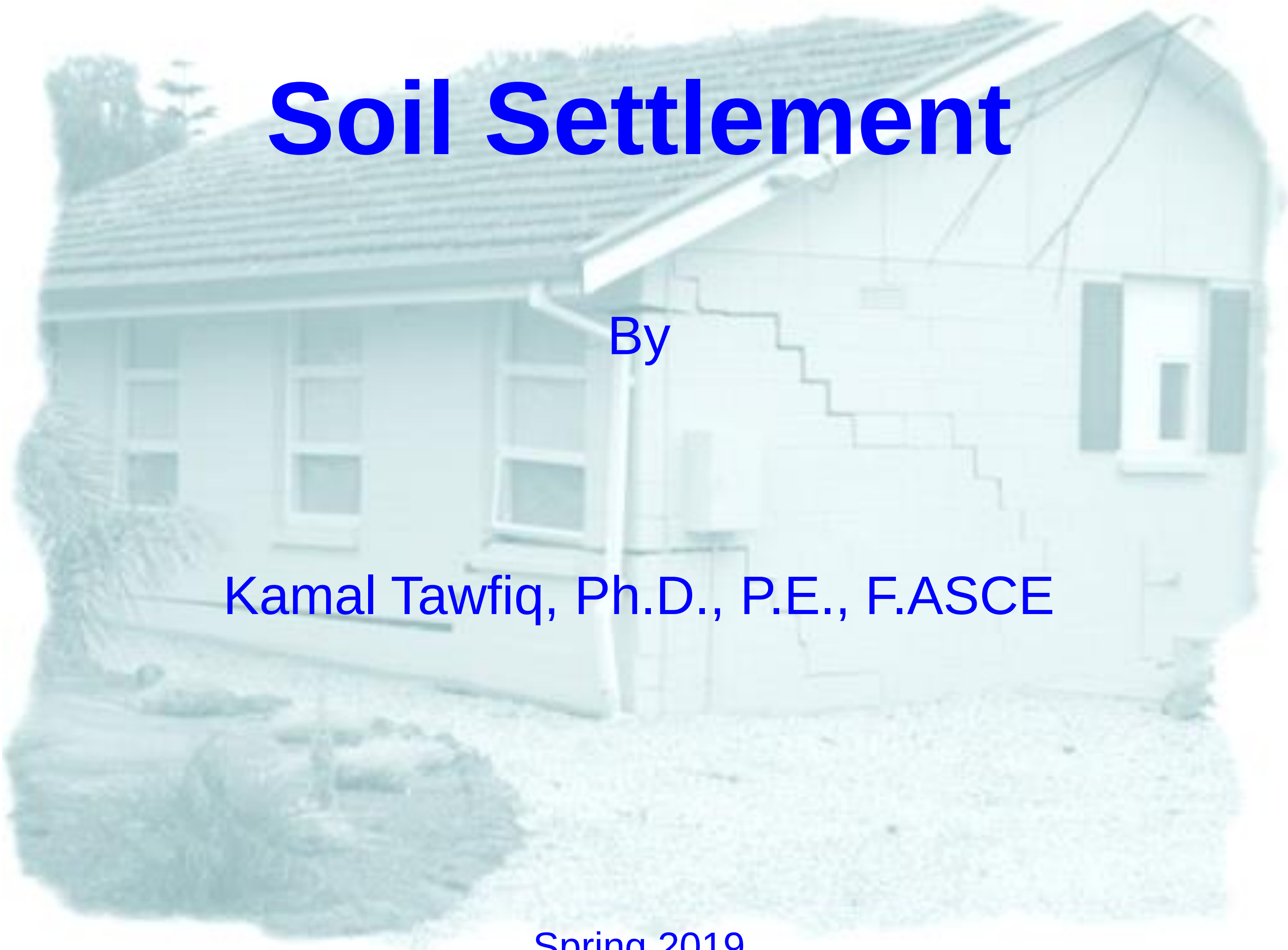

Soil Settlement

By

Kamal Tawfiq, Ph.D., P.E., F.ASCE

Spring 2019

Soil Settlement:

Total Soil Settlement = Elastic Settlement + Consolidation Settlement

$$S_{total} = S_e + S_c$$

Elastic Settlement or Immediate Settlement depends on
- Load Type (Rigid; Flexible)
- Settlement Location (Center or Corner)

Elastic Settlement
- Theory of Elasticity
- Time Depended Elastic Settlement (Schmertman & Hartman Method (1978)

Elastic settlement occurs in sandy, silty, and clayey soils.

