CIVL 311

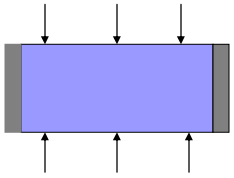
U-U laboratory testing of soils

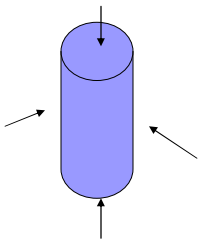
Laboratory shear testing of soils

- Step 1: Specimen preparation
  - Undisturbed specimen (usually for cohesive soils)
  - Reconstituted specimen (usually for cohesionless soils)

Laboratory shear testing of soils

- Step 2: Consolidation
  - 1D consolidation
  - Hydrostatic consolidation





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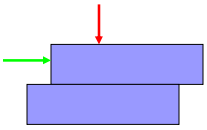
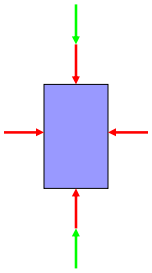
Laboratory shear testing of soils

- Step 3: Shearing
  - By applying direct shear
  - By increasing deviator stress





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Undrained shear testing of soils

- Undrained shear testing correspond to situations when load is applied rapidly and water does not have enough time to escape.
- Examples:
  - End of construction on low permeability soils
  - Earthquakes loading
  - Rapid lowering of water level behind a dam

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Laboratory shear tests

- Unconfined compression test
- Direct shear test
- Triaxial test
- Simple shear test
- Hollow cylindrical test
- Ring shear test

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Unconfined compression test

- Special case of triaxial test
- No lateral support
- Advantages:
  - Simple
- Limitations:
  - Effective stress state is not known
  - Only for cohesive soils

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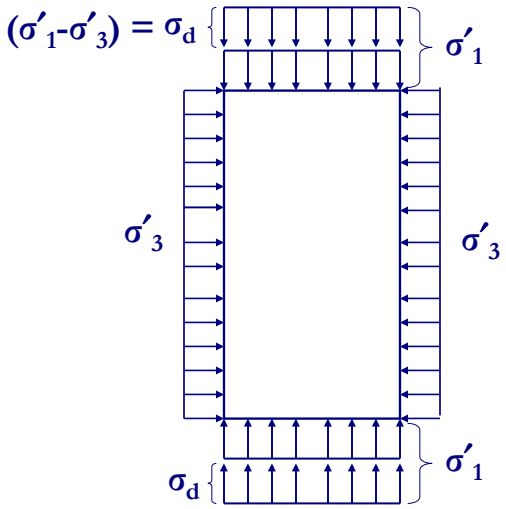
Triaxial testing



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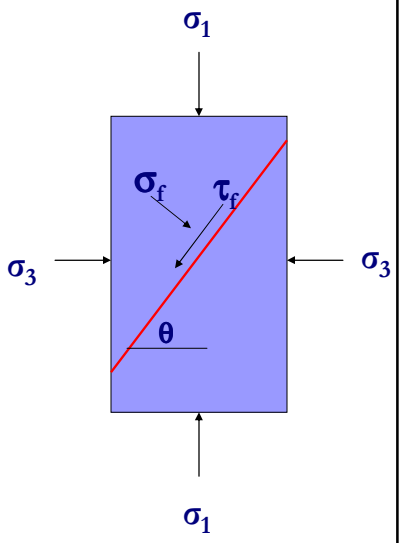
Triaxial testing

- No predefined failure plane
- We only know the magnitude and direction of principal stresses
- Hence, we need to find a relation between principal stresses and the stresses acting on the plane of failure to be able to draw the failure envelop
- We know σ_1 σ_3
- We want to get σ_f τ_f



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Triaxial testing: 2 Phases

- **CONSOLIDATION**
  - Apply equal, all-around pressure
  - Drained or undrained
- **SHEARING**
  - Apply axial stress (until failure)
  - Drained or undrained

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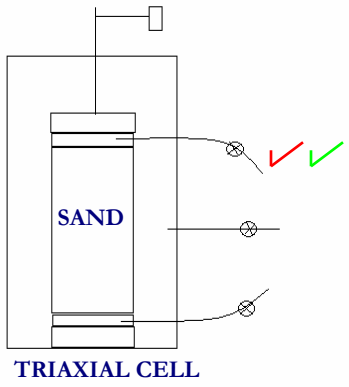
Triaxial Test Types

