Soil consolidation

Example No.1

A soil layer having $e_o = 1.04$ and thickness 9m, it is estimated $e_f = 0.98$ after construction a building. calculat total final settlement may be expected?

solution:

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

دائماً م ركز على e_f
لأنه يحدث انضغاط في التربة
فتقل نسبة الفجوات

$\therefore$

$$S_{cf} = \frac{1.04 - 0.98}{1+1.04} * 9 = 0.26m \approx 26cm$$

EX. 2

Sand layer of 3m depth compacted at $\gamma = 19\ kN/m^3$ over clay layer have thickness 3.5m. calculate final settlement if coefficient of volume change (m_v) is $0.007\ m^2/ton$.

دائماً الانضغاط يحدث في الطين

solution:

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

$$m_v = 0.007 \frac{m^2}{ton} * \frac{1\ ton}{1000\ kg} * \frac{100\ kg}{1\ kN} = 0.0007\ m^2/kN$$

كله لازم بـ KN

$\Delta\sigma_v'$ = stress increment from load applied

$$\Delta\sigma_v' = h_{fill\ sand} \times \gamma_{sand} = 3 \times 19 = 57\ kN/m^2$$

هنا لا توجد أحمال
لكن وجدت طبقة
الرمل وضعت فوق طبقة
الطين عليه تعتبر هذه
الطبقة هي الأحمال

$\therefore$

$$S_{cf} = 0.0007 \frac{m^2}{kN} * 57 \frac{kN}{m^2} * 3.5\ m \quad (\text{سمك طبقة clay})$$

$\therefore$

$$S_{cf} = 0.14m = 14cm$$

Ex.3

soft clay layer 2m thick, have $C_c = 0.315$, the pressure applied is 400 kN/m², the initial void ratio of the soil is 0.67 calculate the final settlement if overburden stress (σ'_{v_0}) of layer is 400 kN/m²

Solution:

$$S_{cp} = \frac{C_c}{1+e_0} \times H \times \log \frac{\sigma'_{v_0} + \Delta\sigma'_v}{\sigma'_{v_0}}$$

$$S_{cp} = \frac{0.315}{1+0.67} \times 2 \times \log \times \frac{400+400}{400}$$

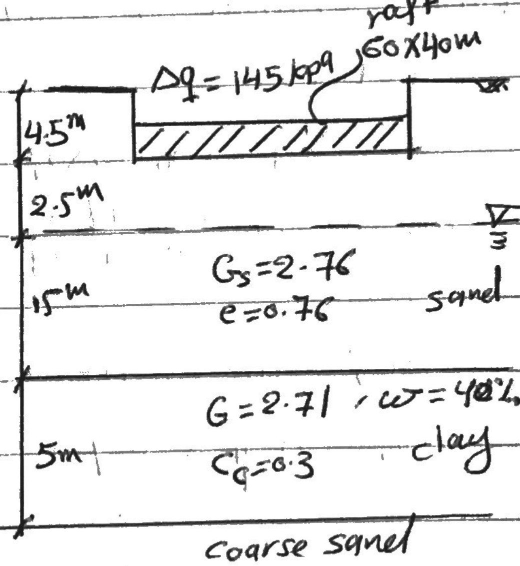
$$S_{cf} = 0.1137\,m = 11.4\,cm$$

هنا استخدمنا هذه
المعادلة لأن التربة هي
(N.C.C) حيث لم يذكر أي
معلومة تدل على (OCC)
ولم يعطي (OCR).

Ex.4

For the soil profile shown find final consolidation settlement at the center of foundation and at the corner of foundation.

m	2	6	1.0
n	3	2	1.5
I_z	0.238	0.24	0.195



Solution:

$$\gamma_{sand\,dry} = \frac{G}{1+e_0}\gamma_w = \frac{2.76}{1+0.76} \times 10 = 15.68\ kN/m^3$$

$$\gamma_{sand\,saturat} = \frac{G+e_0}{1+e_0}\gamma_w = \frac{2.76+0.76}{1+0.76} \times 10 = 20\ kN/m^3$$

