One-Dimensional Consolidation Test

Introduction: When a saturated soil mass subjected to a load increment, the load is usually carried initially by water in the pores because the water is incompressible when compared with the soil "skeleton". The pressure which results in the water because of the loading is called hydrostatic excess pressure because it is in excess of that pressure due to the weight of water, as the water drains from the soil pores, the load increment is gradually shifted to the soil structure. This transfer of load is accompanied by a change in the total volume of soil equal to the volume of water drained. This process is known as consolidation.

For this reason, when any soil is subjected to an increase in pressure, a readjustment in the soil structure occurs which may be considered as consisting primarily of plastic deformation with a corresponding reduction in void ratio. A small amount of elastic deformation may also take place, but considering it as negligible.

Consolidation can be defined as that plastic deformation void-ratio reduction (generally termed settlement) which is a function of time, (S=f (t). The length of time for the process will depend on several factors including:

1. The degree of saturation.
2. The coefficient of permeability.ofthe soil.
3. The properties of the pore fluid
4. The length of the path the expelled pore fluid must take to find equilibrium

Significance

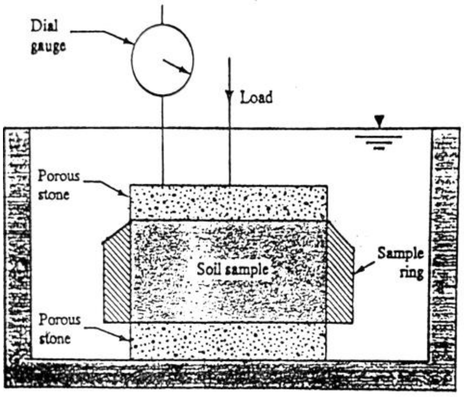
The most important properties furnished by a consolidation test are:

1. The coefficient of consolidation, C_v , which indicates the rate of compression under a load increment.
2. The compressibility index C_c , which indicates the compressibility of normally consolidated soil.
3. The pre-consolidation pressure P_c , the maximum stress that the soil has felt in the past.

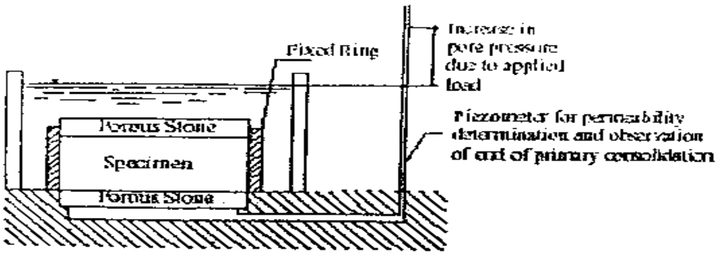
ASTM D 2435 - Standard Test Method for One-Dimensional Consolidation Properties of Soils.

Apparatus:

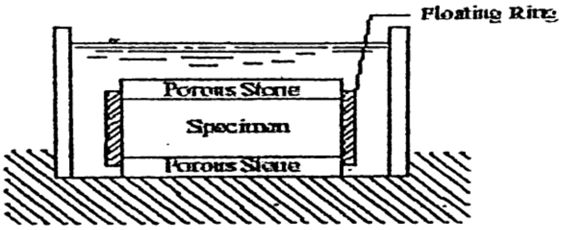
1. Consolidometer may be of the fixed-ring or floating-ring type as shown in Fig.1
2. Dial gage reading to 0.01 mm
3. Loading device.
4. Stop watch or timer.
5. Sample trimming equipment as available or necessary.



Consolidometer



a



(b)

Fig. I: Typical consolidometers. (a) Shows a fixed ring consolidometer. This may also be used to obtain permeability information during a consolidation test if a piezometer is installed. (b) Shows a floating ring consolidometer.

Procedure:

The laboratory consolidation test is performed on specimen with thick of 19-20 mm, placed in a confining metal ring ranging with diameter of 75 mm.

1. Carefully trim a sample to fit the 'consolidation ring. Weight the sample and determine the sample height Hi and the diameter of sample.

