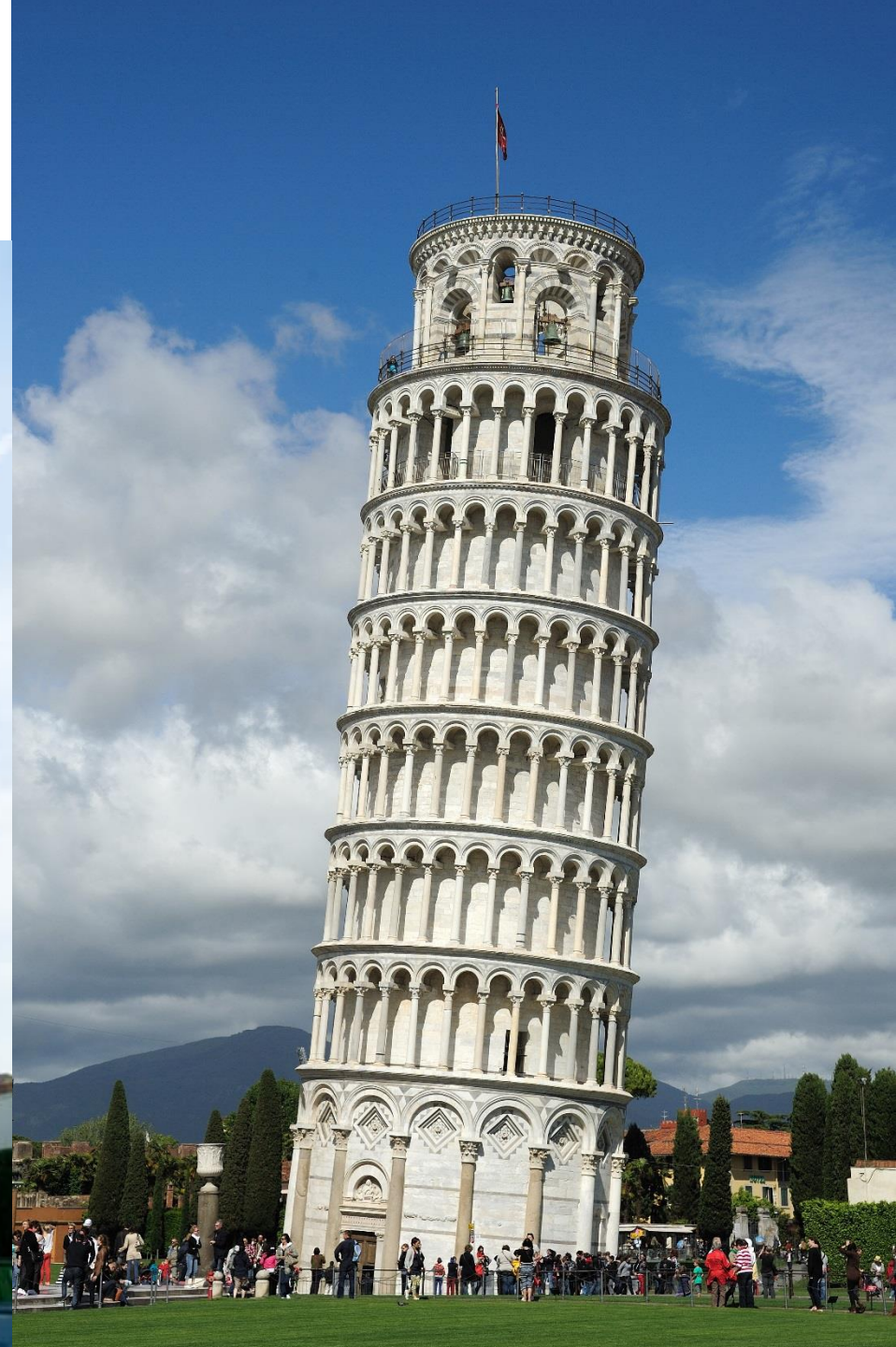
Consolidation Theory

Objectives: *Settlement & Time rate*

- *Consolidation?*
- *Difference between compaction and consolidation*
- *Excess (or transient) pore pressure?*
- *Drained vs. undrained?*
- *Primary and secondary consolidation?*
- *Lab consolidation test (i.e., oedometer test)*
- *Compression index C_c, Recompression index C_r*

