$\therefore$ $e_f = 1.2 - 0.044 \log_{10}$ ...
$= 1.2 - 0.044 \log_{10}$ ...
$\therefore$ $= 1.098$

Settlement. $S = H \times \frac{\Delta e}{1+e}$

$= 7.5 \times 10^3 \times \frac{(1.100 - 1.098)}{(1 + 1.100)}$

$= 7.15$ mm.

PROBLEM – 4

A layer of compressible clay 6m thick lies on an impervious bed of rock and carries an overburden of pervious sand. A large structure founded in the sand causes the pressure on every horizontal section of the clay to increase to the same value. In a standard laboratory oedometer test the void ratio of a sample of the clay (19 mm thick) decreased from 0.765 to 0.750 under a corresponding increase in pressure. Consolidation was 70% complete after 30 min.

Estimate the settlement of the structure and the time elapsing before one half of this amount has taken place. The appropriate time factor/ degree of consolidation curve is defined by the following values

U :	0.40	0.60	0.80
Tv :	0.13	0.28	0.57

SOL.

$h = 6$ m. (CLAY LAYER)
$e_i = 0.765$
$e_f = 0.750$
$h = 19$ mm (sample).

... on test, there is no change in
... mple

$$\frac{\Delta h}{h} = \frac{\Delta e}{1+e}$$

$$\Delta h = \frac{.765 - .750}{1.765} \times 19 = 0.1615 \text{ mm}$$

For similar loading conditions, a stratum 6m thick will settle (by proportion)

$$\Delta h = h \frac{\Delta e}{1+e}$$

$$= 6 \times 1000 \times \frac{.765 - .750}{1.765} = 51 \text{ mm.}$$

For the given values of U and Tv a graph is plotted. From the graph when (values can be obtained from formula or Table)

$U = 0.70$, $T_v = 0.41$

For sample.

$U = .70$

$T_v = .41$

$t = 30 \text{ min} = 30 \times 60 = 1800 \text{ sec}$

$H = 19/2 = 9.5 \text{ mm.}$

$$\therefore \quad C_v = T_v \cdot \frac{H^2}{t} = .41 \times \frac{(9.5)^2}{1800} = 0.0206 \text{ mm}^2/\text{sec}$$

For 50 % of total settlement of structure.

$U = .50$

$T_v = 0.197.$

$$T_v = \frac{C_v \times t}{H^2}$$

$$t = \frac{T_v \times H^2}{C_v} = \frac{0.197 \times (6000)^2}{(0.0206)(60 \times 60 \times 24 \times 365)}$$

$$= 10.9 \text{ years.}$$

PROBLEM 5

The bore hole records at a level site revealed the following details:

0 — 0.25 m topsoil
0.25 — 3.5 m Sand   Water Table at 1.25 m
3.5 — 10 m Clay
10 — base of bore hole. impervious shale.

The bulk density of the topsoil and sand is 18.84 kN/m³. A building is supported on a partially compensated stiff raft of dimensions 18 × 18 m, with its base at 2.25 below ground surface. The gross load from the raft and building is 7.0×10^4 kN. Calculate the settlement of the structure due to consolidation of the clay layer, whose coefficient of volume compressibility decreases linearly from 4.2×10^{-4} m²/kN at its top to 2.7×10^{-4} m²/kN at its base. Use the pressure influence chart.

Describe why the stress-history of the clay might lead you to amend the result of this calculation. How could the additional settlement due to compression of the sand be assessed.   P.98

Sol

Total load $= 7.0 \times 10^4$ kN

Soil load removed in construction of raft

$= 18 \times 18 \times 2.25 \times 18.84 = 1.4 \times 10^4$ kN.

∴ Net load on soil due to structure

$= 7 \times 10^4 - 1.4 \times 10^4 = 5.6 \times 10^4$ kN.

If this is assumed to be uniformly distributed under the raft the contact pressure between the soil and the raft

$$\sigma_0 = \frac{5.6 \times 10^4}{18 \times 18} = 173 \text{ kN/m}^2.$$

For the distribution of stress at a depth equal to the centre of clay layer from the base of the foundation. We divide the loaded area into four rectangles. By taking average of σ_z at centre, quarter or half the value of σ_z comes as

$\sigma_z = 132$ kN/m²

m_v at the centre of clay layer $= \frac{(4.2 + 2.7)}{2} 10^{-4} = 3.45 \times 10^{-4}$

∴ Settlement $= S = m_v \times \Delta p \times H$

$= 3.45 \times 10^{-4} \times 132 \times (10 - 3.5)$

$= 295$ mm.

If clay were over-consolidated the settlement would be likely to be less than that calculated assuming it to be normally consolidated since the e/p curve tends to be a re-compression curve with a flatter slope rather than a compression curve. Thus the values of m_v tend to be smaller over corresponding pressure ranges.

The compression of the sand can be found from the results of standard penetration tests. These give an indication of the relative density of the sand from which an estimate of its likely settlement can be obtained using empirical charts.

PROBLEM. 6

The following results were obtained from a consolidation test on a sample of clay with drainage from both top and bottom surfaces when the load was increased from 100 kN/m² to 200 kN/m².