2. Place the sample in the consolidometer with a saturated porous stone on each face. Place the consolidometer in the loading device and attach the dial gage. Apply a seating load, the consolidation test proceeds by applying loads in a geometric progression with a load ratio, $(P_2-P_1)/P_1= 1$, with a typical load sequence as follows:

Loading Procedure (recommended):

The specimen is subjected to sequence loads that may be done by doubling the applied load every 24 hr.

$$\text{Load — increment ratio (LIR)} = (P_2-P_1)/P_1$$

For the preceding procedure the (LIR) = 1.

In the oedometer press, Fig. (1), and for a beam ratio = 1 : 9 [i.e., 1 kg applied on the beam = 9 kg on the sample), the stress which correspond 1.25 kg equal:

$$\frac{P}{A}=\frac{1.25\times 9}{(\pi/4)\times(0.075)^2}\frac{kg}{m^2}\times\frac{1}{101.9}\frac{kN}{kg}$$

$=25$ kN/m ^{2}, so:

Applied weight on beam (kg)	1.25	2.5	5	10	20	40
Applied stress on sample (kN/m^2)	25	50	100	200	400	800

Therefore, the following series of loads is applied:

(25, 50, 100, 200, 400, 800, 1600 and sometimes 3200) kPa then zero the deformation dial gage. Then unloading the sample to (800,400,200,100) kPa

3. At a convenient starting time, apply the first load increment and at the same time take deformation readings at elapsed

times of (0.25, 0.50, 1, 2, 4, 8, !5, 30, 60 , i20 min, then, say, 4, 8, 16, h etc.). Take the reading of dial gage at the time intervals above to plot DR vs. log t or DR. vs. √ (time)

4. After 24h, change the load to the next value and again take elapsed-time interval readings as done above and continue change the load each 24h to take the readings of dial gage and the elapsed time.

5. Place the sample in the oven at the end of the test to find the weight of soil solids (W_s).

To find the coefficient of consolidation:

1. Log-Time Method (Casagrande Method):

1. Plot dial readings vs. time (time on the logarithmic scale) in minutes for each load increment (a total time interval for a sample to consolidatc under a load increment may be 24 to 48 h or more).

2. to obtain D100 (the dial reading corresponding to 100 percent consolidation, or U=100 percent) from the DR. vs. log time curve, draw tangents to the middle and end parts of the curve, as shown in Fig.. At the intersection of the tangents, project horizontally to the curve ordinate to read D100.

