STRESS

$$\sigma\ (kN/m^2) = \gamma . z$$

where:

γ = unit weight of soil (kN/m^3)

z = depth / thickness from ground surface (m)

STRAIN

$$\varepsilon = \Delta L / L_o$$

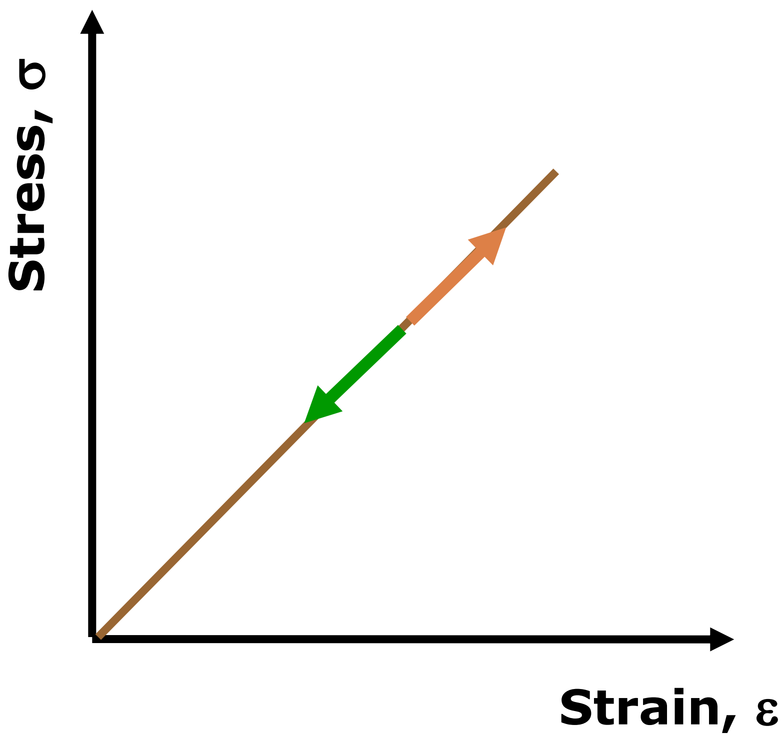
where:

ΔL = difference in length

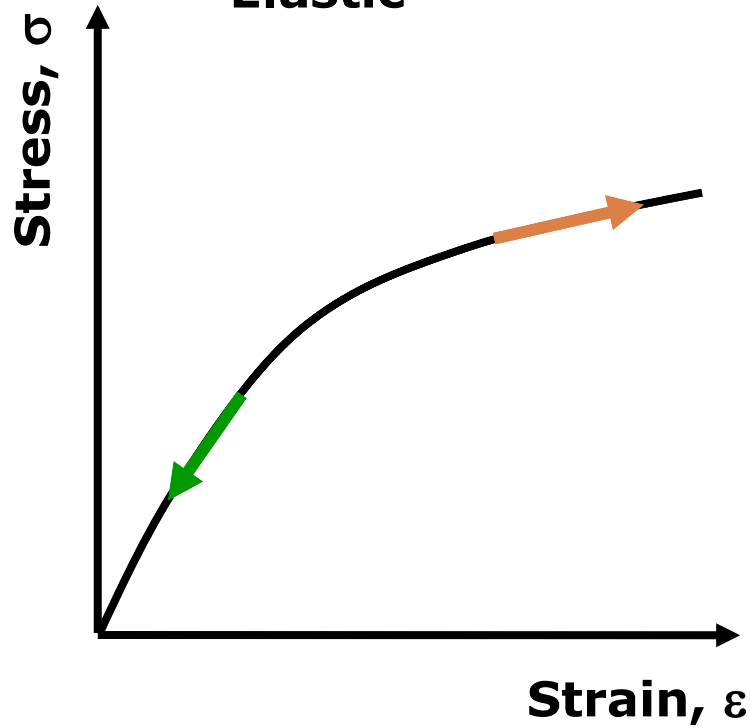
L_o = initial length (m)