Consolidation phase | Shearing phase

- C D

  Sands and clays long time after construction



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Triaxial Test Types

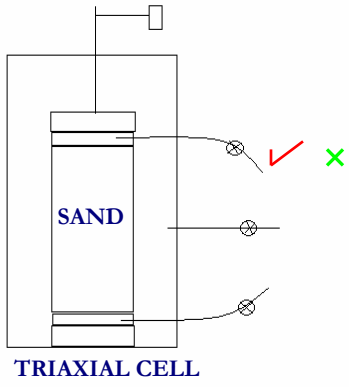
Consolidation phase | Shearing phase

- C D

  Sands and clays long time after construction

- C U

  Clays short time after construction



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Triaxial Test Types

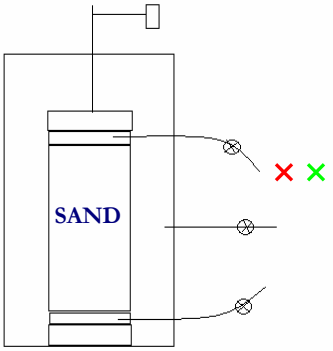
Consolidation phase	Shearing phase
C	D

Sands and clays long time after construction

C	U

Clays short time after construction

U	U



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U-U triaxial testing (specimen preparation)

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U-U Triaxial testing (Triaxial cell)

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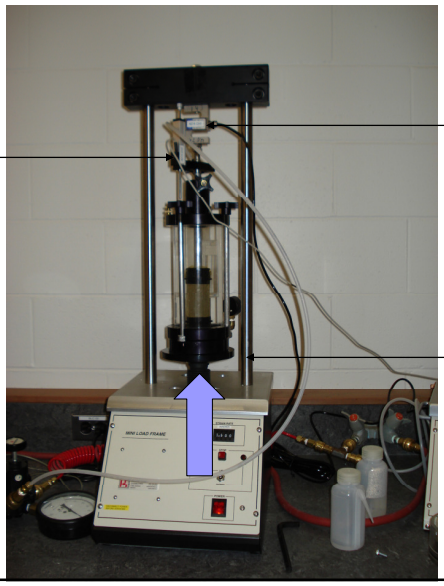
U-U Triaxial testing (Triaxial loading frame)



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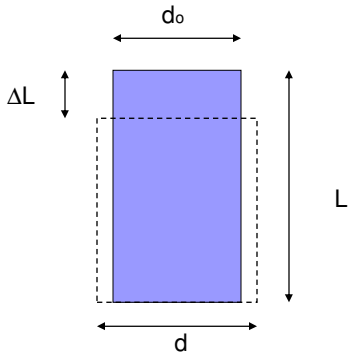
Calculations

$$\varepsilon = \frac{\Delta L}{L}$$

$$A = \frac{A_o}{1-\varepsilon} = \frac{\pi}{4} d^2$$



$$\sigma_1 = \frac{F_a}{A}$$

σ_3 = Cell Pressure

Deviator stress (σ_d) = σ_1-σ_3

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Calculations

- Water content before and after the test. This should tell if there is any leakage.
- Degree of saturation. For undrained conditions the degree of saturation must be 100%

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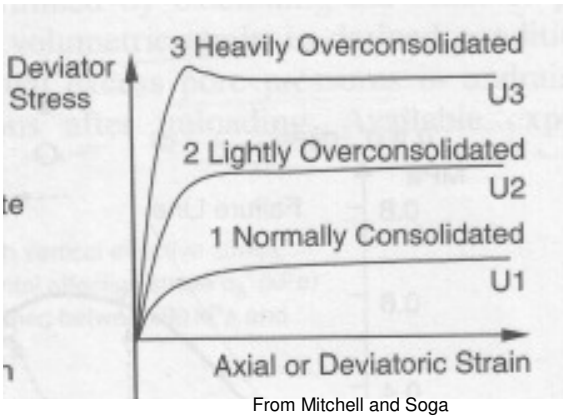
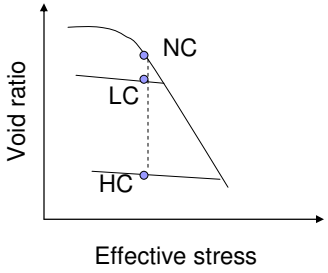
Deviator stress vs. axial strain



From Mitchell and Soga (2005)