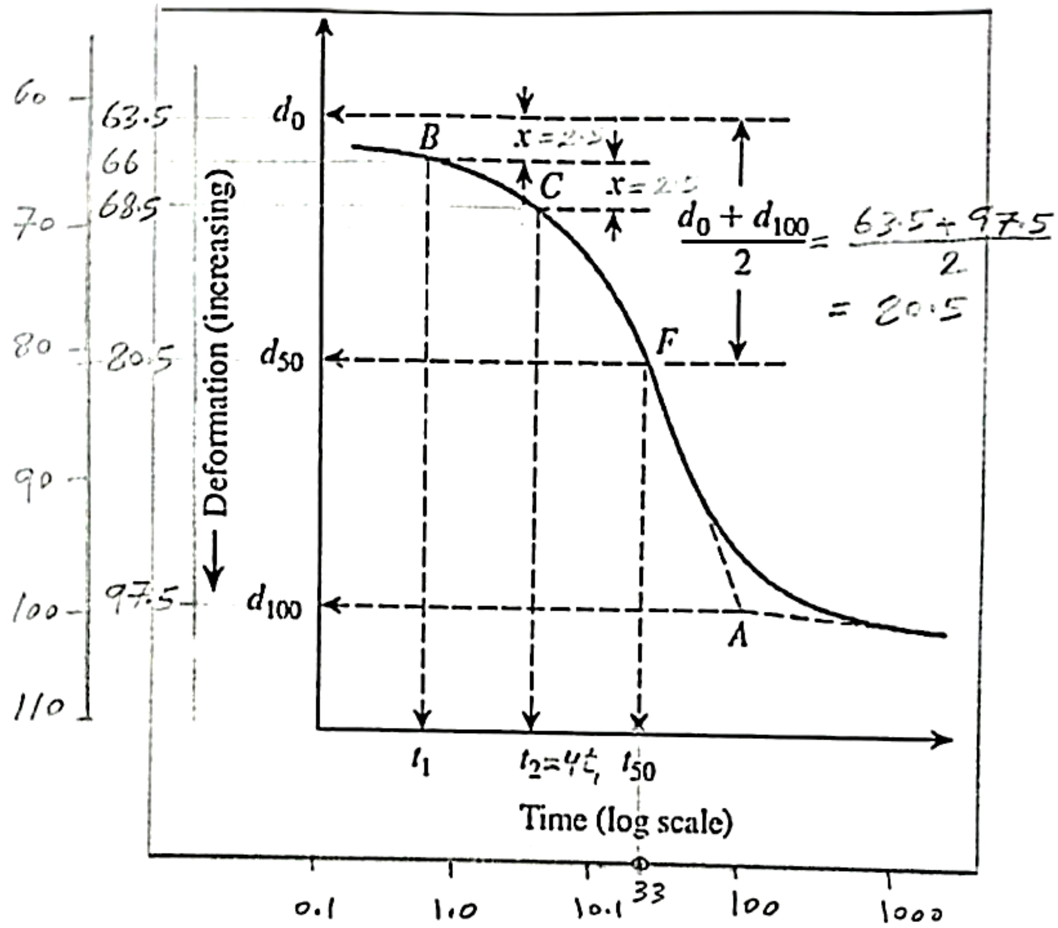
3. to obtain Do on the logarithmic plot, select a time t_1, and $t_2=4t_1$, measure the ordinate y from t_1, to t_2 on the curve and lay the same value of y off vertically above t, then through this point draw a horizontal line to obtain Do, with Do and D100; one may obtain the dial reading corresponding to 50 percent consolidation D50 as

$$D_{50} = \frac{D_0 + D_{100}}{2}$$

Find the time corresponding to D5o to evaluate C_v , as shown

$$C_v = \frac{0.197 d^2}{t_{50}}$$

LOG- TIME METHOD (Casagrande Method) to find the value of the Coefficient Of Consolidation, Cv, (m^2 /yr)