Leaning Tower of Pisa



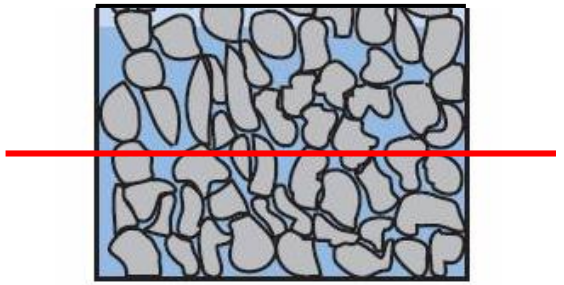
Review – Total/Effective Stress

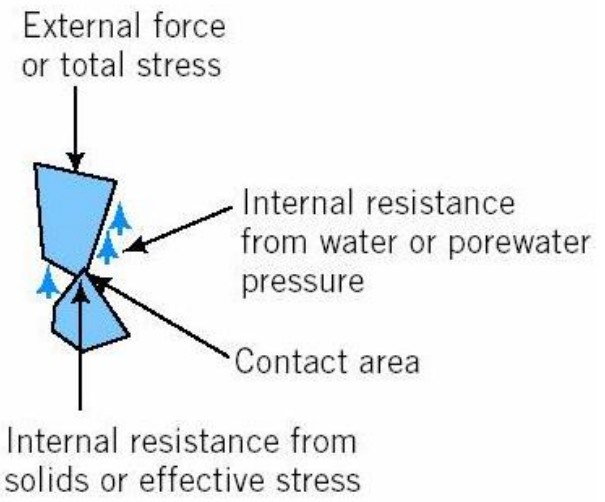
Principle of Effective Stress

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

$$\sigma\left(= \sigma_z\right) = \gamma_t z$$

$$u = \gamma_w z$$

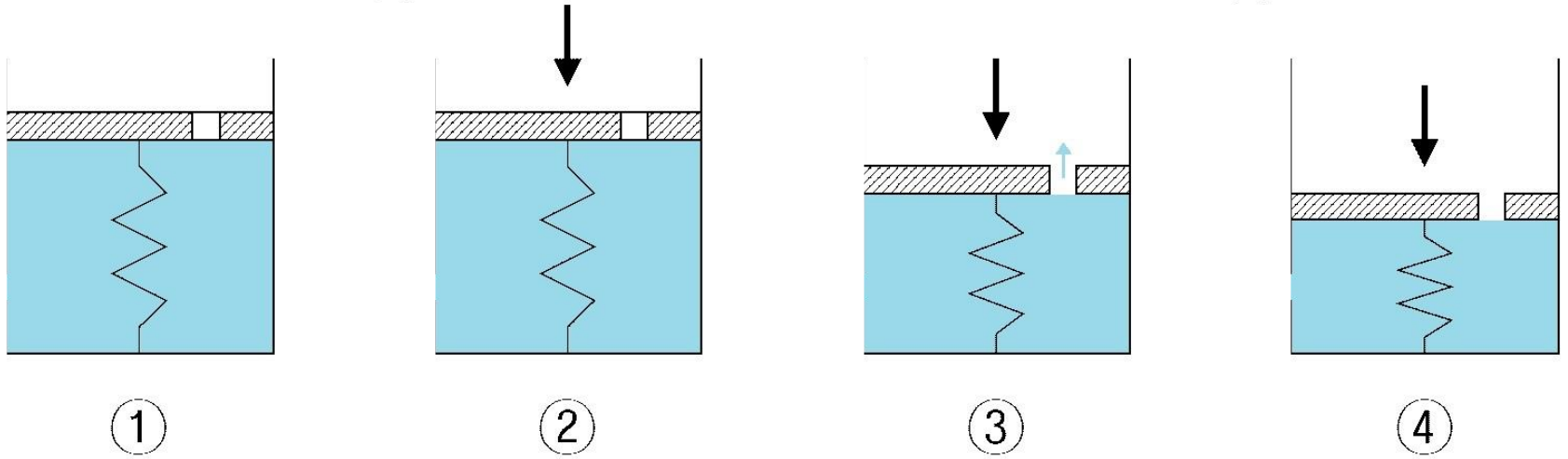




- *Load is carried by both the solid skeleton and the fluid.*
- *Applies only to normal stresses not shear stresses.*
- *Applies only to saturated soils*
- *Soil deformation is determined by effective stress, not total stress.*

Consolidation

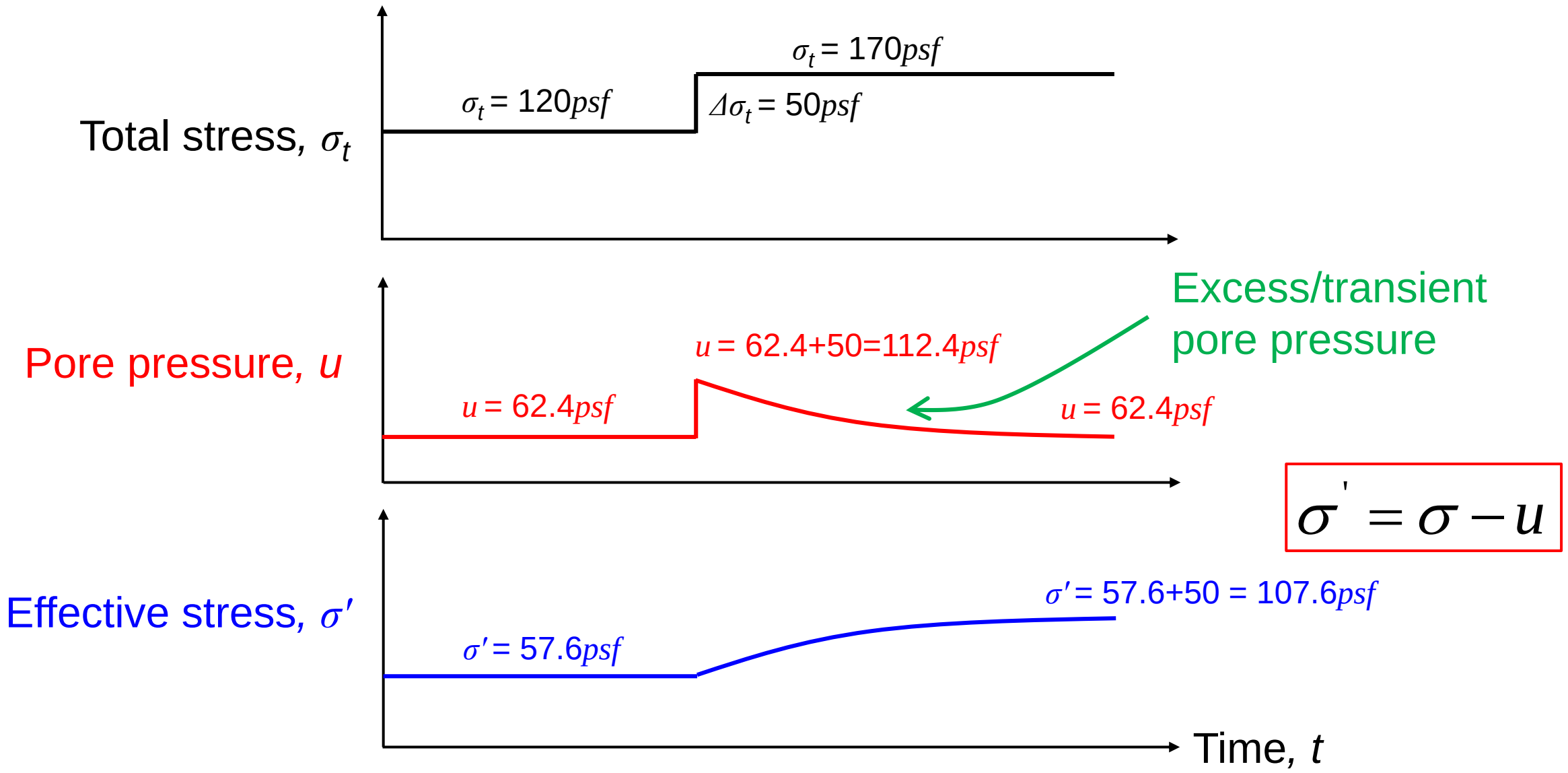
Consolidation The time-dependent settlement of soils resulting from the expulsion of **water** from the soil pores.