Stiffer response for OCC and higher strength

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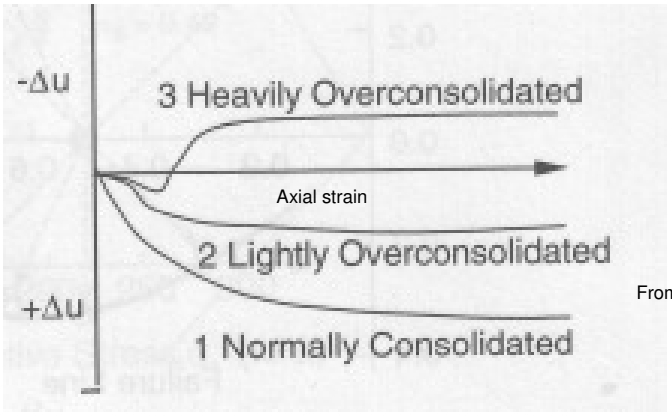
Excess PWP due to undrained shearing



From Mitchell and Soga (2005)

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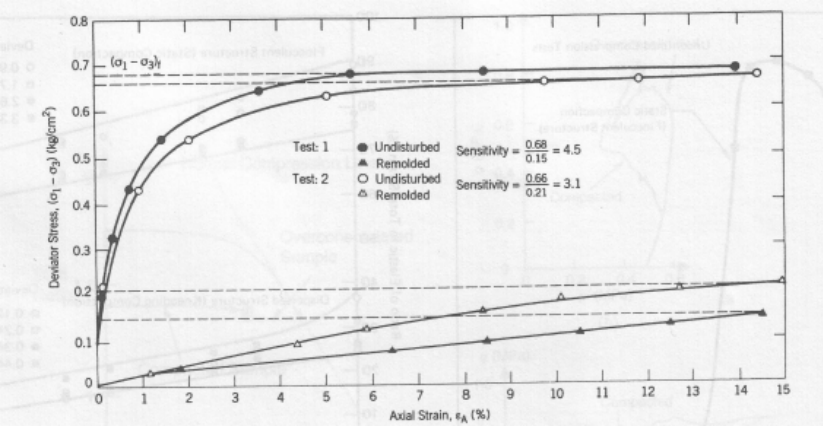
Clay sensitivity

From Mitchell and Soga (2005)



Clay sensitivity = Strength undisturbed/ strength remoulded

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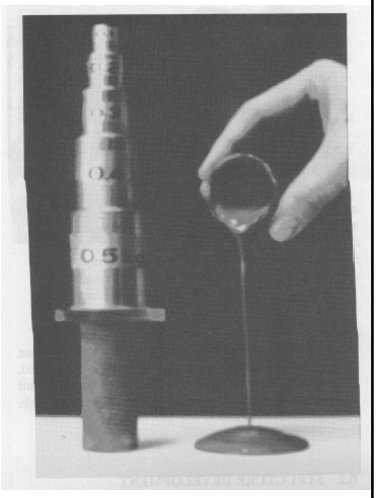
Clay sensitivity

S = 1	Insensitive
S=1-2	Slightly sensitive
S=2-4	Medium sensitive
S=4-8	Very sensitive
S>8	Quick clay

From DAS (2002)



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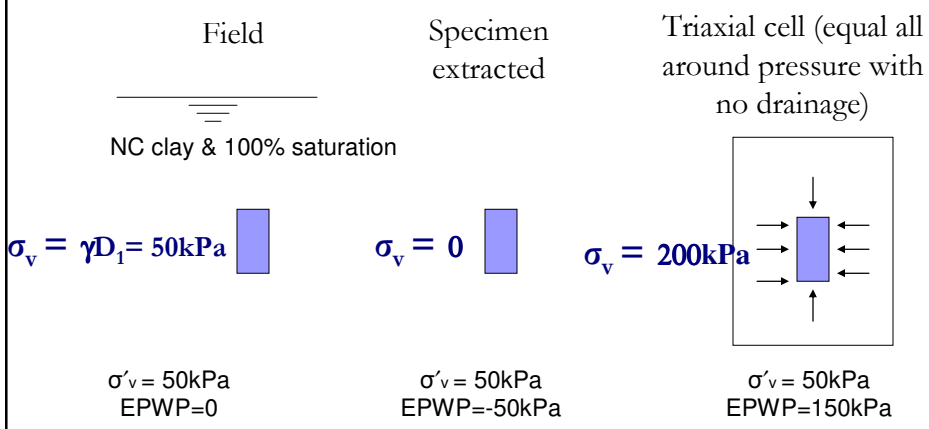
Example