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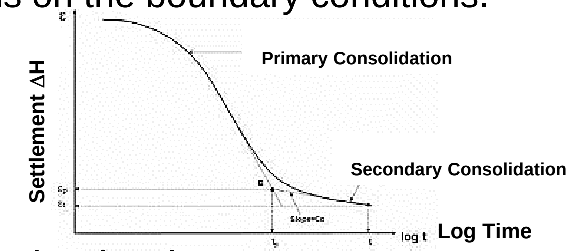
Consolidation Settlement (Time Dependent Settlement)

* Consolidation settlement occurs in cohesive soils due to the expulsion of the water from the voids.
* Because of the soil permeability the rate of settlement may varied from soil to another.
* Also the variation in the rate of consolidation settlement depends on the boundary conditions.

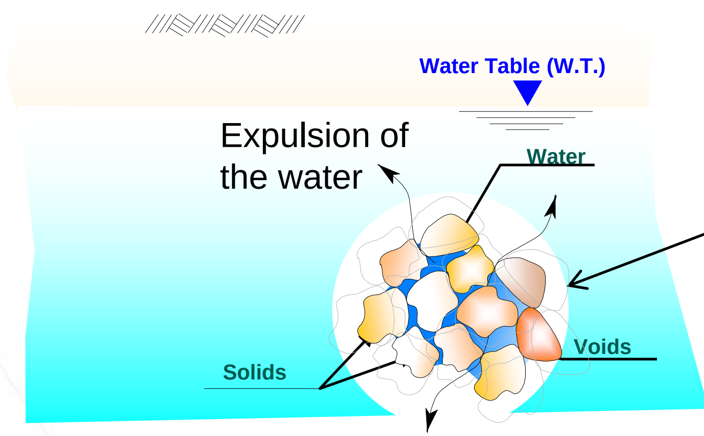
$$S_{Consolidation} = S_{primary} + S_{secondary}$$



Primary Consolidation — Volume change is due to reduction in pore water pressure

Secondary Consolidation — Volume change is due to the rearrangement of the soil particles

(No pore water pressure change, $\Delta u = 0$, occurs after the primary consolidation)



When the water in the voids starts to flow out of the soil matrix due to consolidation of the clay layer. Consequently, the excess pore water pressure (Δu) will reduce, and the void ratio (e) of the soil matrix will reduce too.

Elastic Settlement

$$S_e = \frac{Bq_o}{E_s}(1 - \mu_s^2)\frac{\alpha}{2}$$ (corner of the flexible foundation)

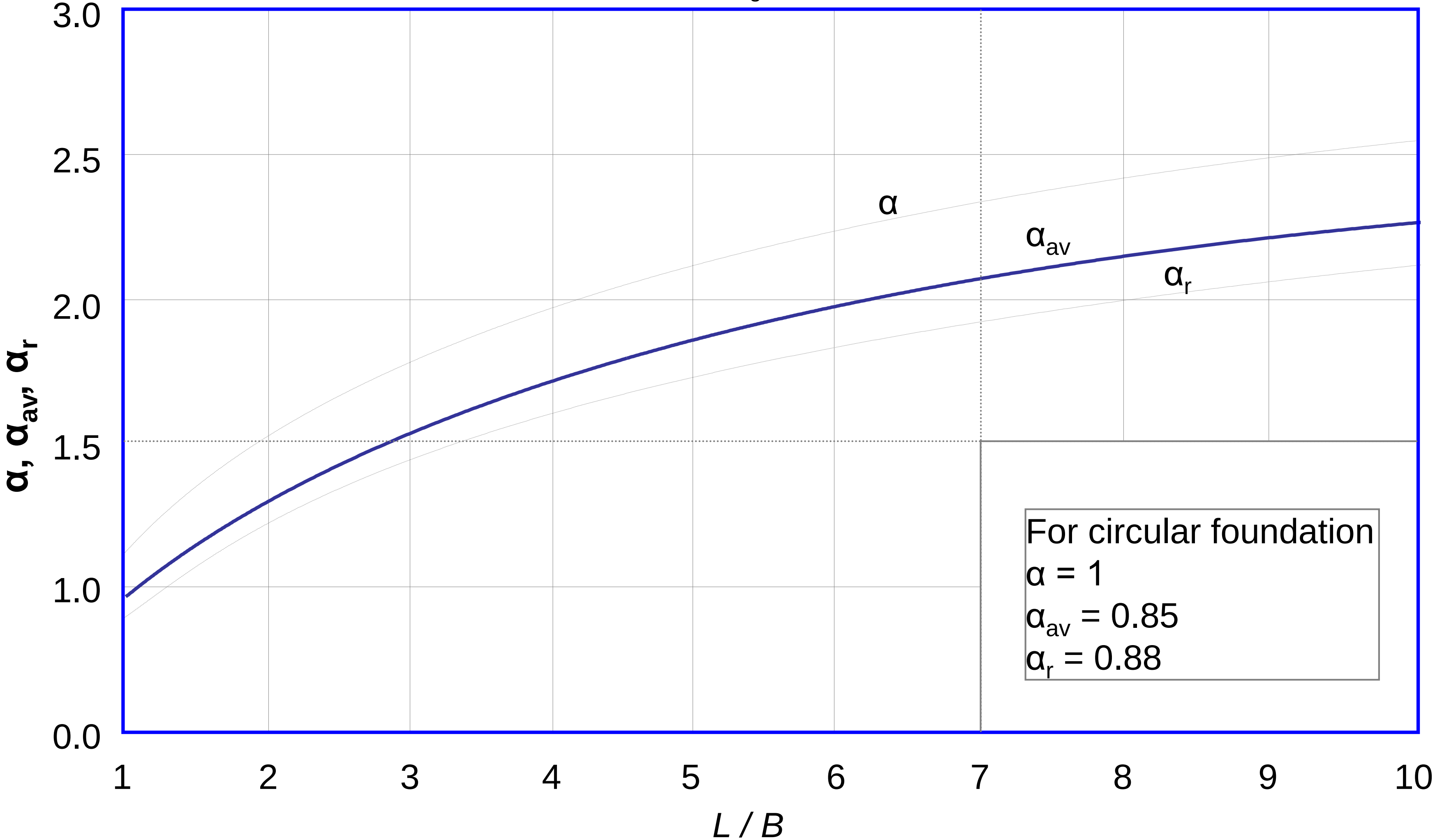
$$S_e = \frac{Bq_o}{E_s}(1 - \mu_s^2)\,\alpha$$ (center of the flexible foundation)

