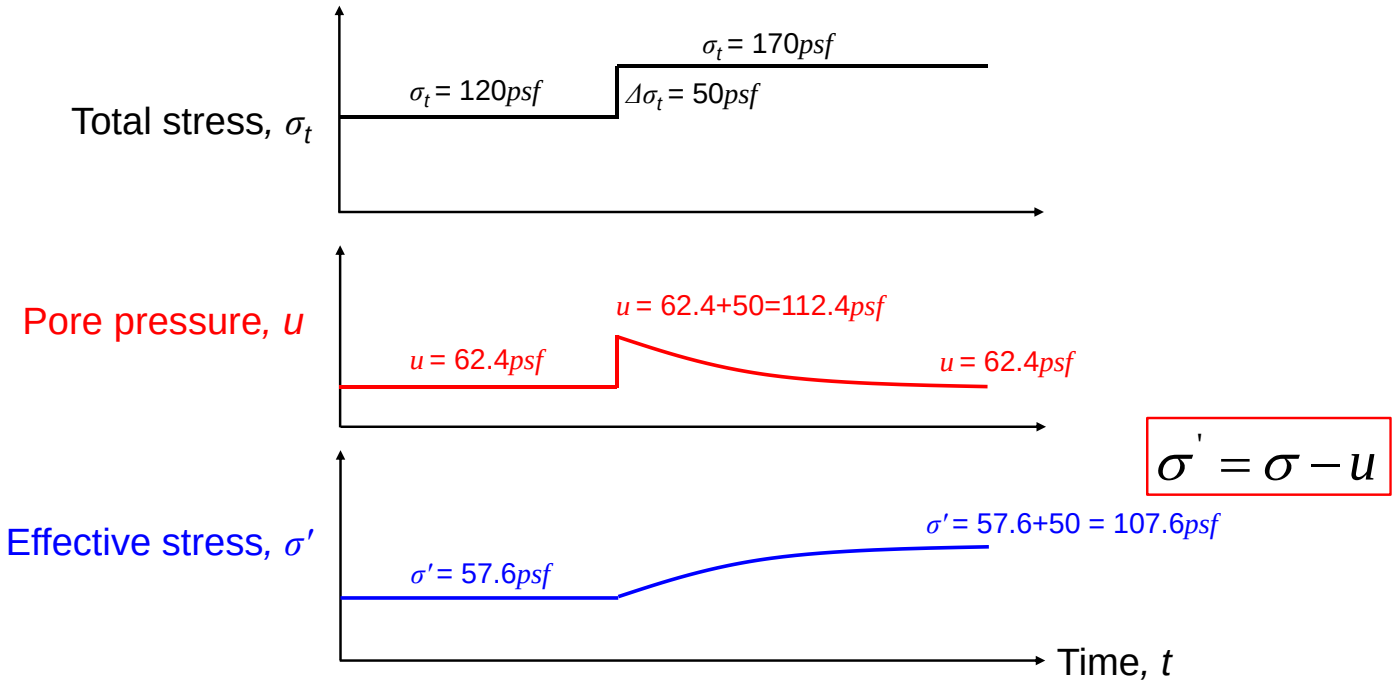
Consolidation II

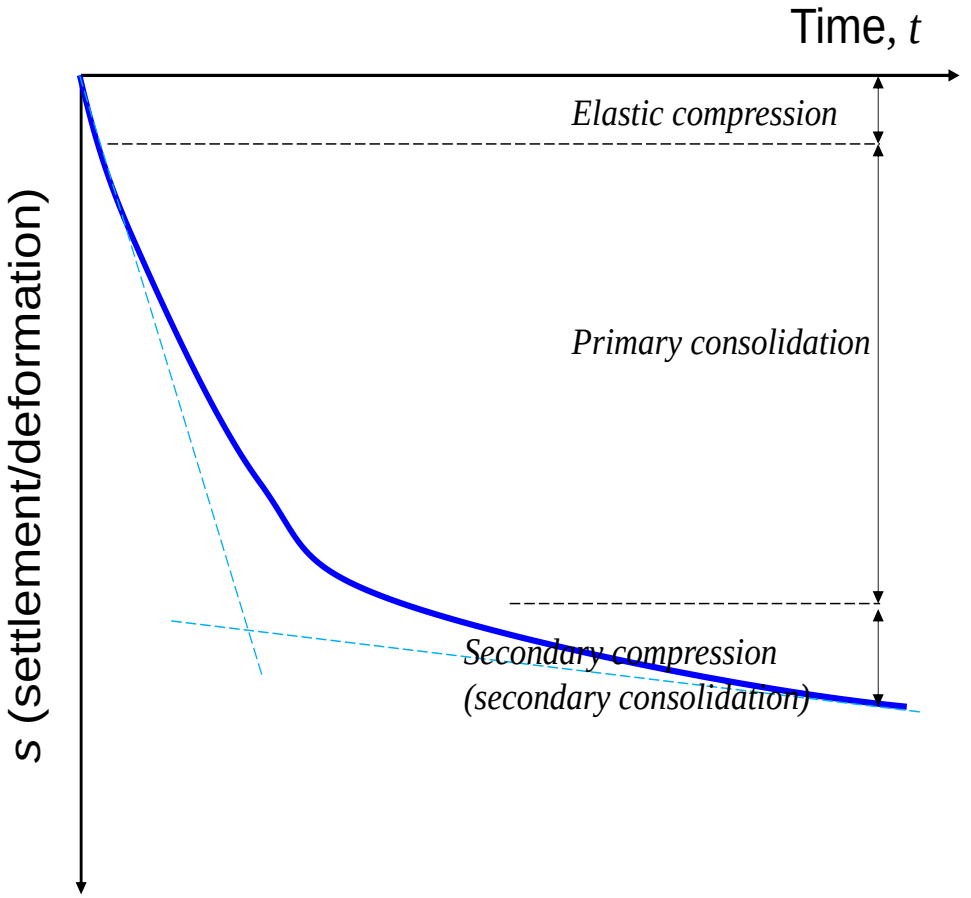
Objectives: *Settlement & Time rate*

- *Modulus of volume (re)compressibility m_v (m_{vr})*
- *Compression index C_c, Recompression index C_r*
- *Pre-consolidation stress σ_c'*
- *Over-consolidation ratio OCR*
- *Initial void ratio e_o*
- *Consolidation settlement analysis*

