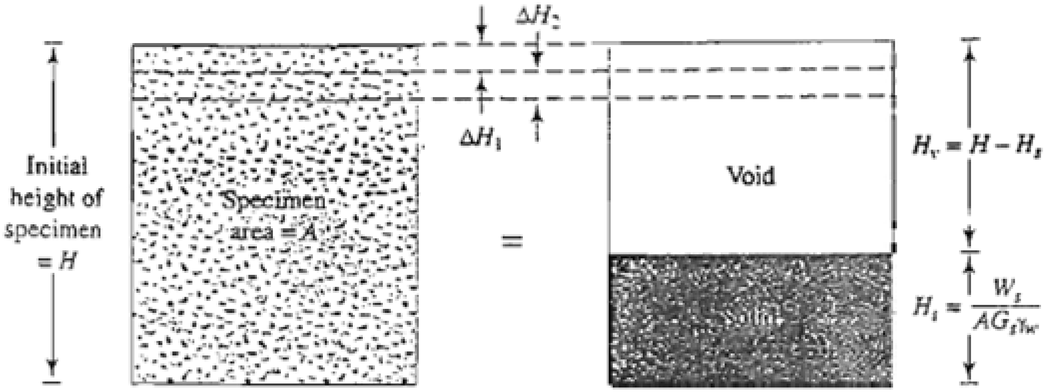
Void Ratio–Pressure Plots

To study the change in the void ratio of the specimen with pressure. Following is a step – by-step procedure for doing so:



Change of height of specimen in one-dimensional consolidation test

1. Calculate the height of solids, H_s, in the soil specimen (Figure 10.11) using the equation

$$H_s = \frac{W_s}{AG_s\gamma_w} = \frac{M_s}{AG_s\rho_w} \tag{10.11}$$

where W_s = dry weight of the specimen
M_s = dry mass of the specimen
A = area of the specimen
G_s = specific gravity of soil solids
γ_w = unit weight of water
ρ_w = density of water

2. Calculate the initial height of voids as

$$H_v = H - H_s \tag{10.12}$$

where H = initial height of the specimen.

3. Calculate the initial void ratio, e_O, of the specimen, using the equation

$$e_O = \frac{V_v}{V_s} = \frac{H_v}{H_s}\frac{A}{A} = \frac{H_v}{H_s} \tag{10.13}$$

4. For the first incremental loading, σ_1 (total load/unit area of specimen), which causes a deformation ΔH_1, calculate the change in the void ratio as

$$\Delta e_1 = \frac{\Delta H_1}{H_s} \tag{10.14}$$

(ΔH_1 is obtained from the initial and the final dial readings for the loading).

It is important to note that, at the end of consolidation, total stress σ_1 is equal to effective stress σ_1'.

5. Calculate the new void ratio after consolidation caused by the pressure increment as

$$e_1 = e_O - \Delta e_1 \tag{10.15}$$

For the next loading, σ_2 (*note:* σ_2 equals the cumulative load per unit area of specimen), which causes additional deformation ΔH_2, the void ratio at the end of consolidation can be calculated as

$$e_2 = e_1 - \frac{\Delta H_2}{H_s} \tag{10.16}$$

At this time, σ_2 = effective stress, σ_2'. Proceeding in a similar manner, one can obtain the void ratios at the end of the consolidation for all load increments.

The effective stress σ' and the corresponding void ratios (e) at the end of consolidation are plotted on semilogarithmic graph paper.

Normally Consolidated and Overconsolidated Clays

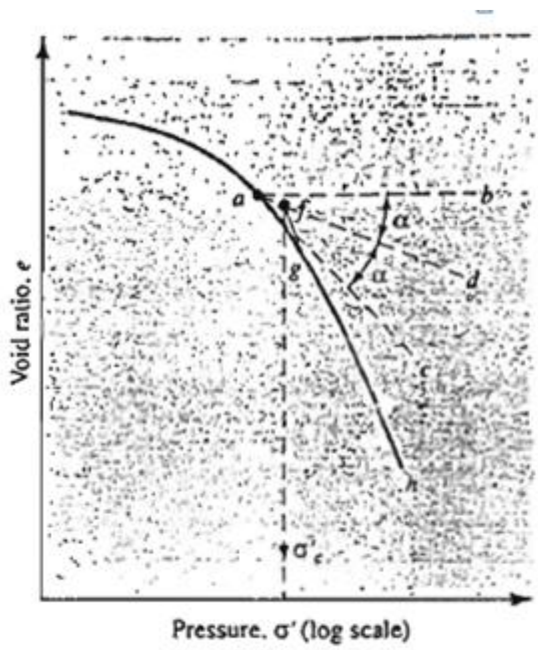
Casagrande (1936) suggested a simple graphic construction to determine the preconsolidation pressure σ'_c from the laboratory e–log σ' plot. The procedure is as follows (see Figure 10.14):

1. By visual observation, establish point a, at which the e–log σ' plot has a minimum radius of curvature.
2. Draw a horizontal line ab.
3. Draw the line ac tangent at a.
4. Draw the line ad, which is the bisector of the angle bac.
5. Project the straight-line portion gh of the e–log σ' plot back to intersect line ad at f. The abscissa of point f is the preconsolidation pressure, σ'_c.