Where $\alpha = \frac{1}{\pi}\left[\ln\left(\sqrt{1+m^2}+m \,/\, \sqrt{1+m^2}-m\right) + m.\ln\left(\sqrt{1+m^2}+1 \,/\, \sqrt{1+m^2}-1\right)\right.$

$m = B/L$

B = width of foundation
L = length of foundation

$$S_e = \frac{Bq_o \ (1 - \mu_s)\ \alpha}{E_s}$$



Values of α, α_{av}, and α_r

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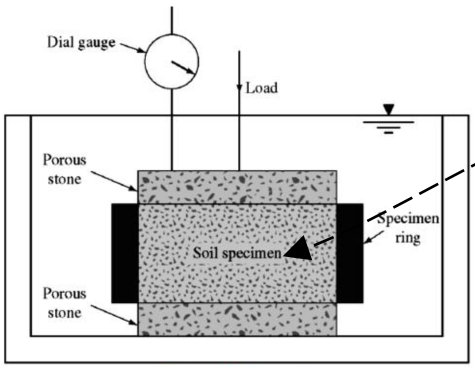
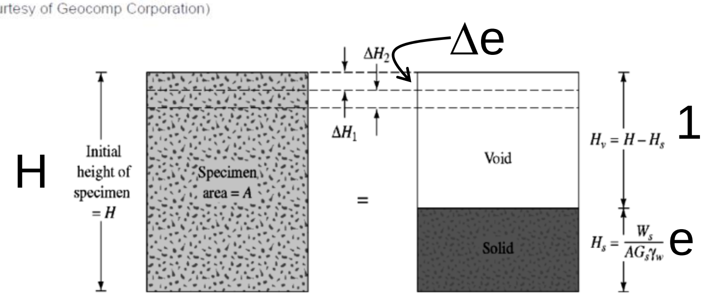
Laboratory Consolidation Test

