

CE394M: Stress-strain-strength relationship of clays

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1 Stress-strain-strength relationship

L-soil v D-soil

L-soils:

- yield at sub-critical stress ratios
- looser than their critical density at their projected yield stress
- lightly over-consolidated at yield
- contractile when sheared slowly
- “wet” when sheared quickly
- tend to strain-harden to a critical state if sheared beyond yield point

D-soils:

- fail at super-critical stress ratios
- denser than their critical density at their projected yield stress
- heavily over-consolidated at yield
- dilatant when sheared slowly
- “dry” when sheared quickly
- tend to strain-soften to a critical state if sheared beyond yield point

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└ Stress-strain-strength relationship

└ L-soil v D-soil

L-soil v D-soil

L-soils:

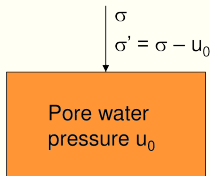
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D-soils:

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- "dry" when sheared quickly
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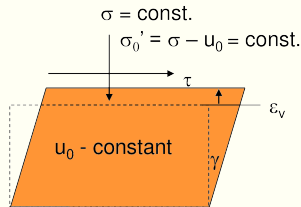
The terms “wet” and “dry” come from the idea of working a specimen of soil by hand. On the wet side of critical state the soil skeleton is too loosely compacted to support pressure stress—such stress, if applied (such as by squeezing the soil by hand) passes immediately into the pore water and thus causes this water to bleed out of the specimen and wet the hands. The opposite effect occurs when the soil is on the dry side of critical state.

Simple shear



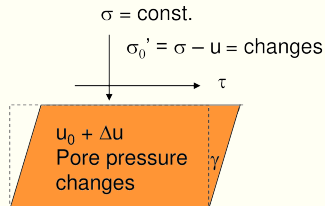
Initial consolidation
Void ratio e_0

Drained test



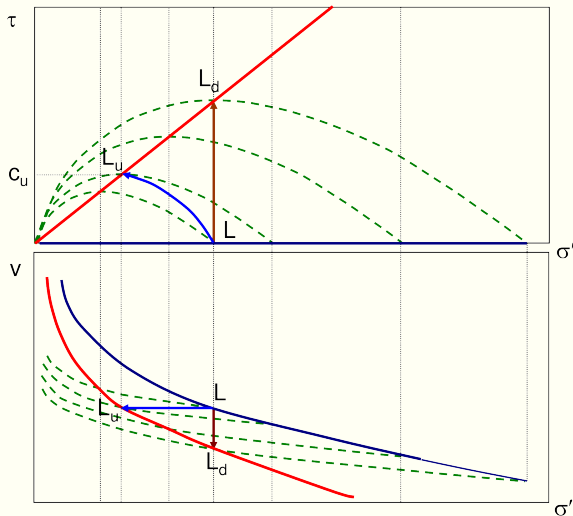
Change in void ratio
 $\epsilon_v = \Delta e / (1 + e_0)$

Undrained test



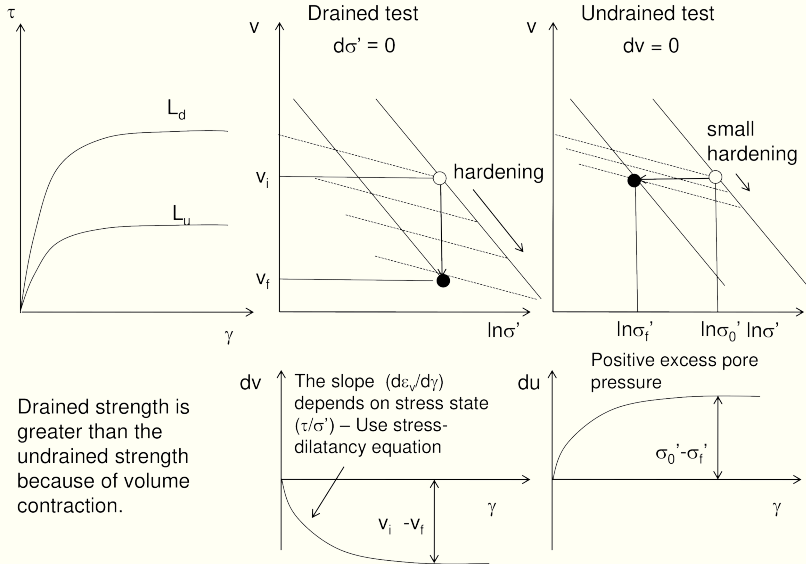
No volume change

Simple shear: Normally Consolidated Clay - L-soil



Drained shear: $L \rightarrow L_d$ and $\delta u = 0$. Undrained shear: $L \rightarrow L_u$ and $\delta v = 0$.