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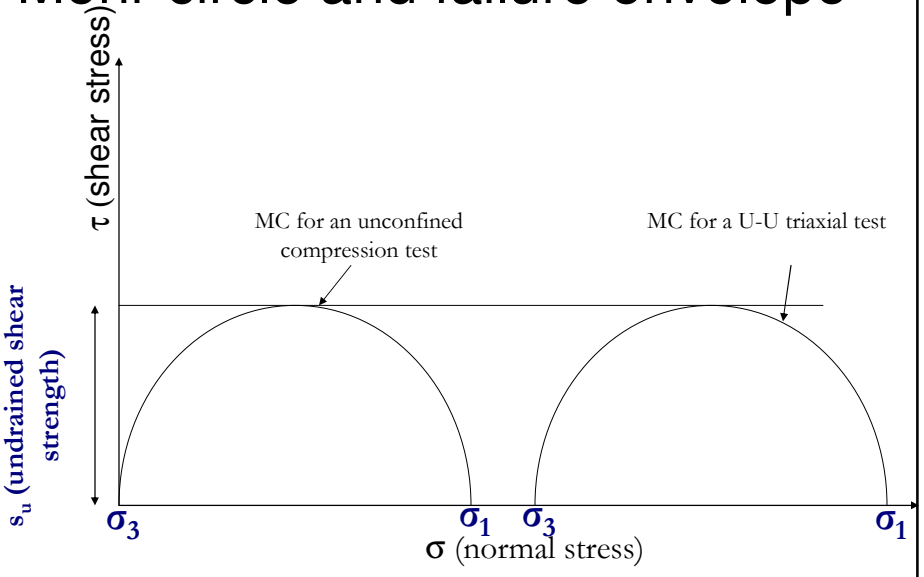
Mohr circle and failure envelope



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Typical s_u values

0-12.5 kPa	very soft clay
12.5-25 kPa	soft clay
25-50 kPa	medium clay
50-100 kPa	stiff clay
100-200 kPa	very stiff clay
>200	hard clay

From DAS (2002)

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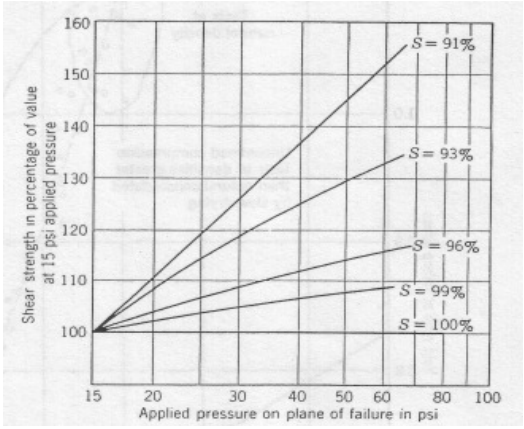
Effect of the degree of saturation



From Soil Testing for Engineers by Lambe

Fully undrained behaviour is at 100% saturation. Shear strength is insensitive to applied pressure.

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Reporting

- Introduction
  - Name of the experiment
  - Soil description and properties
  - Significance of the test (i.e. U-U test can be used to obtain s_u and stress-strain curve)
  - Applicable to rapid loading conditions

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Reporting (con't)

- Method statement
  - Brief summary of U-U testing procedure in your own words
  - Reference
- Results
  - Tabulated results: WC (initial and final), degree of saturation, s_u for U-U tests at different confining pressures, and sensitivity.

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Reporting (con't)

- Graphs:
  - Deviator stress vs. axial strain for 2 U-U tests
  - Mohr circles and total stress failure envelope
- Discussion
  - Brief description of the difference between the different types of triaxial tests.
  - Expected behaviour according to the book:
    - Total stress envelope
    - Deviator stress vs strain

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Reporting (con't)

- Observed behaviour and how does it compare with expected behaviour ? If not matching, what are the possible reasons?
- Typical s_u values
- Comment on clay sensitivity
- Comment on degree of saturation
- Effect of loading rate
- Any difference between WC of the two tests?
- Any difference between WC initial and WC final?

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Reporting (con't)

- Any problems during the experiment? If yes, how are they expected to affect the results?
- Advantages and limitations of the U-U triaxial test.

- Calculations
  - Axial strain
  - Corrected area
  - Axial and deviator stress
  - WC, degree of saturation and clay sensitivity

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