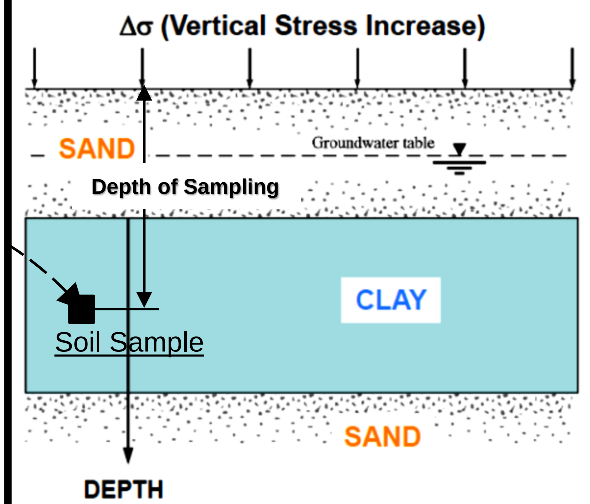
- One Dimensional Consolidation

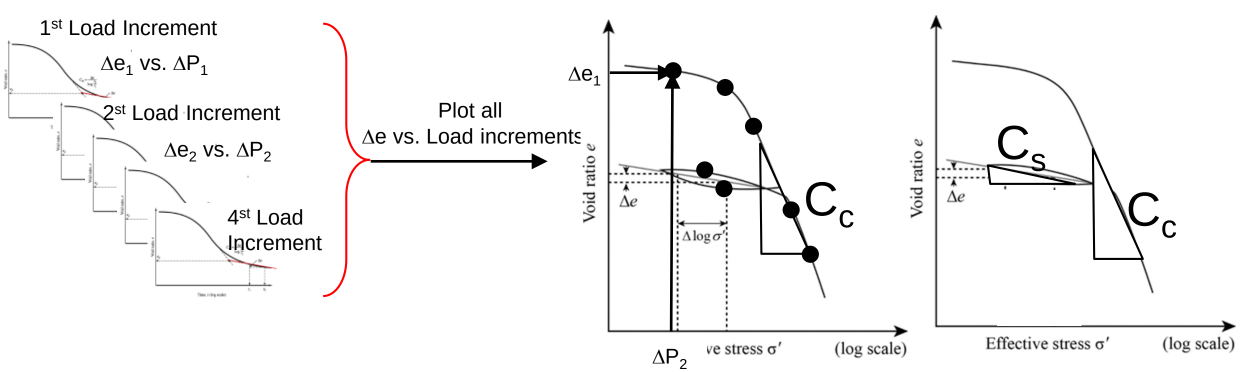
ShearTrac II DSS Equipment
(Courtesy of Geocomp Corporation)