NCL: L-soil (drained v undrained)

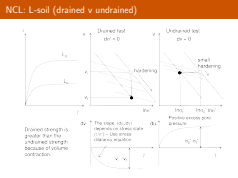


Drained strength is greater than the undrained strength because of volume contraction.

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└ NCL: L-soil (drained v undrained)



Note that the stack of κ -lines with their associated Cam Clay yield surfaces creates a 3D boundary surface in (τ, σ', v) space.

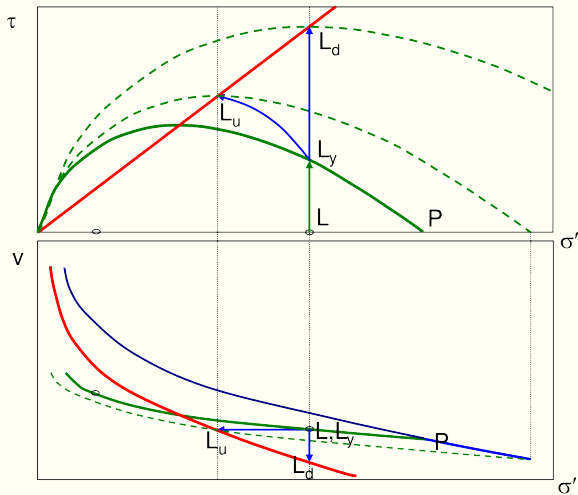
State paths starting inside the boundary surface begin as elastic until they hit the surface. Then they are forced to follow the boundary surface, obeying whatever test constraint is imposed (undrained $v = \text{const}$, or drained $\sigma' = \text{const}$) until the path reaches the critical state line. Then the soil shears at constant (τ, σ', v) state.

VCL: $d\epsilon_p^e + d\epsilon_p^p$ Elasto-plastic yielding RCL: $d\epsilon_p^e$ only elastic

Isotropic loading along VCL ($q = 0$) can develop plastic strains: essentially hardening cap.

VCL: $N - \lambda \ln p'$ $\eta = 0$ RCL: $\Gamma - \lambda \ln p'$ $\eta = M$ $N = \Gamma + (\lambda - \kappa)$

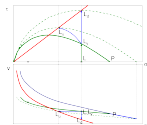
SS: LOC-soil (L-soils)



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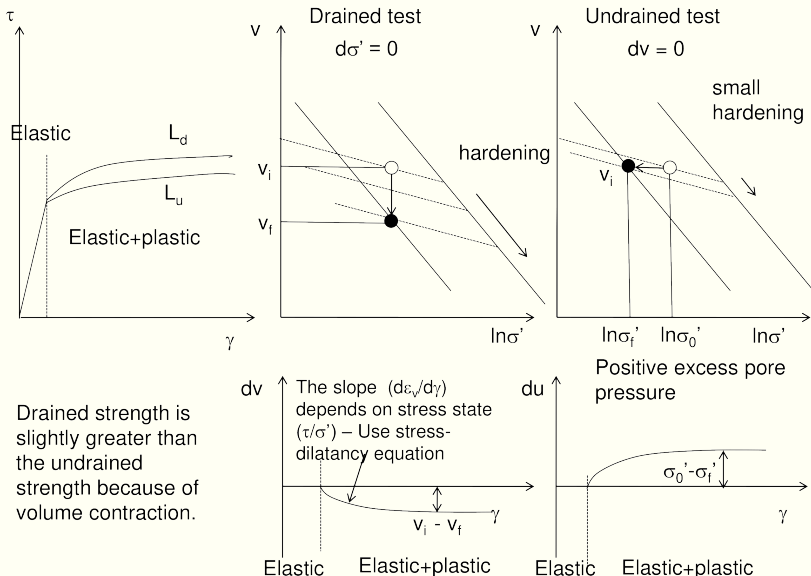


In undrained conditions, the effective stress path will be $d\sigma' = 0$ during elastic response.