STRESS-STRAIN MODELS

Linear and Elastic

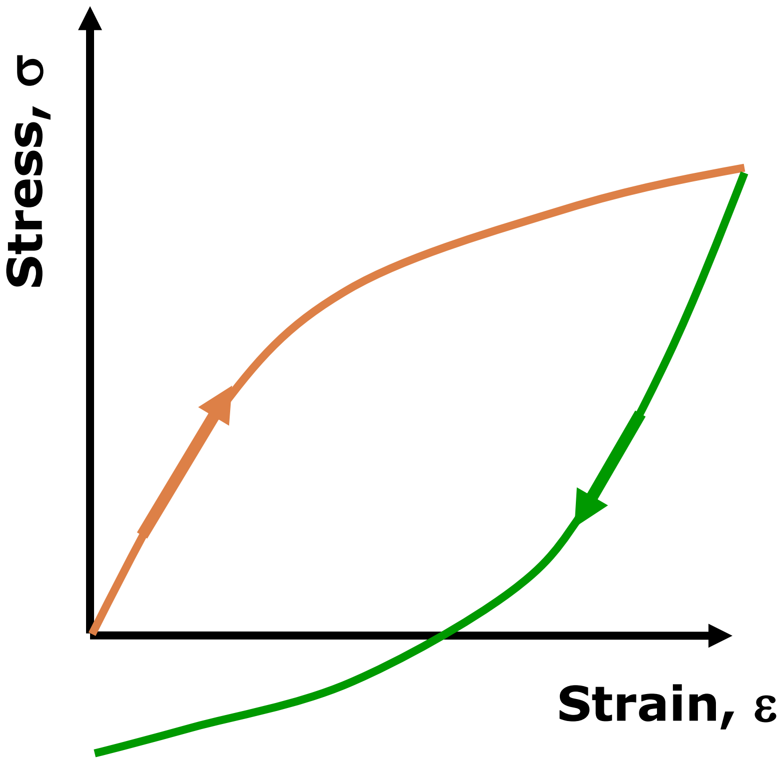


Non-Linear and Elastic

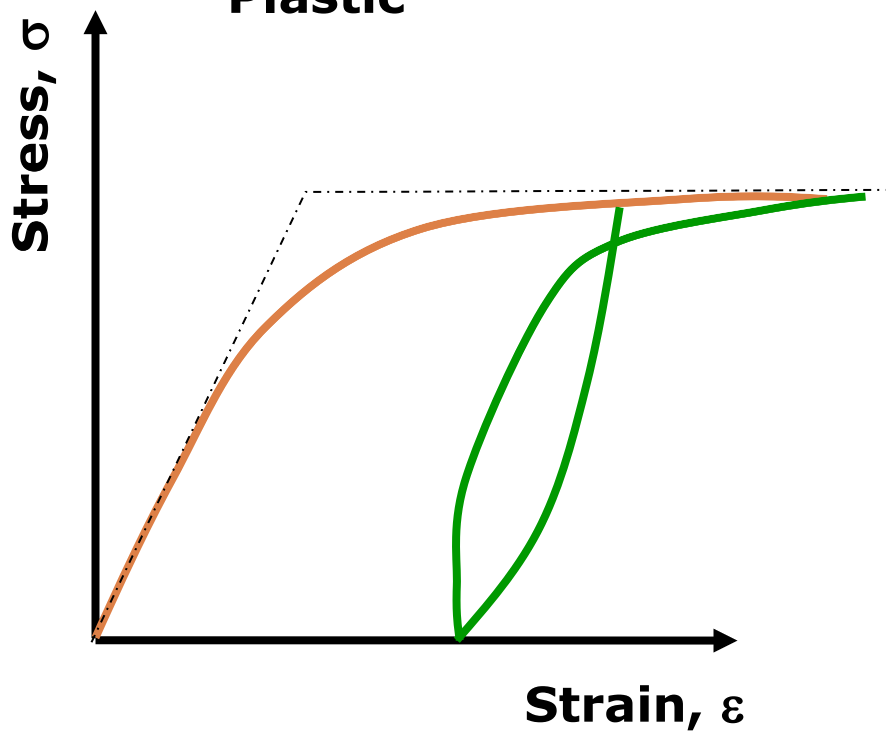


STRESS-STRAIN MODELS

Elasto-Plastic



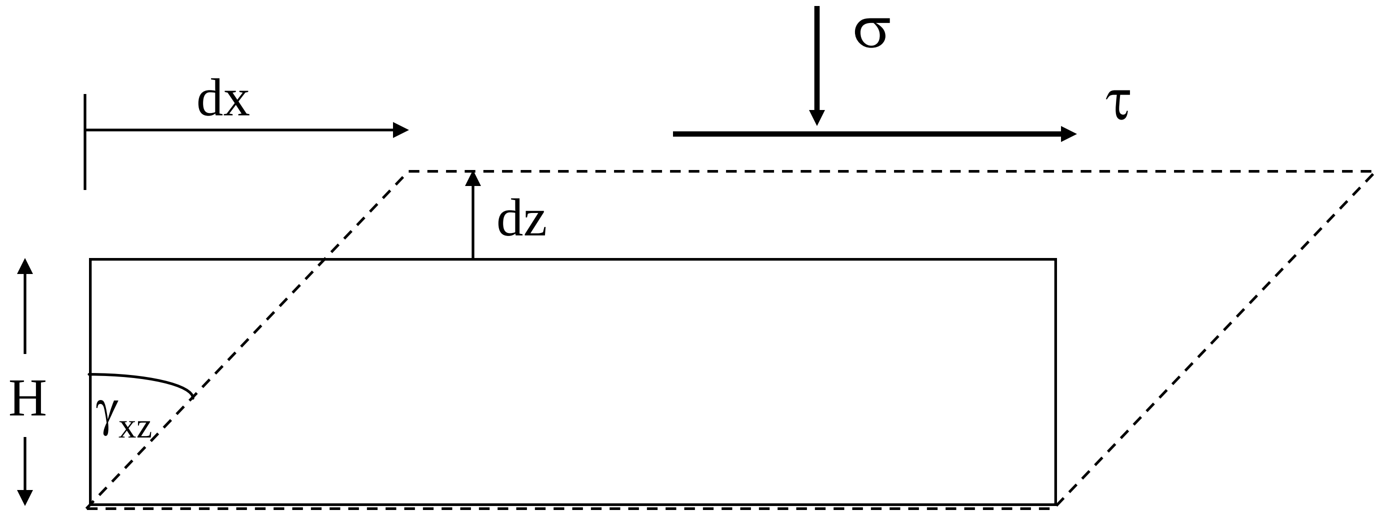
Elastic Perfectly Plastic



STRESS-STRAIN RESPONSE OF SOILS

Triaxial tests are the standard means of investigating the stress-strain-strength response of soils. To simplify, only simple shear tests will be considered.

The simple shear test is an improved shear box test which imposes more uniform stresses and strains.



$\gamma_{xz} = dx/H$ $\varepsilon_z = - dz/H = \varepsilon_v$

SAND BEHAVIOUR

Depends on:

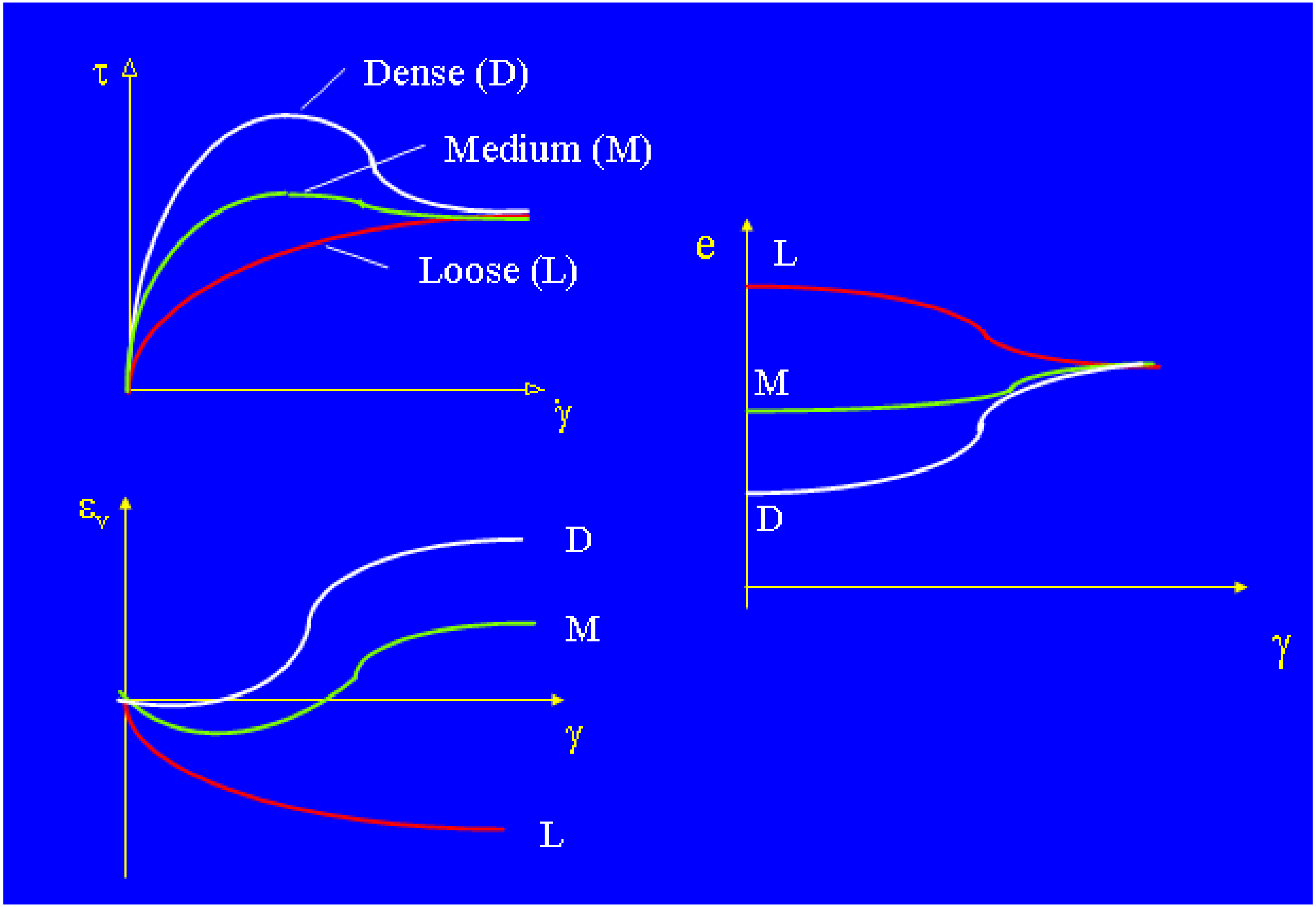
- Mean Effective stress (Normal effective stress in simple shear)
- Relative density, I_d

