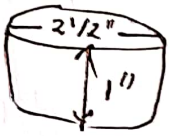
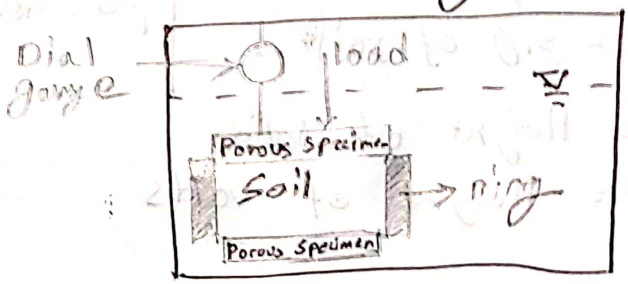
11.5 One-Dimensional Laboratory Consolidation test:

(i) The test is performed in a Consolidometer

(ii) The soil is placed between a steel ring with two porous specimen.





(iii) The load on the specimen is given through a lever arm.

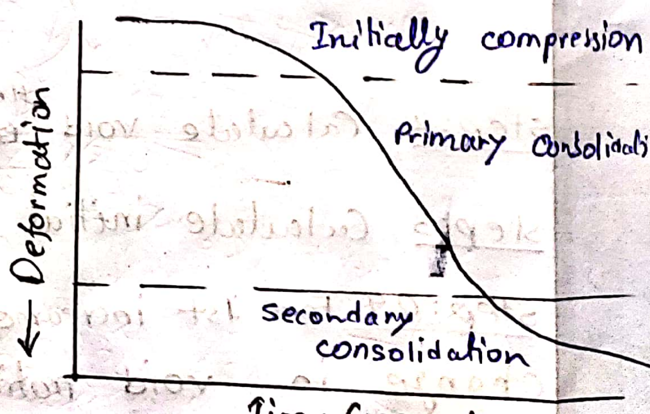
(iv) Compression is measured by a micrometer dial gauge.

(v) Each load is applied for 24hours and the load is usually doubled.

(vi) At the end the dry unit weight and the S.G of the speciment was determined.

(v) e-logp was procured

Time - Deformation Plot:



Stage-I

Initial compression caused by preloading

stage: II Primary

~~Second Initial~~ consolidation because excess water pressure is gradullay transferred to effective pressure beause of the expulsion of water

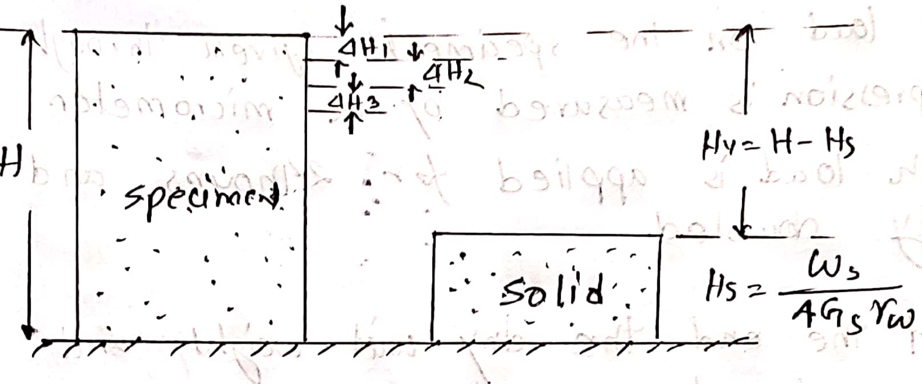
StageIII:

secondary consolidation after complete dissipation of water.

Plotting Void Ratio – Pressure Plots: (e-log P)

W_s = dry ~~unit~~ weight
M_s = dry mass
G_s = s.g of soil
H_s = Height of Solids
H_v = Height of voids

γ_w = unit weight of water
ρ_w = density of water



Step: 1
Calculate height of solid, $H_s = \frac{W_s}{A G_s \gamma_w}$

$W_s = V_s \gamma_s$
$= V_s G_s \gamma_w$
$= (A_s H_s) G_s \gamma_w$

step: 2 Calculate void Height, $H_v = H - H_s$

step: 3 Calculate initial void, $e_0 = \frac{V_v}{V_s} = \frac{H_v}{H_s}$

step: 04 For 1st increamental loading σ_1, deformation ΔH_1 change in void ration,

$$\Delta e_1 = \frac{\Delta H_1}{H_s}$$

step: 05: New void ratio, $e_1 = e_0 - \Delta e_1$

step: 06 Change in void for 2nd loading, $\Delta e_2 = \frac{\Delta H_2}{\Delta H_s}$