from fig $D_{50} = 80.5 \longrightarrow t_{50} = 33$

Ex/ $DR_i = 59 = 0.59\ mm \longrightarrow H_i = 20 - 0.59 = 19.41\ mm$

$DR_f = 98 = 0.98\ mm \longrightarrow H_f = 20 - 0.98 = 19.02\ mm$

$H = 20\ mm$

$H_{(ave.)} = \frac{19.41 + 19.02}{2}$

$= 1.9215\ cm \simeq 1.922\ cm$

$C_v = \frac{0.197\, d^2}{t_{50}}$

$= \frac{0.197\,(1.922/2)^2}{33} = 0.0055\ cm^2/min$

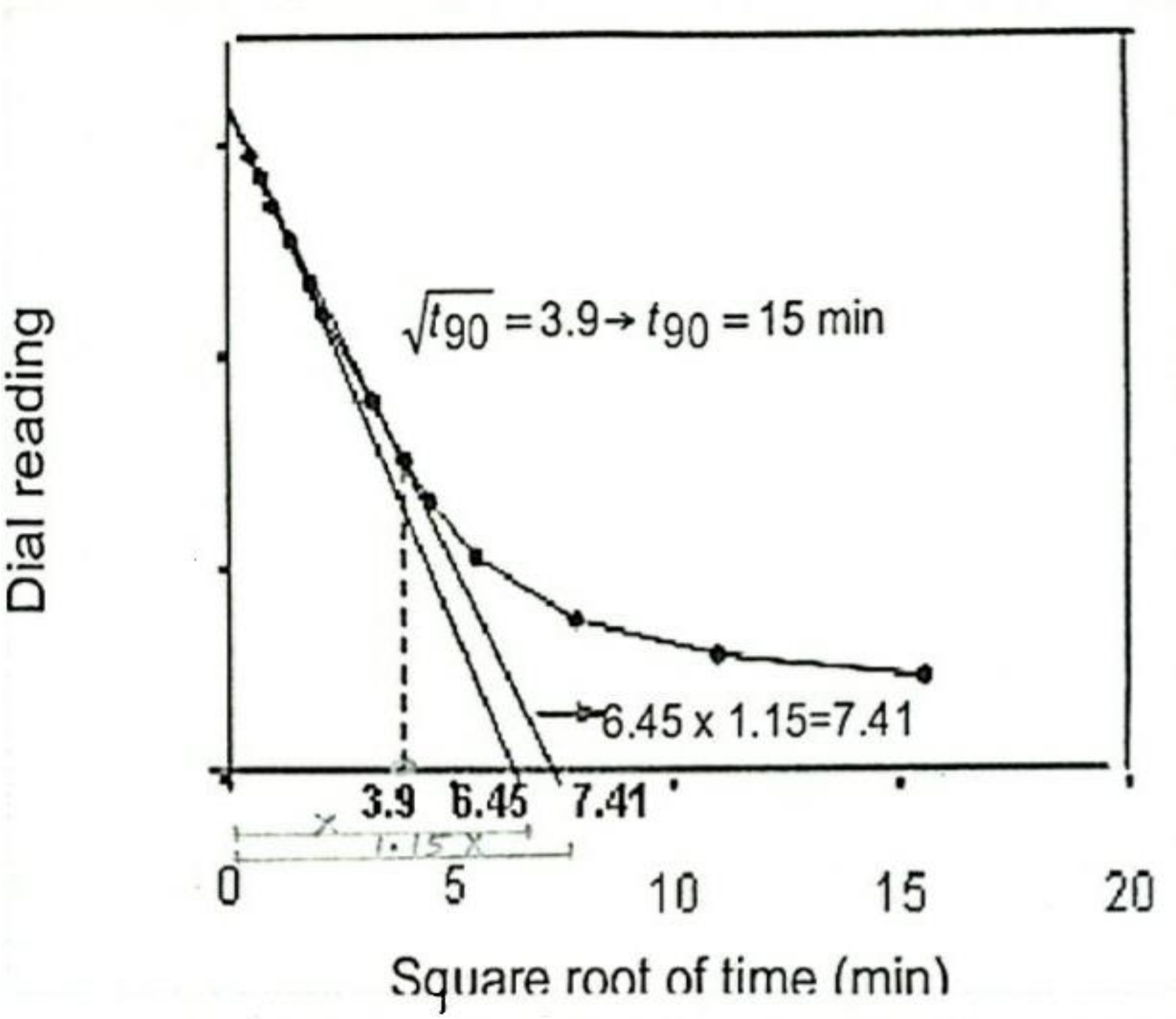
2. Square Root-Time Method (Taylor Method)

To make a plot of dial reading vs. √ (time), locate the coordinates to draw the curve. To find Do draw straight line through the first several (6-8) plotted points and extending this line until in intersects the ordinate (y-axis) to give Do (line A). Next take an abscissa (x) value 15 % greater than the value obtained by the intersection of the straight- line, and from Do draw a straight line through this point (line B). Where the plotted curve crosses the line B (1.15 offset line), the ordinate value is taken as D90. find the corresponding time for D90 to evaluate c, as shown:

$$C_v = \frac{0.848 d^2}{t_{90}}$$

Where d is the average length of sample.
For two way drainage d=H/2, for one way drainage d=H
here d is the average length of sample.