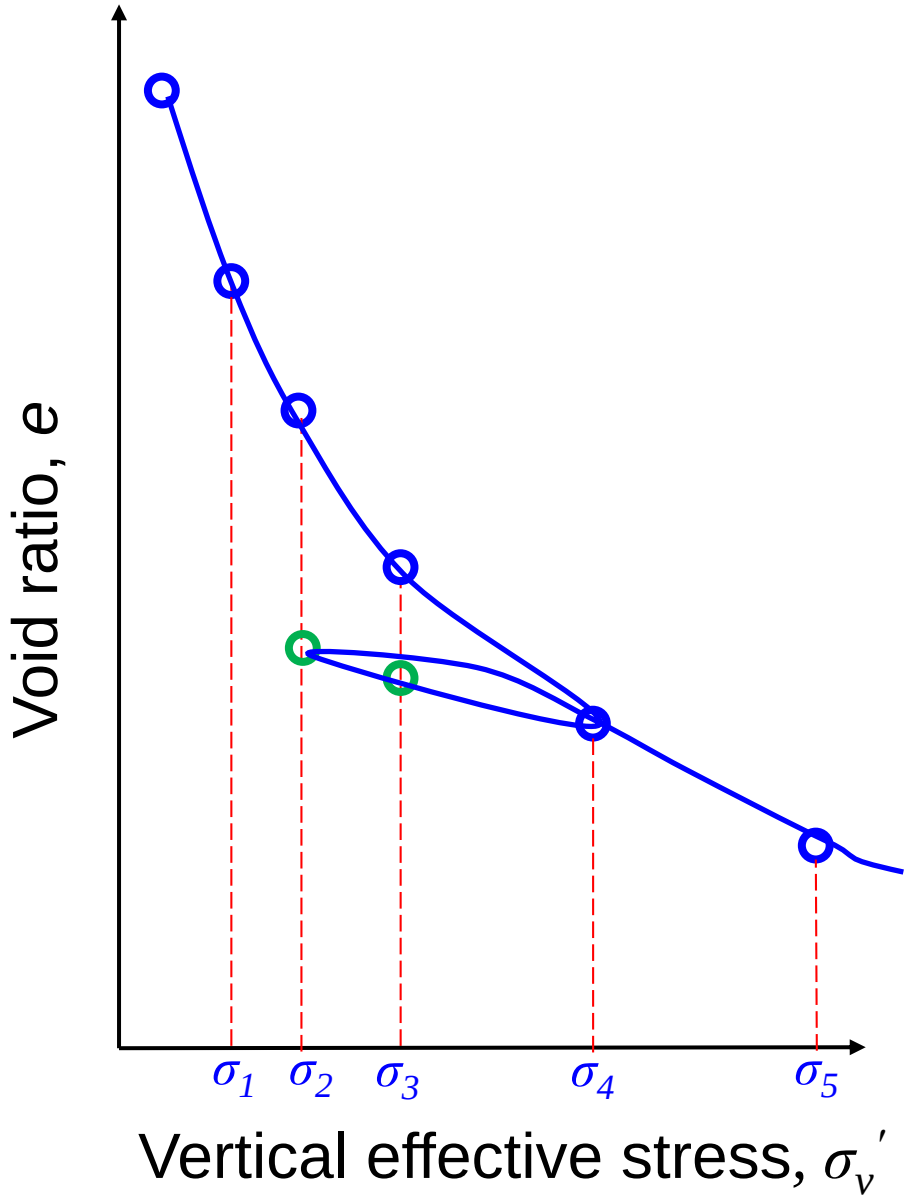
Consolidation



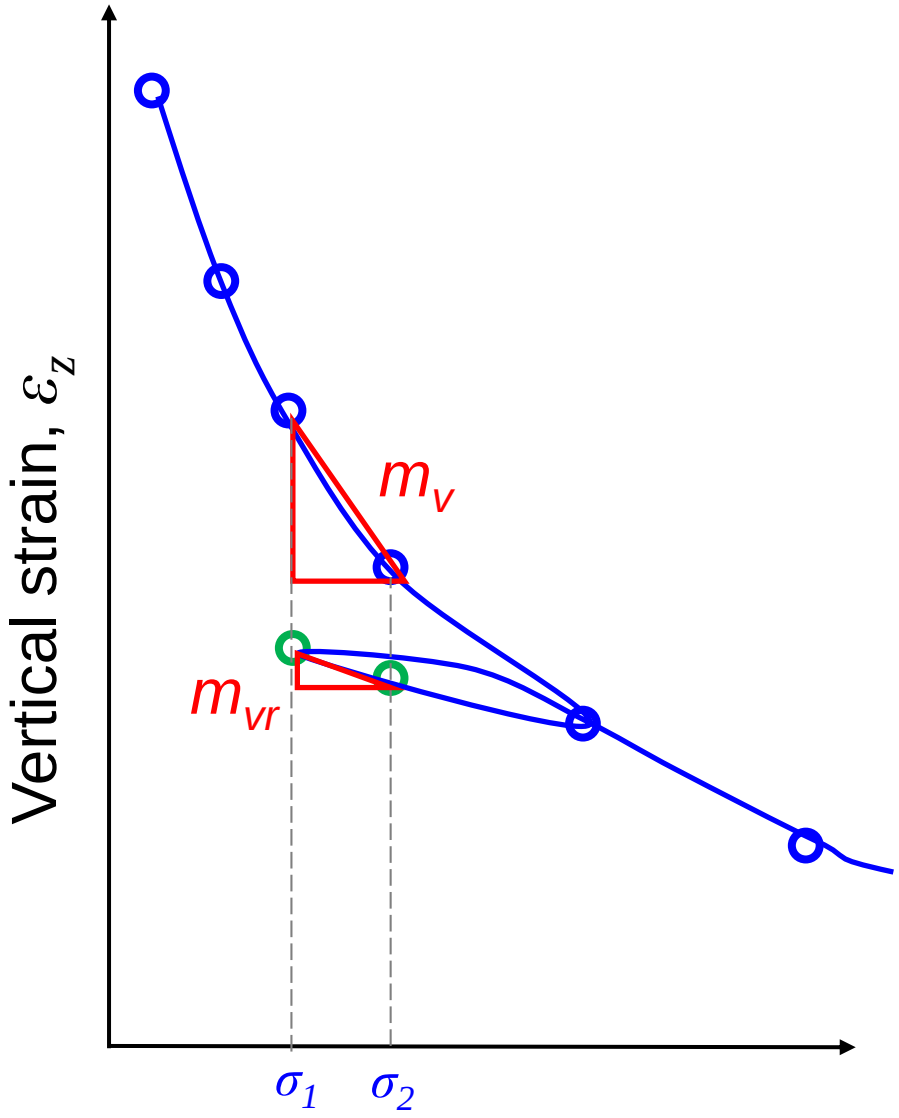
$$\sigma' = \sigma - u$$



Consolidation (Oedometer) Test



m_v, m_{vr}



Modulus of volume (re)compressibility [ft²/lb]