تم حساب γ_{dry} للأول
والأخرى γ_{sat} كونه
مستوى المياه تم
طبقة الحل

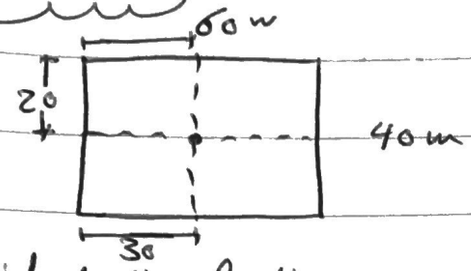
$$\gamma_{clay\,satural} = \frac{G+e}{1+e}\gamma_w \quad , \quad Se = \omega \times G \Rightarrow 1 \times e = 0.4 \times 2.71$$

$$e = 1.084$$

$$\gamma_{clay\,sat} = \frac{2.71+1.084}{1+1.084} \times 10 = 18.2\ kN/m^3$$

$\Delta\sigma_v = ???$

at center:



* divided the footing so each part pass its corner in the point that $\Delta\sigma_v'$ required.

$$m = \frac{B}{Z} \quad , \quad n = \frac{L}{Z}$$

$Z = 20^m \Rightarrow (2.5+15+2.5=20^m)$

$m = \frac{20}{20} = 1$

$n = \frac{30}{20} = 1.5$

* using the value f table given

$\therefore I_Z = 0.195$

$\therefore \Delta\sigma_v' = \sum \Delta q \times I_Z$

$\Delta\sigma_v' = 4 \times 145 \times 0.195 = 113.1\ kN/m^2$

$$S_{cf} = \frac{C_c}{1+e} \times H \times \log \frac{\sigma_{v_0}' + \Delta\sigma_v'}{\sigma_{v_0}'}$$

$\sigma_{v_0}' = 7.5 \times 15.68 + 15 \times 20 + 18.2 \times 2.5 = 288.1\ \frac{kN}{m^2}$

$\therefore S_{cf} = \frac{0.3}{1+1.084} \times (5) \times \log \frac{288.1 + 113.1}{288.1}$

$S_{cf} = 0.0\ m = 1\ cm$

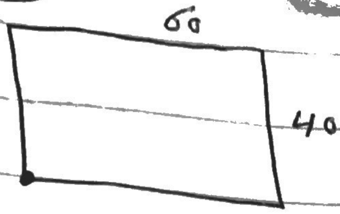
هنا سيتم حساب $\Delta\sigma_v'$ بالاعتماد على I_z factor والذي يتم من ايجاد $\Delta\sigma_v'$ في النقطة التي يتم تحديدها اعتماداً على طول وعرض الاساس والذي سيقع الحمل.

m علاقة بين العرض وعمق الاجهاد
n علاقة بين الطول وعمق الاجهاد
z = يقاس من تحت الاساس الى منتصف طبقة الطين واحياناً يعطى مباشرة

وهنا علاقة عمق (z) لانه توجد اكثر من طبقة.

σ_{v_0}' سبب الاجهاد الناتج من وزن التربة وما فوقها الى منتصف طبقة الطين ويقاس من تحت الاساس الى سطح الارض GS.

at corner



هنا لا نحتاج تقسيم الأساس
الى مربعات او مستطيلات
لان النقطة واقعة في الزاوية corner

$m = \frac{40}{20} = 2$

$n = \frac{60}{20} = 3$

from table ⟹ $I_z = 0.238$

$\Delta\sigma'_v = \sum \Delta q \times I_z = 145 \times 0.238 = 34.51\ \frac{kN}{m^2}$ ⟸ هنا لا يوجد جمع اجزاء فانه جزء واحد

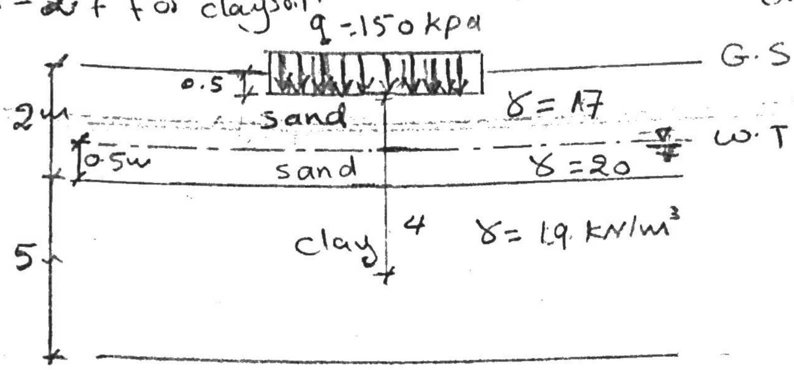
$\sigma'_{v_0} = 384.7\ kN/m^2$ ⟸ من الفرع السابقة

