COMPRESSIBILITY AND SETTLEMENT

Definition:

When a compressor load is applied to soil mass, a decrease in its volume takes place. The decrease in the volume of soil may, under stress is known as Compression and

The property of soil may preparing to its susceptibility In a soil mass, when the voids are filled with air alone, compression of soil occurs rapidly. Because air is compressible and can escape easily form the voids.

Consolidation:

In a saturated soil mars having its voids filled with in compressible water, decrease in volume (or) compression can take place when water is expelled out of the voids.

Such a compression from long term static load and consequent escape of water is termed as Consolidation.

According to Terzaghi:

"Every process involving a decrease in the water content of a saturated soil without replacement of the water by air" is called a process of consolidation.

Compaction:

Compression of soil also takes place by expulsion of air from the voids. Under short duration by moving (or) vibratory loads such a compression in known as compaction.

Settlement:

When a compressor load is applied to a laterally confirmed layer of a soil mars, vertical deformation will occur. This vertical displacement of soil termed as settlement. This may be due to both compression and consolidation

Total vertical settlement:

$$P = P_i + P_c + P_s$$

Sum of three components namely

1. Immediate (or) distortion settlement (P_i)
2. Consolidation (or) primary consolidation (or) primary compression (or) primary time effect settlement (P_c)
3. Secondary consolidation settlement (P_s) (or) secondary compression (or) secondary time effect.

Compression settlement → Significant → Sard and grovel

Consolidation settlement → Significant → Clay

Uniform settlement → Structure settles uniformly damage → in Significant

Non Uniform settlement → Structure settlement non uniformly damage → Significant

Immediate settlement: (0 to < 7 Days)

It occurs immediately after the load is applied as a result of distortion of soil without any volume change. Out flow of water is negligible

Primary Consolidation:

The squeezing out of pure water from a loaded saturated soil results reduction in volume is termed as primary consolidation.

Secondary Consolidation:

Even after the reduction of all excess hydrostatic pressure to zero, some compression of soil takes place at a very slow rate. This is known as secondary consolidation during that time since of high viscous water b/w the pie is forced out from b/w the particles.

Immediate Settlement:

The Reduction in volume of soil (or) the settlement of soil occur. Just after the application of load is known as immediate settlement (or) initial consolidation.

For partially saturated soil – Decrease in volume due to expulsion and compressionof air in the voids.

For saturated soils due to compression of solid particles.

Primary Consolidation settlement:

After initial consolidation, further reduction in volume occurs due to expulsion of water from voids.

In fine grained soils → Primary Consolidation occurs over a time

In coarse grained soils → Primary Consolidation occurs rather quickly Due to high Permeability

Secondary Consolidation Settlement:

The reduction in volume continues at a very slow rate even after the water is fully dissipated and primary consolidation is complete. It is may be due to readjustment of solid particles. In most of the cores the secondary consolidation is ignored its having less magnitude. The settlement means that indicates the primary consolidation.

DETERMINATION OF SETTLEMENT:

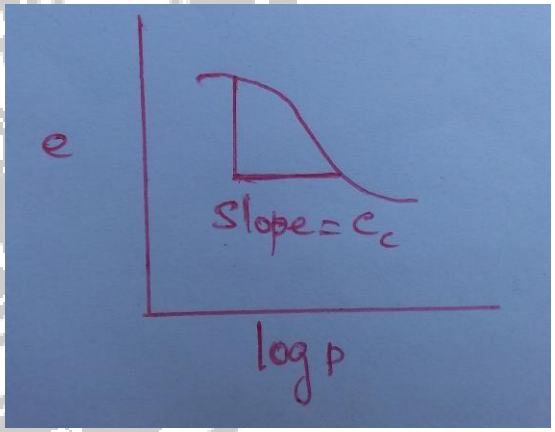
1. $\Delta H = \left[\frac{\Delta e}{1+e_0}\right] H - - - - - - A$

Where , ΔH = settlement;