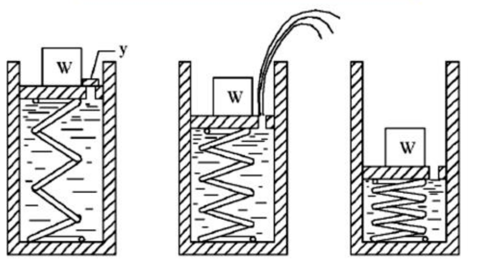
Consolidometer







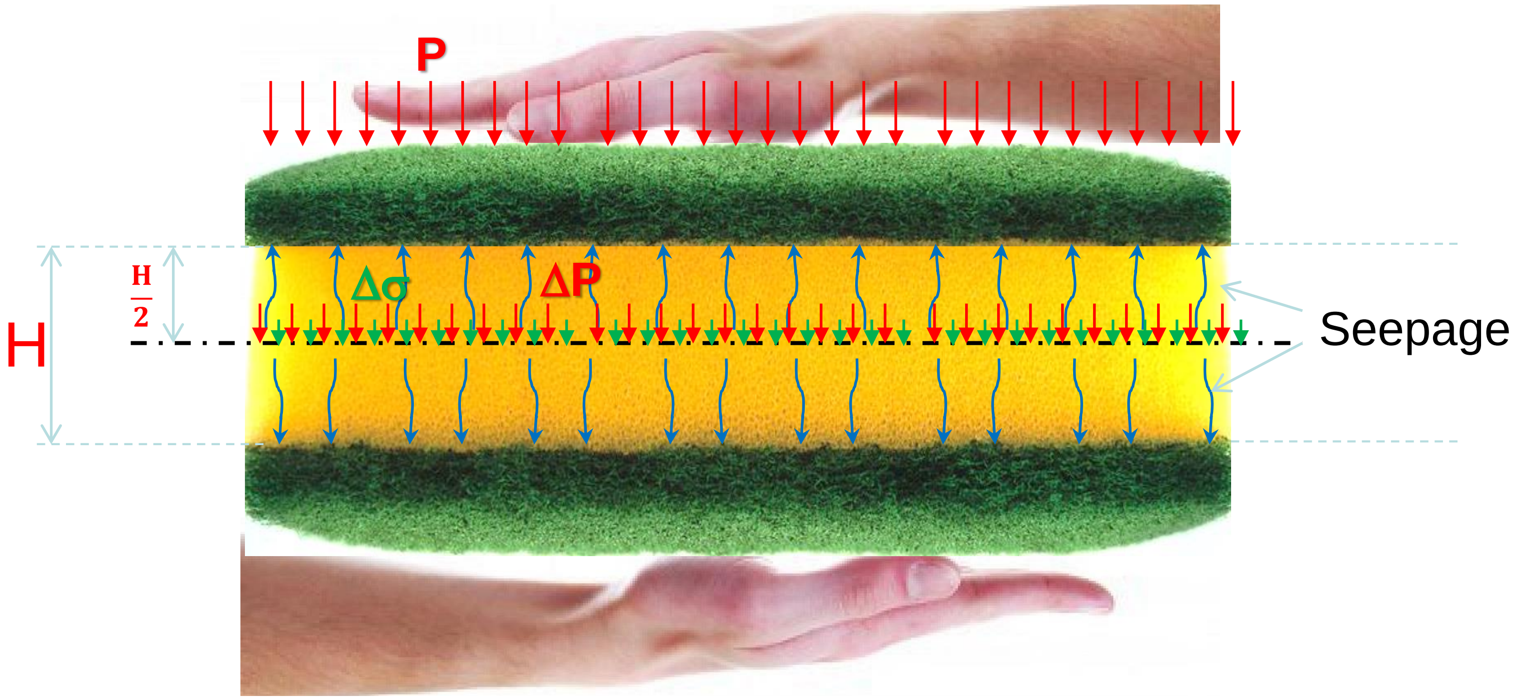
THE SPRING ANALOGY



(a) Initial Loading	(b) Dissipation of Excess Water Pressure	(c) Final Loading
Water takes load	Water dissipating	Water dissipated
Soil (i.e. spring) has no load	Soil starts to	Soil has load

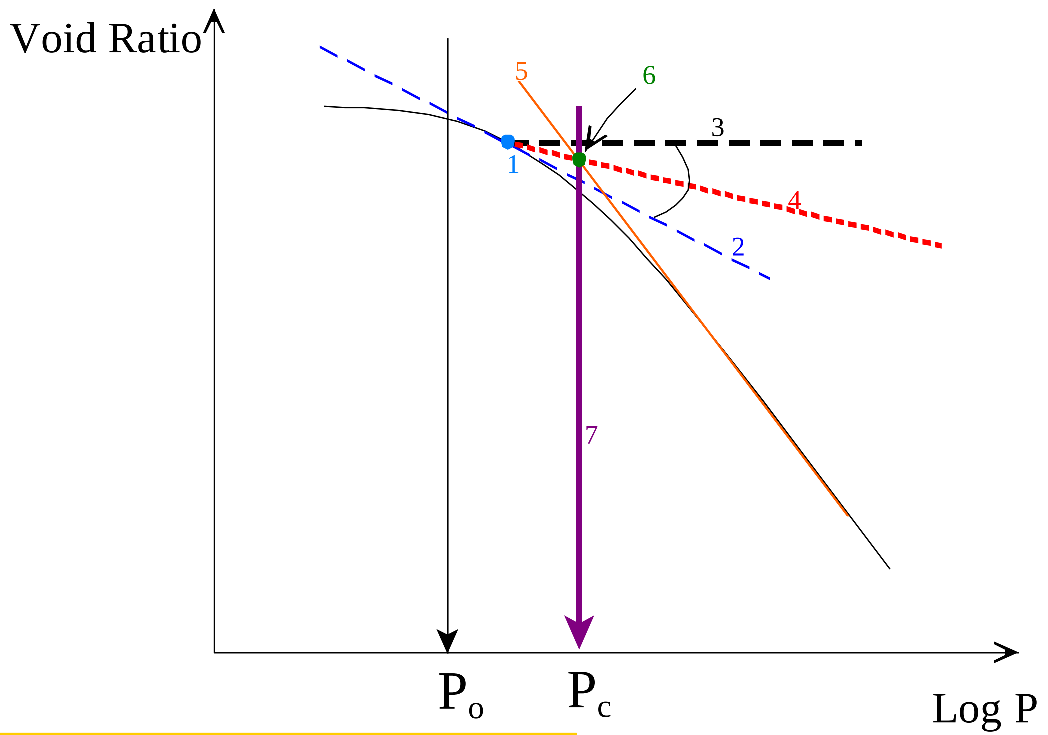
Consolidation Settlement

Assume a fully saturated Sponge



Determining The Preconsolidation Pressure (Pc)