In a confined space, the water phase is incompressible, and is ‘stronger’ than the soil skeleton.

Compaction Densification of soils through expulsion of **air** by mechanical means

Consolidation



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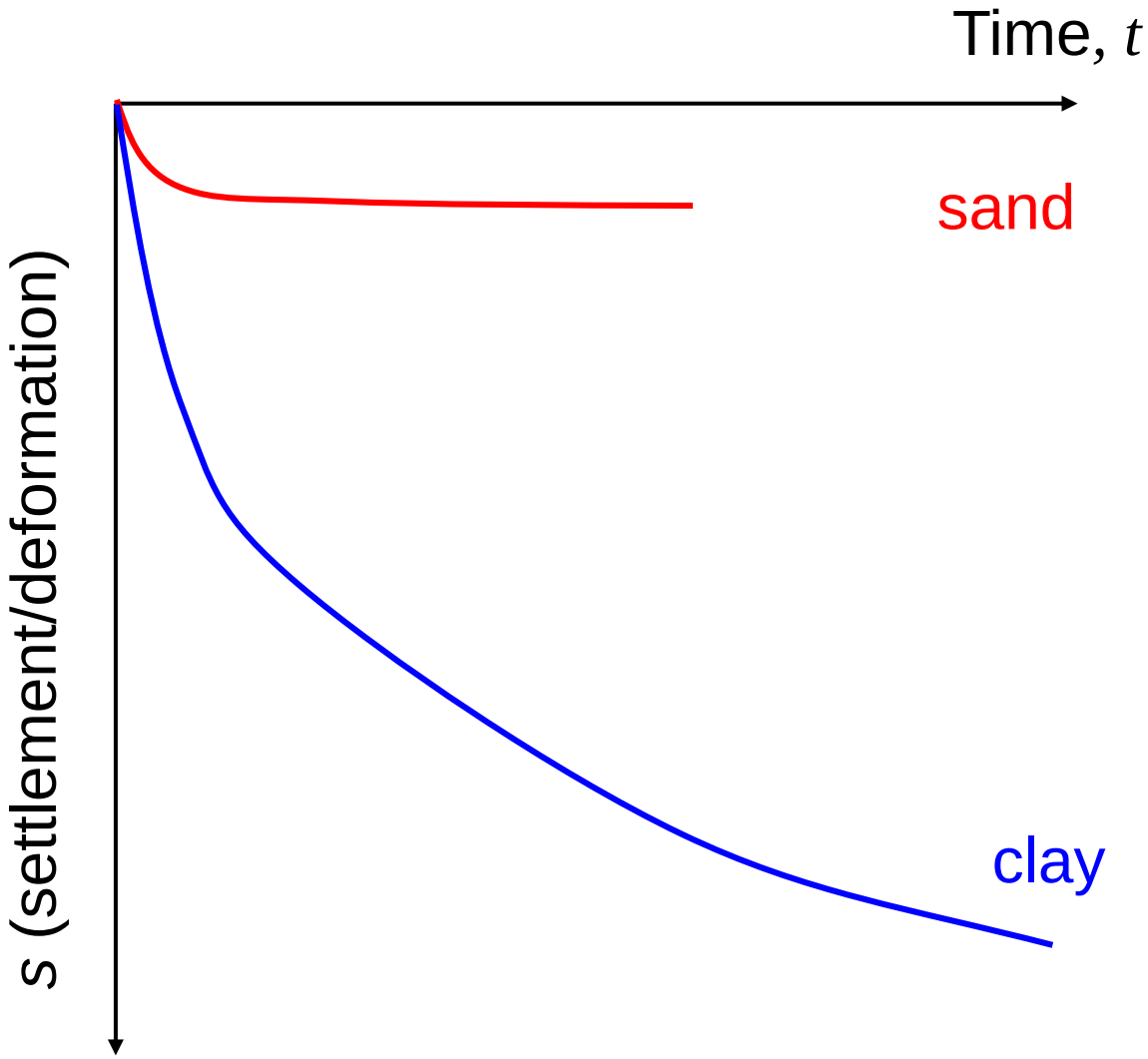
Drained vs. Undrained