$$m_v = \frac{(\varepsilon_z)_2 - (\varepsilon_z)_1}{(\sigma_z')_2 - (\sigma_z')_1}$$

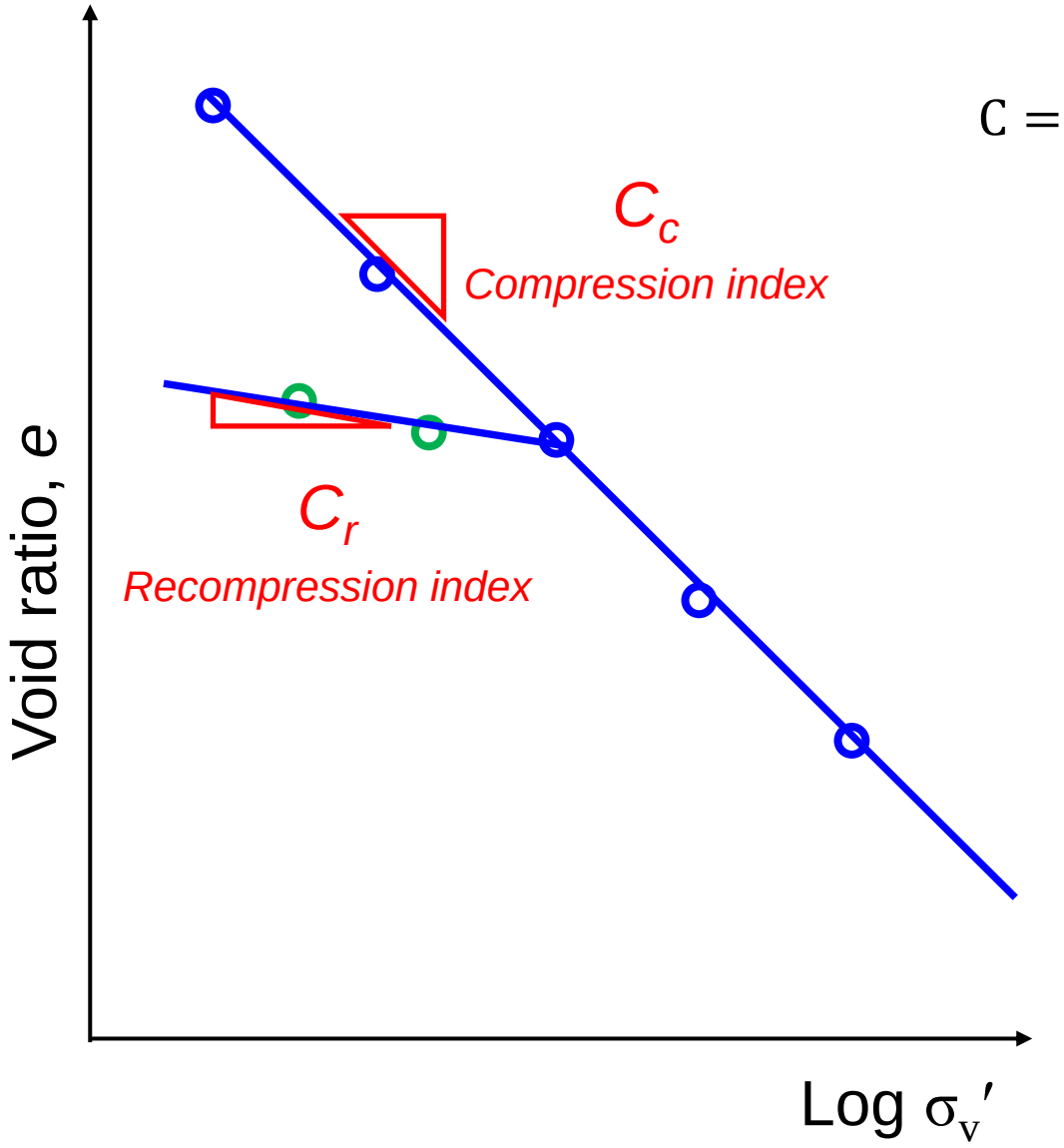
$$\varepsilon_z = \frac{\Delta H}{H_o}$$

$$m_{vr} = \frac{(\varepsilon_z)_2 - (\varepsilon_z)_1}{(\sigma_z')_2 - (\sigma_z')_1}$$

