CIVIL ENGINEERING

Geotechnical Engineering

Compressibility and Consolidation of Soil

Chapter 9

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Lecture no. 05

TOPICS TO BE COVERED

01 Computation of Settlement

→ In the solution of Terzaghi's 1-D consolidation eqn the following non-dimensional parameters are defined.

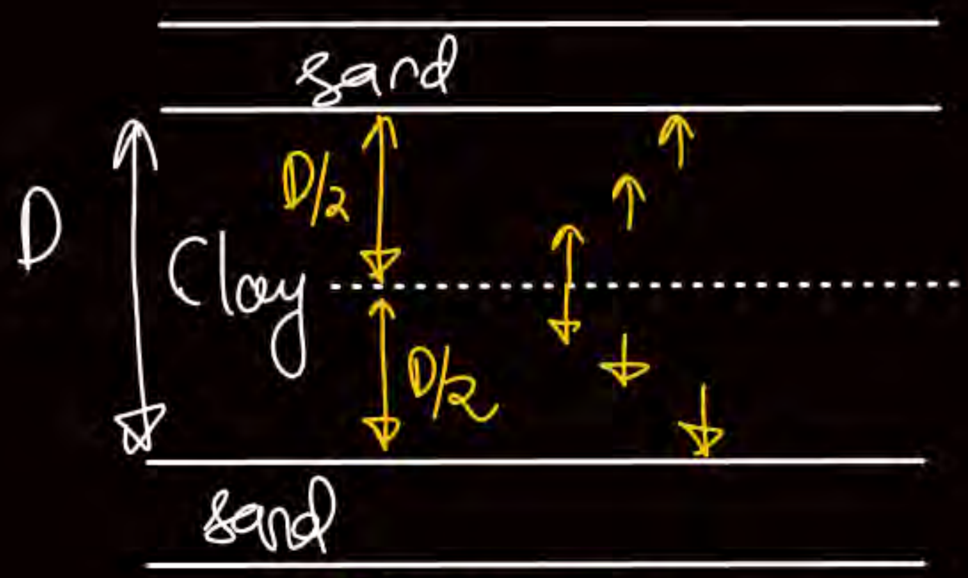
1. Drainage path ratio, $\boxed{Z = z/H}$

2. Time factor, $\boxed{T_v = \dfrac{C_v t}{H^2}}$

3. Degree of consolidation, $\boxed{U_z = \dfrac{u_i - u_z}{u_i}}$

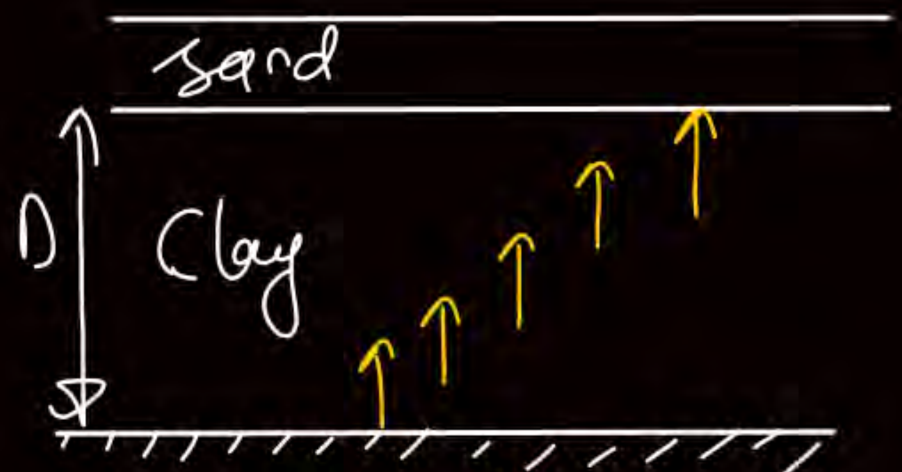
$z \rightarrow$ depth of any point from the top of the clay layer.

$H \rightarrow$ maximum distance that the water has to travel to reach the drainage space. or the length of longest drainage path.



Double drainage.