***Drained*:** excessive pore pressure has dissipated; use effective stress for analysis.

***Undrained*:** pore water does not yet have time to escape; soil can be treated as a solid+water mixture; use total stress for analysis.

Drained vs. Undrained

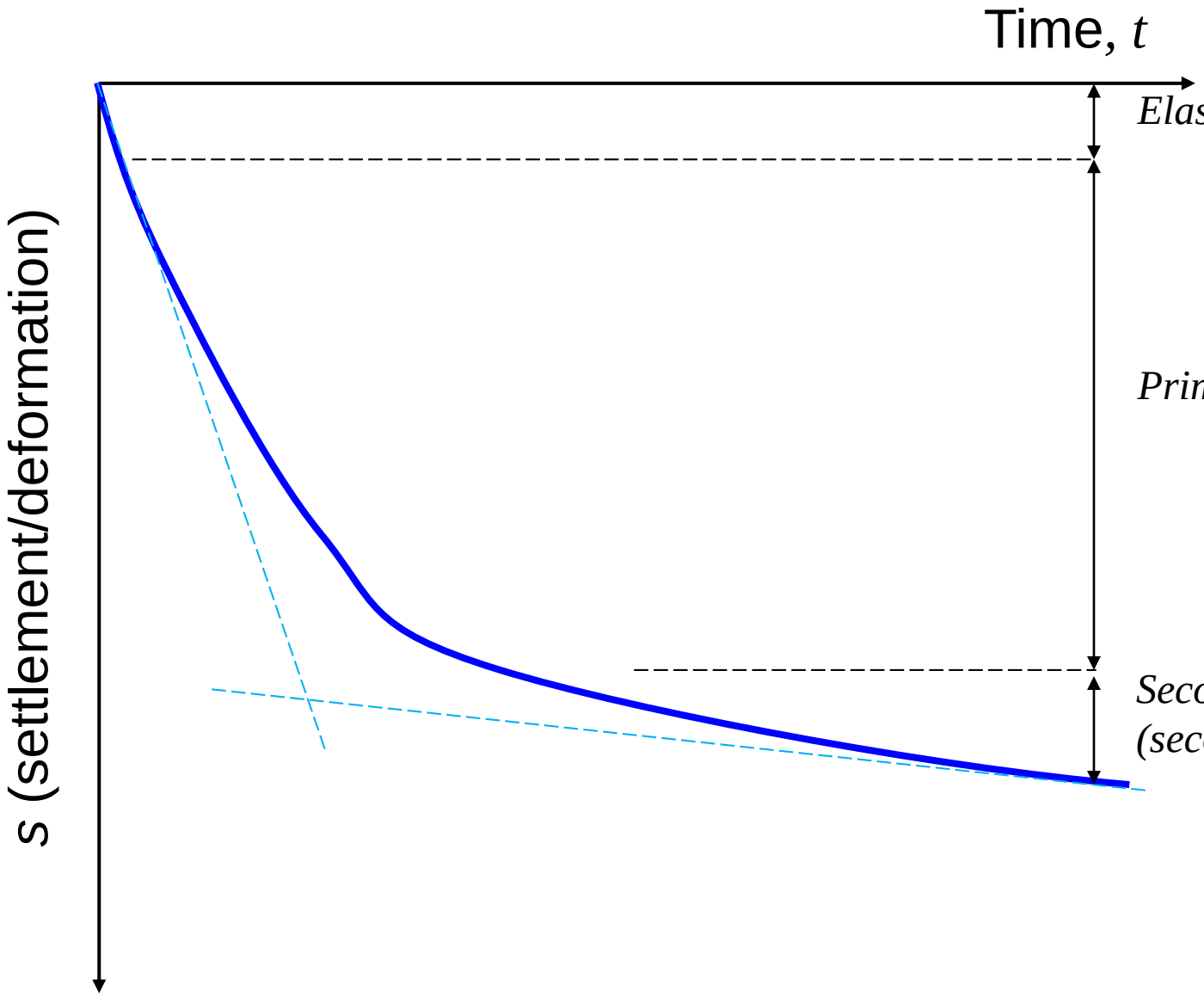
Coarse-grained:

- high permeability, good drainage capability;
- short period of pore pressure dissipation;
- consolidation is not a critical issue in engineering design.

Fine-grained:

- low permeability, poor drainage capability;
- long period of pore pressure dissipation;
- consolidation a critical issue in engineering design.

Primary vs. Secondary Consolidation



Elastic compression

immediate response to change of total stress

Primary consolidation

time-dependent response caused by expulsion of water

Secondary compression
(secondary consolidation)

time-dependent response caused by the change of soil fabric (internal soil structure) after the primary consolidation

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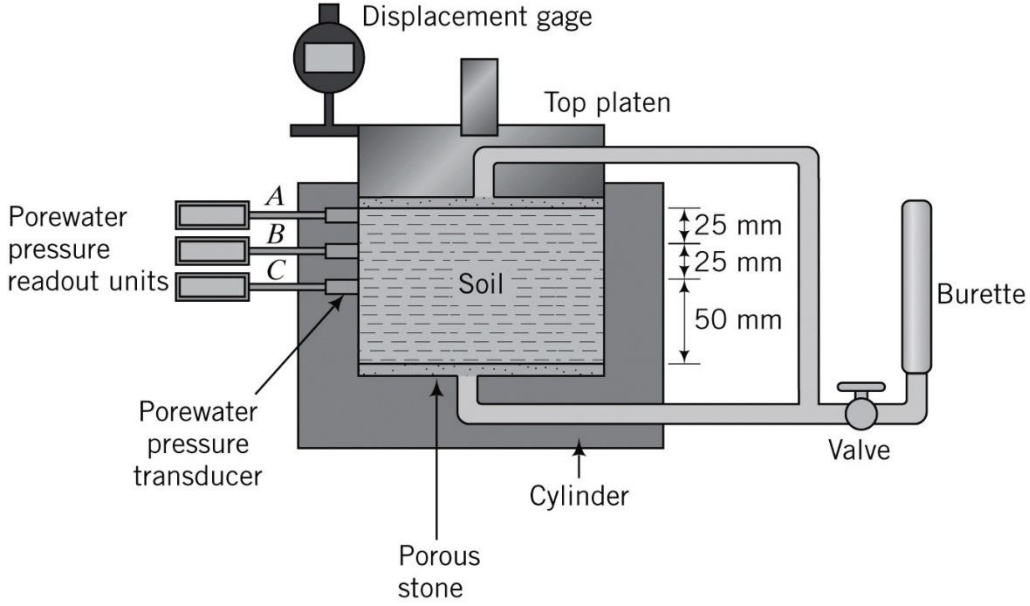
- *Lab consolidation test (i.e., oedometer test): drainage path*
- *Compression index C_c, Recompression index C_r*

One-Dimensional Consolidation

Oedometer test

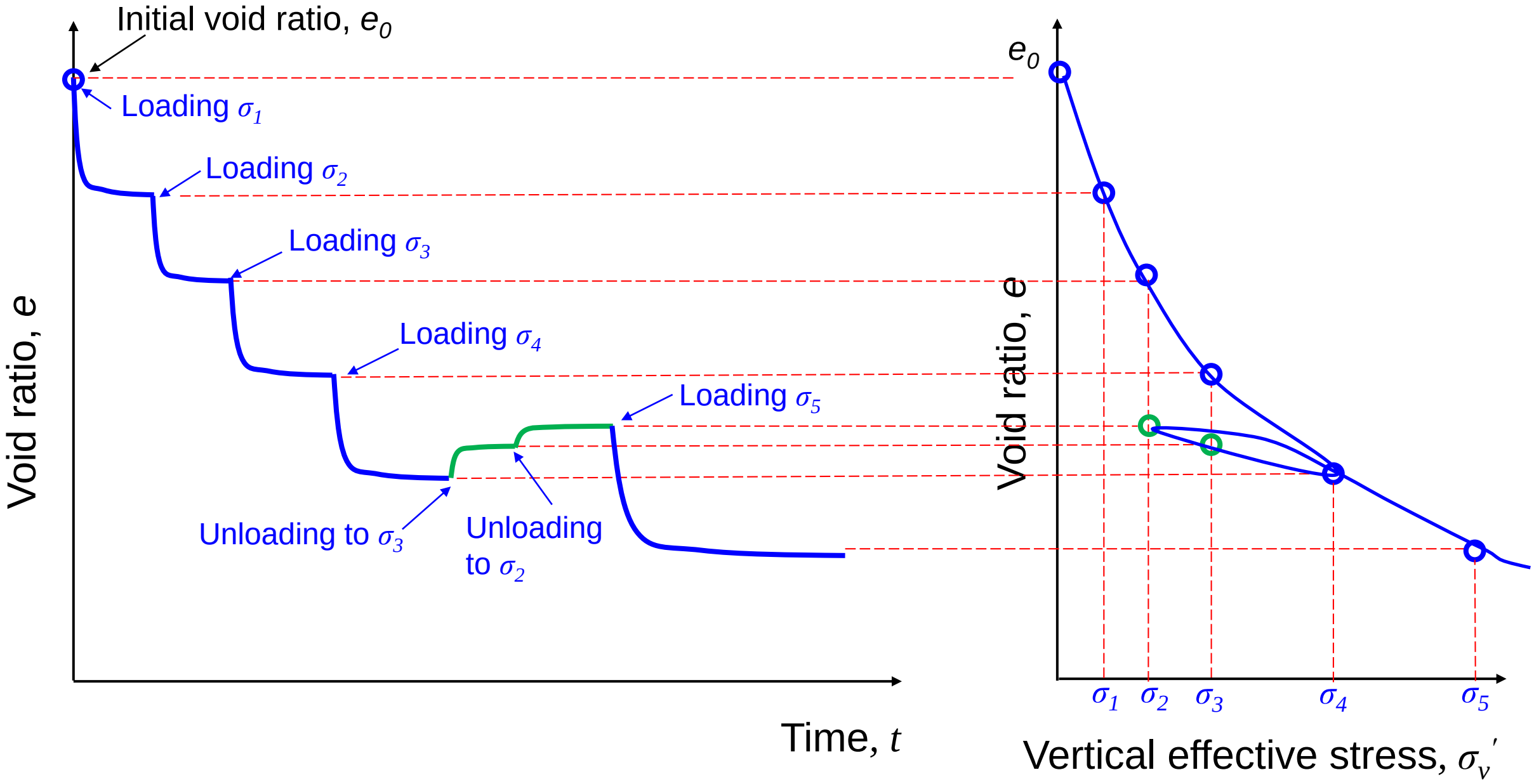


Drainage path - the longest distance that a fluid element travels to exit the soil sample.

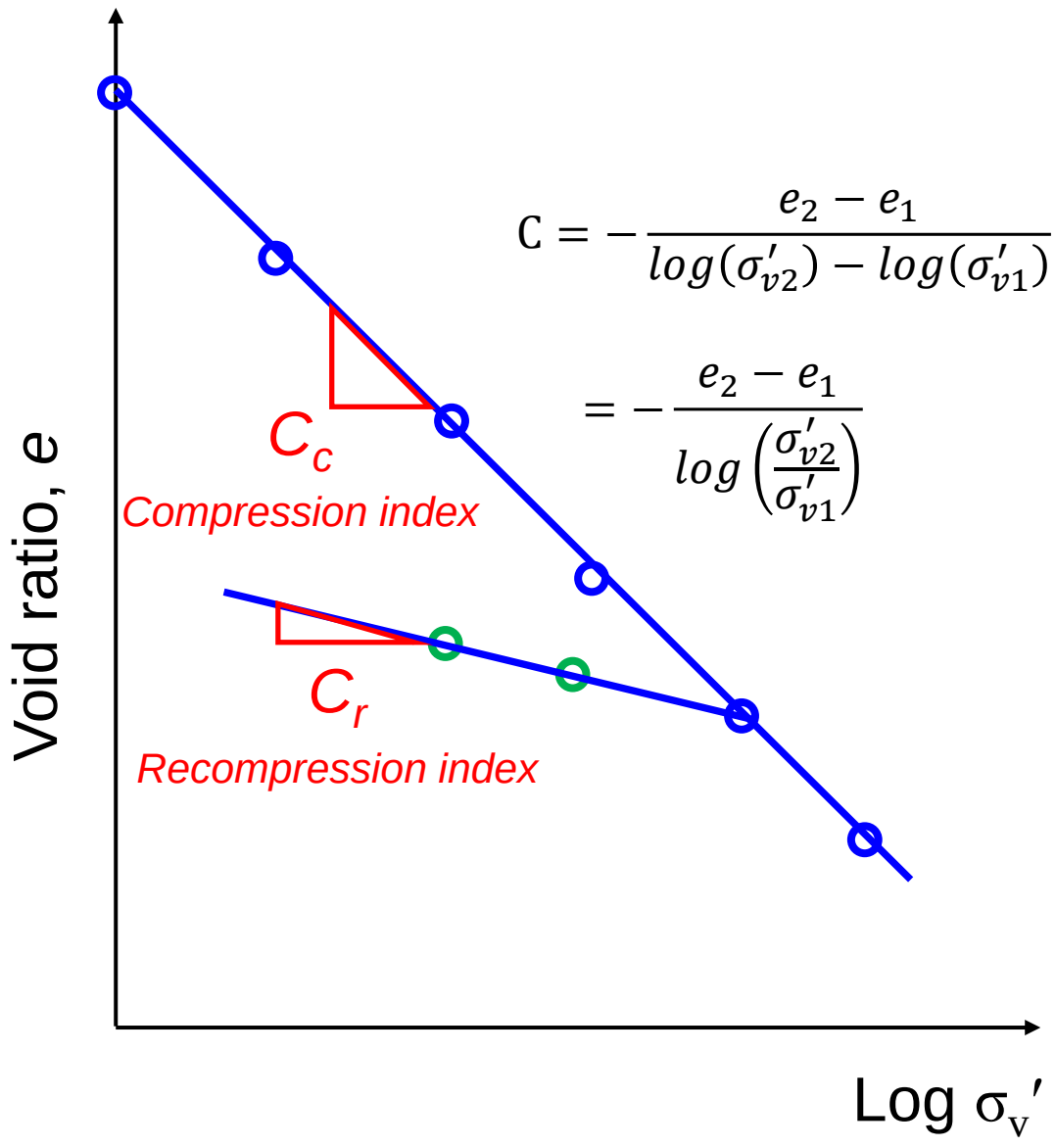
Single drainage - one fluid drainage outlet

Double drainage - two fluid drainage outlets

One-Dimensional Consolidation

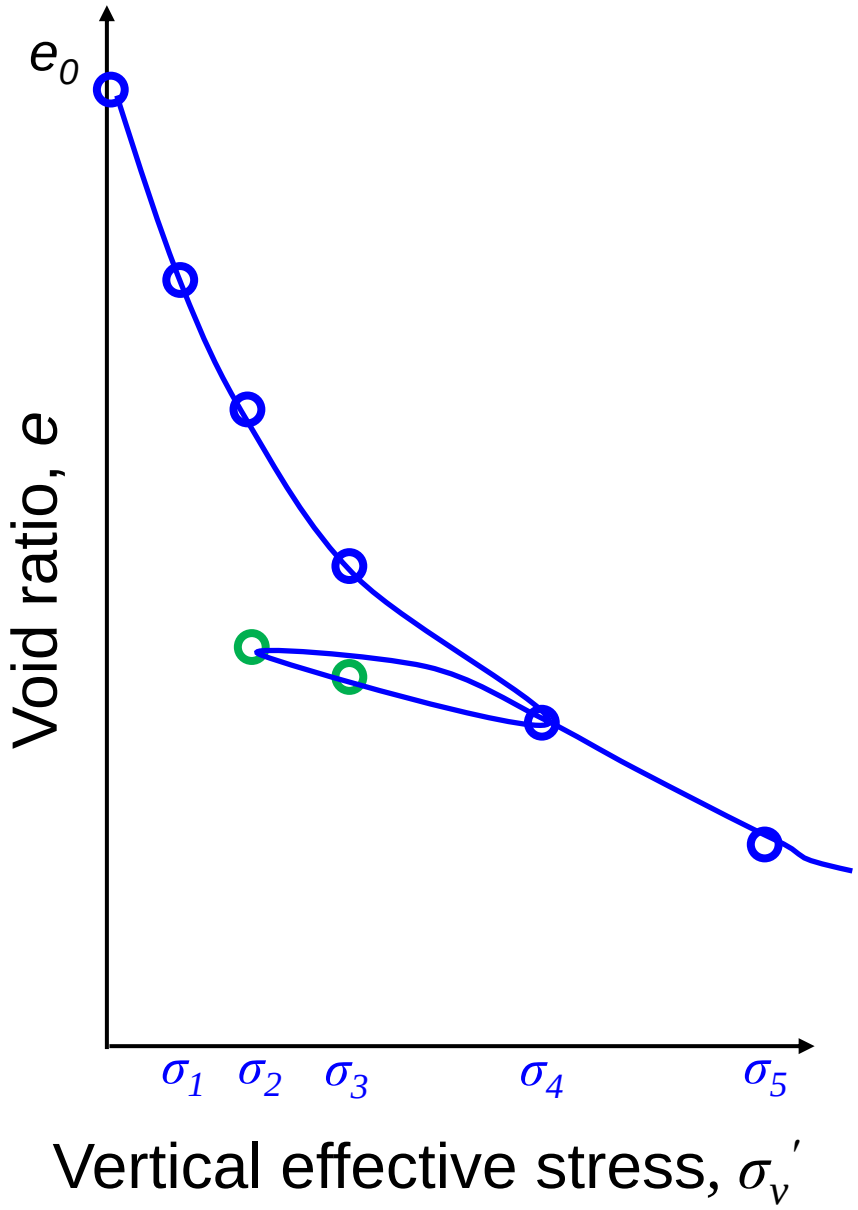


One-Dimensional Consolidation

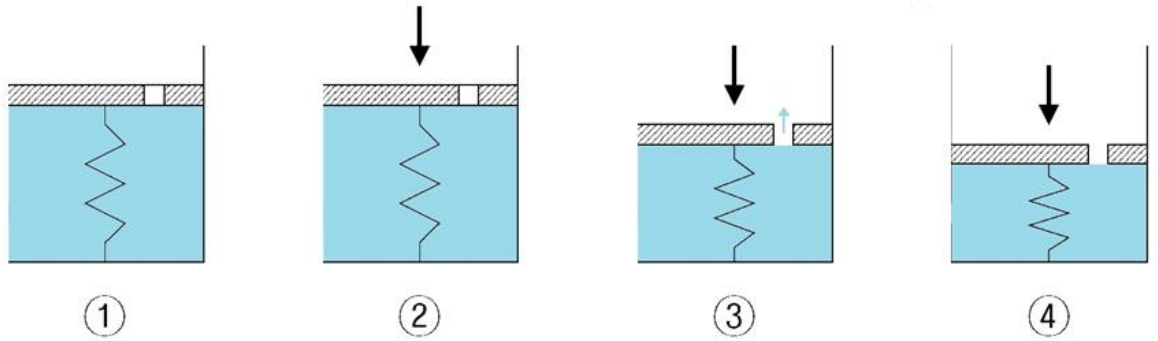


$$C = -\frac{e_2 - e_1}{log(\sigma'_{v2}) - log(\sigma'_{v1})}$$

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



Summary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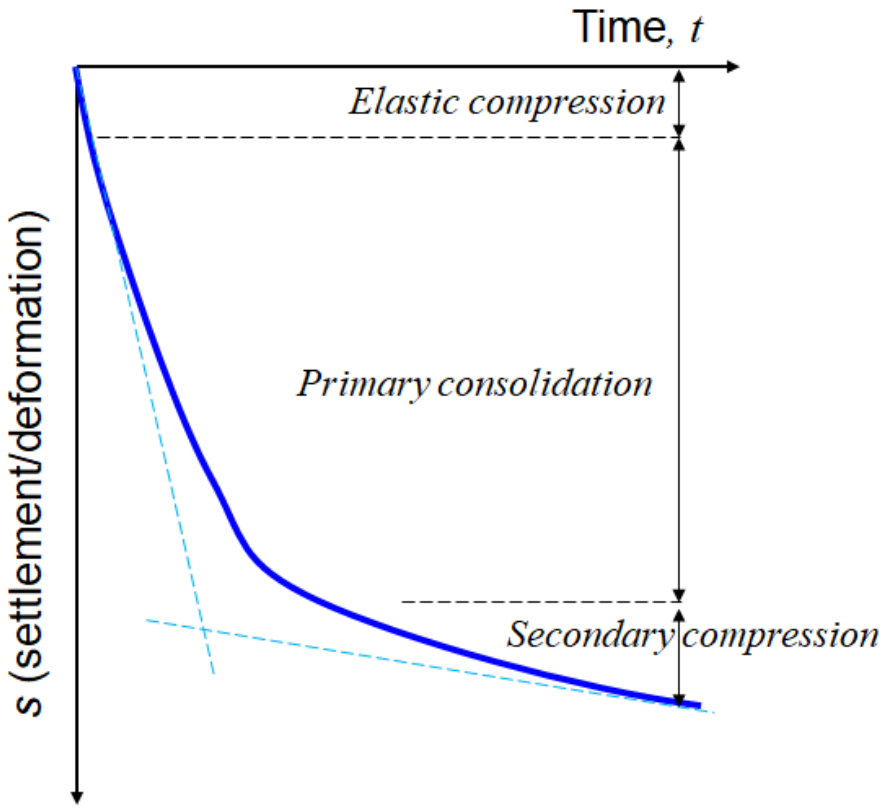