Step: 07 New void ratio, $e_2 = e_1 - \Delta e_2$

e-logP:

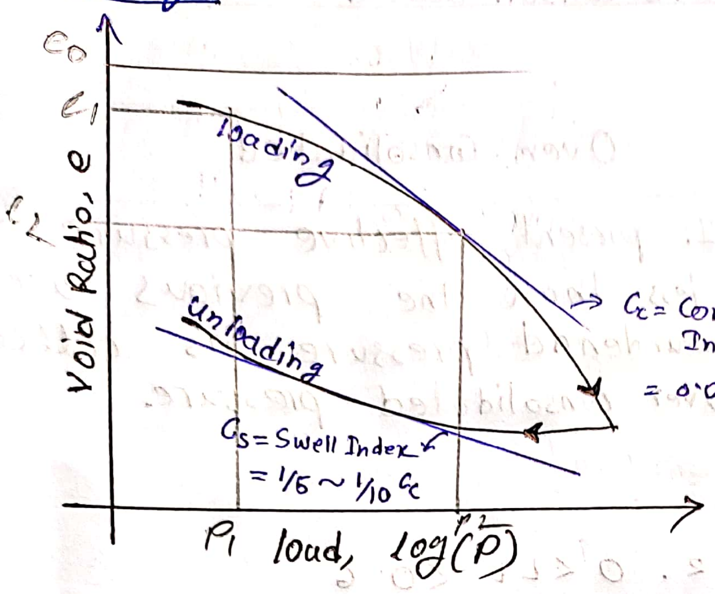


Fig. e-logP Graph

Definition: Change of void ratio with respect to load.

write uses of e-logP curve. (CT)

Nonmally Consolidated and overconsolidated clays:

Difference:

Nonmally Consolidated	Over Consolidated
1. If present ovenbunden pressure is greater than previous pressure, it's called Nonmally Consolidated clays.	1. present effective pressure is less than the previous over-burdendd pressure it's called over consolidated pressure.
2. 0<LL<1	2. 0<LL<0.6
3. Change of void ratio ~~negligible~~ considerable	3. ~~Con~~ Negligible
4. OCR <1	4. OCR >1

Preconsolidation Pressure: The maximum effective past pressure

Causes:

(i) geological over burden later removed by erosion.

(ii) Due to the building structure

(iii) Due to melting of glaciers.

(iv) Due to capillary rise on the past.

Over Consolidation:

P_c = Preconsolidation pressure

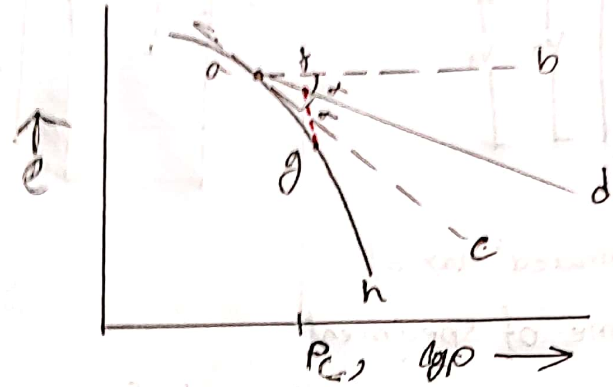
p = present effective ventical pressure

$$OCR = \frac{P_c}{p}$$

(15)

How can you find preconsolidation pressure from it?

