+e_o} H \log \frac{\bar{P_c}}{\bar{P_o}} + \frac{C_c}{1+e_o} H \log \frac{\bar{P_o} + \Delta \bar{P}}{\bar{P_c}}$

$= \frac{0.018}{1+0.81} (5) \log \frac{84.6}{42.3} + \frac{0.2}{1+0.81} (5) \log \frac{42.3 + 51.97}{84.6}$

➡ $S_{cf} = 0.04^m = 4^{cm}$

② Average $S_{cf} = \frac{S_{cf}(R) + S_{cf}(L)}{2} = \frac{2+4}{2} = 3^{cm}$

③ For $U_{av} = 40\%$ ➡ $T_v = \frac{\pi}{4} (U_{av})^2 = \frac{\pi}{4} (0.4)^2$

➡ $T_v = 0.1256$, Since $t = \frac{T_v d^2}{C_v}$

$\therefore t = \frac{0.1256 * (6.5)^2}{(2.5)}$ ➡ $t = 2.124 \ yr$

Note: $d = 6.5^m$ (as average of $\frac{8+5}{2} = 6.5^m$)

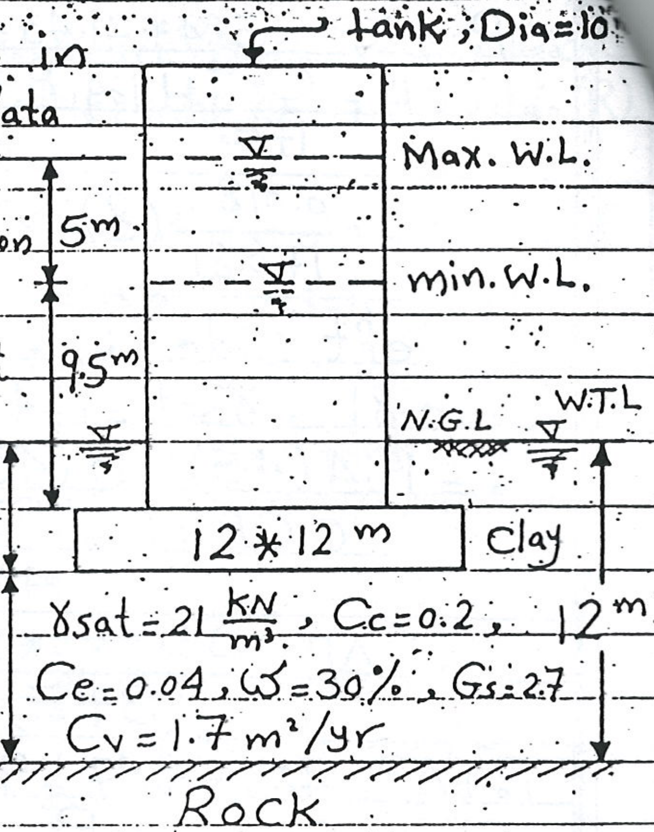
كتب مركز الخزان
دائماً

Ex 34 For the tank shown in figure, the following data are given:

Wt. of tank empty + foundation is equal to 172 ton.

Water in tank is always at its min. level. Determine:

1. Final Consolidation Settlement.
2. Expected Consolidation Settlement (1) yr after service.
3. If after (3) yrs of service, the water was raised rapidly to its max. level shown and then lowered rapidly. The process of raising and lowering lasted for (15) days. What will be the expected final Consolidation Settlement.



Solution: $\Delta q_s = \dfrac{\text{Wt. of tank empty + foundation + Wt. of water in tank}}{\text{Area of foundation}}$

$$\text{Wt. of water in tank} = \text{Volume of water} * \gamma_w$$

$$= \frac{\pi D^2}{4} (h_{min}) * \gamma_w$$

$$= \frac{\pi (10)^2}{4} (9.5) * 10 = 7461.3 \text{ KN}$$

Wt. of tank empty + foundation = 172 ton = 1720 KN

$$\therefore \Delta q_s = \frac{(1720 + 7461.3) \text{ KN}}{(12 * 12) \text{ m}^2} = 63.76 \text{ KN/m}^2$$

$$\Delta q_{s\,net} = \Delta q_s - \gamma h_{(\text{حفر})} = 63.76 - 21 * 3 = 0.76 \text{ KN/m}^2$$

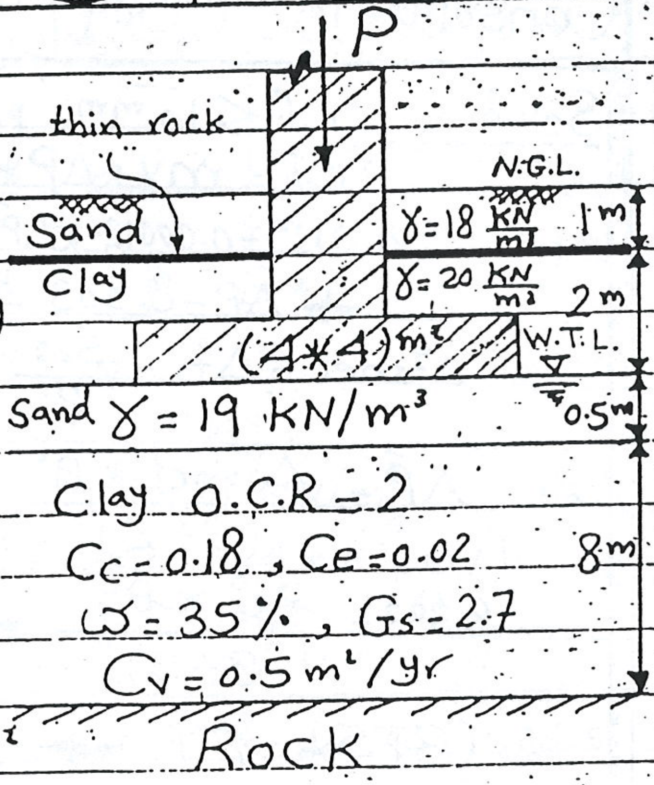
$$\Delta P = \frac{\Delta q_{s\,net} * B^2}{(B+Z)^2} = \frac{0.76 * 12^2}{(12 + 4.5)^2} = 0.4 \text{ KN/m}^2$$

مقدار قليل جداً لا يؤثر كثيراً على SCf فيهمل وبذلك تهمل المطاليب الأخرى الثاني والثالث وينتهي السؤال إلى هنا

Ex 35 For the footing shown in figure. Determine:

① the final Consolidation Settlement.

② Settlement Corresponding to 50% degree of Consolidation. Given:



P = total applied load = 1000 KN

Size of footing = 4 m x 4 m

Solution: P = 1000 KN

Area = 4*4 = 16 m^2

$$\Delta q_s = \frac{1000\ KN}{16\ m^2} = 62.5\ KN/m^2$$

$$\Delta q_{s\,net} = \Delta q_s - \gamma h \text{ (ضع)} = 62.5 - (18*1 + 20*2)$$

$$\rightarrow \Delta q_{s\,net} = 4.5\ KN/m^2$$

$$\Delta P = \frac{\Delta q_{s\,net} * B^2}{(B+Z)^2} = \frac{4.5*4^2}{(4+4.5)^2} = 0.9965\ KN/m^2$$

مقدار قليل جداً نهمل ولا داعي لتكملة السؤال.

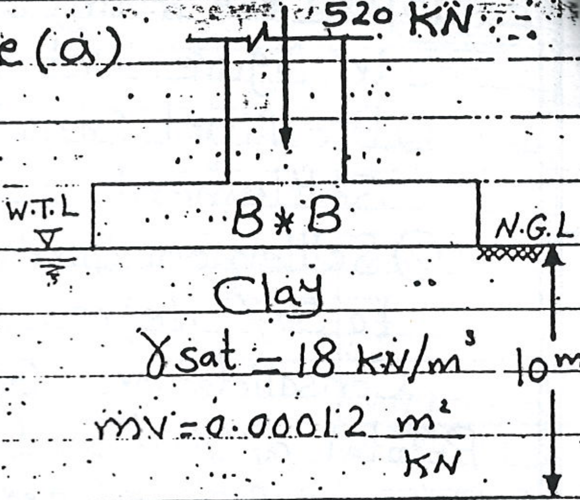
Ex 36 A vertical Column Carring a total load of 520 KN is to be founded on 10 m fully saturated Clay. Given the following data: W.T.L at N.G.L, for the Clay layer $m_v = 0.00012\ m^2/KN$, max Consolidation Settlement ≤ 10 mm, $\gamma_{sat} = 18\ KN/m^3$. Required: Design a square footing to support the column if the footing is to be located:-

ⓐ at N.G.L

ⓑ 1 m below N.G.L.

ⓒ 2 m below N.G.L.

- from your point of View, state which is the most Proper size.



Solution: $S_{cf} \le 10^{mm}$ Case (a)

$S_{cf} = m_v * \Delta P' * H$

$0.01^m = 0.00012 * \Delta P' * 10^m$

→ $\Delta P' = 8.333 \frac{KN}{m^2}$

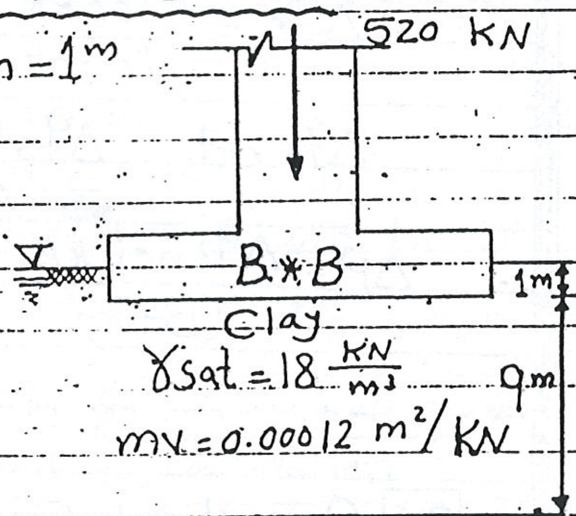
$\Delta q_{s\,net} = \Delta q_s = \frac{520}{B^2}$

∴ $\Delta P' = \frac{\Delta q_{s\,net} * B^2}{(B+Z)^2}$

$8.333 = \frac{\frac{520}{B^2} * B^2}{(B+5)^2}$ → $(B+5)^2 = \frac{520}{8.333} = 62.4$

بجذر الطرفين

∴ $(B+5) = 7.9$ → $B = 2.9^m$ ∴ Use Dimension of footing $2.9^m \times 2.9^m$



Case (b): Depth of excavation $= 1^m$

$S_{cf} = m_v * \Delta P' * H$

$0.01^m = 0.00012 * \Delta P' * 9^m$

→ $\Delta P' = 9.26 \frac{KN}{m^2}$

$\Delta q_s = \frac{520}{B^2}$

but $\Delta q_{s\,net} = \frac{520}{B^2} - 18 * 1$

$\Delta P' = \frac{\Delta q_{s\,net} * B^2}{(B+Z)^2}$ → $9.26 = \frac{(520/B^2 - 18)\, B^2}{(B+4.5)^2}$

→ $9.26 = \frac{520 - 18B^2}{B^2 + 9B + 20.25}$ → $9.26B^2 + 83.3B + 187.5 = 520 - 18B^2$

→ $27.26B^2 + 83.3B - 332.5 = 0$ بالحل بالدستور

→ $B = 2.28^m \simeq 2.3^m$ واهمال القيمة السالبة

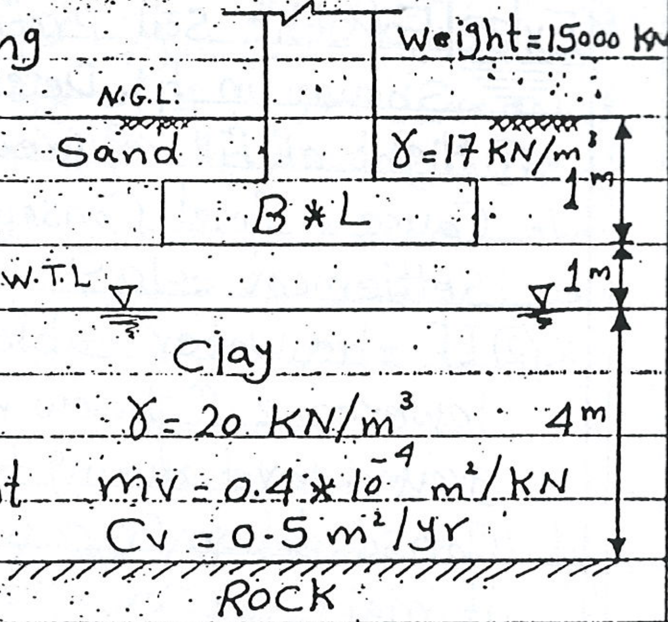
∴ Use square footing by Dimension 2.3×2.3 m

Case (C) H.W. (Ans = $B = 2^m$)

Ex 37 For the site and loading Condition shown in figure. Design the rectangular footing.

