12.0 ILLUSTRATIVE EXAMPLES

Example 12.1: In a consolidation test the following results have been obtained. When the load was changed from 50 kN/m^2 to 100 kN/m^2, the void ratio changed from 0.70 to 0.65. Determine the coefficient of volume decrease, *mv* and the compression index, *Cc*.

Solution:

$e_0 = 0.70 \qquad \bar{\sigma}_0 = 50 \text{ kN/m}^2$

$e_1 = 0.65 \qquad \bar{\sigma} = 100 \text{ kN/m}^2$

Coefficient of compressibility, $a_v = \frac{\Delta e}{\Delta \bar{\sigma}}$, ignoring sign.

$$= \frac{(0.70 - 0.65)}{(100 - 50)} \text{ m}^2/\text{kN} = 0.05/50 \text{ m}^2/\text{kN} = 0.001 \text{ m}^2/\text{kN}.$$

Modulus of volume change, or coefficient of volume decrease,

$$m_v = \frac{a_v}{(1+e_0)} = \frac{0.001}{(1+0.70)} = \frac{0.001}{1.7} \text{ m}^2/\text{kN}.$$

$$= 5.88 \times 10^{-4} \text{ m}^2/\text{kN}$$

Compression index, $C_c = \frac{\Delta e}{\Delta(\log \bar{\sigma})} = \frac{(0.70 - 0.65)}{(\log_{10} 100 - \log_{10} 50)}$

$$= \frac{0.05}{\log_{10} \frac{100}{50}} = \frac{0.05}{\log_{10} 2} = \frac{0.050}{0.301} = \mathbf{0.166}.$$

Example 12.2: A sand fill compacted to a bulk density of 18.84 kN/m^3 is to be placed on a compressible saturated marsh deposit 3.5 m thick. The height of the sand fill is to be 3 m. If the volume compressibility *mv* of the deposit is 7 × 10–4 m^2/kN, estimate the final settlement of the fill.

Solution:

Ht. of sand fill = 3 m

Bulk unit weight of fill = 18.84 kN/m^3

Increment of the pressure on top of marsh deposit $\Delta\bar{\sigma} = 3 \times 18.84$

$= 56.52$ kN/m^2

Thickness of marsh deposit, $H_0 = 3.5$ m

Volume compressibility $m_v = 7 \times 10^{-4}$ m^2/kN

Final settlement of the marsh deposit, ΔH

$$= m_v . H_0 . \Delta\bar{\sigma}$$

$$= 7 \times 10^{-4} \times 3500 \times 56.52 \text{ mm}$$

$$= \mathbf{138.5 \text{ mm}}.$$

Example 12.3: A layer of soft clay is 6 m thick and lies under a newly constructed building. The weight of sand overlying the clayey layer produces a pressure of 260 kN/m^2 and the new construction increases the pressure by 100 kN/m^2. If the compression index is 0.5, compute the settlement. Water content is 40% and specific gravity of grains is 2.65.

Solution:

Initial pressure, $\bar{\sigma}_0 = 260$ kN/m^2

Increment of pressure, $\Delta\bar{\sigma} = 100$ kN/m^2

Thickness of clay layer, $H = 6$ m = 600 cm.

Compression index, $C_c = 0.5$

Water content, $w = 40\%$

Specific gravity of grains, $G = 2.65$

Void ratio, $e = wG$, (since the soil is saturated) = 0.40 × 2.65 = 1.06

This is taken as the initial void ratio, e_0.

Consolidation settlement,

$$S = \frac{H.C_c}{(1+e_0)} \log_{10}\left(\frac{\bar{\sigma}_0 + \Delta\bar{\sigma}}{\bar{\sigma}_0}\right)$$

$$= \frac{600 \times 0.5}{(1+1.06)} \log_{10}\left(\frac{260+100}{260}\right) \text{ cm}$$

$$= \frac{300}{2.06} \log_{10}\left(\frac{360}{260}\right) \text{ cm}$$

$$= \mathbf{21.3\ cm}.$$

Example 12.4: The settlement analysis (based on the assumption of the clay layer draining from top and bottom surfaces) for a proposed structure shows 2.5 cm of settlement in four years and an ultimate settlement of 10 cm. However, detailed sub-surface investigation reveals that there will be no drainage at the bottom. For this situation, determine the ultimate settlement and the time required for 2.5 cm settlement.