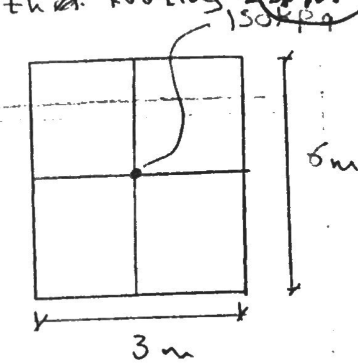
$S_{cf} = \frac{C_c}{1+e_0} \times H \times \log \frac{\sigma'_{v_0} + \Delta\sigma'_v}{\sigma'_{v_0}}$

$S_{cf} = \frac{0.3}{1+1.084} \times 5 \times \log \frac{~~209.7~~\ 288.1 + 34.51}{~~209.7~~\ 288.1} = 0.040\ m = 4.0\ cm$

Example No. 5

Find consolidation settlement for figure shown below. water content at end of test = 10% , $e_o = 0.981$ & $C_c = 0.25$ & $G_s = 2.7$ for clay soil. depth under footing = 4 m ⟹ Z





$$S_c = \frac{C_c}{1+e_o} H \log \frac{\sigma'_{vo} + \Delta\sigma_v}{\sigma'_{vo}}$$

$$\sigma'_{vo} = 1.5 * 17 + 0.5 * 20 + 2.5 * 19 - 3 * 10 = 53.00 \text{ kN/m}^2$$

$$\boxed{\Delta\sigma_v = \frac{\Delta q_s * B * L}{(B+Z)(L+Z)}}$$

← by approxmate method
(لانه هنا لم اعطي ncm)
نطبق هذه الطريقة

$$\Delta\sigma_v = \frac{150 * 6 * 3}{(6+4)(3+4)} = 38.57 \text{ kN/m}^2$$

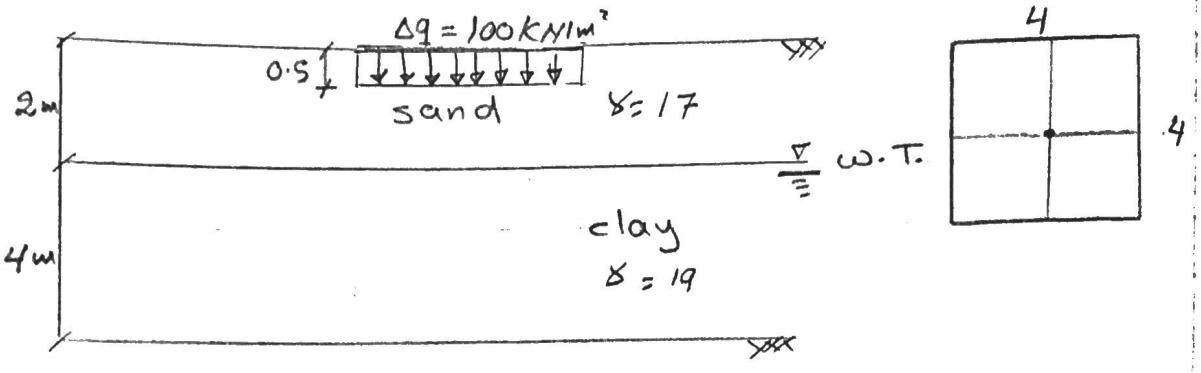
$$S_c = \frac{0.25}{1+0.981} * 5 * \log \frac{53.00 + 25.71}{53.00} = 0.15 \simeq 15 \text{ cm}$$

Soil Mech.