Note: Constrained modulus

$$M = \frac{1}{m_v}$$

Cc, Cr

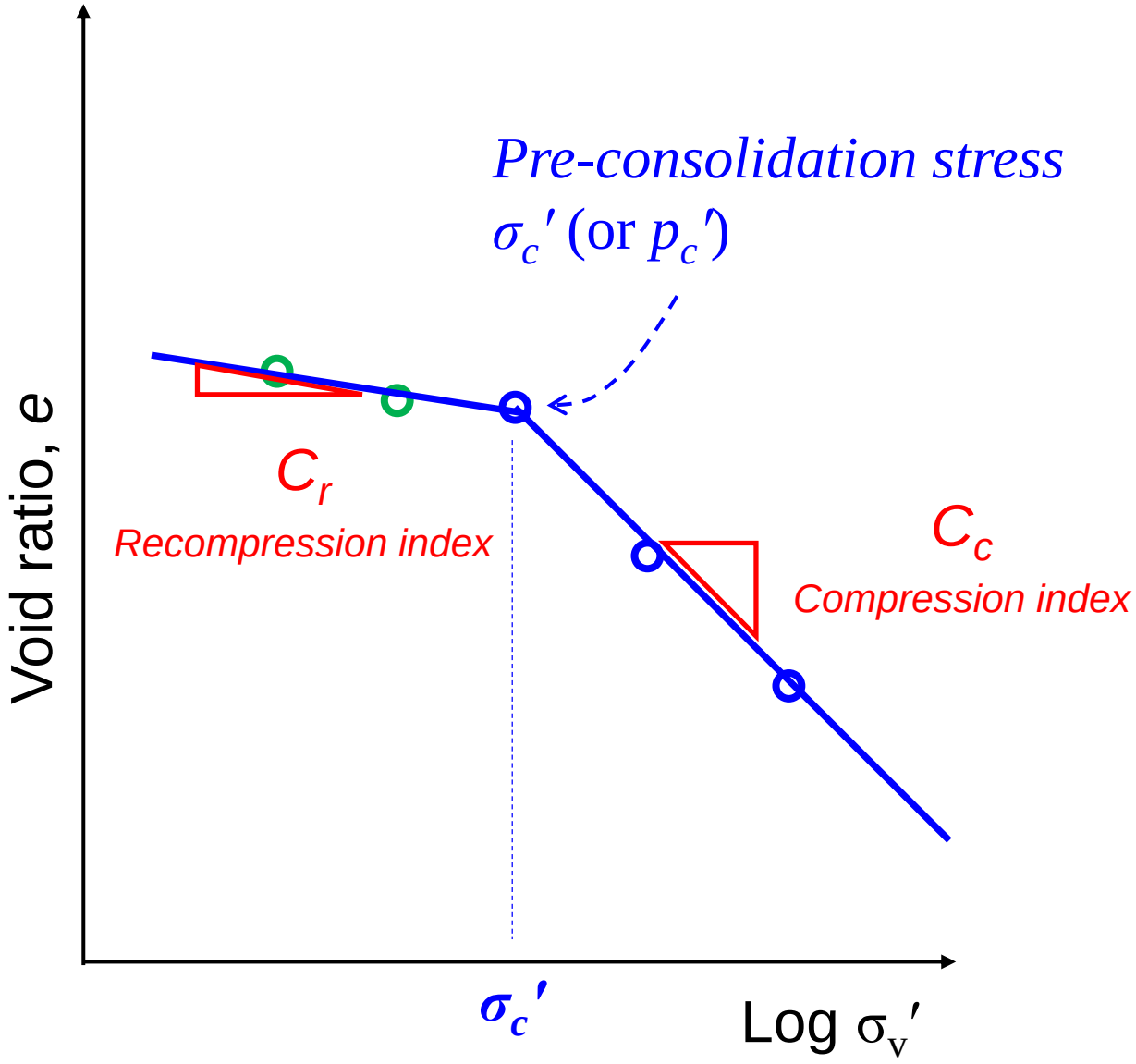


$$C = -\frac{e_2 - e_1}{log(\sigma'_{v2}) - log(\sigma'_{v1})} = -\frac{e_2 - e_1}{log\left(\frac{\sigma'_{v2}}{\sigma'_{v1}}\right)}$$

$$C_c = -\frac{e_2 - e_1}{log\left(\frac{\sigma'_{v2}}{\sigma'_{v1}}\right)}$$

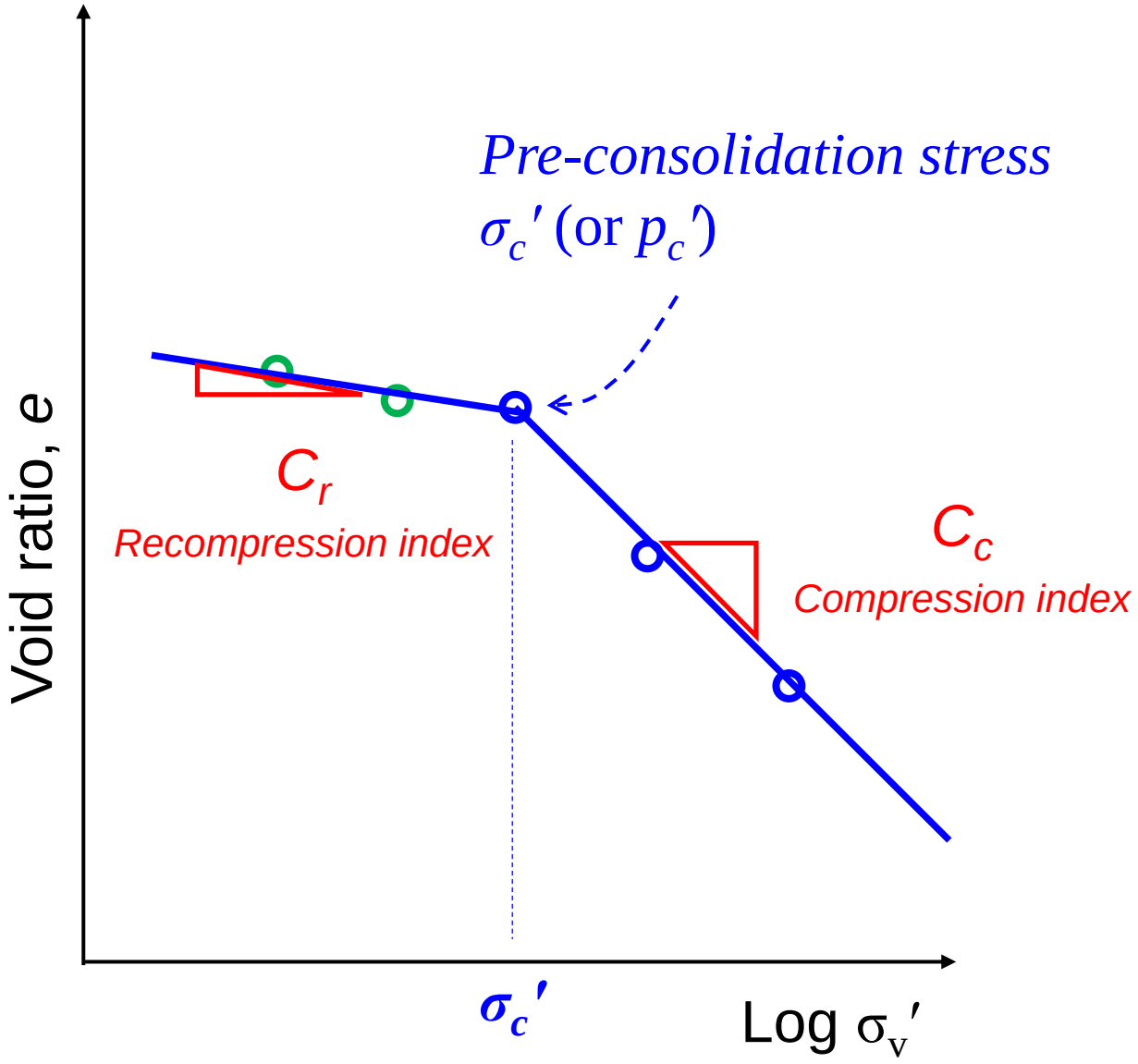
$$C_r = -\frac{e_2 - e_1}{log\left(\frac{\sigma'_{v2}}{\sigma'_{v1}}\right)}$$