Casagrande method:



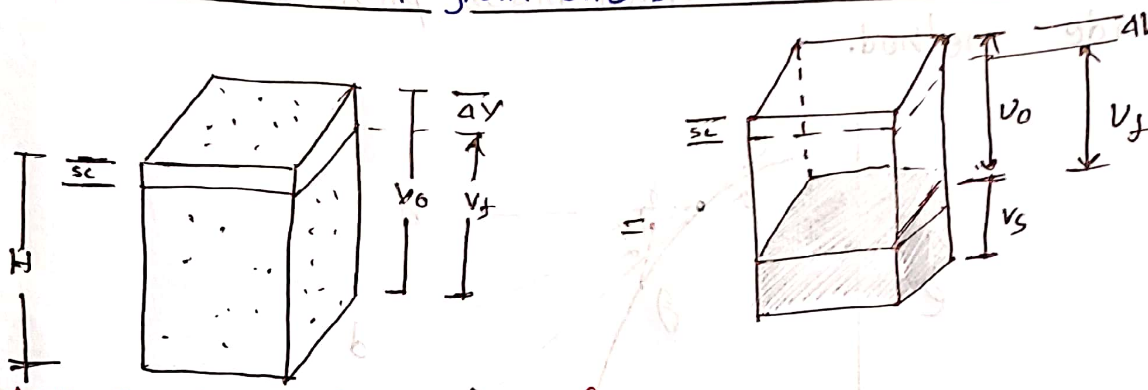
1. establish point 'a' on loading curve at the minimum radius of curvature.

2. Draw horizontal line 'ab'
3. Draw tangent 'ac'
4. " bisector ad
5. " Projection of 'gh' which intersect 'ad' at f
6. The abscissa of point 'f' is P_c or preconsolidation pressure σ_c', which can be acquired from graph.

(17)

Write importance of preconsolidation pressure in settlement analysis.

Settlement Calculation from One-Dimensional Primary Consolidation:



Let us consider a saturated clay of

V_o = ~~primary~~ Initial volume of specimen

V_f = Volume after primary settlement S_c

S_c = primary settlement

V_o = initial volume of voids

V_f = volume of voids after settlement

ΔV = Change in speciment volume

ΔV = " " void "

For Saturated Clay

Now, initial volume, $V_o = AH$

Volume change, $\Delta V = V_o - V_f = AH - (H-S)A$

$\therefore \Delta V = AS$

Now, $\boxed{\Delta V = \Delta V = AS}$

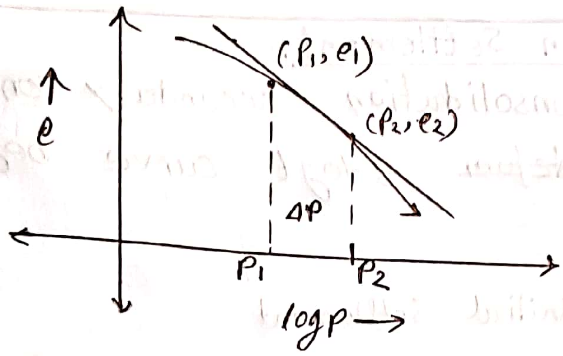
We know, $\Delta e = \dfrac{\Delta V}{V_s}$

$\Rightarrow \Delta V_v = \Delta e\, V_s$

$\Rightarrow \Delta V_v = \Delta e \times \dfrac{V_o}{1+e_o}$

$\Rightarrow AS = \Delta e \times \dfrac{AH}{1+e_o}$

$$\therefore \boxed{S_c = H \frac{\Delta e}{1+e_o}} \longrightarrow \text{settlement}$$



We know,

C_c = slope of loading curve

$$= \frac{e_2 - e_1}{\log P_2 - \log P_1} = \frac{\Delta e}{\log \frac{P_2}{P_1}} = \frac{\Delta e}{\log \frac{P_1 + \Delta P}{P_1}}$$

$$\Delta e = C_c \times \log\left(\frac{P_1 + \Delta P}{P_1}\right)$$

Always Consolidated

$P_0 > P_c$, $P_0 + \Delta P > P_0 > P_c$

$$S = \frac{C_c H}{1 + e_0} \log\left(\frac{P_0 + \Delta P}{P_0}\right) \rightarrow \text{Normally Consolidated (loading curve)}$$

$P_0 < \Delta P + P_0 < P_c$, $P_0 < P_c$

$$S = \frac{C_s H}{1 + e_0} \log\left(\frac{P_0 + \Delta P}{P_0}\right) \rightarrow \text{Over Consolidated (unloading curve)}$$

$$S = \frac{C_s H}{1 + e_0} \log\left(\frac{P_c}{P_0}\right) + \frac{C_c H}{1 + e_0} \log\left(\frac{P_0 + \Delta P}{P_c}\right)$$

$P_0 + \Delta P > P_c > P_0 \rightarrow$ Normally Consolidated ~~again~~ only after loading

~~$P_0 + \Delta P > P_0 > P_c$~~

(17)

Compression Index (C_c):

The modulus of the slope of virgin compression curve.