Square Root-Time Method (Taylor Metkod) to find the value of the Coefficient Of Consolidation , Cv , (m² / yr)



From fig. $\sqrt{t_{90}} = 3.9 \Rightarrow t_{90} = 15$ min

$$C_v = \frac{0.848 (d)^2}{t_{90}}$$

$$C_v = \frac{0.848 (1.922/2)^2}{15}$$

$$= 0.0522 \ cm^2/min$$

EX :

Mass of empty ring= 99.18gr
Mass ring+ dry soil=226.68 gr (at end of test)
w_s= 127.5 gr
h=19mm, Diam. = 75mm, Area=4417.9 mm^2
G_s=2.76

$\gamma s = Ws/Vs$
$\gamma s = Ws/A(Hs)$
$Hs = Ws/A(\gamma s)$
$Hs = Ws/A(Gs)\gamma w = 127.5(1000)/4419(2.76) = 10.45$ mm

$e = Vv/Vs$
$e = A(Hv)/A(Hs)$
$e = Hv/Hs$

Applied pressure kPa	Dial Reading	Adjusted (Dial reading*10^{-2} mm/div)	Thickness of sample at end of each load incr. (after24 hr of each load incr.)mm	$H_v=H-H_s$	$e=\frac{H_v}{H_s}$
0	0	0	19	8.55	0.818
25	32	0.32	18.68	8.23	0.787
50	55	0.55	18.45	8	0.766
100	81	0.81	18.19	7.74	0.741
200	113	1.13	17.87	7.42	0.710
400	152	1.52	17.48	7.03	0.673
800	214	2.14	16.86	6.41	0.613
1600	264	2.64	16.36	5.91	0.566
400	261	2.61	16.39	5.94	0.568
100	152	1.52	17.48	7.03	0.673
0	107	1.07	17.93	7.48	0.716

Example to find d:
at load 25 kPa, H1=19 mm,
H2=18.68 mm (after 24 hr)
Average H of sample=(19+18.68)/ 2= 18.84 mm
for two way drainage (d)= 18.84/2= 9.42 mm

at load 50 kPa, H1=18.68 mm, H2=18.45 mm (after 24 hr)
Average H of sample=(18.68+18.45)/ 2= 18.565 mm
for two way drainage (d)= 18.565/2= 9.2825 mm
Note.H2 at end of 25 kPa= H1 at the begining of the next stress=50kPa

Finding the compressibility index Cc:

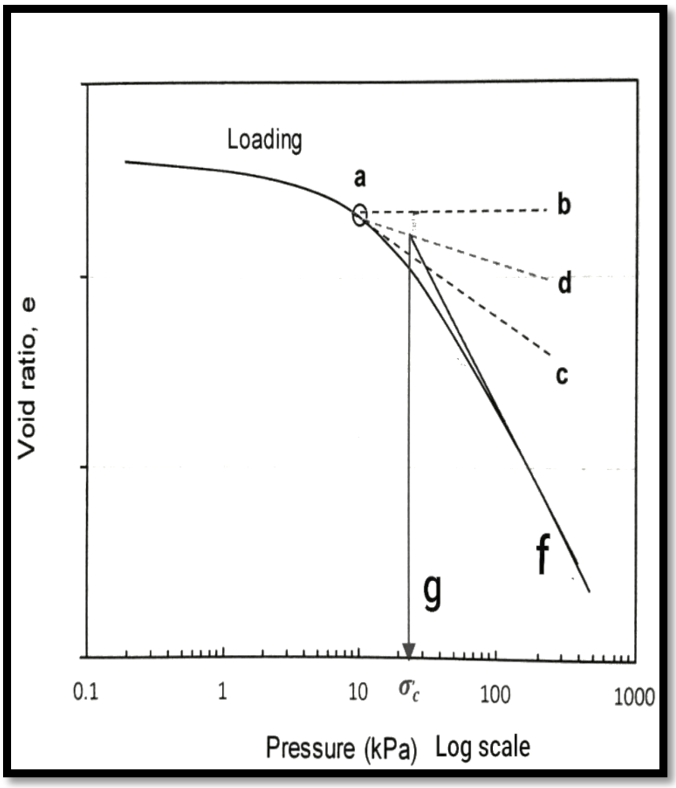
From the plot of void ratio vs. log p, C can be obtained from the slop of the straight line part as: (neglect the -ve sign)

$$C_c = \frac{-\Delta e}{\log \frac{p_2}{p_1}}$$

Finding the preconsolidation pressure, Pc:

From the plot of void ratio vs. log p, Casagrande proposed that the preconsolidation pressure could be estimated as follows:

1- At the sharpest part of the curve, where the maximum curvature occurs, draw a tangent.
2- Through this point draw a horizontal line.
3- Bisect the formed angle.
4- Project the straight line portion of the e-log p plot back to intersect the bisector of angle at a point. The abscissa of this point is the precosolidation pressure Pc.