Pre-consolidation stress σ_c'



Note:
σ_c' reflects the maximum stress the soil has ever experienced, i.e., maximum stress in history

Over-consolidation ratio (OCR)



$$OCR = \frac{\sigma_c'}{\sigma_{zo}'}$$

σ_{zo}': current vertical effective stress

Normally Consolidated	$\mathrm{OCR} = 1$
Overconsolidated	$\mathrm{OCR} > 1$

Lightly overconsolidated	$1 < \mathrm{OCR} \leq 2$
Heavily overconsolidated	$\mathrm{OCR} > 2$

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Initial void ratio, e_0

Void ratio $e = \frac{V_v}{V_s}$

Volumetric strain $\epsilon_v = \frac{\Delta V}{V} = \frac{\Delta e}{1 + e_0}$

One dimensional loading
(e.g., oedometer test)

$$\epsilon_z = \epsilon_v = \frac{\Delta H}{H_0}$$

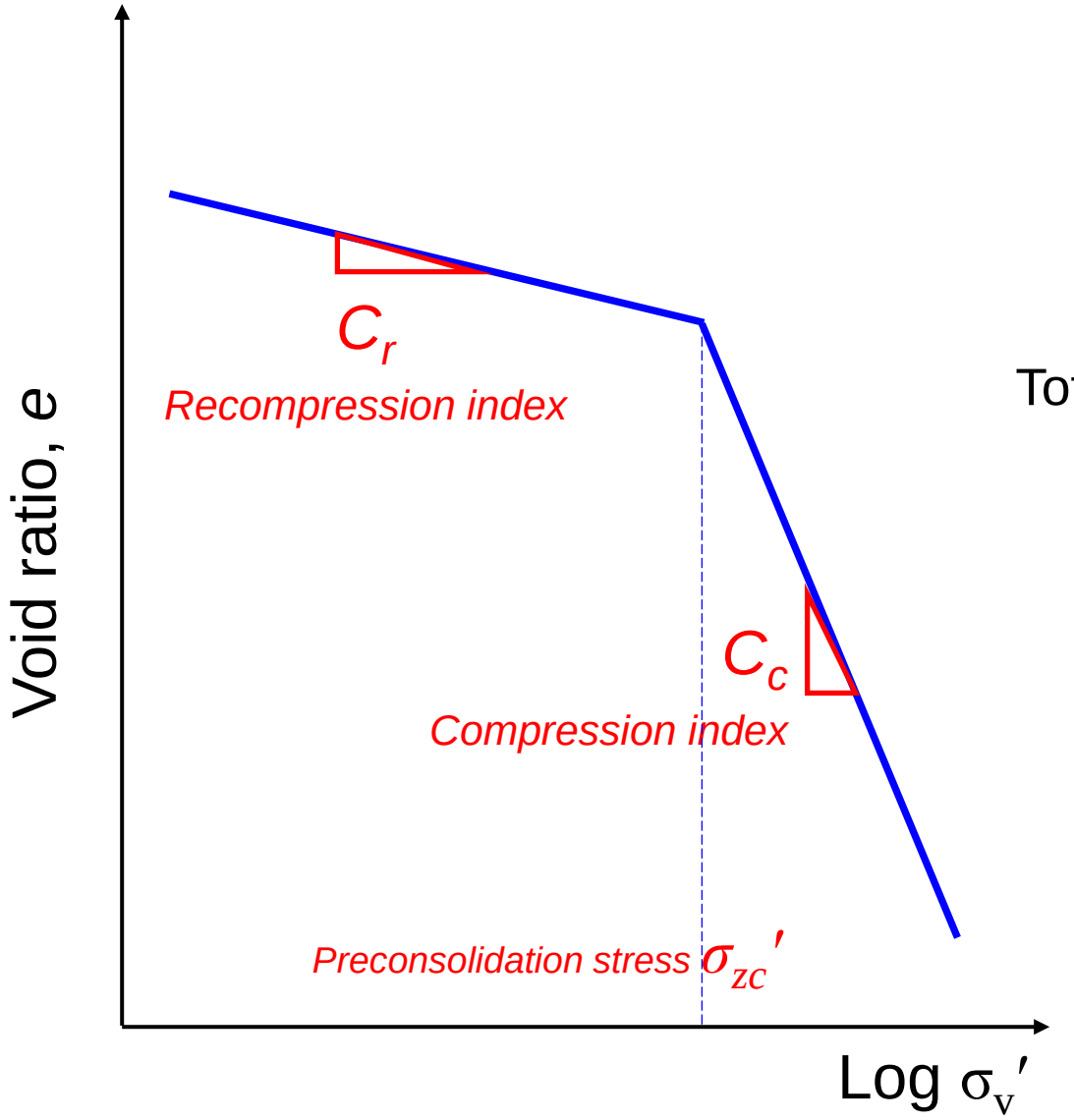
$$\boxed{\frac{\Delta H}{H_0} = \frac{\Delta e}{1+e_0}}$$