The overconsolidation ratio (OCR) for a soil can now be defined as

$$OCR = \frac{\sigma'_c}{\sigma'}$$

where σ'_c = preconsolidation pressure of a specimen
σ' = present effective vertical pressure



Graphic procedure for determining preconsolidation pressure

Calculation of Settlement from One-Dimensional Primary Consolidation

For NCC:

$$S_c = \frac{C_c H}{1 + e_O} \log\left(\frac{\sigma'_O + \Delta\sigma'}{\sigma'_O}\right)$$

For OCR:

A- If $\sigma'_0 + \Delta\sigma' \leq \sigma'_c$

$$S_c = \frac{C_s H}{1 + e_O} \log\left(\frac{\sigma'_O + \Delta\sigma'}{\sigma'_O}\right)$$

B- If $\sigma'_O + \Delta\sigma' > \sigma'_c$, then

$$S_c = \frac{C_s H}{1 + e_O} \log\frac{\sigma'_c}{\sigma'_O} + \frac{C_c H}{1 + e_O} \log\left(\frac{\sigma'_O + \Delta\sigma'}{\sigma'_c}\right)$$

1- The results of a laboratory consolidation test on a clay sample are given below.

Pressure, σ' (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**

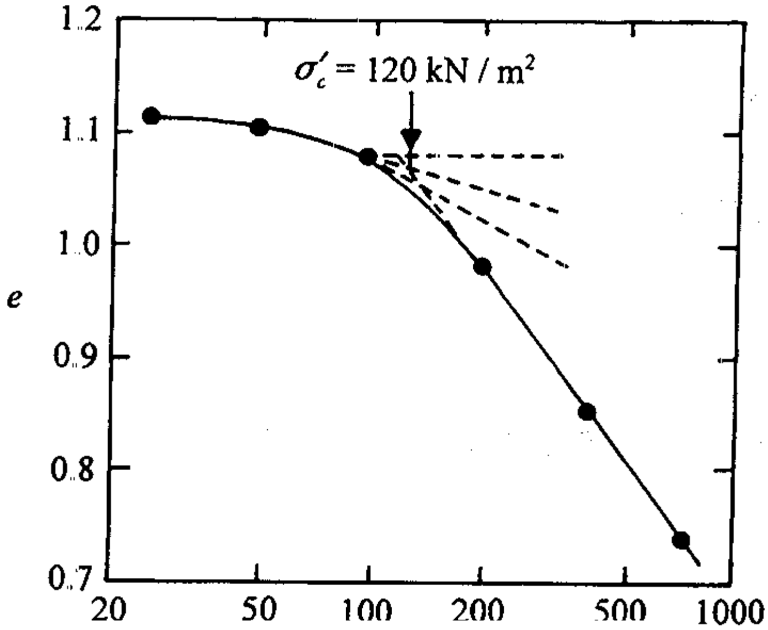
a- Draw e vs. log σ' plot.

b- Determine the preconsolidation pressure, σ_c

c- Find the compression index, C_c.

Sol.

a. The plot is shown.



b. $\sigma'_c = \mathbf{120\ kN / m^2}$

c. $$C_c = \frac{e_1 - e_2}{\log\left(\frac{\sigma'_2}{\sigma'_1}\right)} = \frac{0.985 - 0.85}{\log\left(\frac{400}{200}\right)} = \mathbf{0.448}$$

2- The results of a laboratory consolidation test on a clay sample are given below.

Pressure, σ' (lb/ft^2)	**Dial reading (in)**
500	**0.6947**
1,000	**0.6850**
2,000	**0.6705**
4,000	**0.6250**
8,000	**0.6358**
16,000	**0.6252**

G_s=2.68, Area of the specimen A=4.91 in^2, dry weight of the specimen W_s=95.2 g

d- Draw e vs. log σ' plot.

e- Determine the preconsolidation pressure, σ_c

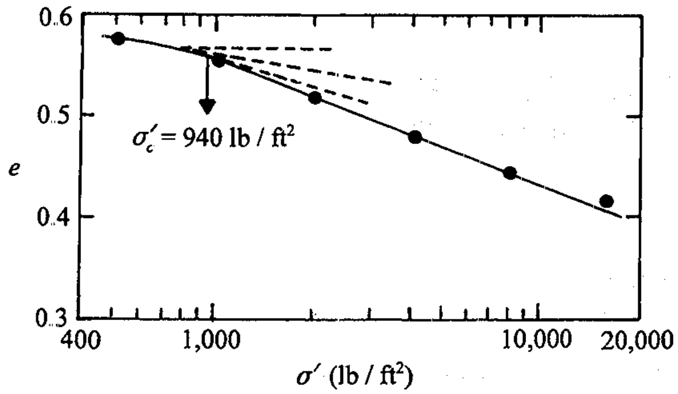
f- Find the compression index, C_c.