Emperical formulae suggested by Skempton:

$$C_c = 0.009 (LL - 10)$$

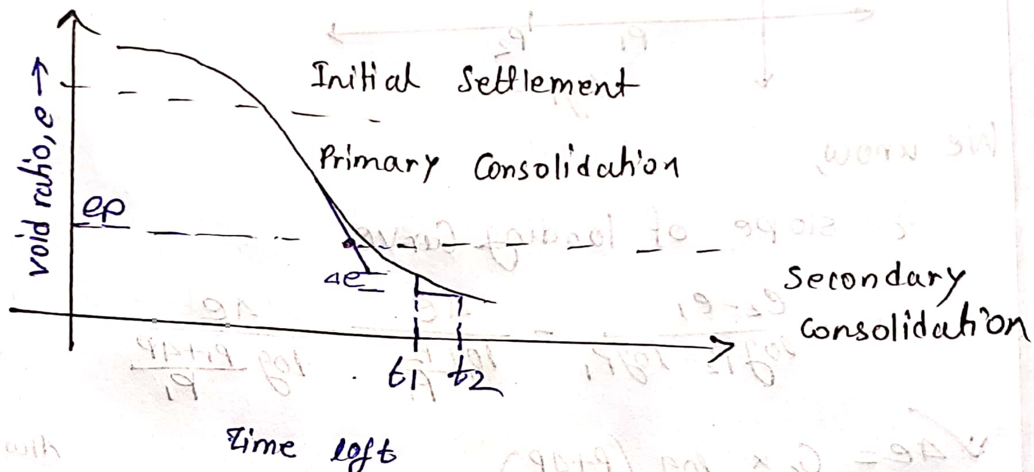
Swell Index (C_s):

It's the measure of increase of volume due to unloading

In most cases $C_s \approx \left(\frac{1}{5} \text{ to } \frac{1}{10}\right) C_c$

II.13 Secondary Consolidation Settlement:

At the end of primary consolidation secondary consolidation takes place and the ~~defor~~ e-log t curve begins to be linear.



C_α = Secondary Compression Index

$\therefore S_s$ = Secondary settlement

$$C_\alpha = \frac{\Delta e}{\log \frac{t_2}{t_1}}$$

$$\therefore \Delta e = C_\alpha \log\left(\frac{t_2}{t_1}\right)$$

$$\therefore S_s = C'_\alpha H \log\left(\frac{t_2}{t_1}\right)$$

$$C'_\alpha = \frac{C_\alpha}{1+e_p}$$

e_p = void ratio at the end of primary consolidation

$$\therefore S_s = \frac{C_\alpha H}{1+e_p} \log \frac{t_2}{t_1}$$

$$e_p = e_0 - \Delta e$$

$$e_p = e_0 - C_c \log\left(\frac{P_0+\Delta P}{P_0}\right)$$

Class: Calculate the settlement at clay layer. Stress increase is 1000 lb/ft².

(i) If Preconsolidation pressure is 900 lb/ft²

(ii) " " " 500 lb/ft²

↓ ↓ ↓

5'	Sand, $\gamma = 110$ lb/ft³ ▽	water table
5'	Clay, $\gamma_{sat} = 120$ lb/ft³	$e = 0.8$, $LL = 40$

(i) Answer:

∴ effective stress at the middle of clay, $P_o = \gamma_1 h_1 + \gamma_2 h_2$

$= 110 \times 5 + (\gamma_{sat} - \gamma_w) \times 2.5$

$= 110 \times 5 + (120 - 62.4) \times 2.5$

$= 694$ lb/ft²

∴ $P_o < P_c$ ∴ Over consolidated soil

After loading of ΔP, $P_o + \Delta P = 1000 + 694 = 1694$ lb/ft²

∴ $P_o + \Delta P > P_c$

∴ Settlement, $S = \frac{C_s H}{1+e_o} \log\left(\frac{P_c}{P_o}\right) + \frac{C_c H}{1+e_o} \log\left(\frac{P_o + \Delta P}{P_c}\right)$