Cassagrande Graphical Method



$OCR = P_c/P_o$

$OCR = 1$ → Normally Consolidated

$OCR > 1$ → Over Consolidated

$OCR > 4$ → Heavily Over Consolidated

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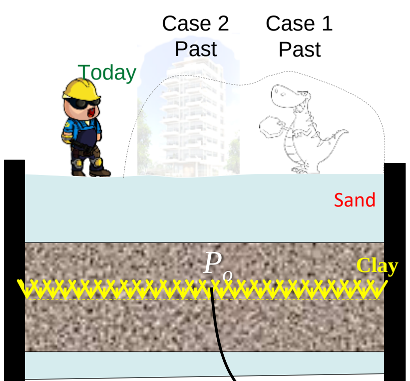
Question

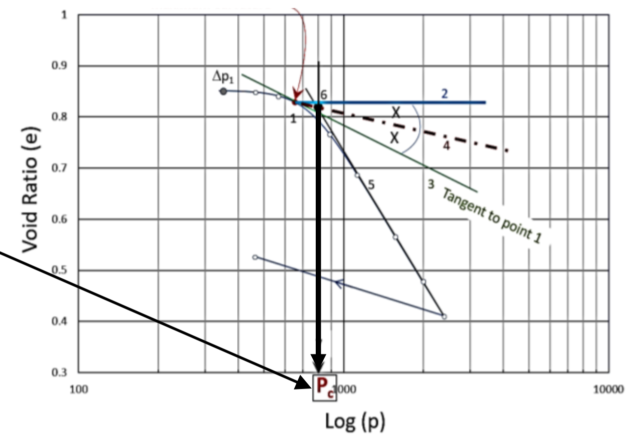
How do you know if the clay layer at the site is



P_o = Vertical effective stress at the mid of the clay layer, It is known

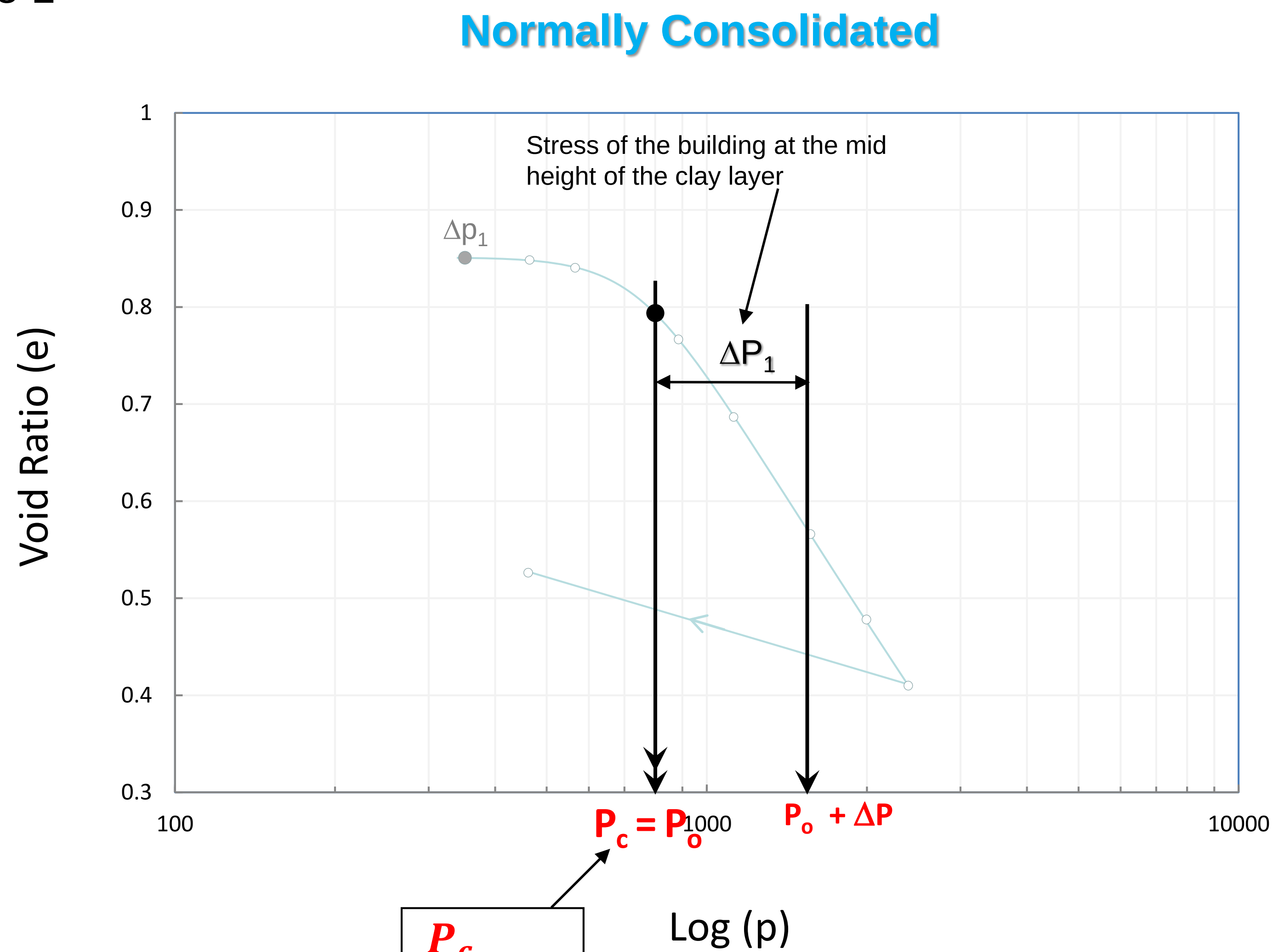
Use Casagrande Graphical Method to determine **Pc**