Sol.

a. Height of solids: $H_s = \frac{W_s}{AG_s\gamma_w} = \frac{95.2 \text{ g}}{(4.91)(2.54)^2(2.68)(1)} = 1.12 \text{ cm} = 0.441 \text{ in.}$

σ' (lb / ft^2)	H (in.)	H_s (in.)	$H_v = H - H_s$ (in.)	$e = \frac{H_v}{H_s}$
500	0.6947	0.441	0.2537	0.575
1,000	0.6850	0.441	0.244	0.553
2,000	0.6705	0.441	0.2295	0.52
4,000	0.6520	0.441	0.211	0.478
8,000	0.6358	0.441	0.1948	0.442
16,000	0.6252	0.441	0.1842	0.418

The e-log σ' graph is plotted.



b. From the graph, $\sigma_c' = 940 \text{ lb / ft}^2$

c. $C_c = \dfrac{e_1 - e_2}{\log\left(\dfrac{\sigma_2'}{\sigma_1'}\right)} = \dfrac{0.52 - 0.478}{\log\left(\dfrac{4000}{2000}\right)} = \mathbf{0.133}$

3-

A soil profile is shown in Figure 10.34. The uniformly distributed load on the ground surface is $\Delta\sigma$. Estimate the primary settlement of the normally consolidated clay layer, given that

- $\Delta\sigma' = 1000\ Ib/ft^2$, H_1=8ft,H_2=15ft,H_3=17ft
- Sand: $\gamma_d = 110\ Ib/ft^2$ $\gamma_{sat} = 115\ Ib/ft^2$
- Clay: $\gamma_{sat} = 120\ Ib/ft^2$ LL =50, e= 0.9

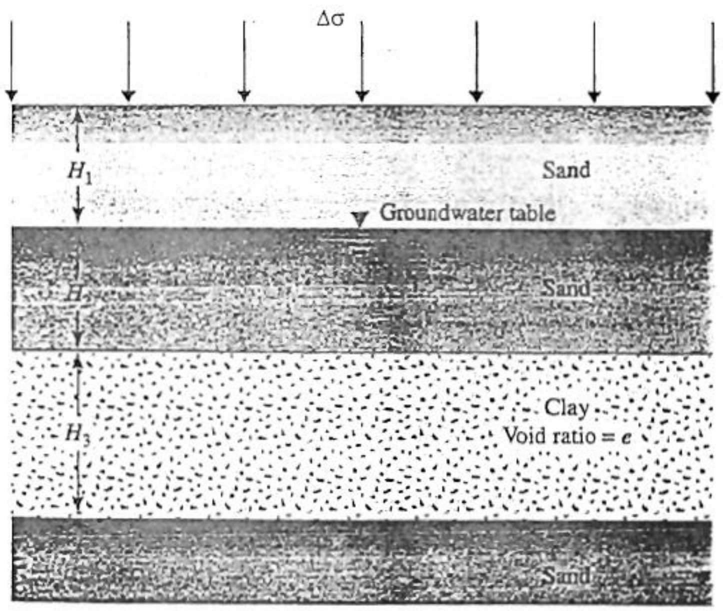


Figure 10.34

Sol.

$$S_c = \frac{C_c H}{1+e_o}\log\left(\frac{\sigma'_o + \Delta\sigma'}{\sigma'_o}\right)$$

$$C_c = 0.009(LL - 10) = 0.009(50 - 10) = 0.36$$

$$\sigma'_o = \gamma_{d(\text{sand})} H_1 + [\gamma_{\text{sat(sand)}} - 62.4] H_2 + [\gamma_{\text{sat(clay)}} - 62.4]\frac{H_3}{2}$$

$$= (110)(8) + (115 - 62.4)(15) + (120 - 62.4)\left(\frac{17}{2}\right) = 2158.6 \text{ lb/ft}^2$$

$$S_c = \frac{(0.36)(17\times 12)}{1+0.9}\log\left(\frac{2158.6+1000}{2158.6}\right) = \mathbf{6.39 \text{ in.}}$$

4- **Refer to Problem 3 assume the clay is to be over consolidated and $\sigma_c = 2600\ Ib/ft^2$, $C_s \approx 1/6\ C_c$.**

S0l.

From problem 3 we obtain $\sigma'_0 = 2158.6\ Ib/ft^2$

$$\sigma'_0 + \Delta\sigma' = 3158.6\ Ib/ft^2 > \sigma'_c$$

Then:

$$S_c = \frac{C_s H}{1+e_o}\log\left(\frac{\sigma'_c}{\sigma'_o}\right) + \frac{C_c H}{1+e_o}\log\left(\frac{\sigma'_o + \Delta\sigma'}{\sigma'_c}\right)$$

$$= \frac{(17)(12)}{1+0.9}\left[\frac{0.36}{6}\log\left(\frac{2600}{2158.6}\right) + 0.36\log\left(\frac{3158.6}{2600}\right)\right] = \mathbf{3.79 \text{ in.}}$$