$$\frac{H_0 - H_f}{H_0} = \frac{e_0 - e_f}{1+e_0}$$

If saturated,

$$Se = wG_s \Rightarrow e = wG_s$$

Consolidation settlement

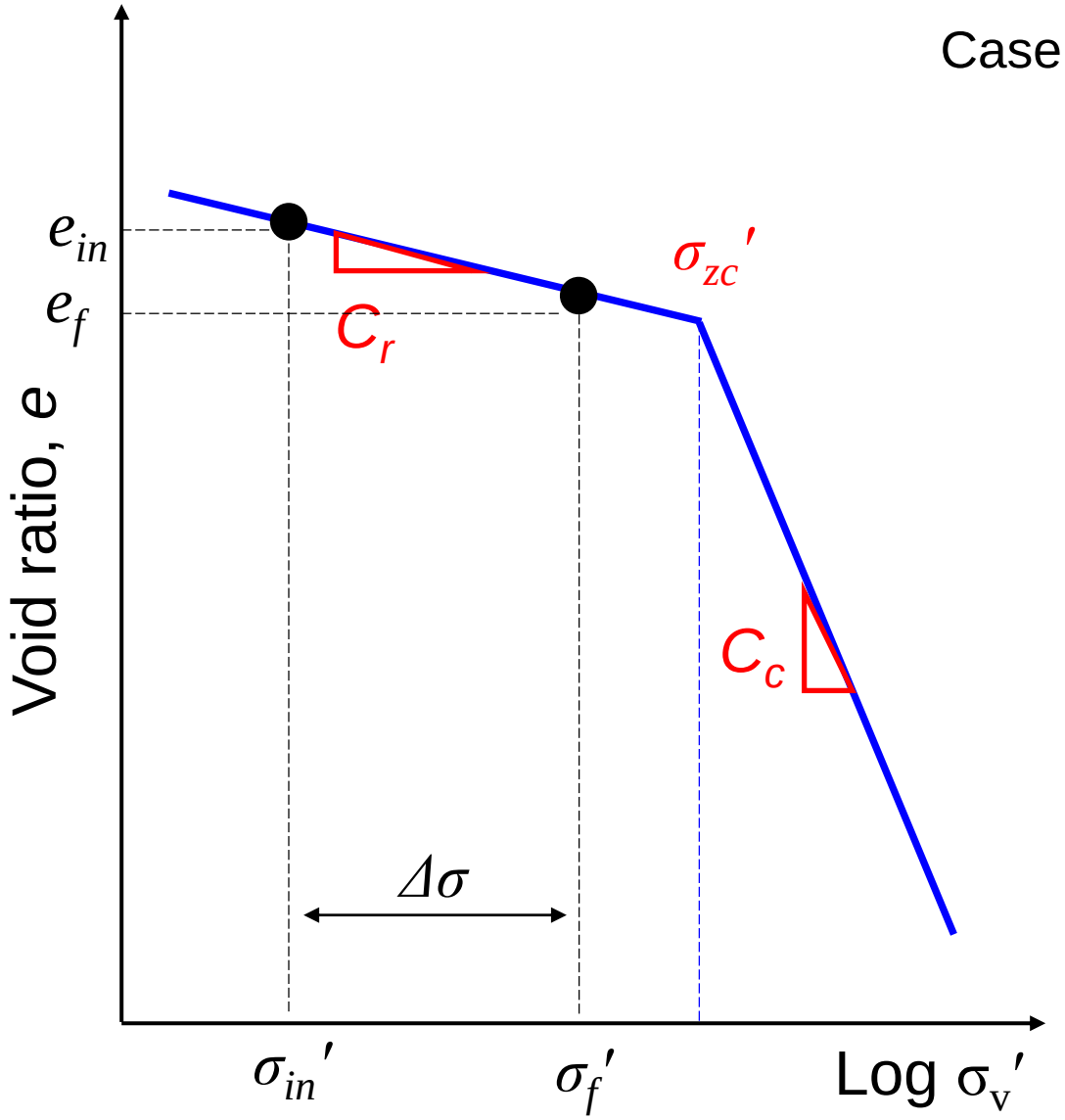


$$\frac{\Delta H}{H_0} = \frac{\Delta e}{1+e_0}$$

Total vertical settlement ΔH: $\Delta H = H_0\left(\frac{\Delta e}{1+e_0}\right)$