Given that:

* $\frac{L}{B} = 1.5$
* The allowable settlement after (2) years is 1 cm.



Solution: $t = 2\,yrs \rightarrow T_v = \frac{C_v t}{d^2} = \frac{0.5*2}{4^2} \rightarrow T_v = 0.0625$

assume $U_{av} \leq 60\% \rightarrow T_v = \frac{\pi}{4}(U_{av})^2$

$\therefore 0.0625 = \frac{\pi}{4}(U_{av})^2 \rightarrow U_{av} = 0.2821 = 28.21\% < 60\%$ o.k.

$S_{ct} = 1^{cm} = 0.01^{m}$ and $U_{av} = 28.21\%$, but $U_{av} = \frac{\delta_{ct}}{\delta_{cf}}$

$\therefore S_{cf} = \frac{0.01}{0.2821} \rightarrow \delta_{cf} = 0.03545\,m$

but $\delta_{cf} = m_v * \Delta P' * H$

$\therefore 0.03545 = 0.4*10^{-4} * \Delta P' * 4 \rightarrow \Delta P' = 221.557\ \frac{KN}{m^2}$

Since $\Delta q_s = \frac{Wt.}{Area} = \frac{15000\,KN}{B*L} = \frac{15000\,KN}{1.5B^2}$ $(L = 1.5B)$

and $\Delta q_{s\,net} = \Delta q_s - \gamma h_{(so)} = \frac{15000\,KN}{1.5B^2} - 17*1$

and $\Delta P' = \frac{\Delta q_{s\,net} * B * L}{(B+Z)(L+Z)} \rightarrow 221.557 = \frac{(\frac{15000}{1.5B^2} - 17) * 1.5B^2}{(B+3)(1.5B+3)}$

$\rightarrow 221.557 = \frac{15000 - 2.25B^2}{1.5B^2 + 7.5B + 9} \rightarrow 332.235B^2 + 1661.6755B + 1994.01 = 15000 - 25.5B^2$

$\rightarrow 357.835B^2 + 1661.6755B - 13005.99 = 0$ حَل عالمستر

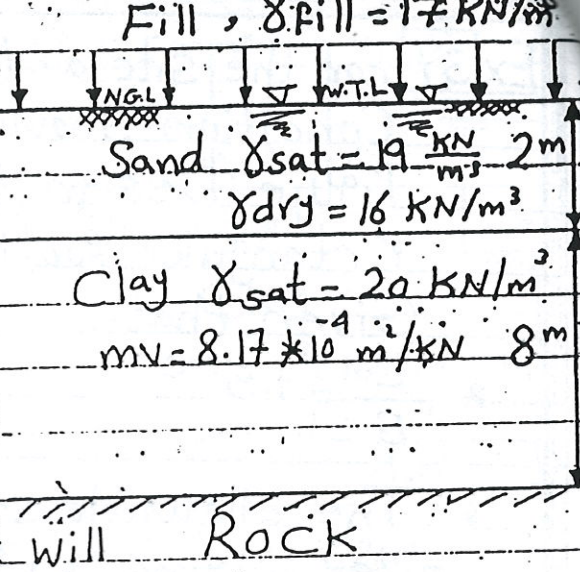
$\rightarrow B = 4.14^{m}$; since $L = 1.5B \rightarrow L = 6.2^{m}$

$\therefore$ Use footing $6.2^{m} * 4.14^{m}$

Ex 38 For the soil profile shown in fig. Determine:

① Hight of fill required to cause a final consolidation settlement = 10 cm.

② If the water table is lowered 2 m below natural ground level during the consolidation process what will it make on consolidation settlement.



Solution: ① $S_{cf} = 10\,cm = 0.1^m = m_v * \Delta \bar{P} * H$

$0.1^m = 8.17 * 10^{-4} * \Delta \bar{P} * 8 \rightarrow \Delta \bar{P} = 15.3\ \frac{KN}{m^2}$

Since $\Delta \bar{P} = \Delta q_s\,(fill) = \gamma_{fill} * h_{fill}$

$\therefore 15.3 = 17 * h_{fill} \rightarrow h_{fill} = 0.9^m$

② من المتعارف عليه ان خفض مستوى المياه الجوفية يؤدي الى زيادة قيمة الاجهاد الفعال بسبب نقصان حاصل في ضغط الماء المسامي وهذا مايتوافق مع مبدأ عملية الانضمام ويزيد في قيمة Scf والتي نحسبها في هذه الحالة بالشكل الآتي:

[a] نحسب قيمة P'_o الى نقطة منتصف الطبقة الطينية المشبعة المنضغطة قبل خفض مستوى المياه الجوفية (حالة السؤال):

$P'_o = \bar{\sigma} = \sigma - U = 19(2) + 20(4) - 10(6) \rightarrow P'_o = 58\ \frac{KN}{m^2}$

[b] نحسب قيمة P' الى نفس النقطة اعلاه بعد خفض مستوى المياه الجوفية (يلاحظ ان المنطقة الواقعة فوق W.T.L. ذات كثافة جافة).

$P' = \gamma_{dry\,(sand)} * 2 + \gamma_{sat\,(clay)} * 4 - h_p \gamma_w = 16(2) + 20(4) - 10(4)$

$\rightarrow P' = 72\ KN/m^2$

يلاحظ هنا دائماً ان: $(P' > P'_o)$ وذلك لنقصاننا في قيمة (U)

c : نجد قيمة (ΔP) الناتجة عن خفض مستوى W.T.L كالآتي:

زيادة في: $\Delta P = P - P_o = 72 - 58 = 14\ KN/m^2$

الإجهاد الفعال نتيجة خفض مستوى W.T.L

d تضاف قيمة ΔP المستخرجة أعلاه مع قيمة ΔP الناتجة من فعل التحميل الخارجي (ان وجد) لإيجاد قيمة ΔP_{final} التي تدخل في حساب S_{cf}.

$\therefore \Delta P_{final} = \Delta P$ نتيجة خفض مستوى W.T.L $+ \Delta P$ من التحميل الخارجي (fill)

$= 14 + 15.3 \rightarrow \Delta P_{final} = 29.3\ \frac{KN}{m^2}$

وعندما لا يكون هنالك حمل خارجي فإن $\{\Delta P_{final} = \Delta P_{\text{خفض W.T.L}}\}$ لأن ΔP(حمل خارجي) $= 0$

e نحسب الآن قيمة S_{cf} اعتماداً على قيمة ΔP_{final}

$\rightarrow S_{cf} = m_v * \Delta P_{final} * H$

$= 8.17 * 10^{-4} * 29.3 * 8 \rightarrow S_{cf} = 0.1915^m = 19.15^{cm}$

(ويلاحظ هنا دائماً ان S_{cf} في هذه الحالة تكون اكبر من الحالة الأولى ($S_{cf} = 10^{cm}$) وذلك لزيادة الإجهاد الفعال.)

Ex 39 An $8^m * 8^m$ footing with total stress intensity ($\Delta q_s = 30\ \frac{KN}{m^2}$) is to be constructed on the site shown in fig. Two proposals were made:

(0 m)

Clay ①, O.C.R = 4, $e_o = 0.7$, $C_c = 0.21$, $C_r = C_e = 0.1$

(−2 m)

$\gamma_{sat} = 18\ KN/m^3$, $\gamma_d = 15\ KN/m^3$

Clay ② O.C.R = 1, $e_o = 1.25$, $C_c = 1$, $C_r = 0.3$, $\gamma_{sat} = 15\ KN/m^3$

(−8 m)

Sand

① To construct the footing directly on the N.G.L.

② To construct the footing 2^m below N.G.L. after permenantly lowering W.T. 2^m below N.G.L.

Required: Calculate the final consolidation settlement for the two proposals and state which one you prefer.

Solution: ① footing at N.G.L., $\Delta q_s = \Delta q_{s\,net} = 30\ KN/m^2$

Clay ①: $\Delta \sigma_v = \Delta \bar{P} = \dfrac{\Delta q_{s\,net} * B^2}{(B+Z)^2} = \dfrac{30 * 8^2}{(8+1)^2} = 23.7\ KN/m^2$

$\bar{P}_o = \bar{\sigma} = \sigma - U = 18*1 - 10*10 = 8\ KN/m^2$

$\because$ O.C.R = 4 ➡ O.C.C., then check $\bar{P}_o + \Delta\bar{P} >$ or $< \bar{P}_c$

$O.C.R = 4 = \dfrac{\bar{P}_c}{\bar{P}_o}$ ➡ $4 = \dfrac{\bar{P}_c}{8}$ ➡ $\bar{P}_c = 32\ KN/m^2$

$\bar{P}_o + \Delta\bar{P} = 8 + 23.7 < \bar{P}_c = 32\ KN/m^2$, then Use

$\therefore Sc_{f①} = \dfrac{C_r}{1+e_o} H \log \dfrac{\bar{P}_o + \Delta\bar{P}}{\bar{P}_o} = \dfrac{0.1}{1+0.7}(2)\log\dfrac{8+23.7}{8} = 0.07^m = 7\ cm$

Clay ②: $\Delta\sigma_v = \Delta\bar{P} = \dfrac{30 * 8^2}{(8+5)^2}$ ➡ $\Delta\bar{P} = 11.36\ KN/m^2$

$\bar{P}_o = \bar{\sigma} = 2*18 + 3*15 - 10*5$ ➡ $\bar{P}_o = 31\ KN/m^2$

since O.C.R = 1 ➡ $\therefore$ N.C.C., then Use

$Sc_{f②} = \dfrac{C_c}{1+e_o} H \log\dfrac{\bar{P}_o + \Delta\bar{P}}{\bar{P}_o} = \dfrac{1}{1+1.25}(6)\log\dfrac{31+11.36}{31} = 0.3616^m = 36.16\ cm$

$\therefore$ total $Sc_f = Sc_{f①} + Sc_{f②} = 0.07 + 0.3616 = \underline{0.4316\ m}$

② footing at EL −2^m (تحت) (at Depth 2^m from N.G.L)

$\therefore \Delta q_{s\,net} = \Delta q_s - \gamma h$ (صفر) $= 30 - 15*2 = 0$ لا يوجد تأثير للحمل الخارجي على الانضمام