Example No. 6

For Figure shown below if (a) preconsolidation = 95 KN/m² & $C_r = 0.031$, $C_c = 0.21$, $e_o = 0.981$, $G_s = 2.7$

(b) preconsolidation pressure = 45 KN/m², $C_r = 0.031$, $C_c = 0.21$, $e_o = 0.981$, $G_s = 2.7$. Find total settlement



a

$\sigma'_{vo} = 2 * 17 + 2 * (19 - 10) = 52.00$ KN/m²

by approx. method

$$\Delta\sigma_v = \frac{\Delta q * B * L}{(B+z)(B+L)} = \frac{100 * 4 * 4}{(4+3.5)(4+3.5)} = 28.44 \text{ KN/m}^2$$

$\sigma_{ve} = 95 > \sigma'_{vo} = 52.5 \longrightarrow$ over consolidated soil (O.C.)

$\sigma'_{vo} + \Delta\sigma_v = 52.5 + 28.44 = 80.44 < \sigma_{ve} = 95$

$$\therefore S_c = \frac{C_r}{1+e_o} H \log \frac{\sigma'_{vo} + \Delta\sigma_v}{\sigma'_{vo}}$$

$$S_c = \frac{0.31}{1+0.981} * 4 * \log \frac{91.44}{63.5} = 0.1 \text{ m} \simeq 10 \text{ cm}$$

b// $\sigma_{ve} = 45 < \sigma'_{vo} = 52.50$

but

$\sigma'_{vo} + \Delta\sigma_v = 52.0 + 28.44 = 80.44 > \sigma_{ve} = 45$ KN/m²

$$\therefore S_c = \frac{C_r}{1+e_o} H \log \frac{\sigma'_{vo}}{\sigma_{ve}} + \frac{C_c}{1+e_o} H \log \frac{\sigma_{ve} + \Delta\sigma_v}{\sigma_{ve}}$$

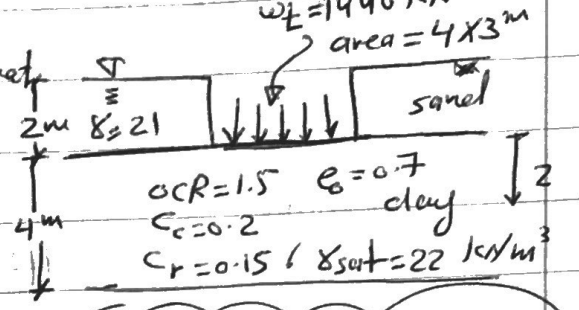
$$S_c = \frac{0.031}{1+0.981} * 4 \log \frac{52}{45} + \frac{0.21}{1+0.981} * 4 * \log \frac{45 + 28.44}{45}$$

$S_c = 0.09 \text{ m} = 9 \text{ cm}$

6

EX.7

For soil profile shown find final consolidation settlement. use approximate method (2:1) ~~method~~.



$$\Delta q = \frac{Wt}{Area} = \frac{1440}{4\times3} = 120 \frac{kN}{m^2}$$

approximate (2:1) method

$$\Delta\sigma_v' = \frac{\Delta q \times B \times L}{(B+z)(L+z)}$$

$\therefore$

$$\Delta\sigma_v' = \frac{120\times3\times4}{(3+2)(4+2)} = 48 \frac{kN}{m^2}$$

$OCR = 1.5 > 1$

$\therefore$ OCC

σ_{v_0}' = 2×21 + 2×22 − (2×10) = 46 kN/m²

check $\sigma_{v_0}' + \Delta\sigma_v' \geq \sigma_c'$ or $\sigma_{v_0} + \Delta\sigma_v < \sigma_c'$

$$OCR = \frac{\sigma_c'}{\sigma_{v_0}'} \Longrightarrow \sigma_c' = OCR \times \sigma_{v_0}' = 1.5 \times 46 = 69 \text{ kN/m}^2$$

46 + 48 = 94 $\geq \sigma_c$ = 69

$\therefore$ used this eq.