$\Delta e \sim \Delta \sigma_z'$ ← Oedometer test results

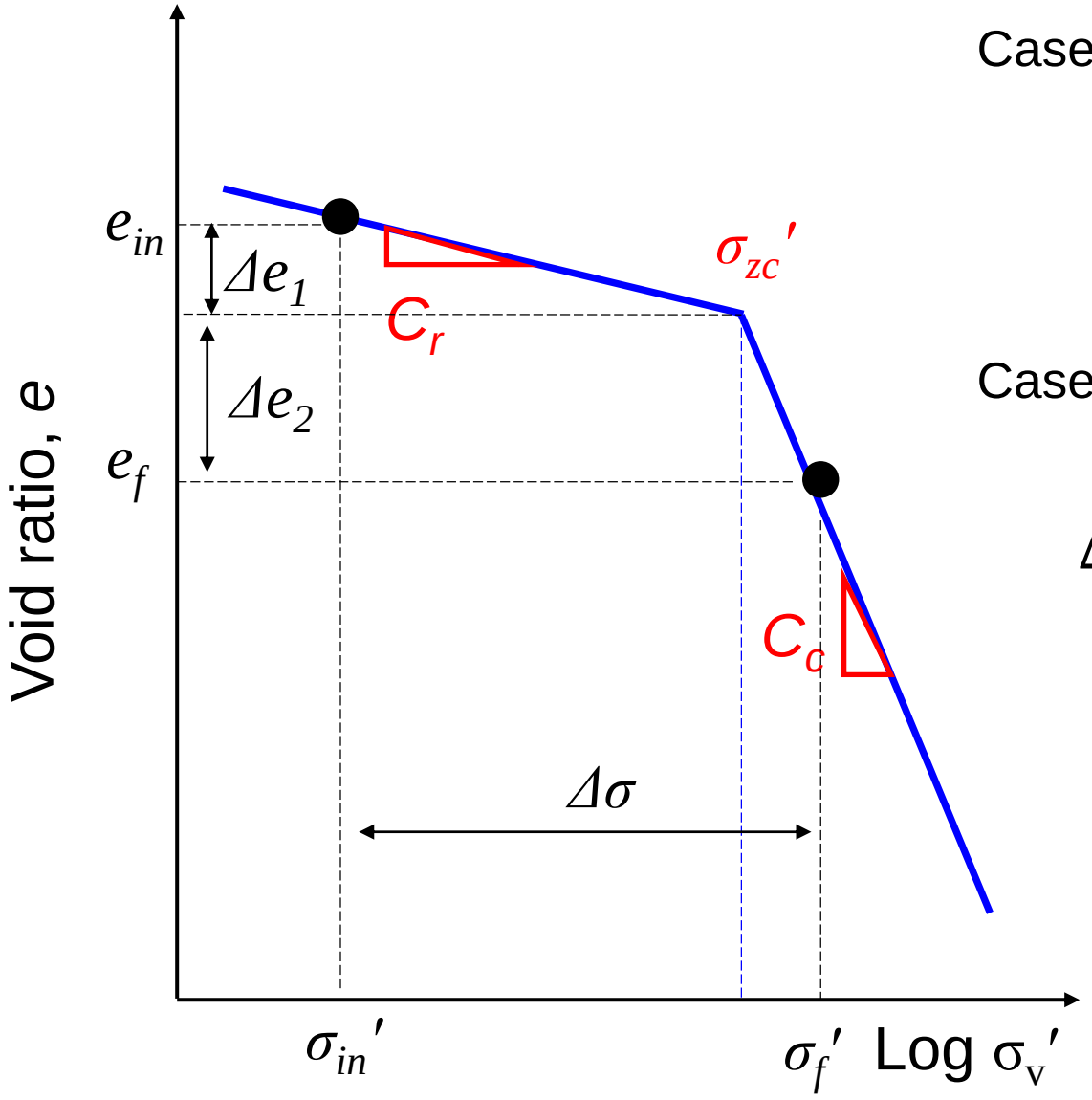
Consolidation settlement



Case 1: $\sigma_{in}' + \Delta\sigma = \sigma_f' < \sigma_{zc}'$

$$\Delta e = C_r log\left(\frac{\sigma_f'}{\sigma_{in}'}\right)$$

Consolidation settlement



Case 1: $\sigma'_{in} + \Delta\sigma = \sigma'_f < \sigma'_{zc}$

$$\Delta e = C_r log\left(\frac{\sigma'_f}{\sigma'_{in}}\right)$$

Case 2: $\sigma'_{in} + \Delta\sigma = \sigma'_f > \sigma'_{zc}$

$$\Delta e = C_r log\left(\frac{\sigma'_{zc}}{\sigma'_{in}}\right) + C_c log\left(\frac{\sigma'_f}{\sigma'_{zc}}\right)$$