If $P_c = P_o$ .. Soil is NC
If $P_c > P_o$ .. Soil is OC



normally consolidated or Over-consolidated ???

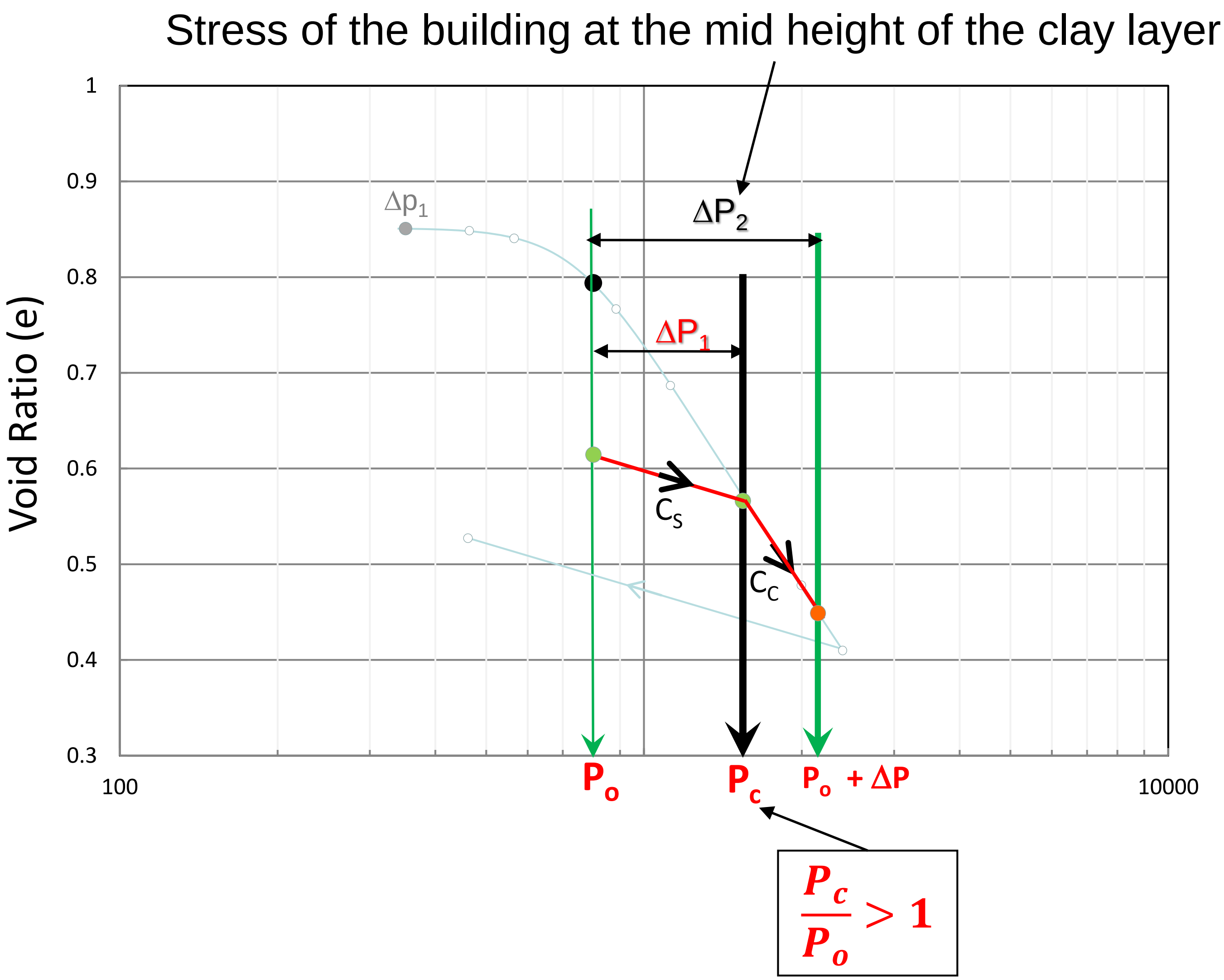
Case 1