ⓐ $\bar{P}_o$ at mid Clay Layer ② befor lowering W.T. = 31 KN/m²

ⓑ $\bar{P}$ at mid clay layer ② After lowering W.T. is =

$2*15 + 3*15 - 3*10$ ➡ $\bar{P} = 45\ KN/m^2$

ⓒ $\therefore \Delta\bar{P}$ due to lowering W.T.L = 45 − 31 = 14 KN/m²

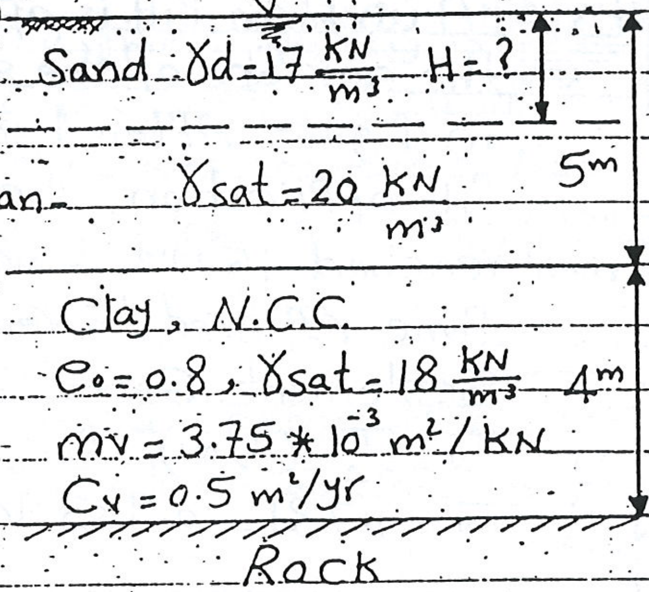
ⓓ $\Delta\bar{P}$ (external loading = 0) ➡ $\Delta\bar{P}_{final} = 14\ KN/m^2$

الانضمام يحصل في هذه الحالة للطبقة Clay ② فقط لأن Clay ① لا تتعرض لحدث عملية الانضغاط وبذلك فأن:

$Sc_f = \dfrac{C_c}{1+e_o} H \log\dfrac{\bar{P}_o + \Delta\bar{P}}{\bar{P}_o} = \dfrac{1}{1+1.25}(6)\log\dfrac{31+14}{31} = \underline{0.4316^m}$

وبذلك فأن Scf هو نفسه في كل من ① و ② ويفضل المقترح ① لأنه اسهل واسرع في الانشاء واقتصادي اكثر.

Ex 40 For the site shown in figure To what level (H = ?) must the water table be lowered permanantly to cause a settlement of 8.4 cm after 4 yrs in the clay layer.



Solution: at t = 4 yrs → $T_v = \frac{C_v t}{d^2} = \frac{0.5*4}{4^2} = 0.125$

assume $U_{av} \leq 60\%$ → $T_v = \frac{\pi}{4}(U_{av})^2$

→ $0.125 = \frac{\pi}{4}(U_{av})^2$ → $U_{av} = 0.4 = 40\% < 60\%$ o.k

$S_{ct} = 8.4\ cm = 0.084\ m$, Since $U_{av} = \frac{S_{ct}}{S_{cf}}$

∴ $0.4 = \frac{0.084\ m}{S_{cf}}$ → $S_{cf} = 0.21\ m = 21\ cm$

$S_{cf} = m_v * \Delta P'_{final} * H$ (لا يوجد حمل خارجي وبذلك فإن) $\Delta P_{final} = \Delta P'$ لخفض منسوب W.T.L.

$0.21 = 3.75 * 10^{-3} * \Delta P' * 4$

→ $\Delta P' = 14\ kN/m^2$

$P'_o = \bar{\sigma} = \sigma - u = 20*5 + 18*2 - 10*7 = 66\ kN/m^2$

$P' = 17*H + 20(5-H) + 18*2 - 10(2+5-H)$

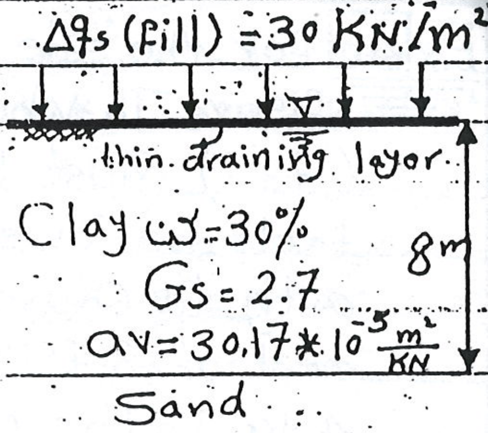
→ $P' = 66 + 7H$

Since $\Delta P' = P' - P'_o$

→ $14 = 66 + 7H - 66$ → $14 = 7H$

→ $H = 2\ m$

Ex 41 A uniform fill is applied on the surface of the soil shown in figure. After 1 year of fill application, the settlement reached 15 mm. Find the time required to reach 30 mm settlement. Given that:



$T_v = \frac{\pi}{4}(U_{av})^2$ for $U_{av} \leq 60\%$

$T_v = 1.781 - 0.933 \log(100 - U_{av})$ for $U_{av} > 60\%$

Solution: $Se = G_s \omega \rightarrow 1 e_o = 2.7(0.3) \rightarrow e_o = 0.81$

$m_v = \frac{a_v}{1+e_o} = \frac{30.17 * 10^{-5}}{1+0.81} \rightarrow m_v = 1.667 * 10^{-4} \frac{m^2}{KN}$

$\Delta q_s(\text{fill}) = \Delta\sigma = \Delta P = 30 \ KN/m^2$, Since $S_{cf} = m_v \Delta P H$

$\therefore S_{cf} = 1.667 * 10^{-4} * 30 * 8 \rightarrow S_{cf} = 0.04^{m} = 4^{cm} = 40^{mm}$

at $t = 1 yr$ the $S_{ct} = 15^{mm} = 1.5^{cm} = 0.015^{m}$

$\therefore U_{av} = \frac{S_{ct}}{S_{cf}} * 100\% = \frac{0.015}{0.04} * 100\% = 37.5\% < 60\%$

$\therefore T_v = \frac{\pi}{4}(0.375)^2 \rightarrow T_v = 0.1104$, Since $C_v = \frac{T_v d^2}{t}$

$\therefore C_v = \frac{0.1104 * 4^2}{1} \rightarrow C_v = 1.767 \ m^2/yr$

When the $S_{ct} = 30^{mm} = 3^{cm} = 0.03^{m}$

$U_{av} = \frac{S_{ct}}{S_{cf}} * 100\% = \frac{0.03}{0.04} * 100\% = 75\% > 60\%$

$\therefore T_v = 1.781 - 0.933 \log(100 - 75) \rightarrow T_v = 0.477$

$\therefore t = \frac{T_v d^2}{C_v} = \frac{0.477 * 4^2}{1.767} \rightarrow t = 4.316 \ yr$

الزمن اللازم لحصول هبوط مقداره 30 mm

Ex 42 Total expected Settlement due to Consolidation of a soil layer under a given loading is 125 mm. Three months after the application of the load a 50 mm Settlement was recorded. How many months will be required to reach 75 mm Sett.

Solution: $S_{cf} = 125^{mm} = 0.125^{m}$

$S_{ct} = 50^{mm} = 0.05^{m}$ after 3 months

$$U_{av} = \frac{S_{ct}}{S_{cf}} * 100\% = \frac{0.05}{0.125} * 100\% \rightarrow U_{av} = 40\% < 60\%$$

$$\therefore T_v = \frac{\pi}{4}(0.4)^2 \rightarrow T_v = 0.1256$$

Since $T_v = \dfrac{C_v t}{d^2} \rightarrow 0.1256 = \dfrac{C_v (3)_{mon.}}{d^2}$

Let $\dfrac{C_v}{d^2} = X \rightarrow 0.1256 = 3X \rightarrow \boxed{X = 0.042}$

When the Settlement $= 75^{mm} = 0.075^{m}$

$$U_{av} = \frac{S_{ct}}{S_{cf}} * 100\% = \frac{0.075}{0.125} * 100\% \rightarrow U_{av} = 60\%$$

$$\therefore T_v = \frac{\pi}{4}(U_{av})^2 = \frac{\pi}{4}(0.6)^2 \rightarrow T_v = 0.283$$

but $T_v = \dfrac{C_v t}{d^2}$ and Since $\dfrac{C_v}{d^2} = X = 0.042$

$$\therefore 0.283 = 0.042 * t \rightarrow t = 6.75 \text{ months}$$

الزمن اللازم بالأشهر للوصول
إلى حصول انضمام $= 75^{mm}$

Note: نفترض المقدار $X = \dfrac{C_v}{d^2}$ يرجع لأن
هذا المقدار مقدار ثابت خلال كل مراحل الانضمام ولعدم
توفر أي معلومات لحساب كل من C_v و d منفصل كل المقدار $= X$
ويستخرج من المرحلة الأولى (كل المقدار $= X$) ويطبق في المرحلة الثانية

Ex 43 The excess Pore water pressures in a Clay layer due to a Certain loading Condition were expected to be: 120 KN/m^2 immediately after loading
90 KN/m^2 (2) years after loading
Find the increase in the effective stress (4) yrs after loading.

Solution: $U_i = 120\ KN/m^2$, $U_e = 90\ KN/m^2$ after 2 yrs

$$\therefore U_{av} = \frac{U_i - U_e}{U_i} = \frac{120-90}{120} = 0.25 = 25\% < 60\%$$

$$\therefore T_v = \frac{\pi}{4}(U_{av})^2 = \frac{\pi}{4}(0.25)^2 = 0.049$$

Since $T_v = \frac{C_v t}{d^2} \rightarrow \frac{T_v}{t} = \boxed{\frac{C_v}{d^2}} \rightarrow X$

$$\therefore X = \frac{0.049}{2} \rightarrow \boxed{X = 0.0245}$$

after 4 yrs (at t = 4 yrs) and since $\frac{T_v}{t} = \frac{C_v}{d^2} = X$

$$\therefore \frac{T_v}{4} = 0.0245 \rightarrow T_v = 0.098$$

assume $U_{av} \leq 60\% \rightarrow T_v = \frac{\pi}{4}(U_{av})^2$

$$\rightarrow 0.098 = \frac{\pi}{4}(U_{av})^2 \rightarrow U_{av} = 0.3533 = 35.33\% < 60\%\ o.k$$

$$U_{av} = \frac{U_i - U_e}{U_i} \rightarrow 0.3533 = \frac{120 - U_e}{120}$$

$\rightarrow U_e = 77.574\ KN/m^2$ الزيادة في ضغط الماء المسامي بعد مرور 4 سنوات على تسليط الحمل

but at any time $\Delta\sigma_v = U_e + \Delta P\ at(t)$
and Since $\Delta\sigma_v = U_i = 120\ KN/m^2$

$$\therefore 120 = 77.574 + \Delta \bar{P}\ at(t = 4yrs)$$

$\rightarrow \Delta \bar{P}\ at(t=4) = 42.426\ KN/m^2$ الزيادة في الاجهاد الفعال بعد 4 سنوات من تسليط الحمل

Ex 44 A 6 m thick clay layer is subjected to an average increase in effective stress of 60 $\frac{KN}{m^2}$ after (1) yr from loading. If drainge occurs in two ways and the Coeff. of Permeability ($K = 0.03$ m/yr) and the Settlement after 1 yr. is 0.3 m. Find :-

① The Coeff. of Consolidation (C_v).
② The final Consolidation Settlement (S_{cf}).
③ Time required to reached to the S_{cf}.