$$I_d = \frac{e_{max} - e}{e_{max} - e_{min}}$$

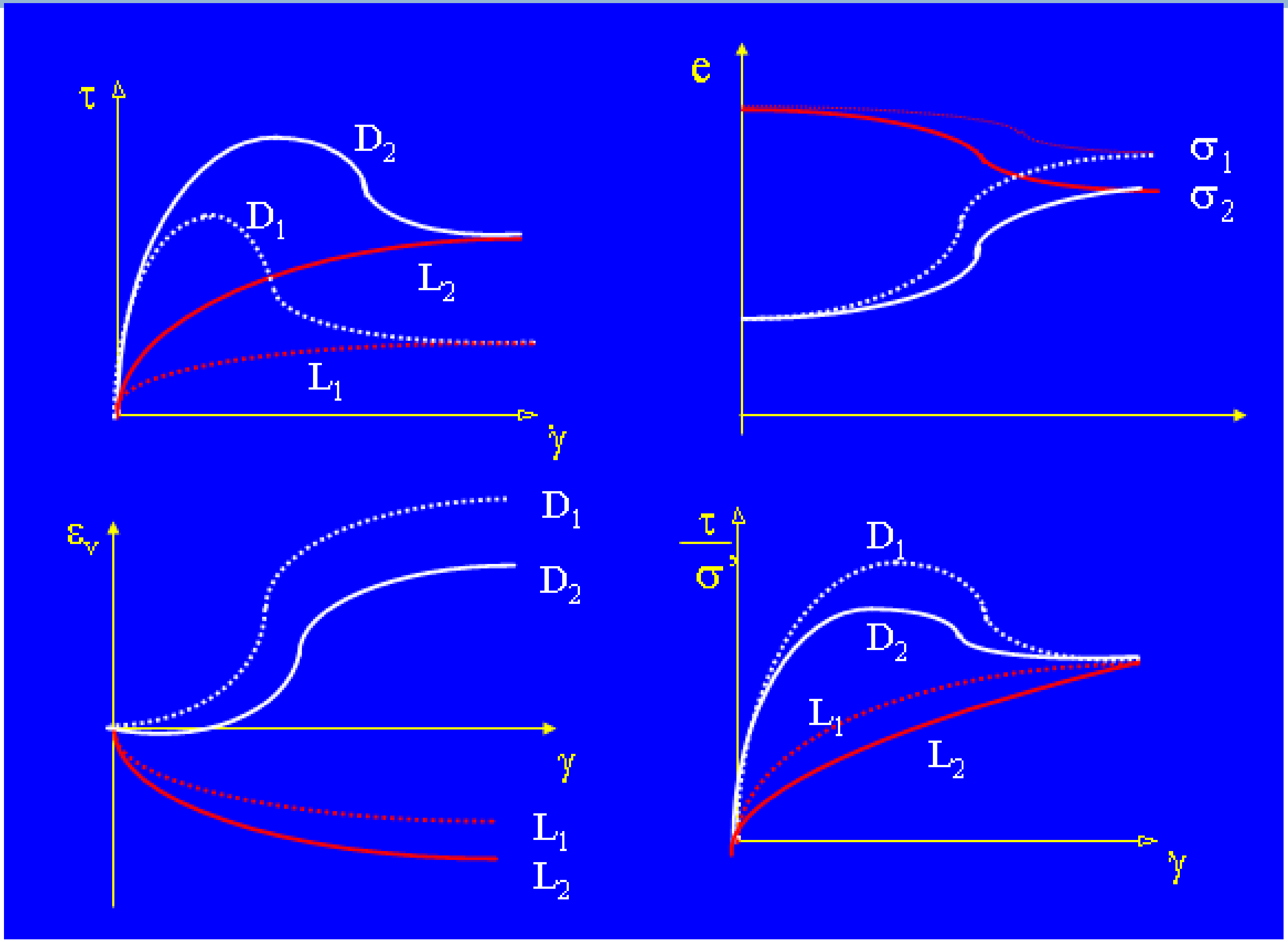
$$\gamma_d = \frac{G_s \gamma_w}{1 + e}$$

$$I_d = \frac{\frac{1}{\gamma_{dmin}} - \frac{1}{\gamma_d}}{\frac{1}{\gamma_{dmin}} - \frac{1}{\gamma_{dmax}}}$$

SAND BEHAVIOUR



SAND BEHAVIOUR



SAND BEHAVIOUR

Find the mistakes???

For tests performed with the same normal stress

- All samples approach the same ultimate shear stress and void ratio, irrespective of the initial relative density
- Initially dense samples attain higher peak angles of friction
- Initially dense soils expand (dilate) when sheared
- Initially loose soils compress when sheared