$\Delta e = change\ in\ oid\ ratio$; e_0 = initial oid ratio ,

H $= thickness\ of\ soil\ layer$

2. **From e – log p curve**



Slope of e – log p curve gives c_c

C_c = compression index

$$C_c = \frac{\Delta e}{\Delta logP} - - - - - - B$$

$\Delta e = C_c\, \Delta \log p$

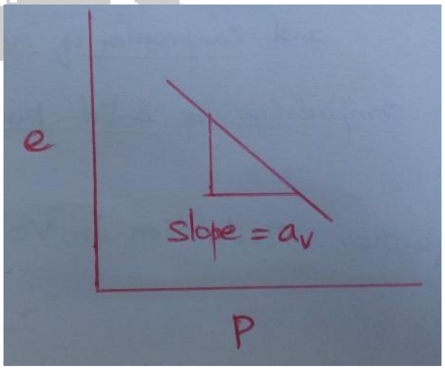
Sub in equation A

$$\Delta H = \left[\frac{C_c \Delta logP}{1 + e_0}\right] H$$

3. **From e – p curve:**

Slope of e – p curve gives a_v

$$a_v = \frac{\Delta e}{\Delta p} - - - - c$$



$a_v \rightarrow$ coefficient of compressibilityFrom C, $\Delta e = a_v.\Delta$p Substitute in A

$$\Delta H = \frac{a_v \Delta P}{(1+e_0)} H$$

M_v = Co - efficient of volume compressibility

$$M_v = \frac{a_v \Delta P}{1+e_0}$$

$C_c = 0.007\,(W_L - 10) \rightarrow$ disturbed soil

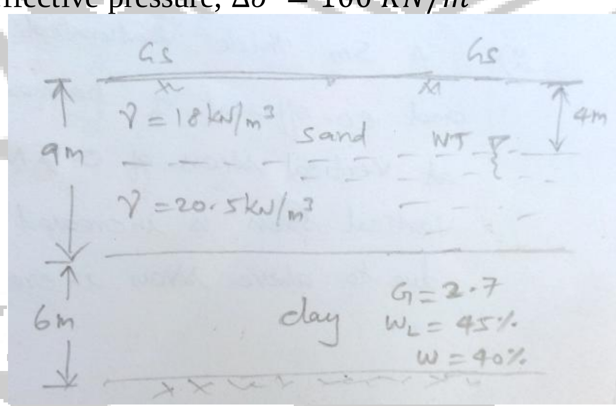
$C_c = 0.009\,(W_L - 10) \rightarrow$ undisturbed soil, $W_L = liquid\ limit\ (\%)$

PROBLEMS ON SETTLEMENTS

1. A 6m thick bed of clay is overlain by 9m thick layer of sand with water table at 4m below ground surface. For the clay layer specific gravity of soil particles is 2.7, average liquid limit 45% and natural water content 40%. For the sand layer the buck unit weights above and below water table are 18 $KN/m^3$and 20.5 KN/m^3respectively. Calculate the settlement of a building constructed on sand layer if it causes an increase in effective verified stress of 100 KN/m^2 at the middle of clay layer.

   Given datas:

   Increase in effective pressure, $\Delta\sigma' = 100\ KN/m^2$



Solution:

Sand : γ above W.T. = 18 KN/m^3

Layer : γ below W.T. = 20.5 KN/m^3

$\therefore \gamma' = r\ sat - \gamma\ w = 20.5 - 9.81$

$\gamma' = 10.69\ KN/m^3$

for clay layer $e_0 = W_{sat} G$. $[\therefore S = 1]$

$= 0.4 \times 2.7$

$e_0 = 1.08$

$$\gamma' = \frac{(G-1)\gamma_w}{1+e} = \frac{(2.7-1)9.81}{1+1.08}$$

$$= 8.02\ KN/m^3$$

At the middle of clay layer,

Initial efficient pressure

$\sigma_0' = 4 \times 18 + 5 \times 10.69 + 3 \times 8.02$
$\sigma_0' = 149.51 KN/m^3$

for clay layer,

C_c = compression index $= 0.009\ [W_c - 10]$

$= 0.009\ [45 - 10]$

$C_c = 0.315$

∴ Settlement at bottom of clay layer

$$S = \frac{C_c H}{1+e_0} \log_{10} \frac{\sigma_0' + \Delta\sigma'}{\sigma_0'}$$

$$= \frac{0.315X6}{1+1.08} \log_{10} \frac{149.51+100}{149.51}$$

$$=$$

$= 0.2021m$

s= $202.1mm$

2. A 5m thick saturated soil stratum has a compression index of 0.25 and co-efficient of permeability 3.2 x 10^{-3} mm/sec. If the void ration is 1.9 at vertical stress of 0.15N/mm^2, compute the void ratio when the vertical stress is increased to 0.2 N/mm^2. Also calculate the settlement due to above stress increase and time required for 50% consolidation.