$$\frac{P_c}{P_o} = 1$$

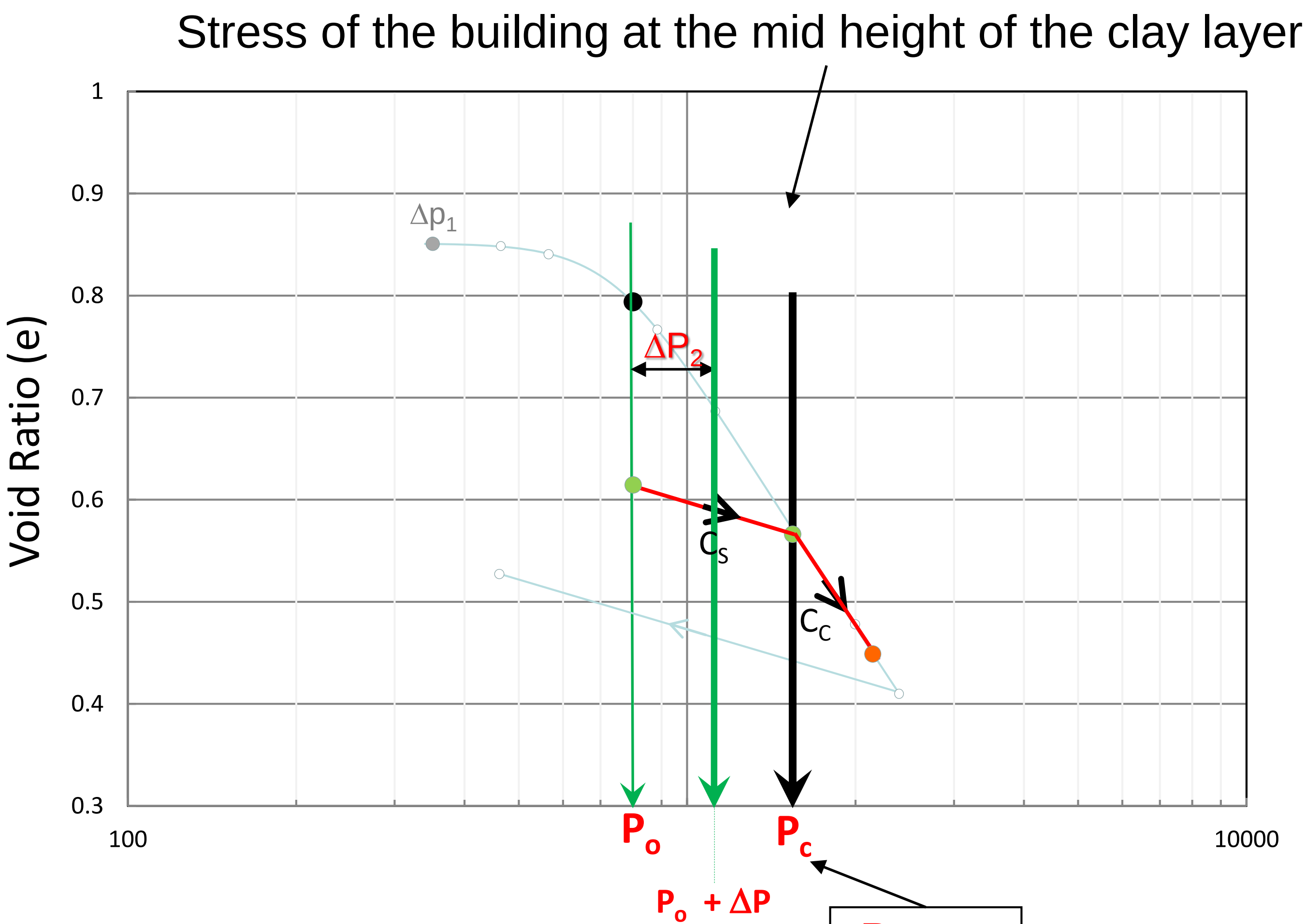
Over-consolidated

Case 2-1



Case 2-2

Over-consolidated



$$\frac{P_c}{P_o} > 1$$