$C_c = 0.009(LL-10) =$ ~~0.45~~ 0.27 | $H = $ ~~10~~ 5 [depth of clay layer]

$C_s = 1/5 \times 0.45 =$ ~~0.09~~ 0.054

∴ $S = \frac{0.054 \times 5}{1+0.8} \times \log\left(\frac{900}{694}\right) + \frac{0.27 \times 5}{1+0.8} \log\left(\frac{694+1000}{900}\right)$

~~= 0.37~~

$= 0.0205$ m

$= 20.55$ mm

(ii) In this case,

$$P_c < P_o < P_o + \Delta P$$

∴ Always consolidated Normally,

$$\therefore S = \frac{C_c H}{1+e_o} \log\left(\frac{\Delta P + P_o}{P_o}\right)$$

$$= \frac{0.27 \ (\text{~~0.45~~})}{1+0.8} \log\left(\frac{624+1000}{1000}\right) =$$

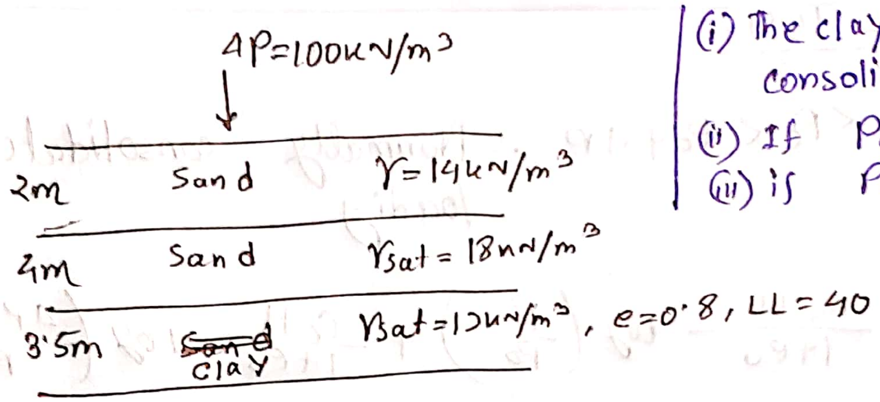
$= 0.03433 m$

$= 3433 mm$ → (বেশির settlement ∴ [illegible]

Answer:

11'4 Example:

Use
$C_s \approx 1/5\, C_c$



(i) The clay is normally consolidated
(ii) If $P_c = 200$ kN/m²
(iii) is $P_c = 150$ kN/m²

Solution:

Here, $\Delta P = 1000$

$h_1 = 2m$

$h_2 = 4m$

$h_3 = 3'5/2$

$H = 3'5$

∴ ~~Po =~~ Effective stress at the middle of clay layer,

$P_o = h_1\gamma_1 + h_2\gamma_2 + h_3\gamma_3 = 2\times14 + 4(\gamma_{sat} - \gamma_w) + 3'5/2 \times (\gamma_{sat} - \gamma_w)$

$= 28 + 4(18 - 9'81) + 3'5/2 \times (17 - 9'81)$

$= 76'8\ kN/m^2$

$\gamma_{dry} = \gamma = \gamma_{sat} - \gamma_w$

$C_c = 0'009(LL - 10) = 0'27$

$C_s = 0'27/5 = 0'054$

(i) If $P_c = 200$, ∴ $P_c > P_o$ ∴ Over consolidated

∴ After loading $P_o + \Delta P = 100 + 76'8 = 176'8$

∴ $P_c > P_o + \Delta P > P_o$ ∴ Still over consolidated

$$\therefore S_c = \frac{C_s H}{1+e_o} \log\left(\frac{P_o + \Delta P}{P_o}\right)$$

$$= \frac{0'054 \times 3'5}{1+0'8} \times \log\left(\frac{76'8+100}{76'8}\right)$$

$= 0'038\ m$

$= 38mm$

(ii) $P_c = 150$:

$\therefore P_o < P_c < P_o + \Delta P$ $\therefore$ Normally consolidated only after loading

$$\therefore S_c = \frac{C_s H}{1+e_o} \log\left(\frac{P_c}{P_o}\right) + \frac{C_c H}{1+e_o} \log\left(\frac{\Delta P + P_o}{P_c}\right)$$

$= 0.068$ m

$= 68$ mm

Ans.

