Lecture Goals

- Students will be able to:
  - define triaxial test procedures,
  - characterize advantages and disadvantages of the triaxial test,
  - interpret data from a triaxial test, and
  - determine soil shear strength parameters from a consolidated drained triaxial test.

Reading List

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<td>11.8</td>
<td>Triaxial Shear Test (General)</td>
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<td>11.9</td>
<td>Consolidated-Drained Triaxial Test</td>
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Overview Triaxial Test

- Soil parameters
  - Cohesive & cohesionless
  - Strength values
- Test procedure
  - Compression, extension
- Test conditions
  - Consolidated Drained (CD) or S-test
  - Consolidated Undrained (CU) or R-test
  - Unconsolidated Undrained (UU) or Q-test

Triaxial Test Apparatus

Basic Triaxial Test Data

- Cell pressure
  - $\sigma_2 = \sigma_3$
- Deviator stress
  - $q = \sigma_2 - \sigma_3$
- Axial strain
  - $\varepsilon = \Delta L / L_0$
- Volume change
  - $\Delta V$
Triaxial Test Characteristics

- Test procedure
  - More complex than direct shear
  - Loading rate to simulate in-situ condition
  - Accurate volume change measurements

- Stress
  - Uniform stress field
  - Principal stress state known
  - Simulate complex stress paths to failure

- Drainage
  - Saturated samples
  - Good control if drainage required

Test Parameters

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<tr>
<th>Test</th>
<th>Parameters Measured</th>
<th>Comments</th>
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| CD (S) | \( \phi', c' \) | * Most reliable for effective stresses  
* Apply \( \sigma_3 \) with sample consolidation until \( u_c = 0 \) (valve open)  
* Apply \( q \) with drainage (can be faster than CD)  
* Applicable for long-term loading (e.g. slope stability)  
* ASTM D3957-04 (new work item) |
| CU (R) | \( \phi, c \) | * Strength values higher than in-situ  
* Apply \( \sigma_3 \) with sample consolidation until \( u_c = 0 \) (valve open)  
* Apply \( q \) without drainage (can be faster than CD)  
* Pore pressure measured during test  
* Applicable for short-term and long-term loading  
* ASTM D4767-04 |
| UU (Q) | \( \sigma_3 = \sigma_1 = \sigma_2 = c, \phi = 0 \) | * Inexpensive (0.25-0.5 CU$), mostly conservative  
* Apply \( \sigma_3 \) with no consolidation or drainage (valve closed)  
* Apply \( q \) without drainage (fastest triaxial test)  
* Applicable for most design & construction conditions  
* ASTM D2850-03a(2007) |

After: Hunt (2005)
Triaxial Test Characteristics

\[ \sigma_1 = \sigma_d + \sigma_3 \]

Hydrostatic Stress
Valve open \(\Rightarrow\) Consolidated
Valve closed \(\Rightarrow\) Unconsolidated

Deviatoric Stress
Valve open \(\Rightarrow\) Drained loading
Valve closed \(\Rightarrow\) Undrained loading

CD Cell Pressure Load Step

- Volume change
  - Length
  - Diameter

CD Deviator Stress Load Step

- Loose sand or normal consolidated clay
  \(c = c' = 0\)

After, Das (2006)
CD Deviator Stress Load Step

- Dense sand or overconsolidated clay
- Clay may swell, why?

Clay – Effective Friction Angle

After, Das (2006)

Clay – Effective Friction Angle

Sabatini et al. (2002)

Clay – Effective Friction Angle

Rowe (2001)
In a triaxial test with an applied deviator stress (q), what are the maximum principal stress and the minimum principal stress directions?

In a CD triaxial test, are pore pressure measurements required to determine c’ and $\phi'$?

In a CD test, for a saturated sample does volume change occur (1) during the application of hydrostatic stress? (2) during the application of deviator stress?

For sands, loading conditions are typically considered to be drained. Can you think of two common design conditions where undrained conditions may occur? What is the significance?

A soil element adjacent to a retaining wall has an average confining pressure of 5 MPa. What would be the effect on the load bearing capacity of the soil element if (a) $\phi' = 0^\circ$ and (b) $\phi' = 30^\circ$?

Two CD triaxial tests were performed on either cohesionless soil or normally consolidated clay samples. The applied axial stress ($\sigma_1$) and confining stress ($\sigma_3$) were provided for each test. Draw representative figures for:

- Deviator stress versus axial strain
- Failure envelope and parameters
References

- http://www.eleusa.com/