$$\boxed{H = D/2}$$



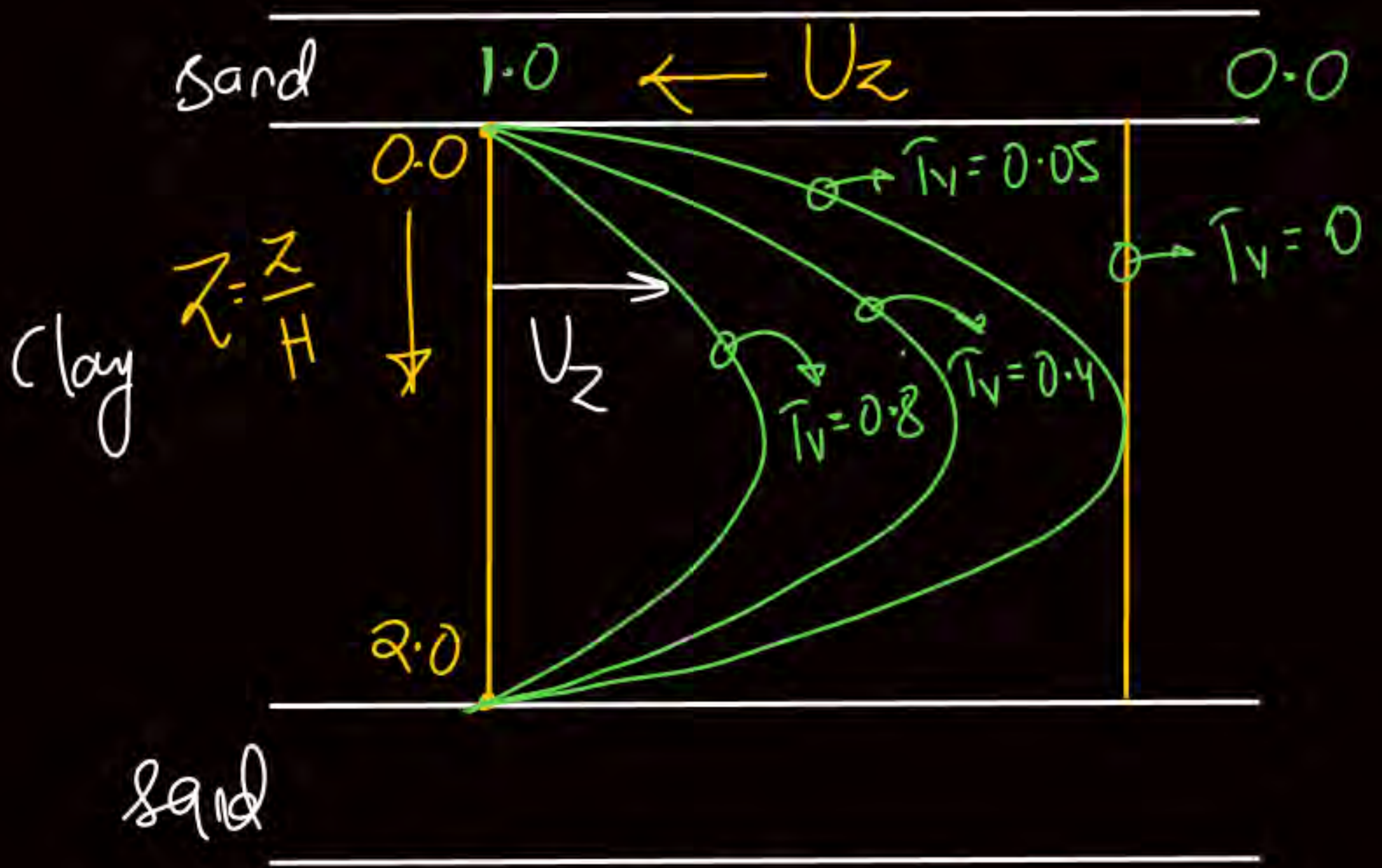
Single drainage

$$\boxed{H = D}$$

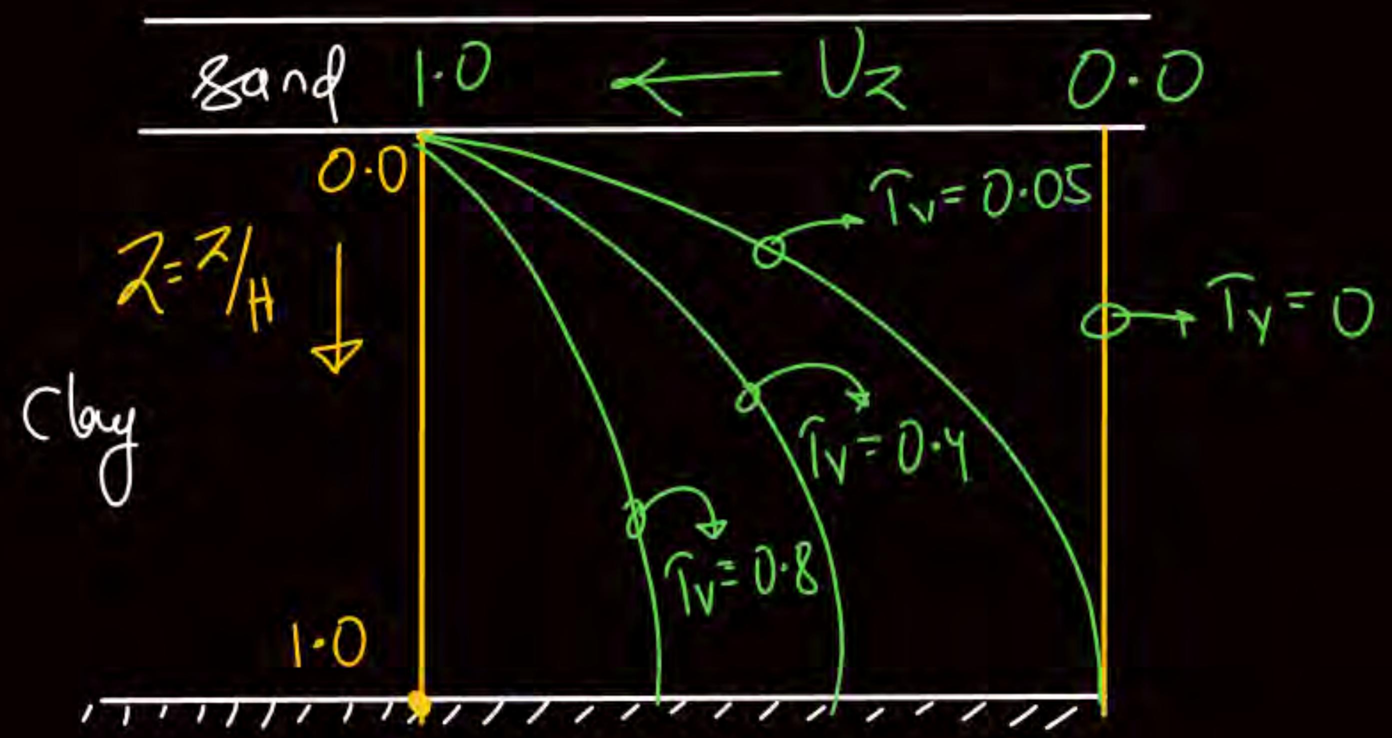
$u_i \rightarrow$ initial excess PWP

$u_z \rightarrow$ excess PWP at any depth 'z'

$U_z \rightarrow$ degree of consolidation at any depth 'z'.



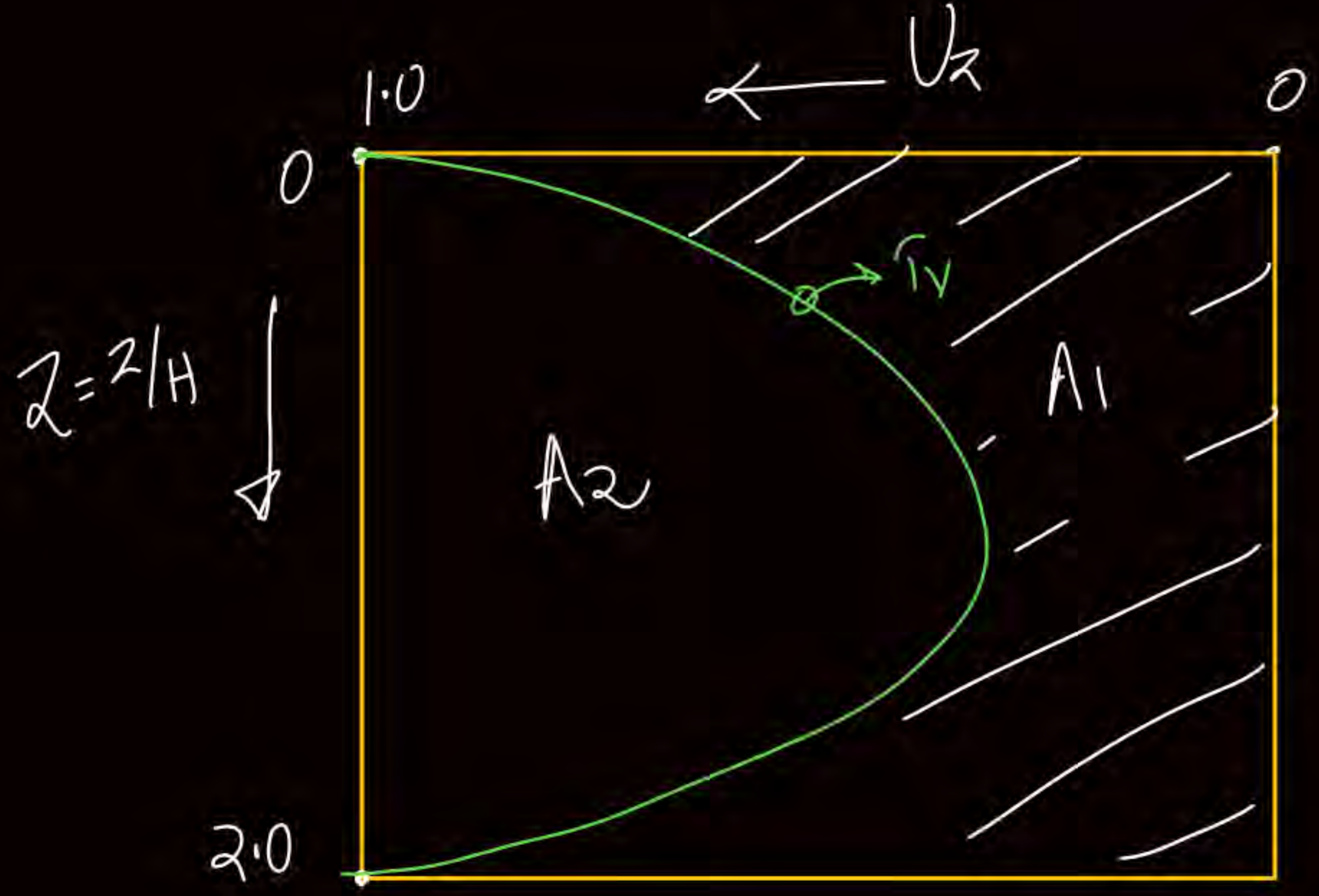
Double drainage



Single drainage

→ As an engineer we are interested in the overall degree of consolidation in the total clay layer not in the degree of consolidation at one point.

→ The average degree of consolidation for the complete clay layer can be obtained for a particular value of 'T_v' by the following relation.



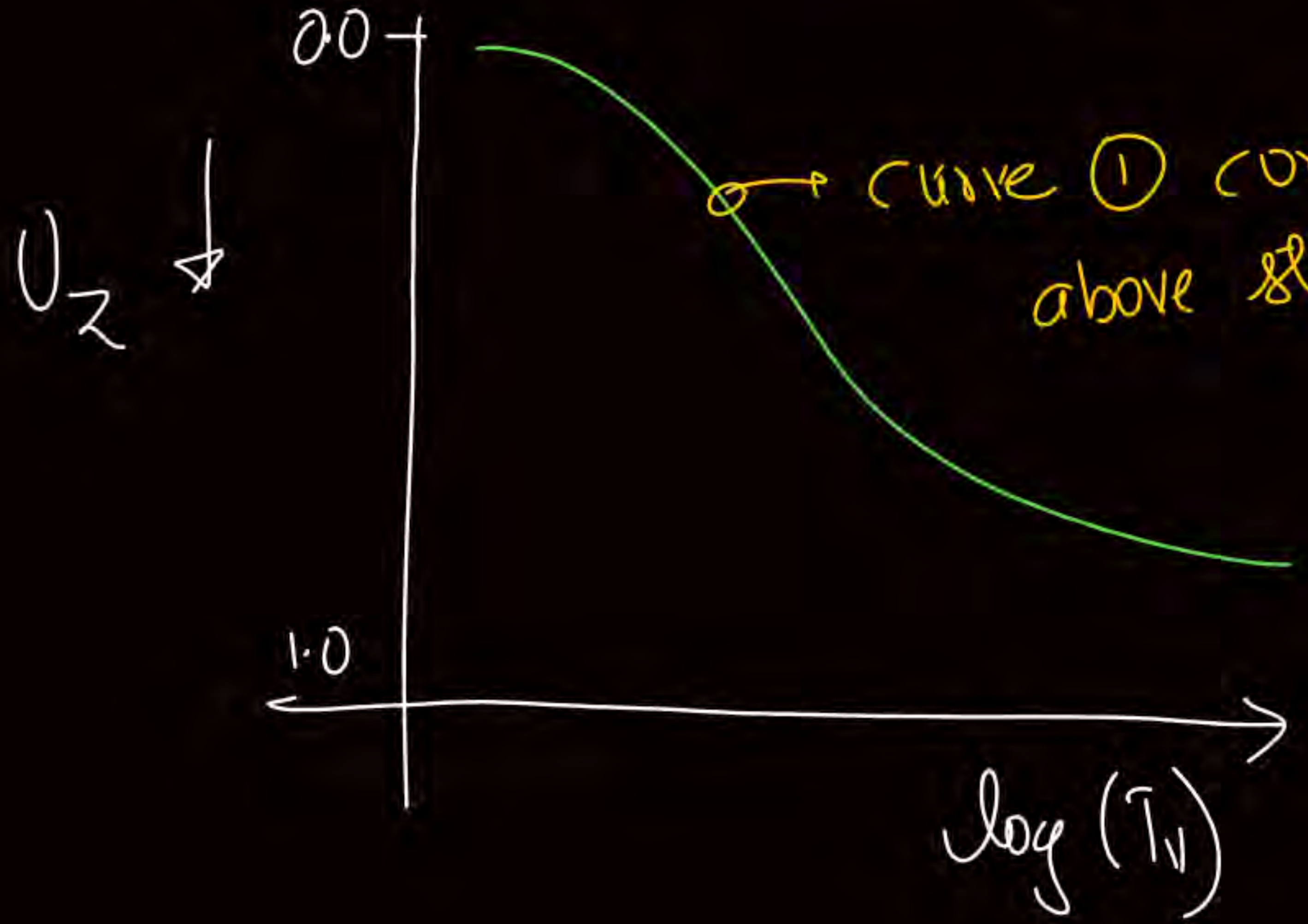
$$\boxed{U = \frac{A_1}{A_1 + A_2}}$$

→ Thus overall degree of consolidation (U) is a function of 'T_v'.

i.e, $\boxed{U = f(T_v)}$

1. $T_v = \pi/4\, U^2$ for $U \leq 0.6$, $T_v \leq 0.283$

2. $T_v = 1.781 - 0.933 \log(100 - U\%)$ for $U > 60\%$, $T_v > 0.283$



curve ① corresponds to above stated equations.

1. $$\boxed{U = \frac{\Delta h}{\Delta H} \times 100\,\%}$$

$\Delta h \rightarrow$ settlement at any time

$\Delta H \rightarrow$ settlement at the end of primary consolidation

2. $$\boxed{U = \frac{e_0 - e}{e_0 - e_f} \times 100\,\%}$$

$e_0 \rightarrow$ initial void ratio

$e \rightarrow$ void ratio at any time

$e_f \rightarrow$ final void ratio at the end of primary consolidation.

Note:

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

$$U = f(T_v)$$

$$\Rightarrow \boxed{t \propto H^2}$$

$\therefore$ time required to reach a particular degree of consolidation is directly proportional to 'H^2'.

9.9 Determination of Coefficient of Consolidation (C_v)

→ 'C_v' can be determined from the data obtained from the Oedometer test. The deformation vs time curve obtained from Oedometer test is similar to U vs T_v curve. This property is used to determine the value of 'C_v' from Oedometer test using curve fitting technique.

Two methods are adopted.

a. Casagrande's logarithm of time fitting method.

b. Taylor's square root of time fitting method.

9.9 Determination of Coefficient of Consolidation (C_v)

a) Casagrande's logarithm of time fitting method

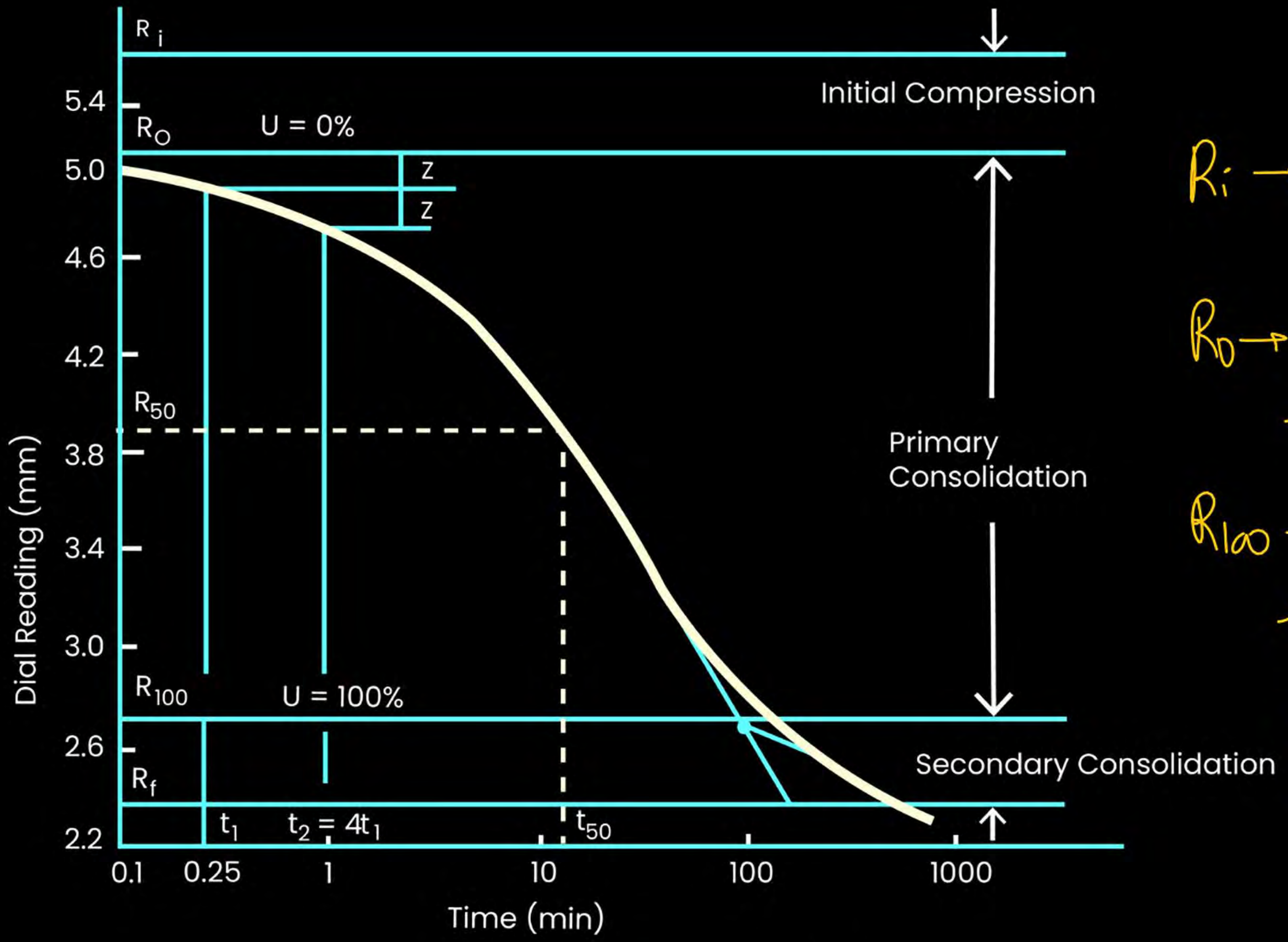
1) Dial reading vs log time curve is plotted.
2) Two values of time t_1 and t_2 is selected on the initial part of the curve such that $t_2 = 4t_1$.
3) Points corresponding to these values of time are marked on the curve and the vertical distance 'z' is measured between them.
4) A horizontal line is drawn above the first point at same vertical distance 'z'. This line cuts the dial reading axis at 'R_0' called the corrected zero reading.
5) U = 100% line is determined by drawing two tangents from the straight portion of the curve.
6) R_{50} is marked midway between R_0 and R_{100} and time corresponding to R_{50} is noted i.e., t_{50}.

9.9 Determination of Coefficient of Consolidation (C_v)

b) Taylor's square root of time fitting method

1) Dial reading vs $\sqrt{time}$ curve is plotted.
2) A straight line is drawn passing through the points on initial straight portion of the curve.
3) The straight line is extended to intersect the dial reading axis at R_0 called the corrected zero reading.
4) Starting from R_0 another straight line is drawn such that its abscissa is 1.15 times the abscissa of the first line.
5) The intersection of the second line and the curve corresponds to R_{90} and t_{90}.

9.9 Determination of Coefficient of Consolidation (C_v)



$R_i \rightarrow$ initial dial gauge reading

$R_0 \rightarrow$ dial gauge reading at the beigning of consolidation

$R_{100} \rightarrow$ dial gauge reading at the end of consolidation

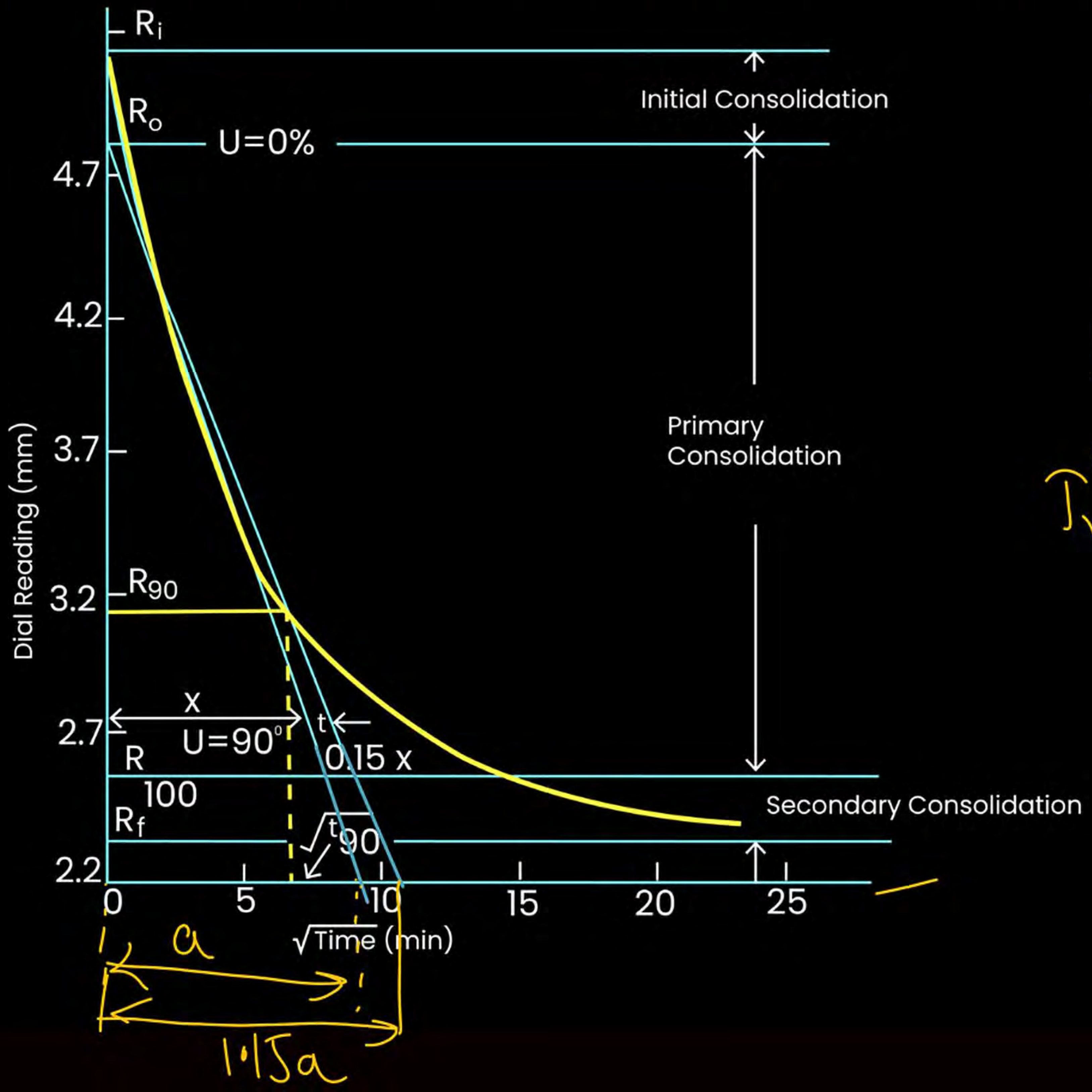
$R_f \rightarrow$ final dial gauge reading.

$$R_{50} = \frac{R_0 + R_{100}}{2} \Rightarrow t_{50}$$

$$T_v^{50} = \frac{C_v t_{50}}{H^2} \quad , \quad T_v^{50} = \pi/4 \times 0.5^2 \quad , \quad U \leq 60\%$$

$$\Rightarrow \boxed{C_v = \frac{T_v^{50} \times H^2}{t_{50}}}$$

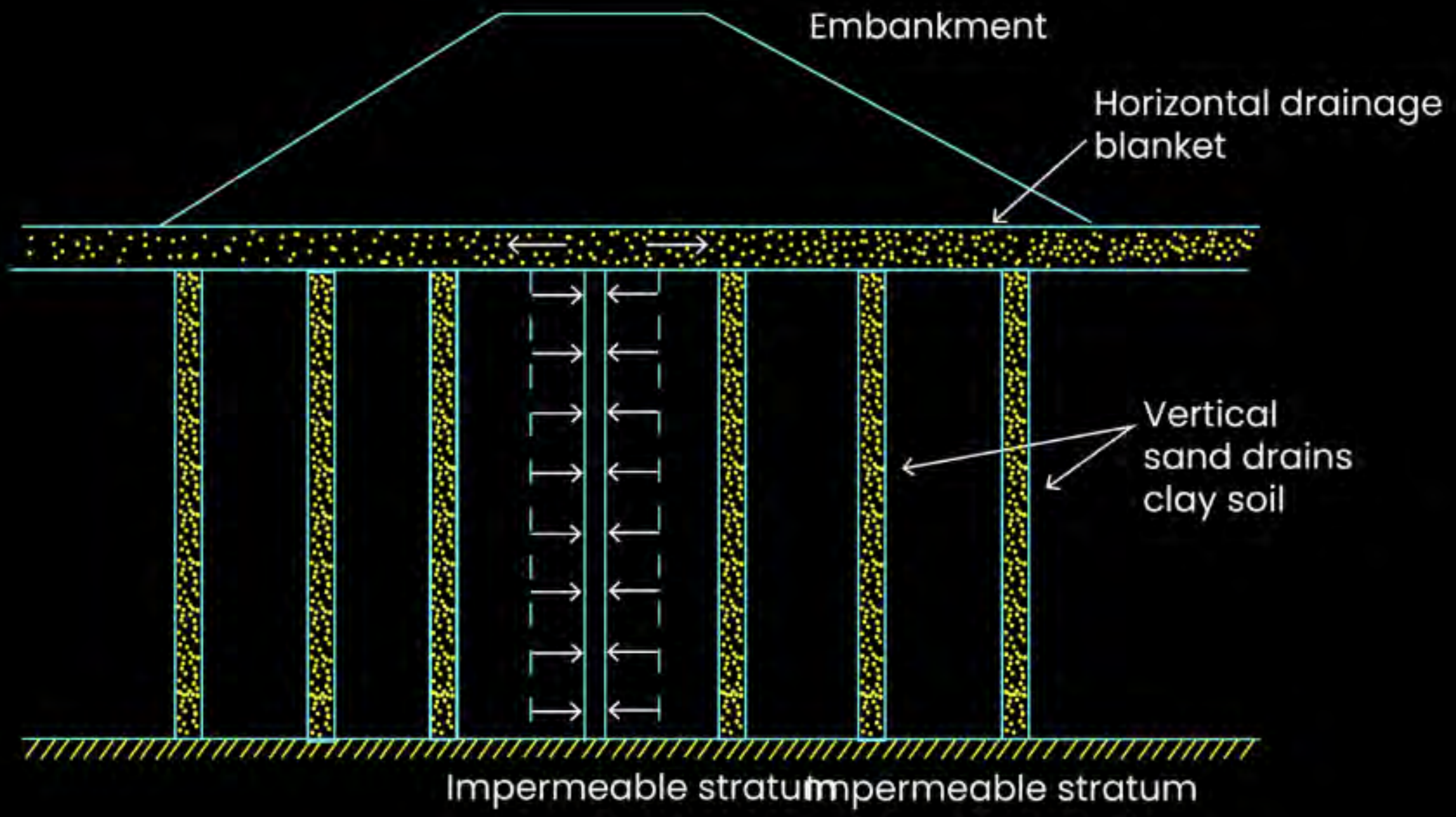
9.9 Determination of Coefficient of Consolidation (C_v)

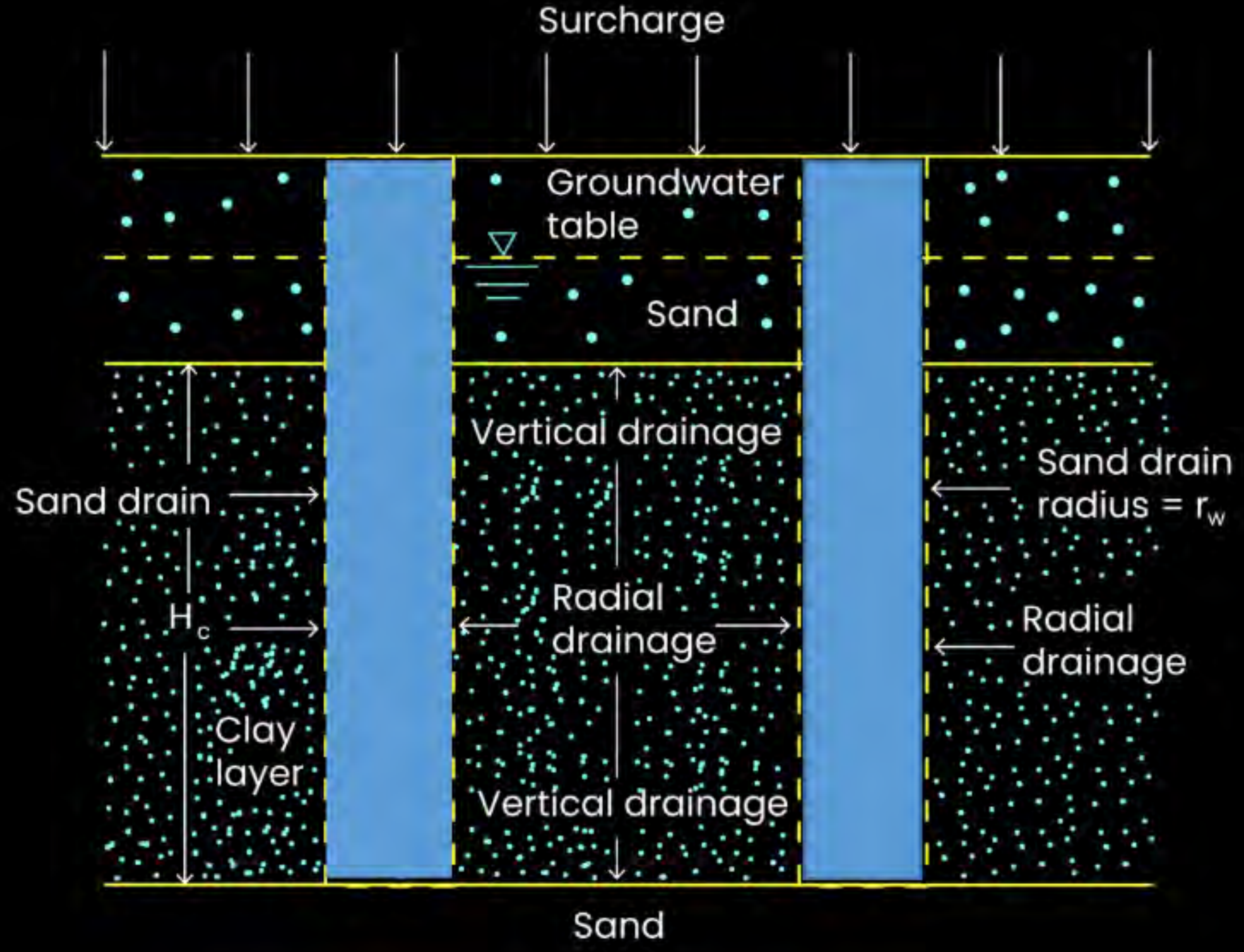


$$\boxed{C_v = \frac{T_v^{90} H^2}{t_{90}}}$$

$$T_v^{90} = 1.781 - 0.933 \log(100 - 90)$$

9.11 VERTICAL SAND DRAINS





9.11 VERTICAL SAND DRAINS

1) The slow rate of consolidation of saturated clay of low permeability may be accelerated by means of vertical sand drains which provides for radial drainage, resulting in shortening of the drainage path.
2) Consolidation is mainly due to horizontal radial drainage which results in faster dissipation of excess pore water pressure.
3) Magnitude of consolidation settlement however is unaffected only the rate of settlement is increased.
4) Sand drains are mostly used when embankments are to be constructed over a highly compressible clay layer.
5) Sand drains are installed by making vertical bore holes and backfilling them with a suitably graded sand having a permeability of at least 1000 times more than the consolidating clay layer.

9.11 VERTICAL SAND DRAINS

6) Sand drains vary in diameter from about 450 to 600 mm. Their spacing depends on the type and permeability of soil and in practice varies from 1.8 to 4.5 m centre to centre.
7) In any natural clay stratum Kh is greater than Kv thus coefficient of consolidation in horizontal direction, Ch is greater than that in the vertical direction, Cv.
8) The higher the ratio of Ch/Cv , the more beneficial a sand drain system will be.
9) During installation of sand drains, the clay around the drains gets remoulded, thus reducing the value of coefficient of consolidation. This is known as smear effect.
10) Sand drains are not successful in soil having high secondary consolidation such as highly plastic clay and peat due their inability to control secondary compression.

Q. **Consolidation test was done in lab a sample of 20 mm thickness consolidated 50% in 15 mins with double drainage. How much time a 5 m thick layer of the same soil having drainage at top and bottom both will take to consolidate by 50% and 30% respectively. If the soil layer has a rock below how much time will it take to consolidate by 50% and 30%.**

Sol in lab → $t_{50} = 15$ mins, $d_{lab} = 20$ mm ⇒ double drainage

in field → $d_{field} = 5$ m

$\left.\begin{array}{l} t_{50} = ? \\ t_{30} = ? \end{array}\right\} \rightarrow$ double drainage. $\left.\begin{array}{l} t_{50} \rightarrow ? \\ t_{30} \rightarrow ? \end{array}\right\} \rightarrow$ single drainage

For double drainage in field

We know for a particular degree of consolidation,

$$t \propto H^2$$

$$\frac{t_{50}^{field}}{t_{50}^{lab}} = \frac{H_{field}^2}{H_{lab}^2}$$

$H = d/2 \rightarrow$ for double drainage

$$\Rightarrow t_{50}^{field} = t_{50}^{lab} \times \left(\frac{d_{field}/2}{d_{lab}/2}\right)^2$$

$$= 15 \times \left(\frac{5\times10^3}{20}\right)^2 \times \frac{1}{60\times24\times365} \text{ years}$$

$$= \boxed{1.784 \text{ years}}$$

$$T_v = \frac{C_v t}{H^2} = \frac{\pi}{4}U^2 \quad \ldots \text{ for } U \leq 60\%$$

$$\Rightarrow t \propto U^2$$

$$\Rightarrow \frac{t_{30}^{field}}{t_{50}^{field}} = \left(\frac{0.3}{0.5}\right)^2$$

$$\Rightarrow t_{30}^{field} = 1.784 \times \left(\frac{3}{5}\right)^2$$

$$= \boxed{0.642 \text{ years}}$$

For single drainage in field

$t \propto H^2$ .. for $U =$ const

$$\frac{t_{single}}{t_{double}} = \left(\frac{H_{single}}{H_{double}}\right)^2 = \left(\frac{d}{d/2}\right)^2$$

$$\Rightarrow \boxed{t_{single} = 4\, t_{double}}$$

$\therefore$ for a given soil time req. for a particular degree of consolidation will be 4 times in the single drainage → as compared to double drainage.

$$t_{50}^{single} = 4 \times 1.784 = \boxed{7.136 \text{ years}}$$

$$t_{30}^{single} = 4 \times 0.642 = \boxed{2.568 \text{ years}}$$

Q. Identical surcharges are placed at ground surface at sites X and Y, with soil conditions shown alongside and water table at ground surface. The silty clay layers at X and Y are identical. The thin sand layer at Y is continuous and free-draining with a very large discharge capacity. If primary consolidation at X is estimated to complete in 36 months, what would be the corresponding time for completion of primary consolidation at Y? [GATE : 2011]

(a) 2.25 months

(b) 4.5 months

(c) 9 months

(d) 36 months

OCR < 1 → forunder consolidated clay.

$OCR = \frac{\bar{\sigma}_z}{\bar{\sigma}_c}$ $\bar{\sigma}_z < \bar{\sigma}_c$.

Q. The time taken to construct a building was from April 1992 to September 1993. In September 1996, the average settlement was found to be 5.16 cm. If the ultimate settlement is estimated to be 25 cm, then the settlement in January 1997 would have been ___ cm

Q. A 6 m thick fine silt stratum ($C_v = 7.2 \times 10^{-3}$ cm^2/sec) underlies a coarse sand deposit and overlies a 0.15 cm thick fine sand layer under which there is a clay stratum 3 m thick ($C_v = 9 \times 10^{-5}$ cm^2/sec). A pervious stratum lies below the clay layer. When the clay layer reaches a degree of consolidation of 20%, what would be the degree of consolidation of the silt layer?

Given :

$T_v = \pi/4\,(U/100)^2$ if % U $\leq$ 60%

$T_v = 1.781 - 0.9332 \log_{10}(100 - U)$ if % U > 60%

(a) 28.42%

(b) 66.60%

(c) 82.81%

(d) 90.51%

Thank You GW Soldiers