Example: 11.6

For a normally consolidated clay layer in the field, the following values are given:

Thicuness layer of clay $= 2.6$ m

$e_o = 0.8$

$C_c = 0.28$

Average effective pressure on the clay layer $= 127$ kN/m^2

Applied load $= 46.5$ kN/m^2

$C_\alpha = 0.02$

What is the total consolidation of the clay layer five years after the completion of primary consolidation? [Time for completion of primary settlement = 1.5 Years]

Solution:

$H = 2.6 m$ | $t_2 = 5$ Yrs

$P_o = 127$ | $t_1 = 1.5$ Yrs

$\Delta P = 46.5$

$\therefore$ Primary Consolidation, $S_c = \frac{C_c H}{1+e_o} \log\left(\frac{\Delta P + P_o}{P_o}\right)$

$= \frac{2.6 \times 0.28}{1+0.8} \log\left(\frac{127+46.5}{127}\right)$

$= 54.8 mm$

Now, $e_p = e_o - \Delta e$

$= e_o - C_c \log\left(\frac{P_o + \Delta P}{P_o}\right)$

$= 0.8 - 0.28 \log\left(\frac{127+46.5}{127}\right)$

$= 0.762$

~~$S_s = \frac{}{1+e_p}$~~ $S_s = \frac{C_\alpha H}{1+e_p} \log\left(\frac{t_2}{t_1}\right)$

$= \frac{0.02 \times 2.6}{1+0.762} \log\left(\frac{5}{1.5}\right)$

$= 15 mm$

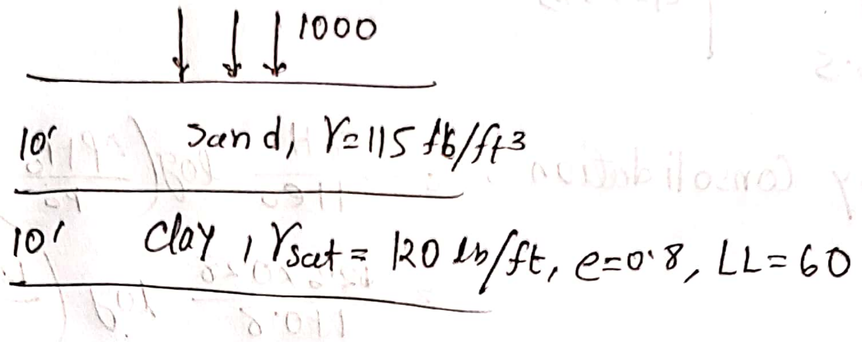
$\therefore$ Total consolidation $= S_c + S_s$

$= 54.8 + 15$

$= 69.8 mm$

Ans:

#CT: Calculate settlement If stress increase 1000 lb/ft² and preconsolidation pressure is 1500 lb/ft²



Solution:

$H = 10$ | $e = 0.8$ | $P_c = 1500$

$h_1 = 10$ | $LL = 60$

$h_2 = 5$

Effective stress,

$\therefore P_o = \gamma_1 h_1 + \gamma_2 h_2 = 10 \times 115 + (120 - 62.4) \times 5 = 1438$ lb/ft²

$\therefore P_o < P_c$ $\therefore$ Overconsolidated

After stress increase,

$P_o + \Delta P = 1000 + 1438 = 2438$ lb/ft²

$\therefore P_o < P_c < P_o + \Delta P$

$C_c = 0.009(60 - 10) = 0.45$

$C_s = 0.45/5 = 0.09$

$$\therefore S_c = \frac{C_s H}{1+e_o} \log\left(\frac{P_c}{P_o}\right) + \frac{C_c \times H}{1+e_o} \log\left(\frac{P_o + \Delta P}{P_c}\right)$$

$$= \frac{10}{1+0.8}\left(0.09 \times \log\left(\frac{1500}{1938}\right) + 0.45 \log\left(\frac{2438}{1500}\right)\right)$$

$= 0.5365$ m

$= 53.65$ cm