Solution: after 1 yr $U_{av} = \frac{S_{ct}}{S_{cf}}$ and $U_{av} = \frac{\bar{P}_t - \bar{P}_o}{\bar{P}_f - \bar{P}_o}$

$\rightarrow U_{av} = \frac{\Delta\bar{P} \text{ at } t = 1\,yr}{\Delta\bar{P} \text{ (at end of Consolidation process)}}$

$\therefore \frac{S_{ct}}{S_{cf}} = \frac{\Delta\bar{P} \text{ at } t = 1\,yr}{\Delta\bar{P}} \rightarrow \frac{S_{cf}}{\Delta\bar{P}} = \frac{S_{ct}}{\Delta\bar{P} \text{ at } t = 1\,yr}$

$\rightarrow \frac{S_{cf}}{\Delta\bar{P}} = \frac{0.3\,m}{60\,KN/m^2} \rightarrow \frac{S_{cf}}{\Delta\bar{P}} = 5 * 10^{-3}\ m^3/KN$

but $S_{cf} = m_v * \Delta\bar{P} * H \rightarrow \frac{S_{cf}}{\Delta\bar{P}} = m_v * H$

$\rightarrow m_v = \frac{S_{cf}}{\Delta\bar{P}} * \frac{1}{H} = 5 * 10^{-3} * \frac{1}{6} \rightarrow m_v = 8.33 * 10^{-4}\ \frac{m^2}{KN}$

① but $C_v = \frac{K}{m_v \gamma_w} = \frac{0.03}{8.33 * 10^{-4} * 10} \rightarrow C_v = 3.6\ m^2/yr$

Since $T_v = \frac{C_v t}{d^2}$ after 1 yr $\rightarrow T_v = \frac{3.6 * 1}{3^2} = 0.4$

assume $U_{av} \leq 60\%$ $\rightarrow T_v = \frac{\pi}{4}(U_{av})^2 \rightarrow U_{av} = 71\% > 60\%$ Not o.k

$\therefore T_v = 1.781 - 0.933 \log(100 - U_{av}) \rightarrow U_{av} = 69.8\% > 60\%$

② but $U_{av} = \frac{S_{ct}}{S_{cf}} \rightarrow 0.698 = \frac{0.3}{S_{cf}} \rightarrow S_{cf} = 0.43\,m$ o.k
$= 43\,cm$

③ $t = \frac{T_v d^2}{C_v} = \frac{1 * 3^2}{3.6} = 2.5\ yrs$ بالتوفيق

Ex 45 Two clay samples (A) and (B) have initial void ratios of 0.55 and 0.632 respectively under a pressure of $1 \frac{kg}{cm^2}$ then the pressure is increased to $1.5 \frac{kg}{cm^2}$ and the void ratios decreased due to this load to 0.495 and 0.616 respectively. The time taken by specimen (A) to reach 50% consolidation is $\frac{1}{3}$ of that required by specimen (B) for reaching the same consolidation. Find the ratio of the coeff. of permeability of the two specimens (A) and (B) if their initial thicknesses were 40 mm and 30 mm respectively.

Solution: for sample (A): $\left.\begin{array}{l} e_o = 0.55 \\ e_f = 0.495 \end{array}\right\} \rightarrow \Delta e = 0.55 - 0.495 = 0.055$

$\Delta P' = 1.5 - 1 \rightarrow \Delta P' = 0.5\ kg/cm^2$

$m_v = \frac{\Delta e}{1+e_o} * \frac{1}{\Delta P'} = \frac{0.055}{1+0.55} * \frac{1}{0.5} \rightarrow m_v = 0.071\ \frac{cm^2}{kg}$

Since $U_{av} = 50\% \rightarrow T_v = \frac{\pi}{4}(0.5)^2 = 0.197$ for both sample (A) and (B)

$C_v = \frac{T_v d^2}{t} = \frac{0.197 * (2cm)^2}{t(A)} \rightarrow \boxed{C_v = 0.788/t_A}$

Now; for sample (B): $\left.\begin{array}{l} e_o = 0.632 \\ e_f = 0.616 \end{array}\right\} \rightarrow \Delta e = 0.632 - 0.616 = 0.016$

$m_v = \frac{0.016}{1+0.632} * \frac{1}{0.5} \rightarrow m_v = 0.0196\ cm^2/kg$

$C_v = \frac{T_v d^2}{t} = \frac{0.197 * (1.5)^2}{t_{(B)}} = \frac{0.44325}{3t_A} = \frac{0.14775}{t_A}$ (since that $t_A = \frac{1}{3} t_B$)

Since $K = C_v * m_v * \gamma_w$

$\therefore \frac{K_A}{K_B} = \frac{\frac{0.788}{t_A} * 0.071 * \cancel{10}}{\frac{0.14775}{t_A} * 0.0196 * \cancel{10}} \rightarrow \frac{K_A}{K_B} = 19.32$

Ex 46 The following results were recorded in the middle of two saturated clay layers due to different loading conditions:

Soil	e_o	e_f	P_o (KN/m²)	P_f (KN/m²)	t_{50} (year)	Thick. (m)	Drainage
Clay ①	0.2	0.79	20	60	10.5	4	One way
Clay ②	1.1	1.02	33	336.8	4	6	Two way

Find: The ratio of the permeabilities of clay ① to clay ② (i.e. $K_① / K_②$).

Solution: For Clay ①

$$\Delta e = e_o - e_f = 0.8 - 0.79 = 0.01$$

$$\Delta P = P_f - P_o = 60 - 20 = 40 \ KN/m^2$$

$$m_v = \frac{\Delta e}{1+e_o} * \frac{1}{\Delta P} = \frac{0.01}{1+0.8} * \frac{1}{40} \rightarrow m_v = 1.39 * 10^{-4} \frac{m^2}{KN}$$

Since $t_{50} = 10.5$ yrs (Casagrande's Method)

$$C_v = \frac{0.197 d^2}{t_{50}} = \frac{0.197 (4)^2}{10.5} \rightarrow C_v = 0.3 \ m^2/yr$$

$$K = m_v * C_v * \gamma_w = 1.39 * 10^{-4} * 0.3 * 10 = 4.17 * 10^{-4} \frac{m}{yr}$$

For Clay ②

$$\Delta e = e_o - e_f = 1.1 - 1.02 \rightarrow \Delta e = 0.08$$

$$\Delta P = P_f - P_o = 336.8 - 33 \rightarrow \Delta P = 303.8 \ KN/m^2$$

$$m_v = \frac{\Delta e}{1+e_o} * \frac{1}{\Delta P} = \frac{0.08}{1+1.1} * \frac{1}{303.8} \rightarrow m_v = 1.254 * 10^{-4} \frac{m^2}{KN}$$

$$C_v = \frac{0.197 d^2}{t_{50}} \text{ (Casagrande's method)} \rightarrow C_v = \frac{0.197 * 3^2}{4} \rightarrow C_v = 0.44325 \frac{m^2}{yr}$$

$$K = C_v * m_v * \gamma_w = 0.44325 * 1.254 * 10^{-4} * 10 = 5.56 * 10^{-4} \frac{m}{yr}$$

$$\therefore \frac{K_1}{K_2} = \frac{4.17 * 10^{-4} \ m/yr}{5.56 * 10^{-4} \ m/yr} \rightarrow \frac{K_1}{K_2} = 0.75$$

Ex 47 Two Clay layers (A) and (B) are (4 m) and (5 m) respectively in thick. The time taken by (A) to reach 50% Consolidation is 6 months. The Coeff. of Consolidation (C_v) of layer B = 0.5 of layer A. Calculate the time required for B to reach the same degree of Consolidation if:

ⓐ both layers have double drainage.
ⓑ both layers have single drainage.

Solution: ⓐ Both layers $d = \frac{H}{2}$

for Clay (A)

{Casagrande's method} $C_v = \frac{0.197\, d^2}{t_{50}} = \frac{0.197\,(2)^2}{6 \text{ mon}} \rightarrow C_v = 0.1313 \text{ m}^2/\text{mon}$

Since $C_{v(B)} = 0.5\, C_{v(A)} = 0.5 * 0.1313 = 0.0656 \text{ m}^2/\text{mon}$

Now; for Clay (B) (and since $U_{av} = 50\% \rightarrow T_v = 0.197$)

$$t = \frac{T_v\, d^2}{C_v} = \frac{0.197 * (2.5)^2}{0.0656} = 18.75 \text{ months}$$

ⓑ both layers $d = H$

for Clay layer (A)

$$C_v = \frac{0.197\, d^2}{t_{50}} = \frac{0.197\,(4)^2}{6} = 0.5253 \text{ m}^2/\text{mon}$$

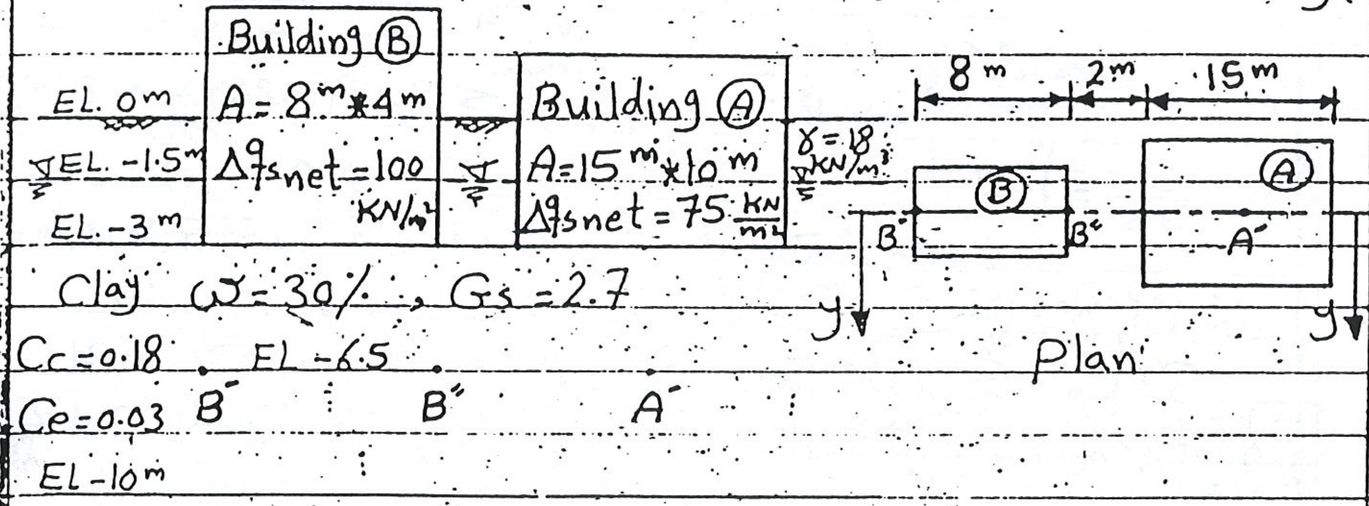
Since $C_{v(B)} = 0.5\, C_{v(A)} = 0.5 * 0.5253 = 0.2626 \ \frac{\text{m}^2}{\text{mon}}$

and Since ($U_{av} = 50\% \rightarrow T_v = 0.197$) for layer (B)

$$\therefore t = \frac{T_v\, d^2}{C_v} = \frac{0.197 * 5^2}{0.2626} \rightarrow t = 18.75 \text{ months}$$

Same ans. for Part (a).

Ex 48 In the figure below, building (A) was constructed near building (B) in the soil profile shown. Determine the amount of rotation expected for Building (B), also the expected settlement at the centre of building (A).