$$S_{cf} = \frac{C_r}{1+e_0} \times H \log\frac{\sigma_c'}{\sigma_{v_0}'} + \frac{C_c}{1+e_0} \times H \times \log\frac{\sigma_{v_0}' + \Delta\sigma_v'}{\sigma_c}$$

$$S_{cf} = \frac{0.15}{1+0.7} \times 4 \times \log\frac{69}{46} + \frac{0.2}{1+0.7} \times 4 \times \log\frac{46+48}{69}$$

$$S_{cf} = 0.062 + 0.063 = 0.125 m = 12.5 cm$$

Ex. 8

clay layer 3m thick have $C_v = 5 \times 10^{-4}$ cm²/sec. Find time required to reach half consolidation (U) after building construction if two way drained.

solution:

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

$U = 50\% \Rightarrow T_v$ at $U = 50\% < 60\%$ found from this eq.

$$T_v = \frac{\pi}{4}(U)^2$$

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

drained ذكر بالسؤال أن إذا طين $\Rightarrow d = \frac{H}{2} = \frac{3}{2} = 1.5$

ف

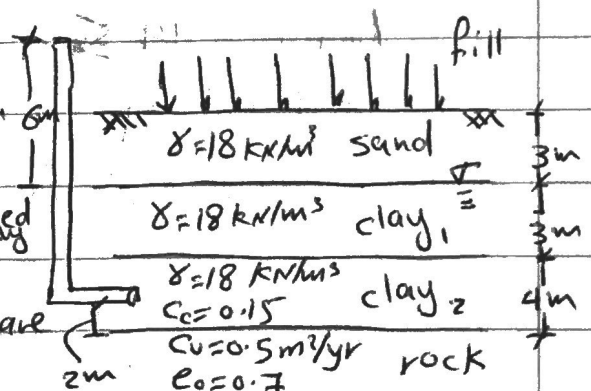
$$5 \times 10^{-4} \times \left(\frac{1 km^2}{100 m^2} \times \frac{3600 sec}{1 hr} \times \frac{24 hr}{day}\right) = \frac{0.196 \times (1.5)^2}{t}$$

تحويل على كل الوحدات

$$\therefore t = 102 \text{ day}$$

Ex. 9

For soil profile shown in fig the reading of piezometer above water table is 6m after fill applied immediately. Find total settlement and time required to have reading 4m above water table.



solution:-

$h_{piezometer} = 6m$ after fill applied immediately

$\therefore \Delta\sigma_v = fill = h \times \gamma_w = 6 \times 10 = 60 \text{ KN/m}^2 = u_i$

$\sigma'_{v_0} = \underset{\text{sand}}{3 \times 18} + \underset{\text{clay}_1}{18 \times 3} + \underset{\text{clay}_2}{2 \times 18} - (5 \times 10) = 194\ kN/m^2$

هنا عم settlement للصيغ (clay₂) لماذا؟؟
⇓
لأن piezometer موضوع فيها

$S_{cf} = \frac{C_c}{1+e_0} \times H \times \log \frac{\sigma'_{v_0} + \Delta\sigma'_v}{\sigma'_{v_0}}$

$S_{cf} = \frac{0.15}{1+0.7} \times 4 \times \log \frac{194+60}{194} = 0.076\ m = 7.6\ cm$

هذه القراءة For reading = 4m abou w.T.

هنا عمل ⇒ $u_e = 4 \times 10 = 40\ kN/m^2$

لأنها اولية فقط بداية وضع الحمل ⇒ $u_i = 60\ kN/m^2$

$U = \frac{u_i - u_e}{u_i} = \frac{60-40}{60} \times 100 = 33.3\% < 60\%$

∴ use $T_v = \frac{\pi}{4}(U)^2 = \frac{\pi}{4}(0.333)^2 = 0.0873$

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

$d = H = 4 \xrightarrow{\text{why ???}}$ the (clay₂) have one way drained from down only.

$0.5\ \frac{m^2}{yr} = \frac{0.0873 \times 4^2}{t}$

∴ $t = 2.8$ year.