Solution:

The ultimate settlement is not affected by the nature of drainage, whether it is one-way or two-way.

Hence, the ultimate settlement = 10 cm.

However, the time-rate of settlement depends upon the nature of drainage.

Settlement in four years = 2.5 cm.

$$T = \frac{C_v t}{H^2}$$

$$U = \frac{2.5}{10.0} = 25\%$$

Since the settlement is the same, $U\%$ is the same;

hence, the time-factor is the same.

$\therefore$ $T/C_v = t/H^2$ = Constant.

or $$\frac{t_2}{H_2^2} = \frac{t_1}{H_1^2},$$

t_2 and H_2 referring to double drainage, and t_1 and H_1 referring to single drainage. The drainage path for single drainage is the thickness of the layer itself, while that for double drainage is half the thickness.

$\therefore$ $$H_1 = 2H_2$$

$\therefore$ $$\frac{t_2}{H_2^2} = \frac{t_1}{4H_2^2},$$

$\therefore$ $t_1 = 4t_2 = 4 \times 4$ yrs = **16 yrs.**

Example 12.5: There is a bed of compressible clay of 4 m thickness with pervious sand on top and impervious rock at the bottom. In a consolidation test on an undisturbed specimen of clay from this deposit 90% settlement was reached in 4 hours. The specimen was 20 mm thick. Estimate the time in years for the building founded over this deposit to reach 90% of its final settlement.

Solution:

This is a case of one-way drainage in the field.

∴ Drainage path for the field deposit, H_f = 4 m = 4000 mm. In the laboratory consolidation test, commonly it is a case of two-way drainage.

∴ Drainage path for the laboratory sample, H_1 = 20/2 = 10 mm

Time for 90% settlement of laboratory sample = 4 hrs.

Time factor for 90% settlement, T_{90} = 0.848

$$\therefore \quad T_{90} = \frac{C_v t_{90_f}}{H_f^2} = \frac{C_v t_{90_l}}{H_l^2}$$

or

$$\frac{t_{90_f}}{H_f^2} = \frac{t_{90_l}}{H_l^2}$$

$$\therefore \quad t_{90f} = \frac{t_{90_l}}{H_l} \times H_f = \frac{4 \times (4000)^2}{10^2} \text{ hrs}$$

$$= \frac{4 \times 400}{24 \times 365} \text{ years}$$

$$\approx \textbf{73 years.}$$

Example 12.6: The void ratio of clay **A** decreased from 0.572 to 0.505 under a change in pressure from 120 to 180 kg/m^2. The void ratio of clay **B** decreased from 0.612 to 0.597 under the same increment of pressure. The thickness of sample **A** was 1.5 times that of **B**. Nevertheless the time required for 50% consolidation was three times longer for sample **B** than for sample **A**. What is the ratio of the coefficient of permeability of **A** to that of **B** ?

Solution:

Clay A

$e_0 = 0.572$

$e_1 = 0.505$

$\bar{\sigma}_0 = 120$ kN/m²

$\bar{\sigma}_1 = 180$ kN/m²

$$a_{v_A} = \frac{\Delta e}{\Delta\bar{\sigma}} = \frac{0.067}{60} \text{ m}^2/\text{kN}$$

$$m_{v_A} = \frac{0.067}{60} / (1 + 0.572)$$

$$= 7.10 \times 10^{-4} \text{ m}^2/\text{kN}$$

Clay B

$e_0 = 0.612$

$e_1 = 0.597$

$\bar{\sigma}_0 = 120$ kN/m²

$\bar{\sigma}_1 = 180$ kN/m²

$$m_{v_B} = \frac{\Delta e}{\Delta\bar{\sigma}} = \frac{0.015}{60} \text{ m}^2/\text{kN}$$