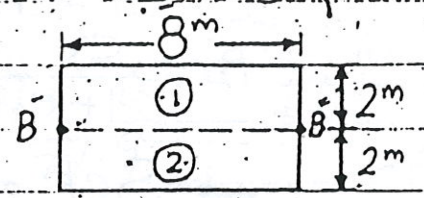


Section y-y

Solution: يتم اولاً ايجاد تأثير البناية B على النقطتين B' , B''

For Part ①: B = 2m , L = 8m

$z = 3.5$ m



$m = \frac{B}{z} = \frac{2}{3.5} = 0.57$

$n = \frac{L}{z} = \frac{8}{3.5} = 2.28$

$\xrightarrow{\text{fig. 8-6}}$ $f = 0.15$ ولتناظر المساحتين

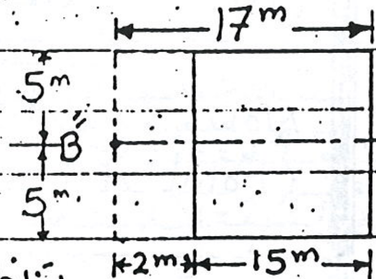
فأن $\sum f = 2 * 0.15 = 0.3$

$\therefore \Delta\sigma_v$ at B' and B'' $= \sum f * \Delta q_s net$

$= 0.3 * 100 = 30$ KN/m²

يتم الآن ايجاد تأثير البناية A على النقطتين B' , B''

For Point B'':



$m = \frac{5}{3.5} = 1.43$

$n = \frac{17}{3.5} = 4.85$

$\xrightarrow{\text{fig. 8-6}}$ $f = 0.226$

لتناظر المساحتين

$m = \frac{2}{3.5} = 0.57$

$n = \frac{5}{3.5} = 1.43$

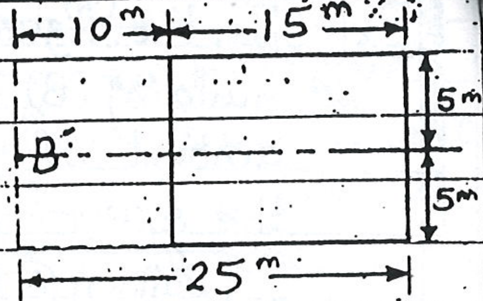
$\xrightarrow{\text{fig. 8-6}}$ $f = -0.143$

$\therefore \sum f = 2(0.226 - 0.143)$

$= 0.166$

$\therefore \Delta\sigma_v$ at B'' $= 0.166 * 75 = 12.45$ KN/m²

Now, for Point B′



$m = \frac{5}{3.5} = 1.43$, $n = \frac{25}{3.5} = 7.14$ → $f = 0.229$

$m = \frac{10}{3.5} = 2.86$, $n = \frac{5}{3.5} = 1.43$ → $f = 0.224$

لتأثير المساحتين → $\sum f = 2(0.229 - 0.224) = 0.01$

→ $\Delta\sigma_v$ at $B' = 0.01 * 75 = 0.75\ kN/m^2$

الآن نحسب قيمة P_o' التي لنقطتي B' و B'' قبل وضع البنايتين.

$S * e_o = G_s * \omega$ → $1\, e_o = 2.7 * 0.3$ → $e_o = 0.81$

$\gamma_{sat}(clay) = \frac{G_s + e}{1+e}\gamma_w = \frac{2.7+0.81}{1+0.81}(10)$ → $\gamma_{sat} = 19.4\ \frac{kN}{m^3}$

$P_o = \bar{\sigma} = \sigma - U = 18 * 3 + 19.4 * 3.5 - 10 * 5 = 71.9\ kN/m^2$

ΔP at $B' = 30 + 0.75 = 30.75\ kN/m^2$

ΔP at $B'' = 30 + 12.45 = 42.45\ kN/m^2$

Scf at $B' = \frac{C_c}{1+e_o} H \log \frac{P_o + \Delta P}{P_o} = \frac{0.18}{1+0.81}(7)\log\frac{71.9+30.75}{71.9}$

→ Scf at $B' = 0.1076\ m = 10.76\ cm$

Scf at $B'' = \frac{0.18}{1+0.81}(7)\log\frac{71.9+42.45}{71.9} = 0.1403\ m = 14.03\ cm$

$\theta = \tan^{-1}\frac{\Delta Scf \text{ between } B' \text{ and } B''}{\text{Distance between } B' \text{ and } B''}$

rotation of building (B) $= \tan^{-1}\frac{(0.1403 - 0.1076)\ m}{8\ m}$ → $\theta = 0.23°$

وبهذا ننهي المطلب الأول

Now, To Calculate the Scf at Center of building (A) (Point A′):-

نجد أولاً تأثير البناية A على هذه النقطة

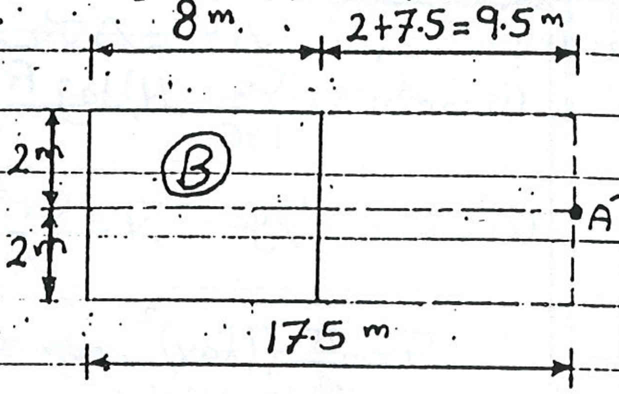
$m = \frac{5}{3.5} = 1.43$, $n = \frac{7.5}{3.5} = 2.14$ → (fig. 8-6) → $f = 0.2225$

ولكون نقطة A' في مركز البناء

→ $\sum f = 4 * 0.2225 = 0.89$

→ $\Delta\sigma_v$ at $A' = 0.89 * 75 = 66.75\ kN/m^2$

لإيجاد تأثير البناية B على النقطة A'



$m = \frac{2}{3.5} = 0.57$, $n = \frac{17.5}{3.5} = 5$ $\rightarrow f = 0.155$

$m = \frac{2}{3.5} = 0.57$, $n = \frac{9.5}{3.5} = 2.17$ $\rightarrow f = -0.15$ لتناظر المساحتين

$\therefore \sum f = 2(0.155 - 0.15) = 0.01$

$\therefore \Delta\sigma_v$ at $A' = 0.01 * 100 = 1\ KN/m^2$

$\therefore \Delta\sigma_v$ total at $A' = 66.75 + 1 = 67.75\ KN/m^2$

Since Point A' at same plane with B', B''

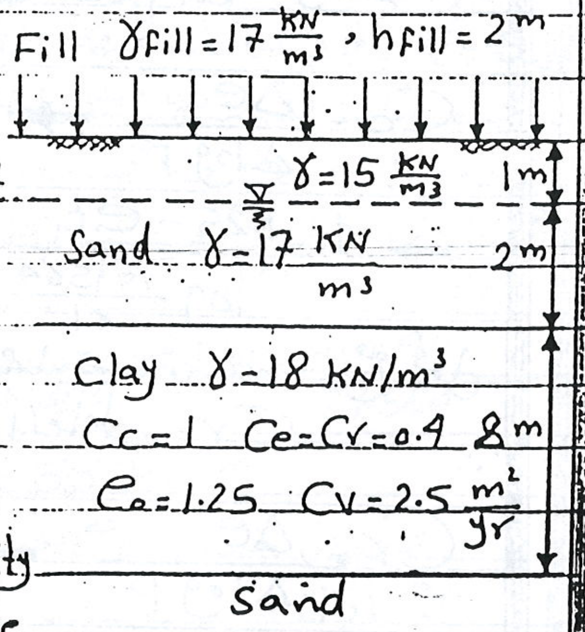
$\therefore P_o = 71.9\ KN/m^2$

$$\therefore S_{cf} = \frac{C_c}{1+e_o}(H) \log \frac{P_o + \Delta P}{P_o}$$

$$= \frac{0.18}{1+0.81}(7) \log \frac{71.9+67.75}{71.9} = 0.2^m = 20^{cm}$$

Ex 49 Given the site Shown in fig. Required:

1. Final Consolidation Settlement.
2. The Settlement (1) yr. after fill application.
3. If the fill is to be removed after (1.5) yr. What will be the final equilibrium void ratio.
4. If a structure with an intensity of stress = 40 KN/m² at the middle of the clay layer is to be Constructed after the fill is removed in Part (3). What is the expected (Scf) for the structure and the final void ratio.



Solution: $\bar{P}_o = \bar{\sigma} = \sigma - U = 1*15 + 2*17 + 4*18 - 6*10 = 61\ \frac{kN}{m^2}$

$\Delta \bar{P} = \Delta\sigma_v = \Delta q_{s\,net}(\text{fill}) = h_{fill} * \gamma_{fill} = 2*17 = 34\ \frac{kN}{m^2}$

① $\therefore S_{cf} = \frac{C_c}{1+e_o}(H)\log\frac{\bar{P}_o+\Delta\bar{P}}{\bar{P}_o} = \frac{1}{1+1.25}(8)\log\frac{61+34}{61} = 0.684\ m = 68.4\ cm$

② after (1) yr. $T_v = \frac{C_v t}{d_r^2} = \frac{2.5*1}{4^2} \rightarrow T_v = 0.15625$

$T_v = \frac{\pi}{4}(U_{av})^2 \rightarrow 0.15625 = \frac{\pi}{4}(U_{av})^2 \rightarrow U_{av} = 0.446 = 44.6\% < 60\%$ o.k

$S_{ct} = U_{av} * S_{cf} = 0.446 * 0.684 = 0.3051\ m = 30.51\ cm$

③ If the fill is removed after (1.5) yr.

$T_v = \frac{C_v t}{d^2} = \frac{2.5*1.5}{4^2} \rightarrow T_v = 0.234 \rightarrow U_{av} = \sqrt{\frac{4T_v}{\pi}}$

$\rightarrow U_{av} = 0.546 \le 60\%$ o.k

$U_{av} = \frac{U_i - U_e}{U_i} \rightarrow 0.546 = \frac{34 - U_e}{34} \rightarrow U_e = 15.436\ kN/m^2$

Since $\Delta\sigma_v = \Delta\bar{P}_{at}(t) + U_e \rightarrow 34 = \Delta\bar{P}_{at}(t) + 15.436$

$\rightarrow \Delta\bar{P}_{at}(1.5\,yr) = 18.564\ kN/m^2$

$\therefore \bar{P}_t$ after 1.5 yr $= \bar{P}_o + \Delta\bar{P}(1.5yr) = 61 + 18.564 = 79.564\ \frac{kN}{m^2}$

الآن ولغرض حساب قيمة (e) بعد (1.5yr) وبما ان العملية هي عملية تحميل من ($t=0$) الى ($t=1.5$) ← يستخدم المؤشر C_c (loading).

$C_c = \frac{\Delta e}{\Delta \log \bar{P}} \rightarrow C_c = \frac{e_o - e_t}{\log\frac{\bar{P}_t}{\bar{P}_o}}$

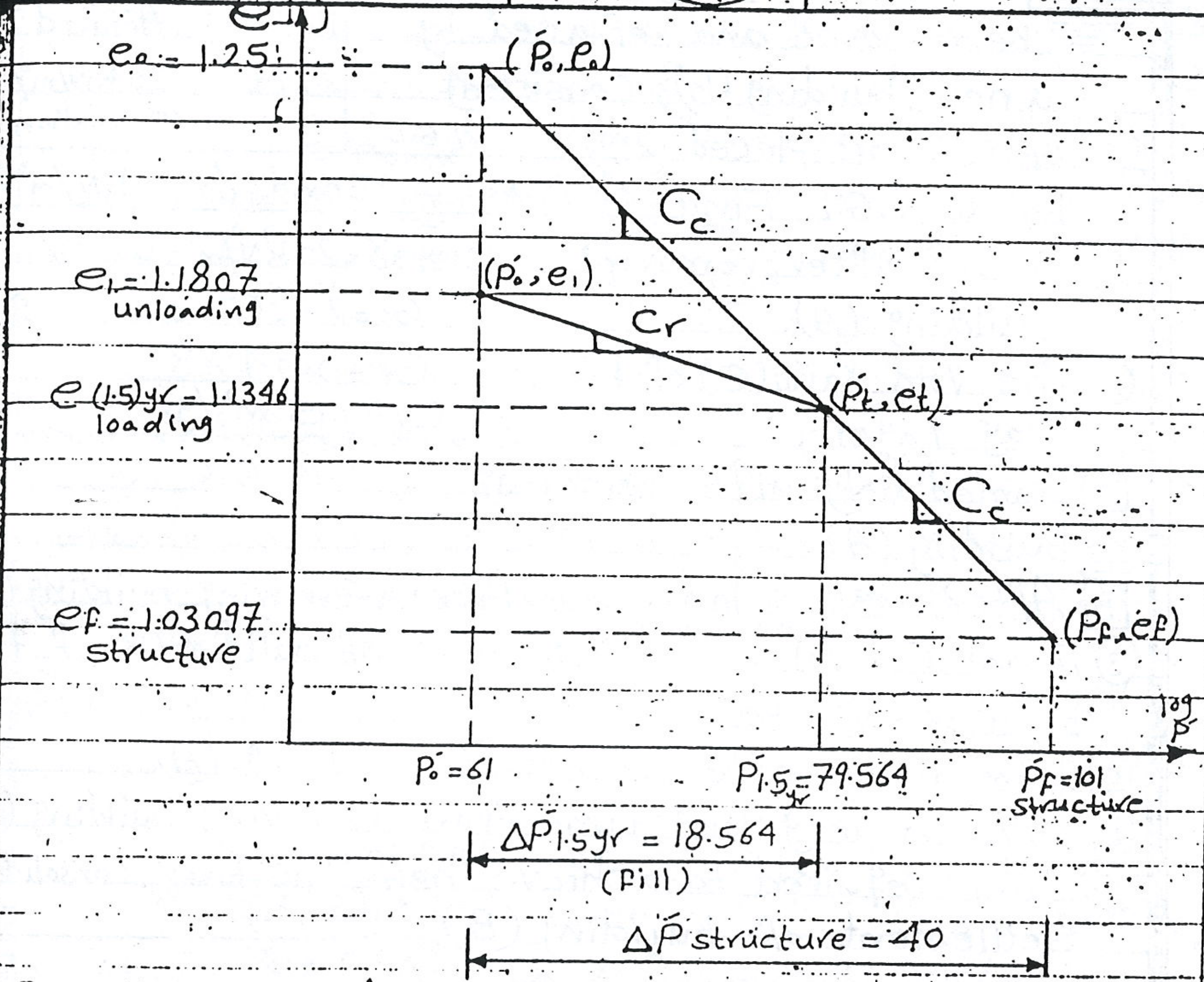
$\rightarrow 1 = \frac{1.25 - e_t}{\log\frac{79.564}{61}} \rightarrow e_t = 1.1346$ نسبة الفجوات بعد فترة 1.5 سنة من التحميل (fill).