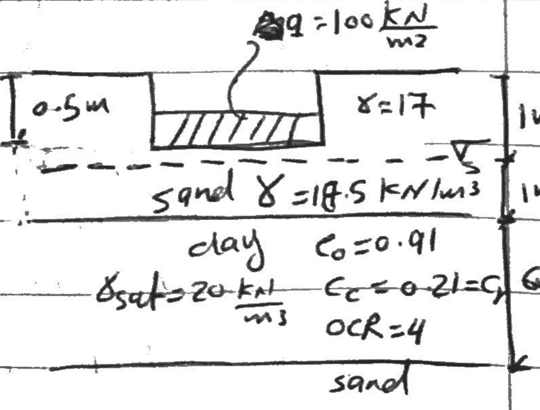
Ex.10

For the soil profil shown in fig. 70% of consolidation occure after one year. Find:-

1- S_{cf}.

2- settlement after 2 year

3. time required to reach 15 cm.



Solution:

1. $OCR = 4 > 1 \Rightarrow \therefore$ OCC.

$\sigma'_{v_0} = 1 \times 17 + 18.5 \times 1 + 3 \times 20 - (4 \times 10) = 55.5$

لانه لم يعطِ أي مساحة $\Rightarrow \Delta\sigma'_v = q = 100\ kN/m^2$

$OCR = \dfrac{\sigma'_c}{\sigma'_{v_0}} \Rightarrow \sigma'_c = 4 \times 55.5 = 222\ kN/m^2$

$\sigma'_{v_0} + \Delta\sigma'_v = 55.5 + 100 = 155.5 < 222 = \sigma'_c$

$\therefore$ used

$$S_{cf} = \frac{C_r}{1+e_0} \times H \times \log \frac{\sigma'_{v_0} + \Delta\sigma'_v}{\sigma'_{v_0}}$$

$$S_{cf} = \frac{0.21}{1+0.91} \times 6 \times \log \frac{55.5+100}{55.5} = 0.295\,m = 29.5\,cm.$$

2. To find settlement at any time use this eq.

$$U = \frac{S_{ct}}{S_{cf}}$$

need to find U after 2 year ???

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

given $U = 70\%$ at $t = 1$ year $\xRightarrow{so}$ we can find $T_v \xRightarrow{then}$ C_v ⇒ ثابت لا يتغير مع الزمن لو جبناه من فحص المختبر واستخدمنا الحسابات في الموقع (v. impo.)

$\therefore U = 70\% > 60\%$

$\therefore T_v = -0.933 \log(1-U) - 0.085$

$T_v = -0.933 \log(1 - 0.7) - 0.085 = 0.402$

but $C_v = \dfrac{T_v\, d^2}{t} = \dfrac{0.402 \times (3)^2}{1\ \text{year}}$

$d = \dfrac{H}{2} = 3$ ⇐ لأنه تصريف من الأعلى والأسفل sand

$C_v = 3.62\ m^2/year.$

Now find T_v for 2 year.

$3.62 = \dfrac{T_v (3)^2}{2} \Rightarrow T_v = 0.805$

Now find U for $T_v = 0.805$

assume $U \leq 60\%$

$\therefore T_v = \frac{\pi}{4}(U)^2$

$0.805 = \frac{\pi}{4}(U)^2 \Rightarrow U^2 = 101.2$ not. o.k.

$\therefore$ used

$T_v = -0.933 \log(1-U) - 0.085$

$0.805 = -0.933 \log(1-U) - 0.085$

$0.89 = -0.933 \log(1-U)$

log عكس $\Rightarrow \log(1-U) = -0.953$

$10^{1-U} = 10^{-0.953}$

$1-U = 0.111 \Rightarrow U = 0.88 = 88\% > 60\%$ o.k.

$\therefore U = \frac{S_t}{S_f} \Rightarrow S_t = U \times S_f = 0.88 \times 0.295$ m

$\therefore$

$S_t = 0.262\ m = 26.2\ cm$

3. To find time at any settlement

$U = \frac{S_t}{S_f} = \frac{15\ cm}{29.5\ cm} = 0.508 = 50.8\% < 60\%$

$\therefore$

$T_v = \frac{\pi}{4}(U)^2 = \frac{\pi}{4}(0.508)^2 = 0.202$

but

$C_v = \frac{T_v d^2}{t} \Rightarrow 3.62\ \frac{m^2}{yr} = \frac{0.202 \times 3^2}{t}$

$\therefore$

$t = 0.503\ year = 184.0\ day$