SAND BEHAVIOUR

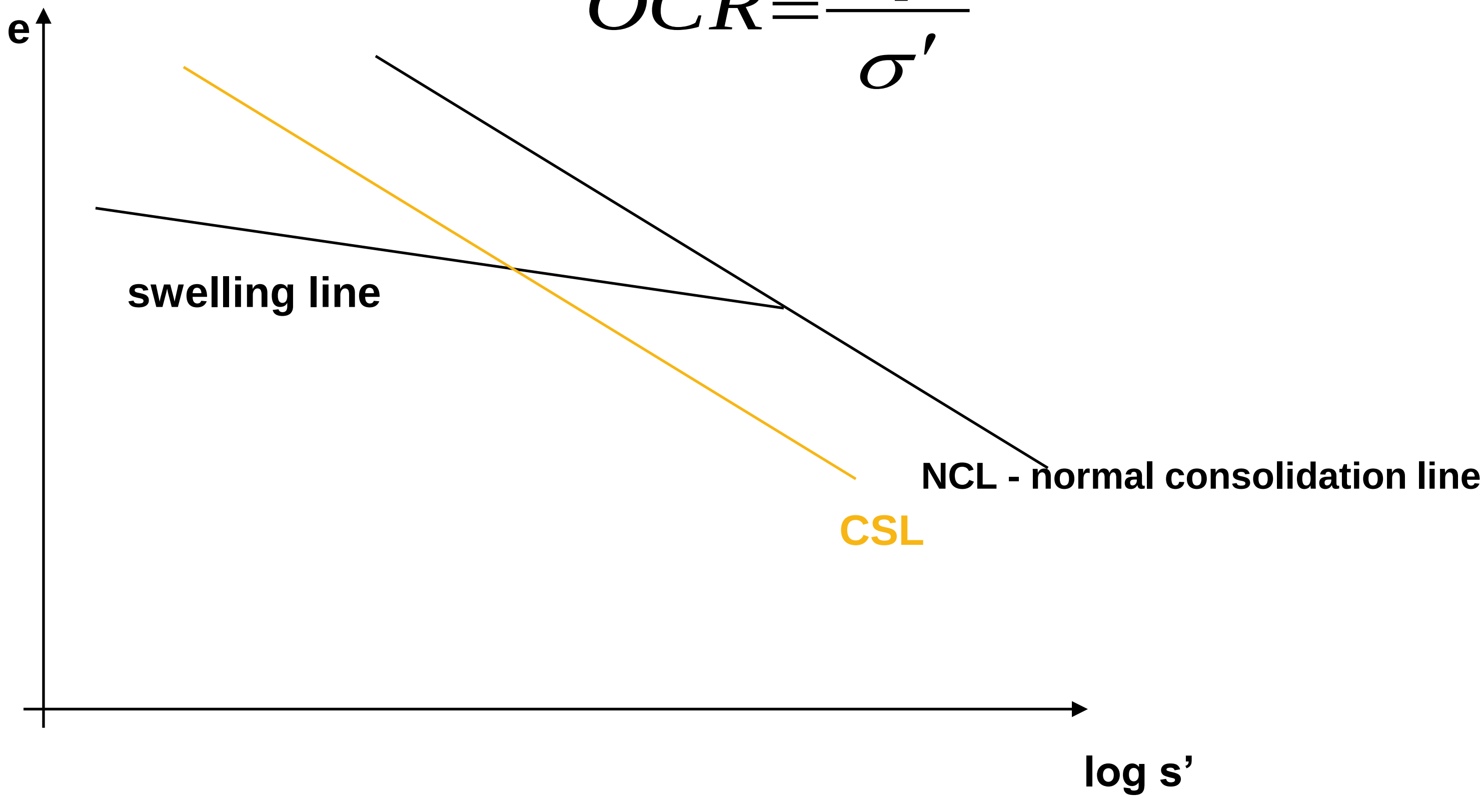
Find the mistakes???