الآن وبعد رفع الحمل (fill) تكون العملية هي عملية رفع حمل (unloading) بعد 1.5 سنة فيستخدم المعامل C_r

$C_r = \frac{\Delta e}{\Delta \log \bar{P}} \rightarrow C_r = \frac{e_1 - e_{1.5yr}}{\log\frac{\bar{P}_{1.5yr}}{\bar{P}_o}}$

$0.4 = \frac{e_1 - 1.1346}{\log\frac{79.564}{61}} \rightarrow e_1 = 1.1807$ unloading

لاحظ الرسم التوضيحي



④ والآن ولغرض حساب SCf بعد اضافة حمل المنشأ الجديد الذي يولد $\Delta\bar{P} = 40\ \frac{kN}{m^2}$ في منتصف الطبقة الطينية فيجب ملاحظة ان التربة تحولت من N.C.C الى O.C.C. لأنها سبق لها الانضغاط تحت الحمل الأول (Fill) والذي رفع بعد 1.5 سنة وبذلك فأن: $\bar{P}_c = \bar{P}_{t_{1.5yr}} = 79.564$ و $\Delta\bar{P} = 40$ و $\bar{P}_o = 61$

$$\therefore \bar{P}_o + \Delta\bar{P} > \bar{P}_c \rightarrow SCf = \frac{C_r}{1+e_o} H \log\frac{\bar{P}_c}{\bar{P}_o} + \frac{C_c}{1+e_o} H \log\frac{\bar{P}_o + \Delta\bar{P}}{\bar{P}_c}$$

$$\therefore SCf = \frac{0.4}{1+1.1807}(8)\log\frac{79.564}{61} + \frac{1}{1+1.1346}(8)\log\frac{61+40}{79.564}$$

$$\rightarrow SCf = 0.5576\ m = 55.76\ cm$$

ولغرض حساب e_f تحت تأثير الحمل الجديد (المنشأ) (loading) فأن:

$$C_c = \frac{e_{1.5yr} - e_f}{\log\frac{101}{79.564}} \rightarrow 1 = \frac{1.1346 - e_f}{\log\frac{101}{79.564}} \rightarrow e_f = 1.03097$$

Ex 50 The old building (A) is to be removed and replaced by a new building (B); Consisting of (5) floors placed (2m) below N.G.L. Find:

OLD Building "A"	3 Floors Applied stress 20 KN/m²/Floor Foundation 6m×5m

N.G.L

W.T.L. Sand $\gamma = 15\ KN/m^3$ 2m

Clay $\gamma = 20\ KN/m^3$, $\omega = 30\%$, $G_s = 2.7$, $C_c = 0.2$, $C_r = 0.04$, $C_v = 0.5\ m^2/yr$ 8m

ROCK

1. O.C.R after removing building (A).
2. The void ratio (e) of the Clay Layer:
   - a) Immediately after removing building (A).
   - b) After a very long time from removing building (A).
3. Final Consolidation Settlement of building (B) if to be Constructed:
   - a) Immediately after removing building (A).
   - b) After a very long time from removing building (A).
4. Time required to achieve half the final Consolidation Settlement of building (B).

Solution: $\bar{P_o} = \bar{\sigma} = \sigma - U$ تحديد قيمة $\bar{P_o}$ قبل وجود أي بناية

$= 15 * 2 + 4 * 20 - 10 * 4 \rightarrow \bar{P_o} = 70\ KN/m^2$

نحدد الآن قيمة $\Delta\bar{P}$ اي منتصف الطبقة الطينية نتيجة تحميل البناية (A)

$$\Delta\bar{P} = \frac{3 * 20 * 5 * 6}{(6+6)(5+6)} \rightarrow \Delta\bar{P} = 13.64\ KN/m^2$$

وبذلك يكون الإجهاد الفعال النهائي في منتصف الطبقة الطينية بعد انتهاء الانضمام الناتج عن وجود البناية (A):

$\bar{P_f} = \bar{P_o} + \Delta\bar{P}$

$\rightarrow \bar{P}_{f(A)} = 70 + 13.64 = 83.64\ KN/m^2$

الآن بعد رفع البناية A بفترة طويلة سوف يعود الإجهاد الفعال في منتصف الطبقة الطينية الى قيمته الأولية ($\bar{P_o} = 70$) وذلك لرفع كل الحمل المسلط السابق عن البناية (A) وبذلك يصبح $\bar{P}_{f(A)}$ مساوي الى $\bar{P_c}$

Since $O.C.R = \frac{\bar{P_c}}{\bar{P_o}} = \frac{83.64}{70} \rightarrow O.C.R = 1.195$

تحديد نسبة الفجوات (e) قبل وجود أي بناية $S * e_o = G_s * \omega$

نسبة الفجوات هذه هي عند $1 * e_o = 2.7 * 0.3 \rightarrow e_o = 0.81$

اجهاد فعال اولي مقداره ($P'_o = 70$). ولغرض تحديد نسبة الفجوات النهائية بالنسبة للبناية (A) عند انتهاء الانضمام الناتج عن تحميل البناية (A) فان

ⓐ $C_c = \frac{\Delta e}{\Delta \log P'} \rightarrow 0.2 = \frac{0.81 - e_{f(A)}}{\log \frac{83.64}{70}} \rightarrow e_{f(A)} = 0.79454$

نسبة الفجوات هذه ($e = 0.79454$) هي عند اجهاد فعال (83.64) وهي نفسها قيمة (e) مباشرة بعد رفع البناية (A). ولكن لغرض تحديد قيمة (e) بعد فترة زمنية طويلة من رفع البناية (A) والبناية (B) غير موجودة يجب استخدام المعامل C_r لأن العملية هي رفع التحميل (unloading)

ⓑ $C_r = \frac{\Delta e}{\Delta \log P'} \rightarrow 0.04 = \frac{e_1 - 0.79454}{\log \frac{83.64}{70}} \rightarrow e_1 = 0.7976$

③ⓐ اذا كانت البناية (B) ستشيد مباشرة بعد رفع البناية (A) فأن الحالة الاولية للبناية (B) من حيث الاجهاد الفعال ونسبة الفجوات

$P'_o = 83.64\ KN/m^2,\ e_o = 0.79454$

$\Delta P'_{(B)} = \frac{\Delta q_{snet} * B * L}{(B+Z)(L+Z)}$ since $\Delta q_{snet} = \Delta q_s - \gamma h$

$= 5*20 - 2*15 = 70\ KN/m^2$

$\therefore \Delta P'_{(B)} = \frac{70*5*6}{(5+4)(6+4)} \rightarrow \Delta P'_{(B)} = 23.33\ KN/m^2$

يجب حساب الزيادة الصافية في الاجهاد الفعال بين البنايتين (A) و (B) لذلك

$\Delta P'_{net} = \Delta P'_{(B)} - \Delta P'_{(A)} = 23.33 - 13.64 = 9.7\ KN/m^2$

وبما ان وضع البناية (B) يكون مباشرة بعد رفع البناية (A) فأن التربة تبقى في حالة N.C.C. ويكون الهطول الناتج

$S_{cf} = \frac{C_c}{1+e_o}(H)\log\frac{P'_o + \Delta P'_{net}}{P'_o} = \frac{0.2}{1+0.79454}(8)\log\frac{83.64+9.7}{83.64}$

$\rightarrow S_{cf} = 0.0425\ m = 4.25\ cm$

ⓑ اذا كانت البناية (B) ستشيد بعد فترة زمنية طويلة من رفع البناية (A) فأن الحالة الاولية للبناية (B) من حيث الاجهاد الفعال ونسبة الفجوات هي: $e = 0.7976$ ، $P'_o = 70\ KN/m^2$ وستصبح التربة (O.C.C.) وتكون قيمة $P'_c = 83.64$ ولا داعي لحساب $\Delta P'_{net}$ بل يتم التعامل مع $\Delta P'_{(B)}$

∴ the soil is O.C.C → Check $P'_o + \Delta P' > \text{or} < P'_c$

$$P'_o + \Delta P' = 70 + 23.33 = 93.33 > P'_c = 83.64$$

$$\therefore S_{cf} = \frac{C_r}{1+e_o} H \log \frac{P'_c}{P'_o} + \frac{C_c}{1+e_o} (H) \log \frac{P'_o + \Delta P'}{P'_c}$$