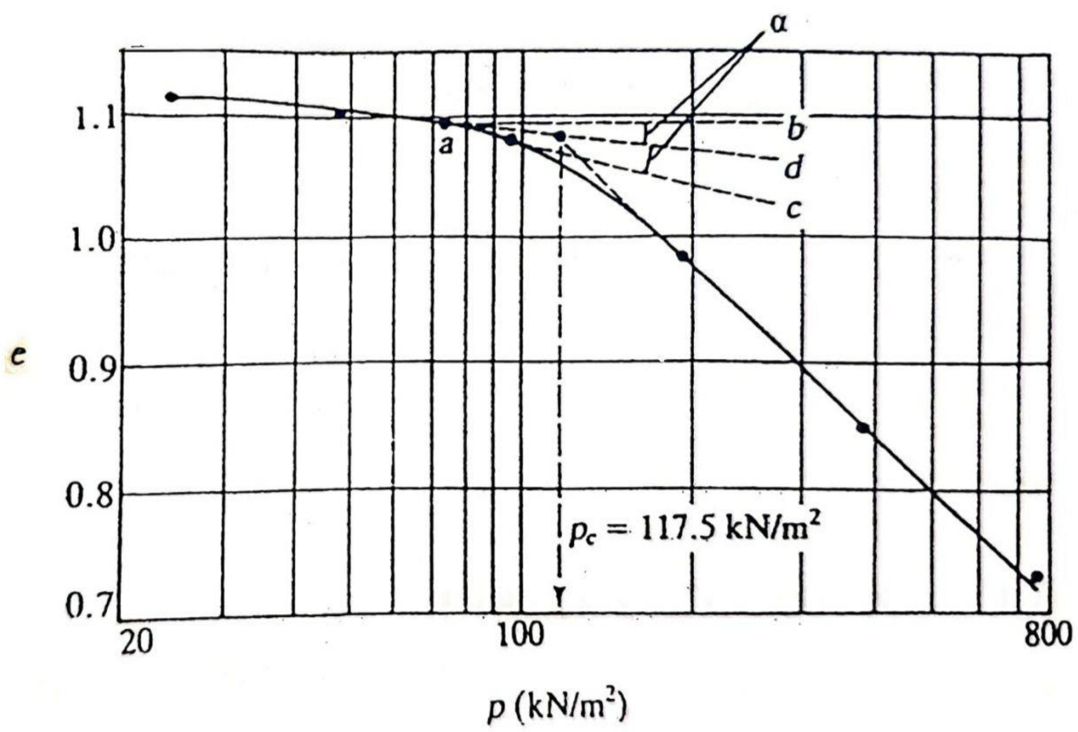
EX:

The results of a laboratory consolidation test on a clay sample are given below:

Pressure, p (kN/m^2)	Void ratio, e
23.94	1.112
47.88	1.105
95.76	1.080
191.52	0.985
383.04	0.850
766.08	0.731

Draw void ratio Vs. log p plot, then determine the precosolidation pressure, Pe and find the compression index, Cc.

Solution:
Refer to the e-log p plot shown in figure below



By using the procedure mentioned above, P=117.5 kN/m^2
From the e-logp plot
P2= 500 kN/m^2, e2=0.8
P1= 300 kN/m^2, e,=0.9
So:

$$C_c = \frac{e_2 - e_1}{\log \frac{p_2}{p_1}} = \frac{0.8 - 0.9}{\log \frac{500}{300}} = 0.451$$

H.W .
Following are the results of a consolidation test:

Pressure, p (kN/m^2)	Void ratio, e
0.25	1.1
0.5	1.085
1.0	1.055
2.0	1.01
4.0	0.94
8.0	0.79
16.0	0.63

1-Plot the e-log P curve, then

2- Using Casagrande's method, determine the precosolidation pressure,Pc.

2- Calculate the compression index, Cc