$$\Delta H = H_0\left(\frac{\Delta e}{1 + e_0}\right)$$

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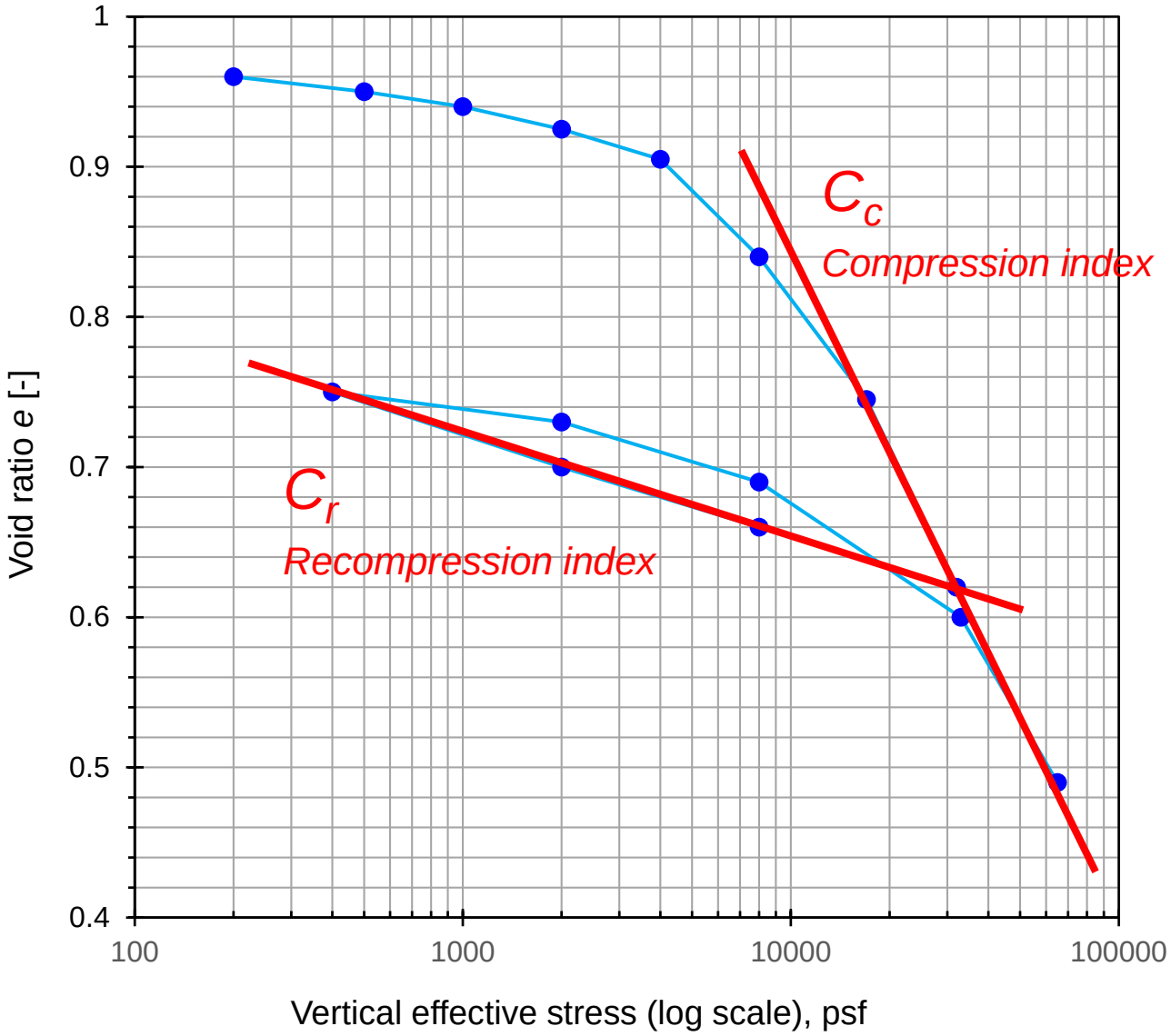
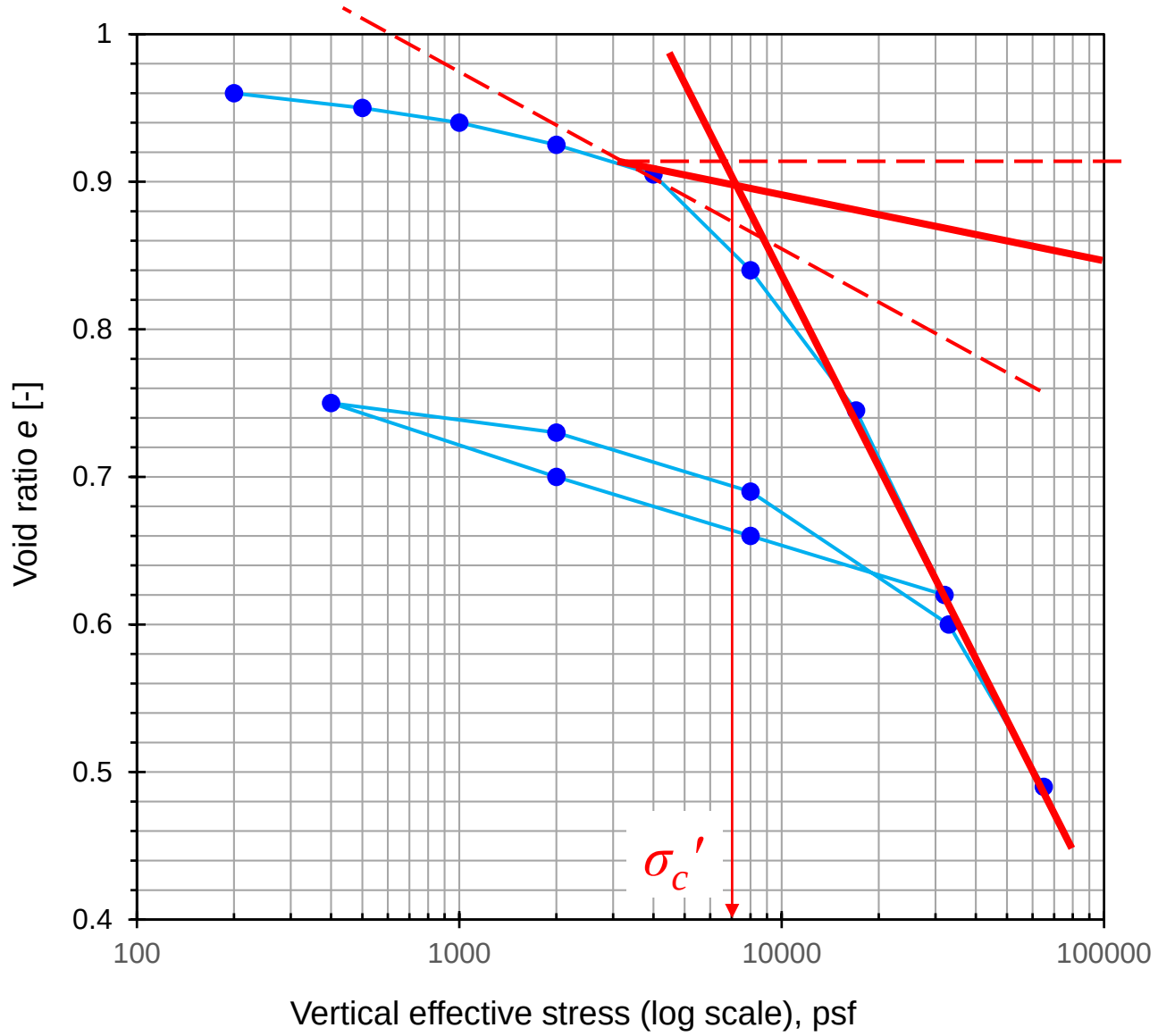
Oedometer test results: C_c and C_r



$$C_c = -\frac{e_1 - e_2}{\log\left(\frac{\sigma_1'}{\sigma_2'}\right)} = -\frac{0.745 - 0.49}{\log\left(\frac{18000}{65000}\right)} = 0.47$$

$$C_r = -\frac{e_1 - e_2}{\log\left(\frac{\sigma_1'}{\sigma_2'}\right)} = -\frac{0.75 - 0.62}{\log\left(\frac{400}{31000}\right)} = 0.07$$

Oedometer test results: σ_c'



Past maximum vertical effective stress

$$\sigma_c'$$

- Casagrande's method

$$\sigma_c' = 7000\,psf$$