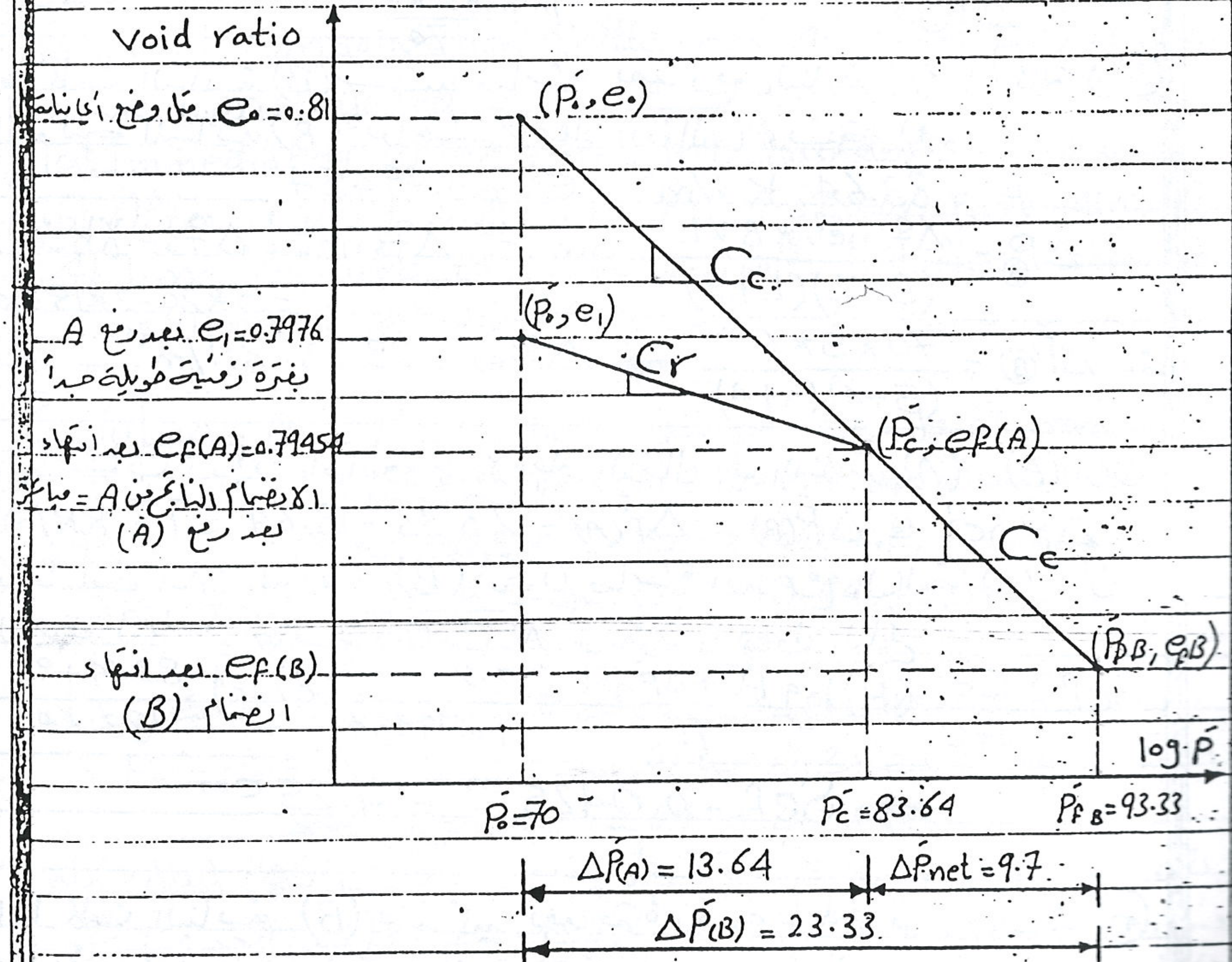
$$= \frac{0.04}{1+0.7976} (8) \log \frac{83.64}{70} + \frac{0.2}{1+0.79454} * (8) \log \frac{70+23.33}{83.64}$$

$$\rightarrow S_{cf} = 0.0562\ m = 5.62\ cm$$

لاحظ المخطط التوضيحي ادناه

④ For $U_{av} = 50\%$ → $T_v = \frac{\pi}{4}(0.5)^2 = 0.197$

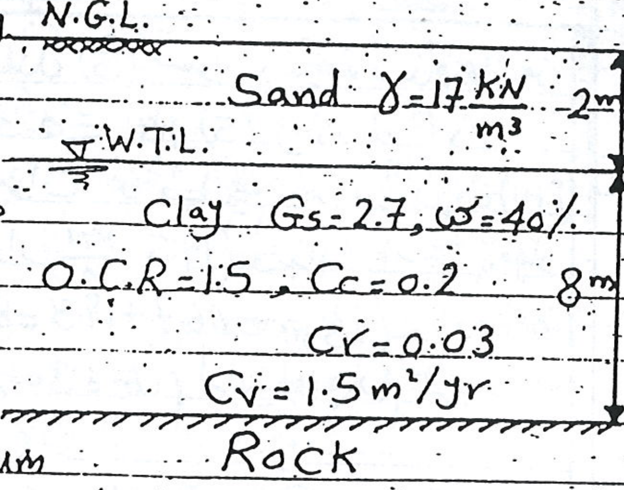
$$\therefore t = \frac{T_v d^2}{C_v} = \frac{0.197 * 8^2}{0.5} \rightarrow t = 25.2\ yr$$



Ex 51 For the site shown in fig.

ⓐ Find (SCf) if 2.5ᵐ fill was applied ($\gamma_{fill} = 20 \frac{KN}{m^3}$).

ⓑ If after 5yrs. a structure with $\Delta q_{s\,net} = 40 \frac{KN}{m^2}$ was constructed 1ᵐ below N.G.L. with dimensions 6ᵐ * 4ᵐ. Calculate maximum final Consolidation Settlement



Solution: ① $S * e_o = G_s * \omega$ حساب e_o قبل وضع الأحمال

$1 * e_o = 2.7 * 0.4 \rightarrow e_o = 1.08$

$\gamma_{sat} = \frac{G_s + e}{1+e} \gamma_w = \frac{2.7+1.08}{1+1.08}(10)$ Clay حساب الكثافة المشبعة لـ

$\rightarrow \gamma_{sat} = 18.17\ KN/m^3$

$\bar{P_o} = \bar{\sigma} = \sigma - U = 2*17 + 4*18.17 - 40$ Clay حساب $\bar{P_o}$ في منتصف

$\rightarrow \bar{P_o} = 66.7\ KN/m^2$ قبل وضع اي حمل

$\Delta \bar{P} = \Delta q_{s\,net\,fill} = h_{fill}\ \gamma_{fill}$ حساب الإجهاد الإضافي $(\Delta \bar{P})$

$= 2.5 * 20 \rightarrow \Delta \bar{P} = 50\ KN/m^2$

تكون $O.C.R = 1.5 > 1$ ← O.C.C ويجب حساب $\bar{P_c}$

$\bar{P_c} = O.C.R * \bar{P_o} = 1.5 * 66.7 \rightarrow \bar{P_c} = 100\ KN/m^2$

Now we must check $\bar{P_o} + \Delta \bar{P}$ > or < $\bar{P_c}$

$66.7 + 50 = 116.7 > \bar{P_c} = 100$

$\therefore SCf = \frac{C_r}{1+e_o} H \log \frac{\bar{P_c}}{\bar{P_o}} + \frac{C_c}{1+e_o} H \log \frac{\bar{P_o} + \Delta \bar{P}}{\bar{P_c}}$

$= \frac{0.03}{1+1.08}(8) \log \frac{100}{66.7} + \frac{0.2}{1+1.08}(8) \log \frac{66.7+50}{100} = 0.0719^m = 7.19^{cm}$

② After 5yrs. $T_v = \frac{C_v t}{d^2} = \frac{1.5 * 5}{8^2} \rightarrow T_v = 0.1172$

and $T_v = \frac{\pi}{4}(U_{av})^2 \rightarrow 0.1172 = \frac{\pi}{4}(U_{av})^2$

$\rightarrow U_{av} = 0.3863 = 38.63\% < 60\%$ o.k

الآن يتم حساب الزيادة في الإجهاد الفعال خلال (5) سنوات نتيجة تسليط الحمل الدفن

ΔP during (5) yrs $= 0.3863 * 50 = 19.3 \quad KN/m^2$

من الحسابات اعلاه نلاحظ بأنه وبعد 5 سنوات من تسليط الحمل الأول (fill) fill

فأن الإجهاد الفعال قد ازدادت قيمته بمقدار ($19.3 \frac{KN}{m^2}$) وبذلك اصبح الإجهاد

الفعال $= (66.7 + 19.3 = 86)$ أي ان ($P_{5yrs} = 66.7 + 19.3 = 86$) وبالاحظ ايضا

بأنه لايزال هناك ضغط ماء زائد ($U_e = 30.7 \frac{KN}{m^2}$) لم يتسرب رغم مرور

5 سنوات على وضع الحمل (fill).

الآن ولغرض حساب (e_c) عند الضغط المسبق للانضمام (P_c) يستخدم

$$C_r = \frac{\Delta e}{\Delta \log P} \rightarrow 0.03 = \frac{1.08 - e_c}{\log \frac{100}{66.7}} \rightarrow e_c = 1.0747$$

ولغرض حساب e_f بعد انتهاء المقطع الأول من السؤال يستخدم الانضمام

$$C_c = \frac{\Delta e}{\Delta \log P} \rightarrow 0.2 = \frac{1.0747 - e_f}{\log \frac{116.7}{100}} \rightarrow e_f = 1.0613$$

ولحساب الهطول خلال اول 5 سنوات وتحت تأثير الحمل الأول (fill)

$$P_o + \Delta P = 66.7 + 19.3 = 86 < P_c = 100$$

وبذلك تكون نسبة الفجوات (e) بعد انتهاء (5) سنوات

$$C_r = \frac{\Delta e}{\Delta \log P} \rightarrow 0.03 = \frac{1.08 - e_{5yrs}}{\log \frac{86}{66.7}} \rightarrow e_{5yrs} = 1.0767$$

وبذلك يمكن حساب الهطول خلال 5 سنوات يستخدم

$$S_{cf} = \frac{\Delta e}{1 + e_o}(H) \rightarrow S_{c\,5yrs} = \frac{1.08 - 1.0767}{1 + 1.08}(8) = 0.0127\ m = 1.27\ cm$$

أو يمكن حساب الهطول بالشكل الآتي :

$$P_o + \Delta P = 66.7 + 19.3 = 86 < P_c = 100$$

$$\therefore S_{c\,5yrs} = \frac{C_r}{1 + e_o} H \log \frac{P_o + \Delta P}{P_o}$$

$$= \frac{0.03}{1 + 1.08}(8) \log \frac{66.7 + 19.3}{66.7} = 0.0127\ m = 1.27\ cm$$

ان هذا المقدار (1.27 cm) يمثل الهطول خلال 5 سنوات وتحت تأثير الحمل الاول (fill) فقط.

ولحساب الهطول من السنة الخامسة فأكثر وتحت تأثير الحمل المشترك (الحمل الجديد (structure) + المتبقي من ضغط الماء الزائد (U_e) من fill)

يجب تعريف الحالة الابتدائية (initial Condition) بعد 5 سنوات هي

$e_o = 1.0767$, $\bar{P}_o = 86$, $\bar{P}_c = 100\ KN/m^2$

اما الزيادة التي يولدها الحمل الجديد (structure) في منتصف الطبقة الطينية

$$\Delta\bar{P} = \frac{40*6*4}{(6+5)(4+5)} = 9.7\ KN/m^2 = U_i\ (\text{structure})$$

وبذلك تصبح $\Delta\bar{P}$ total = (U_i total) هي

$$\Delta\bar{P}_{total} = 30.7 + 9.7 = 40.4\ KN/m^2$$

ولكون التربة هي O.C.C. ولغرض حساب الهطول النهائي يجب ان نتحقق

$$\bar{P}_o + \Delta\bar{P} < \text{or} > \bar{P}_c$$

$$86 + 40.4 = 126.4 > \bar{P}_c = 100\ KN/m^2$$

$$\therefore S_{cf} = \frac{C_r}{1+e_o} H \log\frac{\bar{P}_c}{\bar{P}_o} + \frac{C_c}{1+e_o} H \log\frac{\bar{P}_o+\Delta\bar{P}}{\bar{P}_c}$$

$$= \frac{0.03}{1+1.0767}(8)\log\frac{100}{86} + \frac{0.2}{1.0747}(8)\log\frac{86+40.4}{100}$$