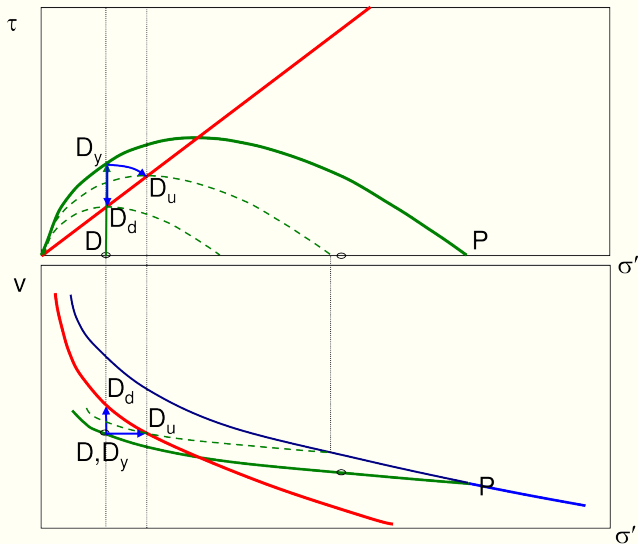
$$d\sigma' = (vp'/\kappa)d\varepsilon_v.$$

$$d\varepsilon_v = 0 \text{ hence } d\sigma' = 0.$$

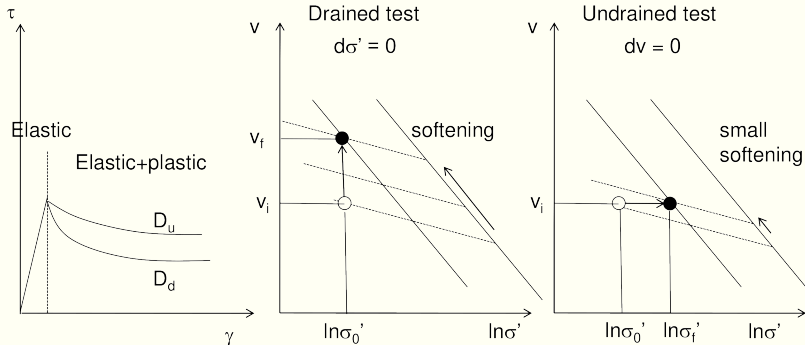
SS: LOC-soil (L-soils) (drained v undrained)



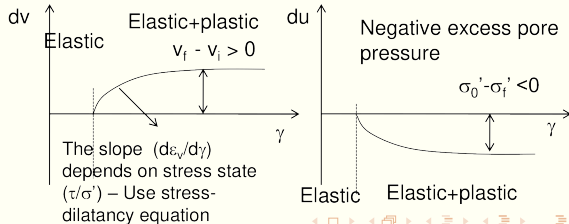
SS: HOC-soil (D-soils)



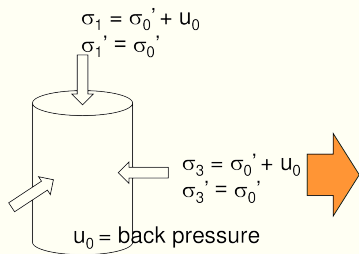
SS: HOC-soil (D-soils) (drained v undrained)



Drained strength is smaller than the undrained strength because of volume dilation.

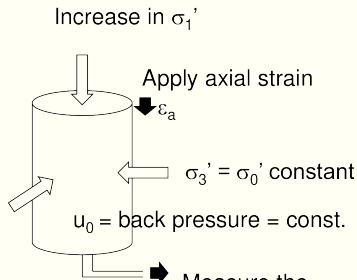


TXC: Drained strength and volume at failure using CS



Initial consolidation condition

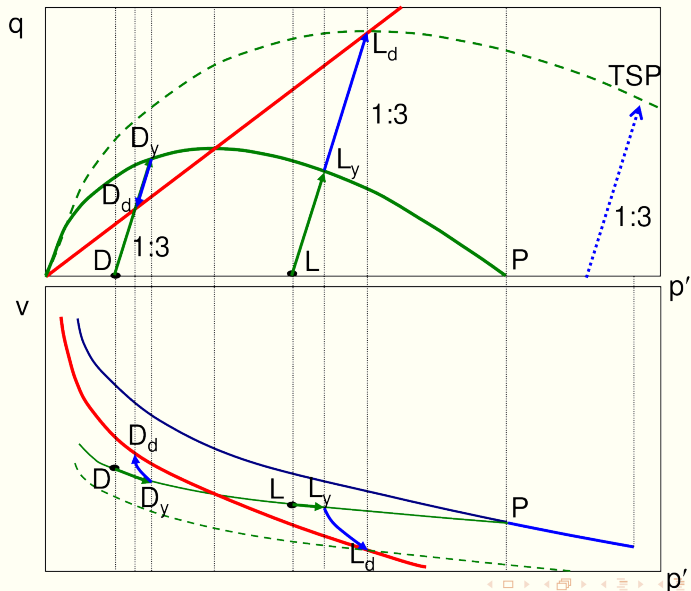
$$e_0 = Gsw_0$$



$$\epsilon_v$$

Changes in void ratio $\epsilon_v = de/(1+e_0)$

TXC Drained (axial loading)

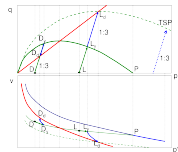


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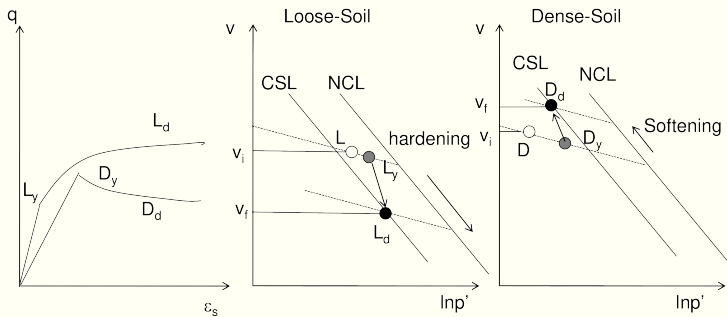
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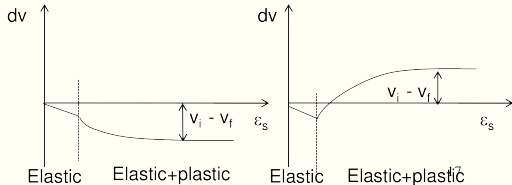


The total stress path of triaxial compression has a slope of 1:3. In drained test, the pore pressure is kept constant. Hence, the effective stress path will have a slope of 1:3.

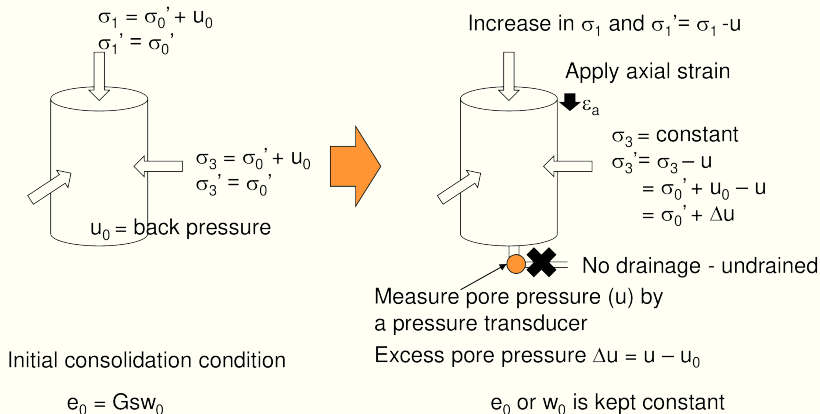
TXC Drained (axial loading)



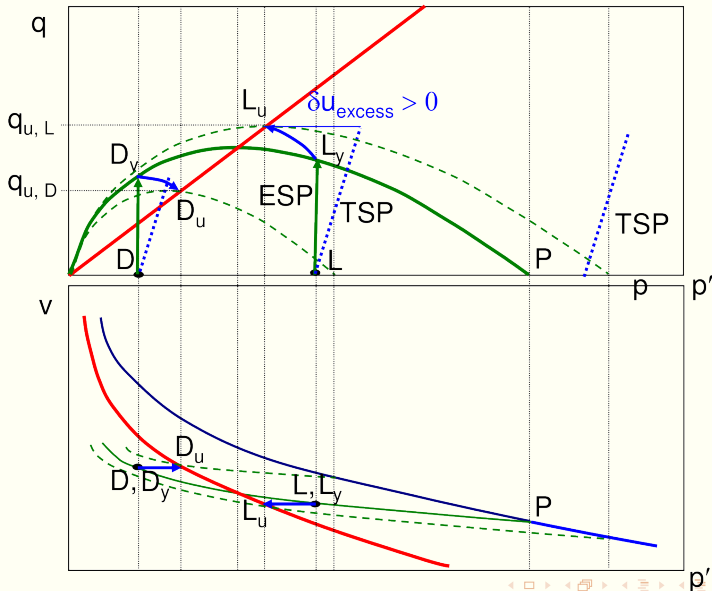
Drained test



TXC: Undrained strength and excess PWP at failure



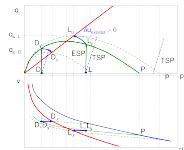
TXC Undrained (axial loading)



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└ TXC Undrained (axial loading)



Elastic deformation: $dp' = Kd\varepsilon_v$ and $dq = 3Gd\varepsilon_s$.

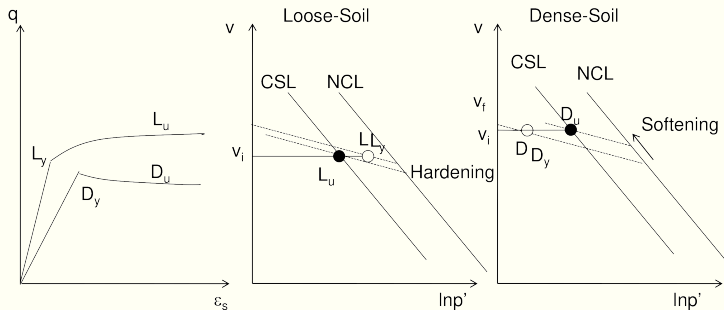
$$K = \frac{\nu p'}{\kappa}$$

$$G = \frac{3K(1 - 2\nu)}{2(1 + \nu)}$$

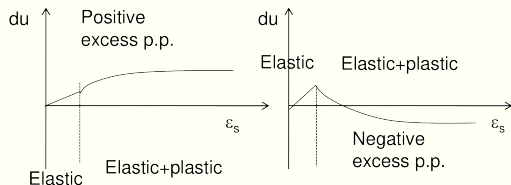
In undrained conditions, the effective stress path will be $dp' = 0$ during elastic response.

$$d\varepsilon_v = 0 \quad dp' = 0$$

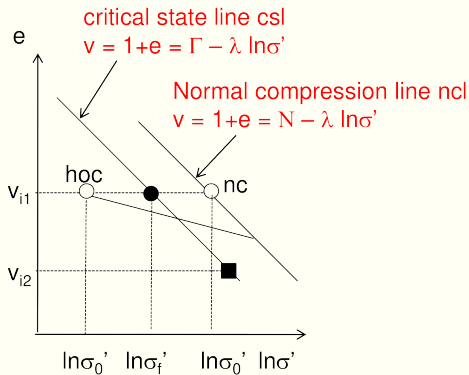
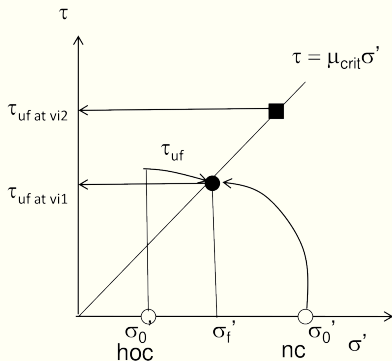
TXC Undrained (axial loading)



Undrained test



Critical state concept



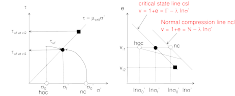
2020-04-25

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└ Critical state concept

Critical state concept



The critical state concept shows that undrained shear strength is purely a function of initial void ratio (or water content).