Time 't' from application of pressure increment (min)	Decrease in thickness of sample (mm)
1/4	0.175
1	0.305
2 1/4	0.432
4	0.558
6 1/4	0.658
9	0.752
16	0.884
25	0.968
36	1.011
24 h	1.104

The initial thickness of the sample was 19.65 mm. Plot the curve of decrease in thickness against $\sqrt{t}$. Correct the curve using the "square root of time" fitting method to allow for the effects of secondary consolidation and hence calculate the value of the coefficient of consolidation C_v assuming the formula for the straight portion of the graph.

$U = \frac{2}{d}\sqrt{\frac{C_v \cdot t}{\pi}}$ where U - degree of consolidation
d - length of the drainage path.

SOLUTION

The curve of decrease in thickness versus $\sqrt{t}$ is plotted.

From the graph the value of $U = .9$ is against $\sqrt{t} = 4.4$

$\therefore C_v = \frac{T_v \times d^2}{\sqrt{t_{90}}}$ and $d = \frac{1}{2}\left(19.65 - \frac{0.93}{2}\right)$
$= 9.09$

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$$C_v = \frac{0.848 \times (9.09)^2}{4.4} = 15.92 \ mm^2/min$$

$$= .27 \ mm^2/sec$$

PROBLEM 7

The following data come from a consolidation test on an undisturbed sample of saturated clay.

Pressure KN/m²	Dial gauge reading at equilibrium (mm).
16.25	9.15
32.50	8.96
65.00	8.64
130.00	8.01
260.00	6.48
520.00	4.45

What was the previous overburden pressure on this sample? The sample was taken from a continuous layer of clay at a depth of 6m below an unloaded ground surface. Is the clay normally consolidated or over consolidated?

(b) Briefly discuss the merits of basing settlement estimates on the results of conventional consolidation pressure tests.

SOLUTION:

A graph is plotted between dial gauge reading on natural scale and pressure on logarithmic scale. From the empirical construction of the graph the amount of pre-consolidation is calculated. From the graph the consolidation pressure to which the soil has been subjected is 145 KN/m².

The present over burden pressure assuming that the clay has a density of 1750 kg/m³

$= (1750 \times 9.81 \times 10^{-3}) \times 6 = 103$ KN/m².

Since this is some 40% lower than the value indicated on fig it may be concluded that the soil is over-consolidated.

b) The one dimensional consolidation test involves one dimensional strain and it has been found from a comparison of calculated and observed settlements, that the calculated values tend to underestimate the rate of settlement. More complex methods of analysis have been proposed based on three dimensional strain. In general such refinements are not justified since differential settlement between different parts of a structure are of more significance. A case where more elaborate calculations might be justified is where a soft compressible clay is required to carry a heavy load.

PROBLEM - 8

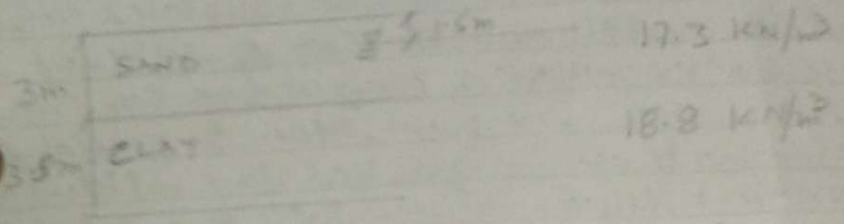
A raft foundation is installed in a dense deposit of uniform sand which extends to a depth of 3m below ground level, and is underlain by a layer of compressible clay 3.5 m thick. The water table lies at 1.5m below ground level. The sand, which is saturated throughout its depth has a mean bulk density of 1760 kg/m^3 (17.3 kN/m^3); that of the clay is 1920 kg/m^3 (18.8 kN/m^3)

If the raft loading increases the effective vertical pressure to 130 kN/m^2 on all horizontal sections in the clay below the centre of the raft (Divide) find the settlement at this position in the raft (dividing the clay stratum into two layers of 1.75 m thickness).

Effective Pressure (kN/m^2)	Void ratio (e)
30	1.24
40	1.21
60	1.16
80	1.12
100	1.09
130	1.05

Discuss the phenomenon of pre-consolidation in clays, and its engineering importance.

SOL.



The e/p curve for the soil is plotted

Initial effective pressure $= 17.3 \times 1.5 + (17.3 - 9.81)1.5$
$= 37.3\ kN/m^2$ at top of clay

AT middle of clay
Initial effective pressure $= 37.3 + (18.8 - 9.81)\ 1.75$
$= 53.1\ kN/m^2$.

At Bottom of clay
Initial effective pressure $= 53.1 + (18.8 - 9.81)\ 1.75$
$= 68.9\ kN/m^2$

Final effective pressure on all layers $= 130\ kN/m^2$
Considering top layer of clay (1.75m thick).

Average effective pressure initially $= \frac{37.3 + 53.1}{2} = 45.2\ kN/m^2$
finally $= 130\ kN/m^2$
$\therefore$ From fig
$e_i = 1.195$
$e_f = 1.05$
$\therefore$ Settlement $= S = H \frac{\Delta e}{1 + e_i}$

$= 1.75 \frac{(1.195 - 1.05)}{1 + 1.195} = 0.21m$

Considering bottom layer (1.75 m thick).
Average effective pressure initially $= \frac{53.1 + 68.9}{2}$
$= 61.0\ kN/m^2$
finally $= 130.0\ kN/m^2$
$e_i = 1.155$
$e_f = 1.05$
Settlement $= \frac{(1.155 - 1.05)}{(1 + 1.155)} \times 1.75 = 0.085m$.

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