$$\rightarrow S_{cf} = 0.086\ ^{m} = 8.6\ ^{cm}$$ لاحظ الرسم التوضيحي

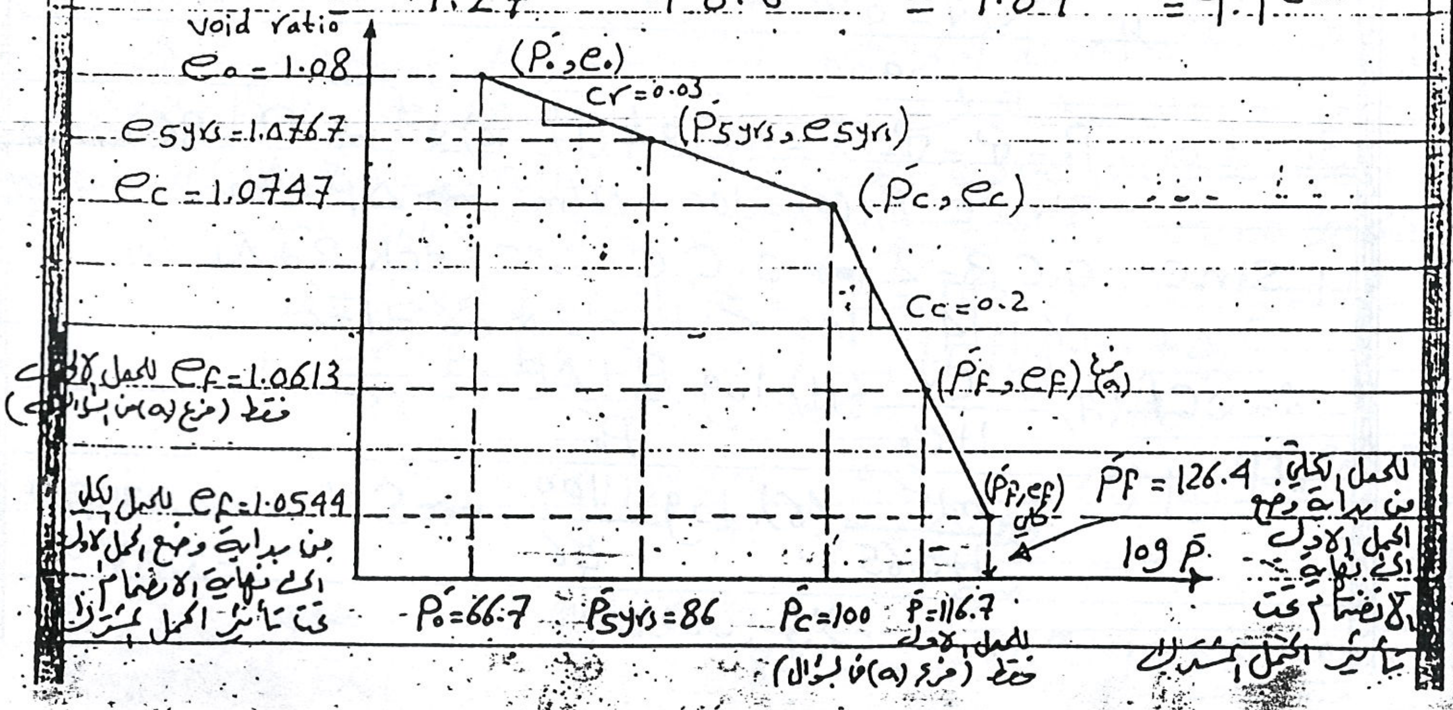
واذا اردنا حساب نسبة الفجوات النهائية e_f نستخدم

$$C_c = \frac{\Delta e}{\Delta \log P} \rightarrow 0.2 = \frac{1.0747 - e_f}{\log\frac{126.4}{100}} \rightarrow e_f = 1.0544$$

وبذلك يصبح مقدار الهطول الكلي من بداية وضع الحمل الأول الى انتهاء الانضمام الحمل المشترك

$$S_{cf}\ \text{total} = S_c\ \text{حمل اول} + S_c\ \text{مشترك}$$

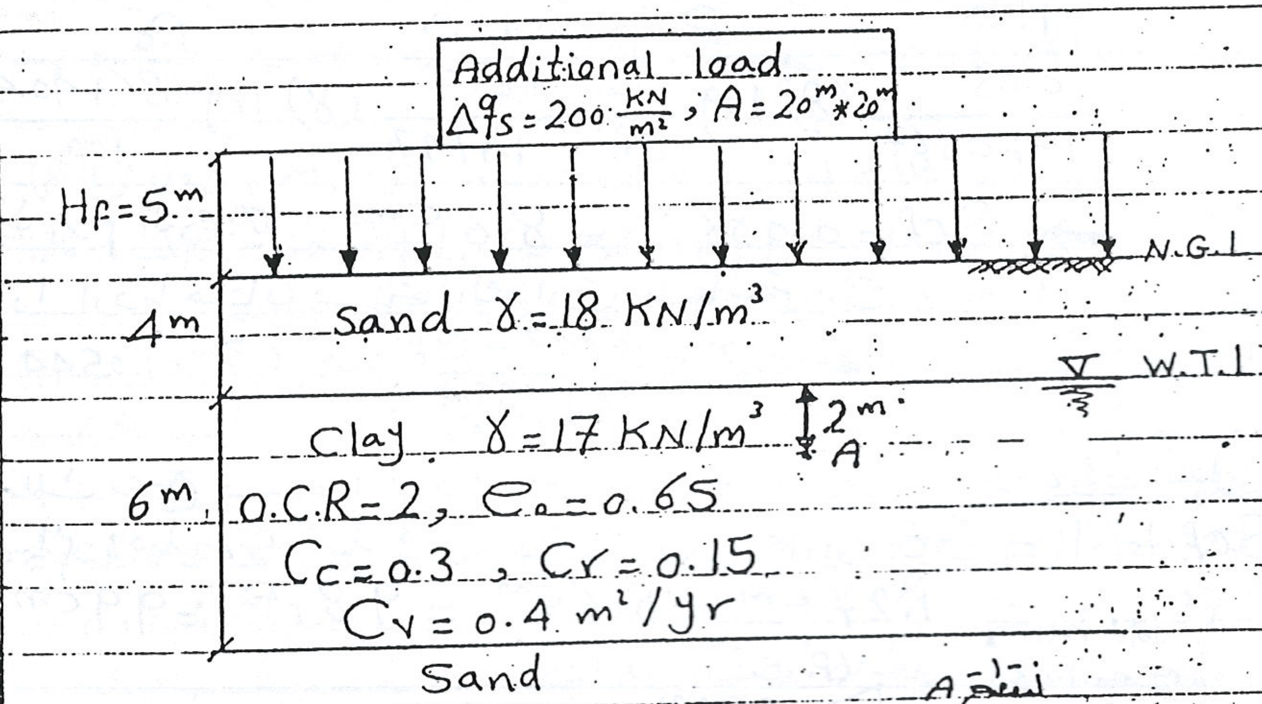
$$= 1.27\ ^{cm} + 8.6\ ^{cm} = 9.87\ ^{cm} = 9.9\ ^{cm}$$



Ex 52 (A) For the soil profile shown in figure, (5)^m fill was applied on the surface. At the end of Consolidation Process, the effective stress increment at point (A) was 100 KN/m^2. Calculate the final Consolidation Settlement.

(B) If additional pressure 200 $\frac{KN}{m^2}$ is applied on the surface of the fill, through a square area $20^m * 20^m$, after the average degree of Consolidation in the clay layer reached 50% under the effect of the fill only. Find:

1. The total Consolidation Settlement due to the total Pressure.
2. Time required to reach 12 cm Settlement from the start of the fill application.



Solution: (عند A)
$P_o' = \bar{\sigma} = \sigma - U = 4*18 + (17-10)*2 \rightarrow P_o' = 86$ KN/m^2

Since $P_f(A) = 100$ KN/m^2 $\rightarrow \Delta \bar{P} = 100 - 86 = 14 \frac{KN}{m^2}$

Since O.C.R = 2 $\rightarrow$ O.C.C $\therefore$ check $P_o' + \Delta \bar{P} >$ or $< P_c'$

$86 + 14 = 100 < P_c' = 2 * 86 = 172$

$$\therefore SCf(A) = \frac{C_r}{1+e_o} (H) \log \frac{P_o' + \Delta \bar{P}}{P_o'}$$

$$= \frac{0.15}{1+0.65} (6) \log \frac{100}{86} \rightarrow SCf(A) = 0.0357^m = 3.57^{cm}$$

وإلى هنا ينتهي الفرع الأول من السؤال

(B) When $U_{av} = 50\%$ $\rightarrow$ $\Delta P' = 0.5 * 14 = 7 \; KN/m^2$

and $P_t' (\text{at } U_{av} = 50\%) = 86 + 7 = 93 \; KN/m^2$

or $U_{av} = \dfrac{P_t' - P_o'}{P_f' - P_o'} \rightarrow 0.5 = \dfrac{P_t' - 86}{100 - 86} \rightarrow P_t' = 93 \; KN/m^2$

الآن فإن الإجهاد الفعال أصبح يساوي $(93 \; \frac{KN}{m^2})$ والذي هنا ينبغي حساب S_{ct} الى هذه المرحلة $(U_{av} = 50\%)$

$S_{ct} = \dfrac{0.15}{1+0.65} (6) \log \dfrac{93}{86} \rightarrow S_{ct} = 0.0185^{m} = 1.85^{cm}$

وبذلك تكون نسبة الفجوات (e_t) في هذه المرحلة $(U_{av} = 50\%)$

$C_r = \dfrac{\Delta e}{\Delta \log P'} \rightarrow 0.15 = \dfrac{0.65 - e_t}{\log \frac{93}{86}} \rightarrow e_t = 0.6449$

اما بالنسبة لحساب (e_c) عند الضغط المسبق للانضغاط $(P_c' = 172 \frac{KN}{m^2})$

$C_r = \dfrac{\Delta e}{\Delta \log P'} \rightarrow 0.15 = \dfrac{0.65 - e_c}{\log \frac{172}{86}} \rightarrow e_c = 0.60485$

الآن بالنسبة للحمل الجديد يتم حساب الزيادة في الاجهاد الفعال التي تتولد في نقطة (A) نتيجة تسليط هذا الحمل

$\Delta P' = \dfrac{200 * 20^2}{(20+11)^2} \rightarrow \Delta P' = 83.247 \; KN/m^2$

هذه الزيادة في الإجهاد الفعال ناتجة عن تأثير الحمل الجديد فقط ولكن هناك ضغط ماء زائد $(U_e = 7 \frac{KN}{m^2})$ من الحمل الأول (fill) لم يتسرب وذلك لأن درجة انضغاط الحمل الأول كانت = 50% عند تسليط الحمل الثاني وبذلك

$\Delta P'_{total} = 7 + 83.247 \rightarrow \Delta P'_{total} = 90.247 \frac{KN}{m^2}$

والآن بالنسبة للحمل المشترك (المتبقي من الحمل الأول + fill الجديد) فإن الحالة الابتدائية (initial Condition) تكون كالآتي

$P_o' = 93 \; KN/m^2$, $e_o = 0.6449$; $P_c' = 172$, $e_c = 0.60485$

$P_o' + \Delta P'_{total} = 93 + 90.247 = 183.247 > P_c' = 172$

$\therefore S_{cf} = \dfrac{C_r}{1+e_o} H \log \dfrac{P_c'}{P_o'} + \dfrac{C_c}{1+e_c} H \log \dfrac{P_o' + \Delta P'}{P_c'}$

$= \dfrac{0.15}{1+0.6449} (6) \log \dfrac{172}{93} + \dfrac{0.3}{1+0.60485} (6) \log \dfrac{93+90.247}{172}$

$\rightarrow S_{cf} = 0.177^{m} = 17.7^{cm}$

$\therefore$ total $S_{cf} = 0.177 + 0.0185 = 0.1955^{m} = 19.55^{cm}$

الآن بالنسبة للمطلب الأخير: حساب الزمن الذي يصبح عنده الانضمام مساوي إلى 12^{cm} من بداية التحميل فإن:

$$U_{av} = \frac{S_{ct}}{S_{cf}} = \frac{12\ cm}{19.55\ cm} \rightarrow U_{av} = 0.6138 > 60\%$$

$$\therefore T_v = 1.781 - 0.933 \log(100 - 61.38) \rightarrow T_v = 0.3$$

$$\therefore t = \frac{T_v d^2}{C_v} = \frac{0.3 * 2^2}{0.4} \rightarrow t = 3\ yrs$$

(أقرب سطح تصريف للنقطة A) من بدء التحميل الأولي (fill)

الآن لنضع المخطط التوضيحي: