IIT KHARAGPUR

NPTEL ONLINE
CERTIFICATION COURSES

NPTEL

# SOIL MECHANICS/GOTECHNICAL ENGINEERING I

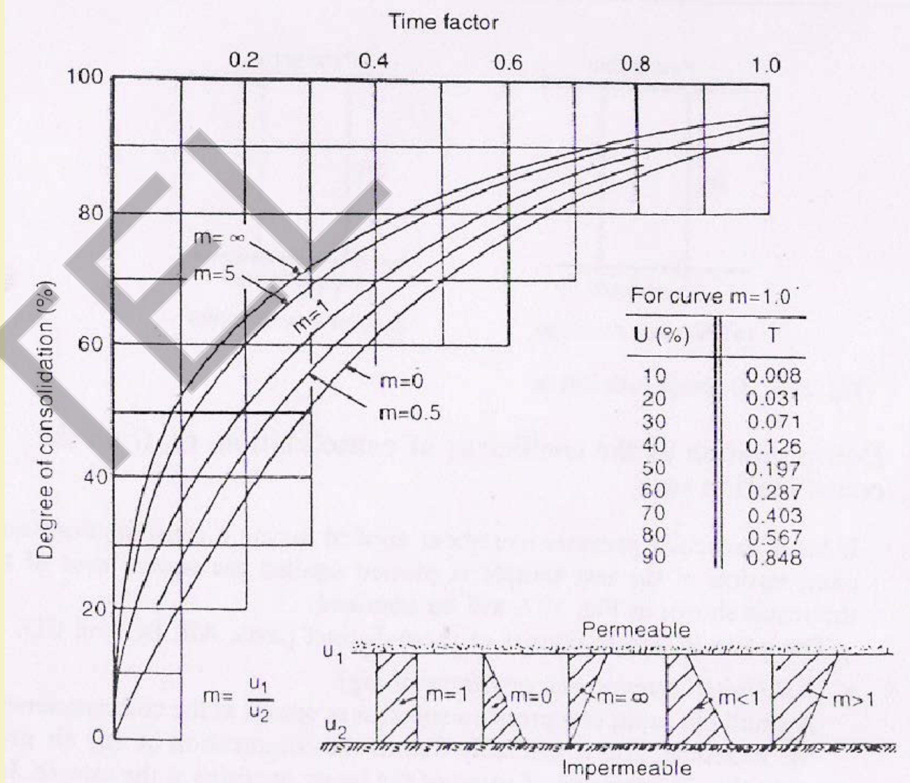
## COMPRESSIBILITY OF SOILS

DILIP KUMAR BAIDYA
DEPARTMENT OF CIVIL ENGINEERING
IIT KHARAGPUR

# COMPRESSIBILITY OF SOILS

$$U = 1 - \sum_{m=0}^{m-\infty} \frac{2}{M^2} e^{-M^2 T}$$

This is the relationship between U and T



# COMPRESSIBILITY OF SOILS

| U% | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 |
|---|---|---|---|---|---|---|---|---|---|---|
| T | 0 | 0.008 | 0.031 | 0.071 | 0.126 | 0.197 | 0.287 | 0.405 | 0.565 | 0.48 |

T versus U data can be fitted approximately in two parts. U between 0 and 60% it can be fitted by the following equation

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

And the same can fitted for U between 60 and 100% by the following equation

$$T = 1.781 - 0.933\ log_{10}(100 - U\%)$$




DILIP KUMAR BAIDYA
DEPARTMENT OF CIVIL ENGINEEERING
IIT KHARAGPUR

# COMPRESSIBILITY OF SOILS

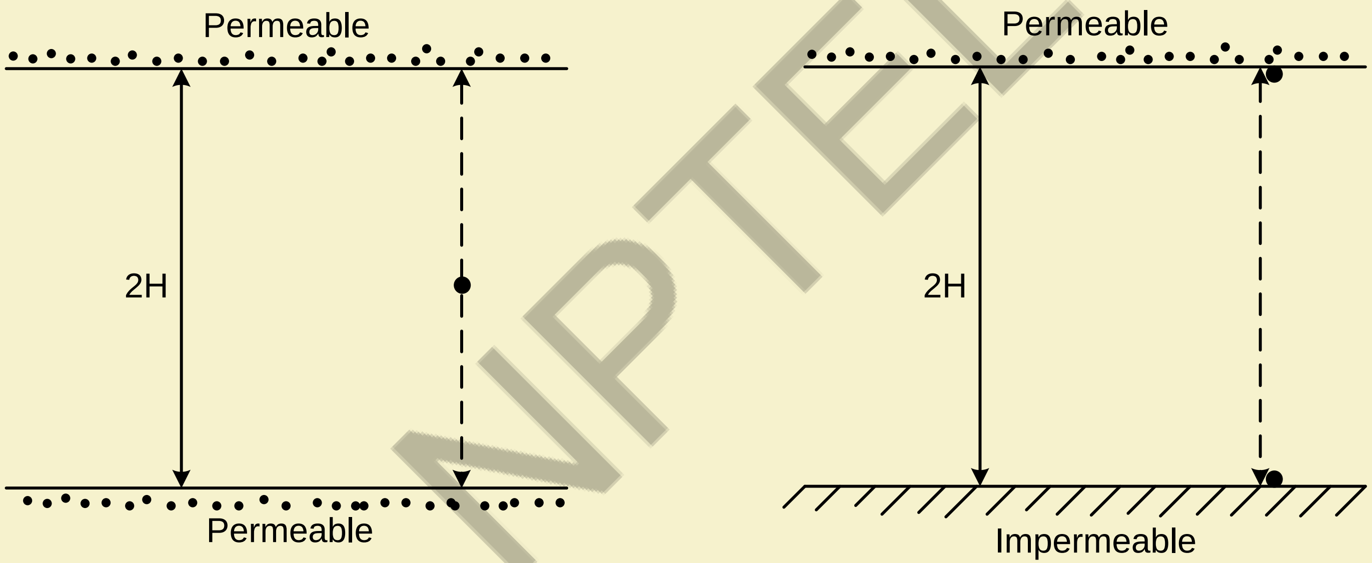
If the soil above and below the consolidating layer are pervious, the water under pressure in the layer will travel either upwards or downwards. This case is known as two-way drainage and the length of the drainage path, i.e., the maximum length that a water particle needs to travel for dissipating pore pressure from the consolidating layer = Thickness of the layer /2 = H





DILIP KUMAR BAIDYA
DEPARTMENT OF CIVIL ENGINEEERING
IIT KHARAGPUR

# COMPRESSIBILITY OF SOILS





DILIP KUMAR BAIDYA
DEPARTMENT OF CIVIL ENGINEEERING
IIT KHARAGPUR

# COMPRESSIBILITY OF SOILS

If one of the soil layers either above or below the consolidating layer is impervious, water will travel in one direction and the case is known as one way drainage. The length of drainage path, i.e., the longest path a water particle need to travel for dissipating pore pressure for this case is H

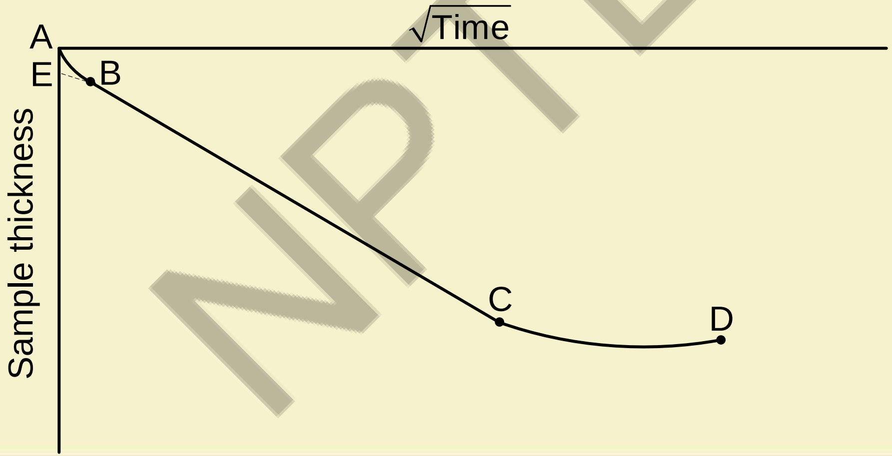




DILIP KUMAR BAIDYA
DEPARTMENT OF CIVIL ENGINEEERING
IIT KHARAGPUR

# COMPRESSIBILITY OF SOILS

If for a particular pressure increment applied during a consolidation test the compression of the test sample is plotted against the square root of time, the result shown in Figure in the next slide will be obtained.







DILIP KUMAR BAIDYA
DEPARTMENT OF CIVIL ENGINEEERING
IIT KHARAGPUR

# COMPRESSIBILITY OF SOILS

The curve is seen to consist of three distinct parts: AB, BC and CD

1. AB (Initial Compression or Frictional lag):A small but rapid compression sometimes occurs at the commencement of the increment and is probably due to the compression of any air present or to reorientation of some of the larger particles in the sample. In the majority of tests this effect is absent and points A and B are coincident. Initial compression is not considered to be due to any loss of water from the soil and should be treated as a zero error for which a correction is made




DILIP KUMAR BAIDYA
DEPARTMENT OF CIVIL ENGINEEERING
IIT KHARAGPUR

# COMPRESSIBILITY OF SOILS

2. BC Primary compression: All the compression in this part of the curve is taken as being due to the expulsion of water from the sample, although some secondary compression will also occur. When the pore pressure has been reduced to a negligible amount it is assumed that 100 percent consolidation has been attained
3. CD (Secondary compression): The amount by which this effect is evident is a function of the test conditions and can hardly be related to an insitu value

# COMPRESSIBILITY OF SOILS

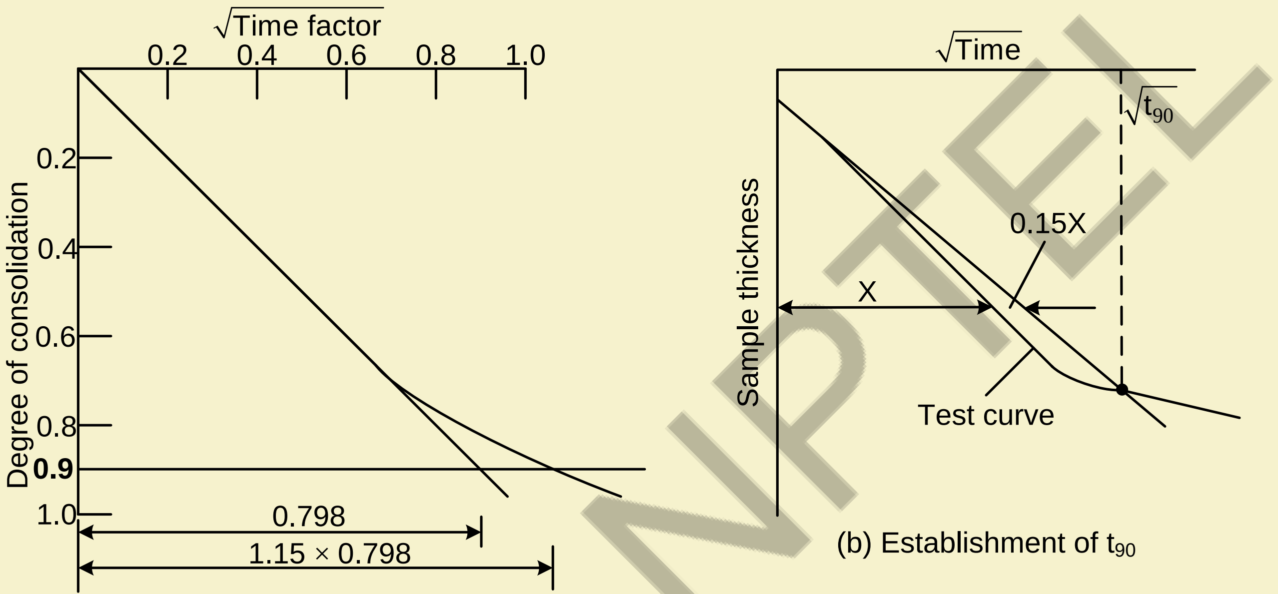
To evaluate the coefficient of Consolidation it is necessary to establish the point C corresponding to 100% consolidation, but it is difficult from a study of the test curve to fix C with accuracy and a procedure in which the test curve is fitted to the theoretical curve becomes necessary

Method by Taylor (1948): If the theoretical curve U against $\sqrt{T}$ is plotted for the case of a uniform initial excess pore pressure distribution, the curve will be like that shown in the fig a in the next slide. Up to values of U equal to about 60 percent, the curve is a straight line of equation $U = 1.13\sqrt{t}$, but if this straight line is extended to cut the ordinate U = 90 percent the abscissa of the curve is seen to be 1.15 times the abscissa of the straight line. This fact is used to fit the test and theoretical curves




DILIP KUMAR BAIDYA
DEPARTMENT OF CIVIL ENGINEEERING
IIT KHARAGPUR

# COMPRESSIBILITY OF SOILS




(a) Theoretical curve

(b) Establishment of $t_{90}$






DILIP KUMAR BAIDYA
DEPARTMENT OF CIVIL ENGINEEERING
IIT KHARAGPUR

# COMPRESSIBILITY OF SOILS

With the test curve a corrected zero must first be established by projecting the straight line part of the primary compression back to cut the vertical axis at E. A second line starting through E is now drawn such that all abscissas on it are 1.15 the corresponding values on the laboratory curve, and the point at which this second line cuts the laboratory curve is taken to be the point representing 90 percent primary consolidation.

To obtain cv, T90 is first found from the theoretical curve that fits the drainage conditions, t90 is determined from the test curve.




DILIP KUMAR BAIDYA
DEPARTMENT OF CIVIL ENGINEEERING
IIT KHARAGPUR

# COMPRESSIBILITY OF SOILS

$$t_{90} = \frac{T_{90} H^2}{c_v}$$

Time factor corresponding to 90 percent degree of consolidation is 0.48

Hence $$t_{90} = \frac{0.48 H^2}{c_v}$$

# Thank You!!

IIT KHARAGPUR

NPTEL ONLINE CERTIFICATION COURSES

NPTEL

# SOIL MECHANICS/GEOTECHNICAL ENGINEERING I

## MPRESSIBILITY OF SOILS

DILIP KUMAR BAIDYA
DEPARTMENT OF CIVIL ENGINEERING
IIT KHARAGPUR

# COMPRESSIBIITY OF SOILS

Coefficient of consolidation by log of time method: Similarity between logT vs U curve and sample thickness vs log t is observed (shown in the next slide). Hence sample thickness versus log plot can be utilised to determine the coefficient of consolidation.

Determination of thickness corresponding to 100% consolidation: The intersection formed by the final straight line produced backward and the tangent to the curve at point of inflection is accepted as the 100% primary consolidation point and the dial reading designated as R100

# COMPRESSIBIITY OF SOILS

Determination of thickness corresponding to 0% primary consolidation:

Step1: select two points on the initial parabolic portion of the curve in such a way that time are in the ratio of 1:4

Step 2: The difference in thickness between these two points is then equal to the difference between the first point and the dial reading corresponding to zero primary consolidation. If z is the ordinate difference between A and B, a point C will be chosen at z above point B. Intersecting the horizontal through point C to Dial reading axis gives the point corresponding to zero primary consolidation

# COMPRESSIBIITY OF SOILS

Step 3: The interval between 0 and 100% consolidation is divided into equal intervals of percent consolidation. Since it has been found that the laboratory and the theoretical curve s have better correspondence at the central portion , the value of cv is computed by taking the time t and time factor T at 50% consolidation.

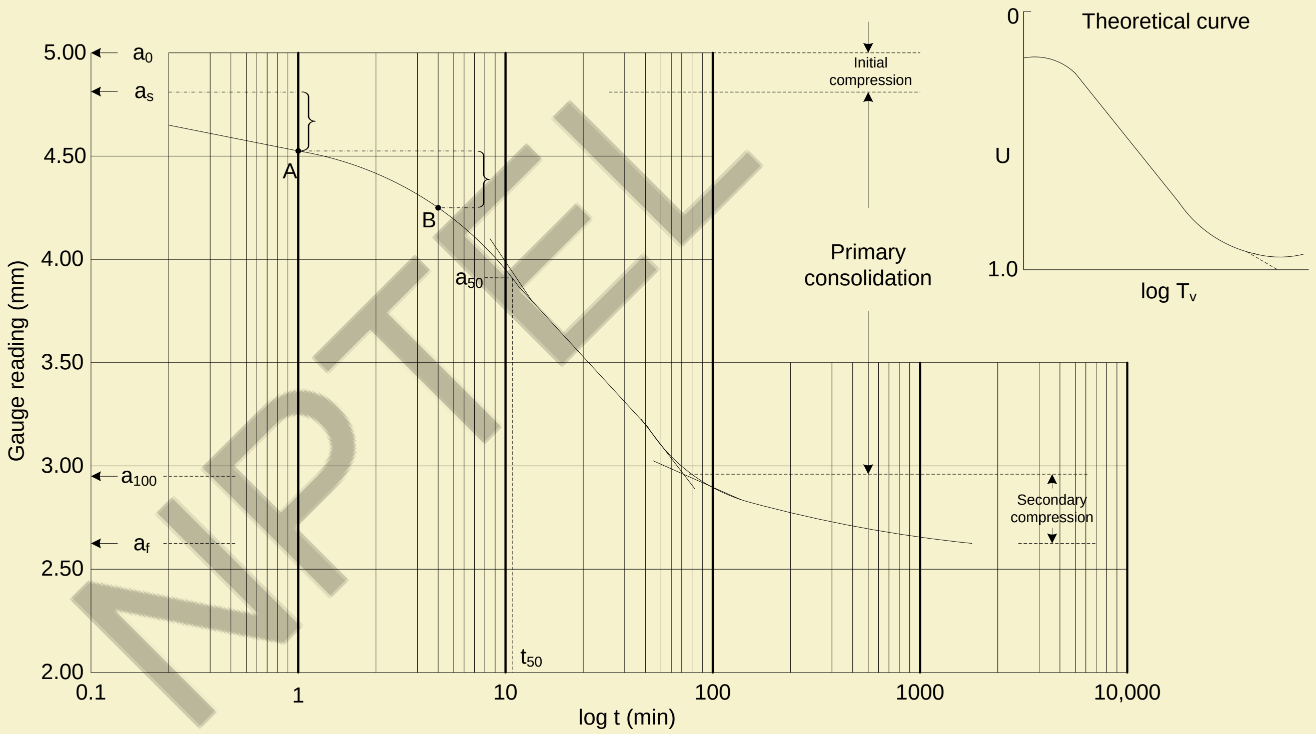
$$T_{50} = \frac{c_v t_{50}}{H^2} \quad \text{Or} \quad c_v = \frac{T_{50} H^2}{t_{50}}$$




DILIP KUMAR BAIDYA
DEPARTMENT OF CIVIL ENGINEERING
IIT KHARAGPUR

# COMPRESSIBIITY OF SOILS

Coefficient of consolidation by log of time method





DILIP KUMAR BAIDYA
DEPARTMENT OF CIVIL ENGINEERING
IIT KHARAGPUR

# COMPRESSIBIITY OF SOILS

If two layers of the same clay soil with different drainage path H1 and H2 are acted upon by the same pressure increase and reach the same degree of consolidation in times t1 and t2 respectively, then theoretically their coefficients of consolidation must be equal as must their time facto T1 and T2

$$T_1 = \frac{c_{v1} t_1}{{H_1}^2} \qquad T_2 = \frac{c_{v2} t_2}{{H_2}^2}$$

Equating: $$\frac{t_1}{{H_1}^2} = \frac{t_2}{{H_2}^2}$$

# COMPRESSIBIITY OF SOILS

## Important terminology and its implication:

Coefficient of volume compressibility, a or $a_v = \frac{de}{dp}$ = slope of e versus log p plot (m2/kN)

$m_v = coefficient\ of\ volume\ compressibility = \frac{a_v}{1+e}$ (unit same as av, m2/kN)

$$m_v = \frac{dH}{H_1}\frac{1}{dp} = \frac{1}{H_1}\frac{dH}{dp}$$

$$total\ settlement = \rho_c = m_v\, dp\, H$$

# COMPRESSIBIITY OF SOILS

$$\frac{dH}{H_1} = \frac{de}{1 + e_1}$$

Where H1 is the original thickness and e1 is the initial void ratio

$$e = \frac{H - H_s}{H_s}$$

$$c_c = \frac{e_1 - e_2}{log\left(\frac{p_2}{p_1}\right)}$$

Approximate value of cc $c_c = 0.009(w_l - 10)$

$$\rho_c = \frac{c_c H_1}{1 + e_1} \log_{10} \frac{p_2}{p_1}$$

Normally consolidated clay




DILIP KUMAR BAIDYA
DEPARTMENT OF CIVIL ENGINEERING
IIT KHARAGPUR

# COMPRESSIBIITY OF SOILS

Over consolidated – when $\sigma_c'$ is larger than $\sigma_0'$, the clay is known to be overconsolidated

$$\sigma_0' + \Delta\sigma \langle \sigma_{pc}' \qquad \rho_c = \frac{c_r H}{1+e_0}\log_{10}\left(\frac{\sigma_0' + \Delta\sigma}{\sigma_0'}\right)$$

$$\sigma_0' + \Delta\sigma \rangle \sigma_{pc}' \; \rho_c = \frac{c_r H}{1+e_0}\log_{10}\left(\frac{\sigma_{pc}'}{\sigma_0'}\right) + \frac{c_c H}{1+e_0}\log_{10}\left(\frac{\sigma_0' + \Delta\sigma}{\sigma_{pc}'}\right)$$

# COMPRESSIBIITY OF SOILS

Time factor, $T = \frac{c_v t}{H^2}$

$T = \frac{\pi}{4}\left(\frac{U\%}{100}\right)^2$ For U <60%

$T = 1.781 - 0.933\, log_{10}(100 - U\%)$ For U > 60%

U is the degree of consolidation = consolidation attain at time t /total expected consolidation settlement, cv is the coefficient of consolidation , H is half the thickness of the layer for double drainage and thickness of the layer for single drainage

# COMPRESSIBIITY OF SOILS

Determination of cv:

1. Taylor's root time method: determine t90 from the plot and procedure proposed by Taylor and determine

$$c_v = \frac{0.48H^2}{t_{90}}$$

2. Casagrande's log time method: determine t50 from the plot and following the procedure proposed by Casagrande and determine

$$c_v = \frac{0.197H^2}{t_{50}}$$

# COMPRESSIBIIITY OF SOILS




DILIP KUMAR BAIDYA
DEPARTMENT OF CIVIL ENGINEERING
IIT KHARAGPUR

# TOPIC NAME

✓**Sub Heading Name:**

✓**Sub Heading Name:**

# Thank You!!

IIT KHARAGPUR

NPTEL ONLINE CERTIFICATION COURSES

NPTEL

# SOIL MECHANICS/GEOTECHNICAL ENGINEERING I

## COMPRESSIBILITY OF SOIS

DILIP KUMAR BAIDYA
DEPARTMENT OF CIVIL ENGINEERING
IIT KHARAGPUR

# COMPRESSIBILITY OF SOILS

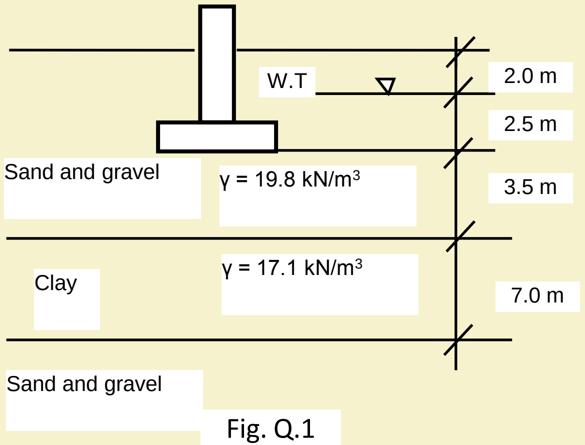
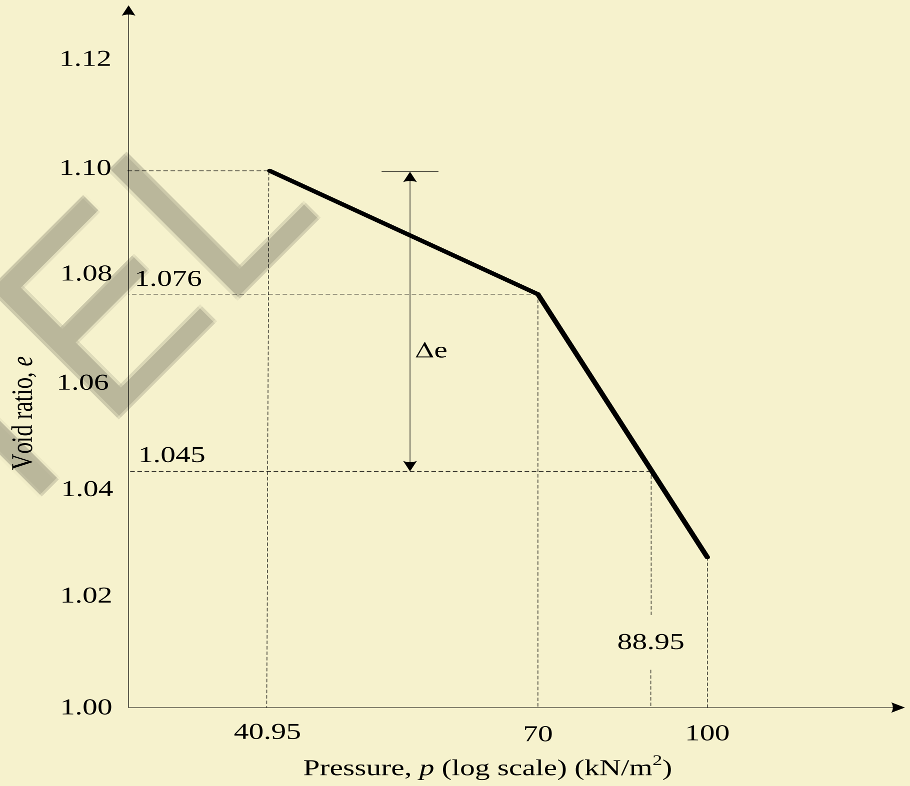


Fig. Q.1

A foundation is to be constructed at a site where the soil profile is as shown in Fig. Q. 1. The base of the foundation is 2.5m by 2.5m and, it exerts a total load of 2000 kN, which includes the weight of the structure, foundation and soil surcharge on the foundation. The initial void ratio and compression index of the compressible clay layer is respectively, 1.2 and 0.60. Determine the settlement of the foundation due to the primary consolidation of the clay layer.

# COMPRESSIBILITY OF SOILS

A 10 m thick clay layer has a saturated unit weight of 18 kN/m3 and void ratio of 1.1. The water table is at the ground surface. Laboratory consolidation test is conducted on a specimen collected from the middle of the clay layer. The field consolidation curve interpolated from the laboratory test results is shown in the figure. Determine the consolidation settlement if 2 by 2 m footing constructed on the surface of the clay layer with a load (i) 1000 kN and (ii) 1800 kN








DILIP KUAR BAIDYA
DEPARTMENT OF CIVIL ENGINEERING
IIT KHARAGPUR

# Thank You!!

IIT KHARAGPUR

NPTEL ONLINE CERTIFICATION COURSES

NPTEL

# SOIL MECHANICS/GEOTECHNICAL ENGINEERING I

## COMPRESSIBILITY OF SOILS

DILIP KUMAR BAIDYA

DEPARTMENT OF CIVIL ENGINEERING

IIT KHARAGPUR

# COMPRESSIBILITY OF SOILS

During a pressure increment a consolidation test sample attained 25 per cent primary consolidation in 5 minutes with a mean thickness of 18 mm. How long would it take a 20 m thick layer of the same soil to reach the same degree of consolidation if (i) the layer was drained on both surfaces and (ii) it was drained on the top surface only?





DILIP KUMAR BAIDYA
DEPARTMENT OF CIVIL ENGINEERING
IIT KHARAGPUR

A 19.1 mm thick clay sample, drained both at top and bottom, reached 30 percent consolidation in 10 minutes. How long would it take the sample to reach 50 per cent consolidation?





DILIP KUMAR BAIDYA
DEPARTMENT OF CIVIL ENGINEERING
IIT KHARAGPUR

# COMPRESSIBILITY OF SOILS

Results obtained from a consolidation test on a clay sample for a pressure increment of 100 – 200 kN/m2 were:

| Thickness of the sample(mm) | Time (min) |
|---|---|
| 12.200 | 0 |
| 12.141 | 0.25 |
| 12.108 | 1.0 |
| 12.075 | 2.25 |
| 12.046 | 4 |
| 11.985 | 9 |
| 11.922 | 16 |
| 11.865 | 25 |
| 11.827 | 36 |
| 11.809 | 49 |
| 11.800 | 64 |

Determine the coefficient of Consolidation of the soil





DILIP KUMAR BAIDYA
DEPARTMENT OF CIVIL ENGINEERING
IIT KHARAGPUR

How long would a layer of this clay, 10 m thick and drained on its top surface only, take to reach 75 per cent primary consolidation?

If the void ratios at the beginning and end of the increment were 0.94 and 0.82 respectively, determine the value of the coefficient of permeability

# COMPRESSIBILITY OF SOILS




DILIP KUMAR BAIDYA
DEPARTMENT OF CIVIL ENGINEERING
IIT KHARAGPUR

# COMPRESSIBILITY OF SOILS




DILIP KUMAR BAIDYA
DEPARTMENT OF CIVIL ENGINEERING
IIT KHARAGPUR

# COMPRESSIBILITY OF SOILS





DILIP KUMAR BAIDYA
DEPARTMENT OF CIVIL ENGINEERING
IIT KHARAGPUR

# COMPRESSIBILITY OF SOILS

# COMPRESSIBILITY OF SOILS

# COMPRESSIBILITY OF SOILS




DILIP KUMAR BAIDYA
DEPARTMENT OF CIVIL ENGINEERING
IIT KHARAGPUR

# TOPIC NAME

✓ **Sub Heading Name:**

✓ **Sub Heading Name:**

# Thank You!!

IIT KHARAGPUR

NPTEL ONLINE CERTIFICATION COURSES

NPTEL

# SOIL MECHANICS/GEOTECHNICAL ENGINEERING I

## COPESSIBILITY OF SOILS

DILIP KUMAR BAIDYA
DEPARTMENT OF CIVIL ENGINEERING
IIT KHARAGPUR

In an oedometer test, a clay specimen initially 25 mm thick attains 90% consolidation in 10 minutes. In the field, the clay stratum from which the specimen was obtained has a thickness of 6.0 m and sandwiched between two sand layers. For a structure constructed on this clay layer, the ultimate settlement is estimated as 200 mm. Estimate the settlement at the end of 100 days after construction.

A reasonably homogeneous layer of clay, 4 m thick, is expected to experience an ultimate settlement of 160 mm. After 3 years the average settlement was measured to be 55 mm. How long will it take for the average settlement to double (110 mm)?

# Thank You!!