Given datas:

$C_c = 0.25$; $H = 5m$

K_I 3.2 x $10^{-3}\ mm/sec$

$k = 1.9$; $\sigma_0 = 0.5\ N/mm^2$

$\sigma_1 = 0.2\ N/mm^2$, $e_1 = ?$

Solution:

We know, compression index,

$$c_c = \frac{\Delta e}{\Delta \log \sigma} = \frac{e_0 - e_1}{log\sigma_1 - log\sigma_0}$$

$$c_c log\frac{\sigma_1}{\sigma_0} = e_{0-}e_1$$

$$0.25 log\frac{0.2}{0.15} = e_0 - e_1$$

$$e_0 - e_1 = 0.0312$$

$Void\ ratio\ \therefore\ e_{1\,=}\ 1.9 + 0.312 = 1.869$

ii) Settlement:

$$\Delta H = \frac{C_c H_0}{1 + e_0} log\frac{e_1}{e_0}$$

$$\Delta H = 53.8mm$$

iii) Time required: (t)

$$T_v = \frac{\pi}{4}\left(\frac{U}{100}\right)^2$$

$$T_v = \frac{\pi}{4}\left(\frac{50}{100}\right)^2$$

$$= 0.196$$

Co-efficient of volume change $m_v = \frac{a_v}{1+e_0}$

$$a_V = \frac{\Delta e}{\Delta\sigma'}$$

$$m_v = \frac{\Delta e}{(1 + e_0)\Delta\sigma'}$$

$$= \frac{1.9 - 1.869}{(1 + 1.9)(0.2 - 0.15)}$$

$m_v = 0.214mm^2/m$

Co-efficient of consolidation

$$C_v = \frac{k}{m_v \gamma_w} = \frac{3.2x10^{-3}}{0.214X9.81X10^{-6}}$$

$$\Rightarrow 1524\ mm^2/\ sec.$$

Also, $T_v = time\ factor = \frac{C_v t}{d^2}\ and\ d = H\ for\ single\ drainage$

$$t = \frac{T_v d^2}{C_v} = \frac{(0.196)x(5000)^2}{1524} = 3215.2\ sec$$

t = 53.58 $minutes$ time required for 50 % consolidation

4)20 mm thick undisturbed sample of saturated clay is tested in laboratory with drainage allowed through top and bottom. Sample reaches 50% consolidation in 35 min. If clay layer from which sample was obtained is 3m thick and is free to drain through top and bottom surfaces, calculate the time required for same degree of consolidation in the field. What is the time required if the drainage in the field is only through the top?

Given data:

Thick of laboratory soil=20mm

50% consolidation in 35 min

Thick of field layer=3m

To find:

Time required in drainage field=?

Solution:

For same consolidation C_v and T_v are same.

$$t \alpha d^2$$

$$\frac{t_2}{t_1} = \left(\frac{d_2}{d_1}\right)^2$$

Case 1) If it double drainage

d_2 =drainage path in field =3/2=1.5m

d_1 =drainage path in laboratory =20/2=10mm=0.01m

t_1=50% consolidation in lab =35 min

$$t_2 = \left(\frac{d_2}{d_1}\right)^2 x t_1$$

$$= \left(\frac{1.5}{0.01}\right)^2 x35 = 787.5x10^3$$

Case 1) If it single drainage

d_2 =drainage path in field =3m

d_1 =drainage path in laboratory =20mm=0.02m

$$t_2 = \left(\frac{d_2}{d_1}\right)^2 x t_1$$

$$= \left(\frac{3}{0.01}\right)^2 x35 = 2188\, days$$

NC/OC SOIL:

- **Normal consolidated clay:** It is not subjected to pressure greater than the existing pressure
- **over consolidated clay:** It is subjected in the past to a pressure in excess of present pressure
- **under consolidated clay**: clay deposit does not reached equilibrium under the applied over burden load