$$m_{v_B} = \frac{0.015}{60} / (1 + 0.612)$$

$$= 1.55 \times 10^{-4} \text{ m}^2/\text{kN}$$

$$H_A/H_B = 1.5 \text{ and } t_{50_B} / t_{50_A} = 3$$

$$T_{50} = C_v t_{50}/H^2$$

$$\therefore \quad T_{50} = \frac{C_v . t_{50_A}}{H_A^2} = \frac{C_{v_B} . t_{50_B}}{H_B^2}$$

$$\frac{C_{v_A}}{C_{v_B}} = \frac{t_{50_B}}{t_{50_A}} . \frac{H_A^2}{H_B^2} = 3 \times (1.5)^2 = 6.75$$

But $\quad C_v = k/m_v \gamma_w$

or $\quad k = C_v m_v . \gamma_w$

$$\therefore \quad k_A/k_B = \frac{c_{v_A} . m_{v_A}}{c_{v_B} . m_{v_B}} = 6.75 \times \frac{7.10 \times 10^{-4}}{155 \times 10^{-4}} = 30.92 \approx 31.$$

Example 12.7: A saturated soil has a compression index of 0.25. Its void ratio at a stress of 10 kN/m2 is 2.02 and its permeability is 3.4 × 10–7 mm/s. Compute:

(*i*) Change in void ratio if the stress is increased to 19 kN/m2;

(*ii*) Settlement in (*i*) if the soil stratum is 5 m thick; and

(*iii*) Time required for 40% consolidation if drainage is one-way.

Solution:

Compression index, $C_c = 0.25$

$e_0 = 2.02 \qquad \bar{\sigma}_0 = 10$ kN/m² $\qquad k = 3.4 \times 10^{-7}$ mm/s

$\bar{\sigma}_1 = 19$ kN/m²

(*i*) $$C_c = \frac{\Delta e}{\log_{10} (\bar{\sigma}_1 / \bar{\sigma}_0)} \therefore 0.25 = \frac{\Delta e}{\log_{10} (19/10)}$$

$$\therefore \quad \Delta e = 0.25 \log_{10} (1.9) \approx \mathbf{0.07}$$

or Void ratio at a stress of 19 kN/m² = 2.02 – 0.07 = 1.95

$a_v = \Delta e / \Delta\bar{\sigma} = 0.07/9 = 0.00778$ m²/kN

$m_v = a_v/(1 + e_0) = 0.00778/(1 + 2.02) = 2.575 \times 10^{-3}$ m²/kN

(*ii*) Thickness of soil stratum, $H = 5$ m.

Settlement, $$S = \frac{H . C_c}{(1 + e_0)} \log_{10} \left(\frac{\bar{\sigma}_0 + \Delta\bar{\sigma}}{\bar{\sigma}_0} \right) = \frac{H . C_c}{(1 + e_0)} \log_{10} \left(\frac{\bar{\sigma}_1}{\bar{\sigma}_0} \right)$$

$$= \frac{5 \times 1000 \times 0.25}{(1+2.02)} \log_{10} (19/10) \text{ mm} \simeq \mathbf{115.4 \text{ mm}}$$

(*iii*) If drainage is one way, drainage path, H = thickness of stratum = 5 m

$$T_{40} = \frac{C_v t_{40}}{H^2}; \quad T_{40} = (\pi/4)U^2 = (\pi/4) \times (0.40)^2 = 0.04\,\pi = 0.125664$$

$$C_v = k/m_v.\gamma_w$$

$$= \frac{3.4 \times 10^{-7} \times 10^{-3}}{2.575 \times 10^{-3} \times 9.81} \text{ m}^2/\text{s} = 1.346 \times 10^{-8} \text{ m}^2/\text{s}$$

$$\therefore \qquad t_{40} = \frac{T_{40}.H^2}{C_v}$$

$$= \frac{0.125664 \times 5 \times 5}{1346 \times 10^{-8} \times 60 \times 60 \times 24} \text{ days}$$

$$\simeq \mathbf{270.14 \text{ days}}.$$

Example 12.8:

Solution:

Example 12.9:

Solution:

https://www.yourarticlelibrary.com/soil/consolidation-process-of-deformation-of-soils/45560