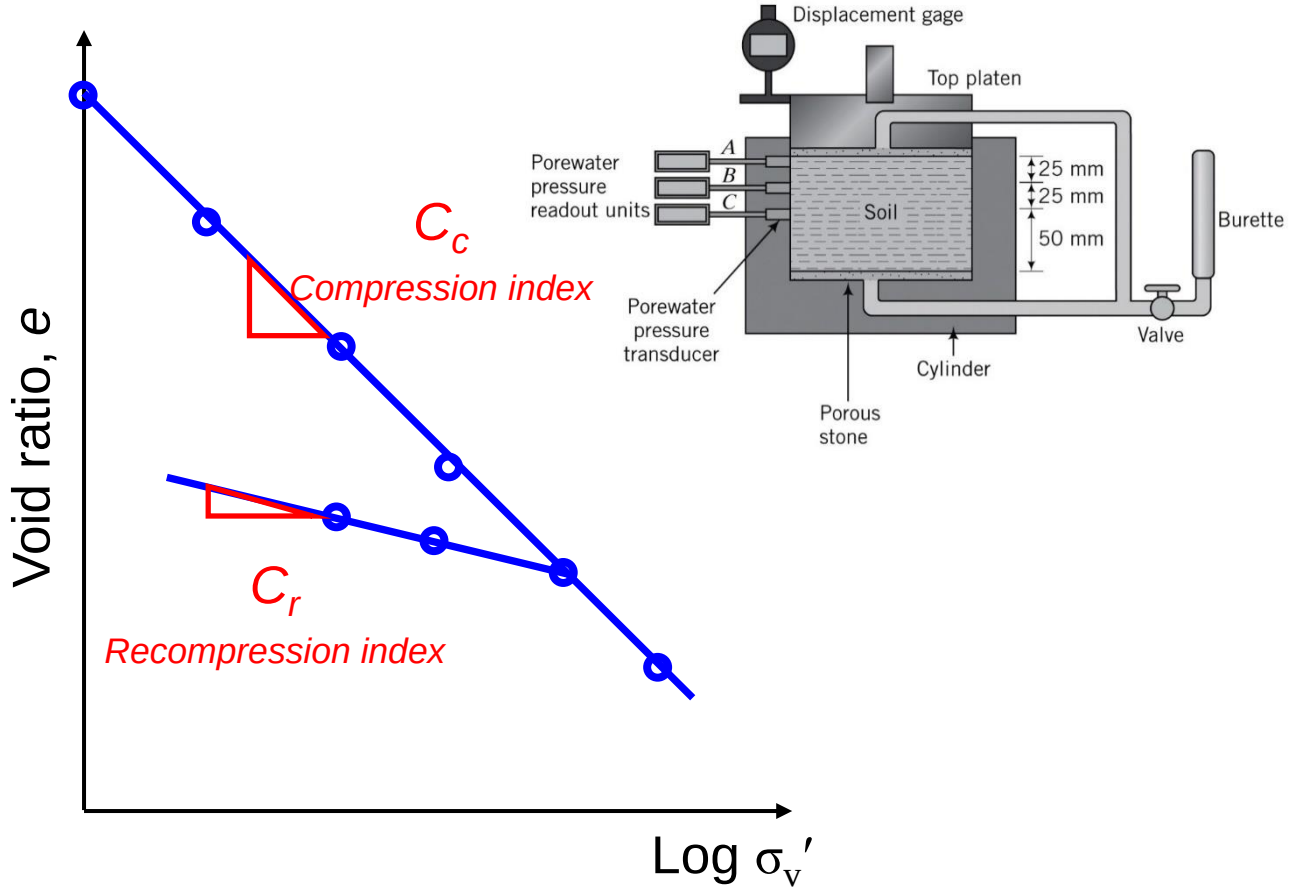

Time, t
Elastic compression
Primary consolidation
Secondary compression
s (settlement/deformation)


Void ratio, e
Log σv′
Cc
Compression index
Cr
Recompression index
Displacement gage
Top platen
Porewater pressure readout units
A
B
C
Soil
25 mm
25 mm
50 mm
Burette
Porewater pressure transducer
Cylinder
Valve
Porous stone