- The ultimate values of shear stress and void ratio depend on the applied normal stress
- The ultimate stress ratio and angle of friction are independent of density and stress level
- Initially dense samples attain higher peak angles of friction, but the peak friction angle decreases as the stress increases
- Initially dense soils expand and initially loose soils compress when sheared. Increasing the normal stress causes less dilation (more compression)

CLAY BEHAVIOUR

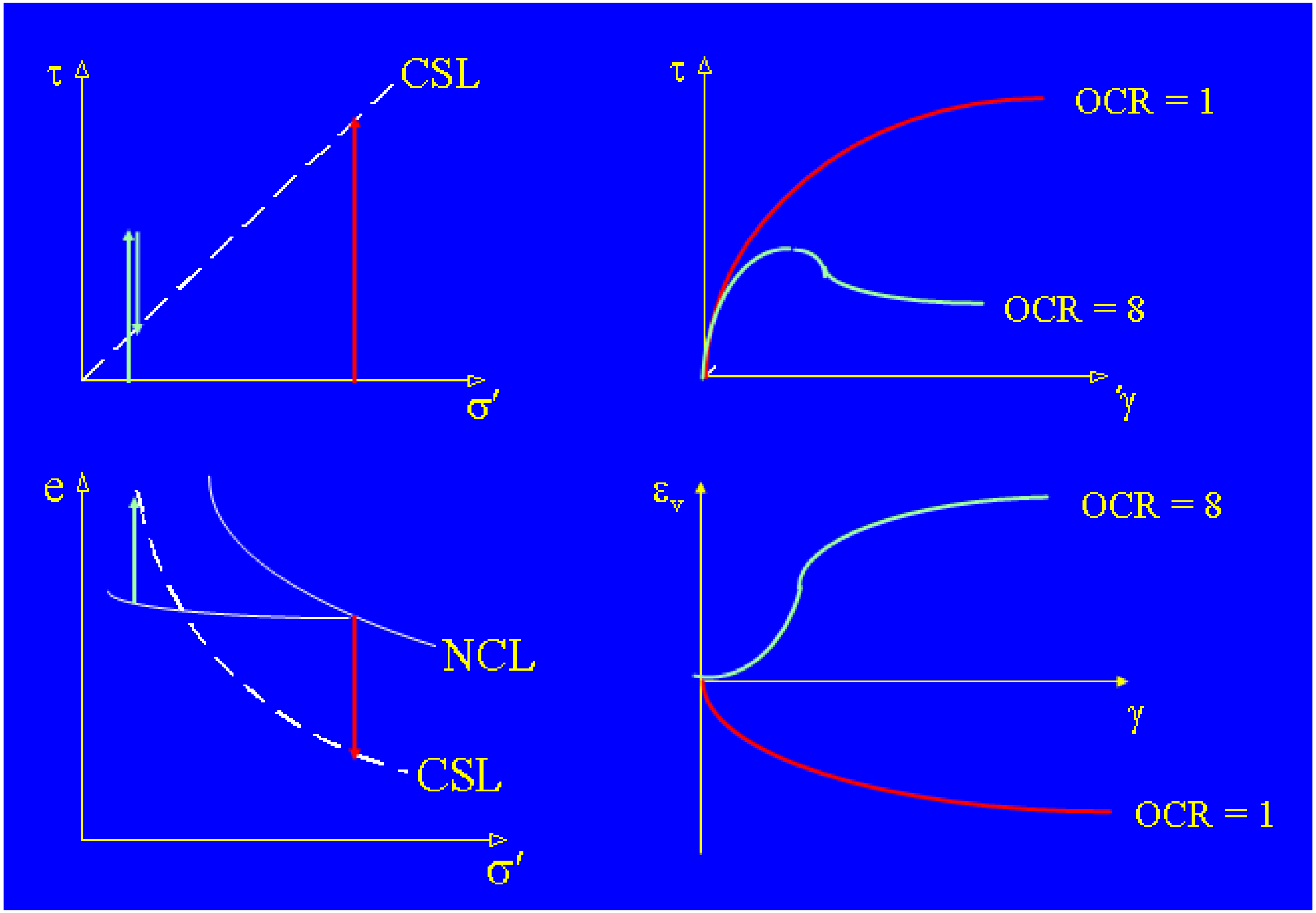
Essentially the same as sands. However, data presented as a function of OCR rather than relative density. OCR is defined as

$$OCR = \frac{\sigma'_{pc}}{\sigma'}$$



It is found that NCL and CSL have the same slope in e-log s'

CLAY BEHAVIOUR – DRAINED CONDITION



CLAY BEHAVIOUR – DRAINED CONDITION

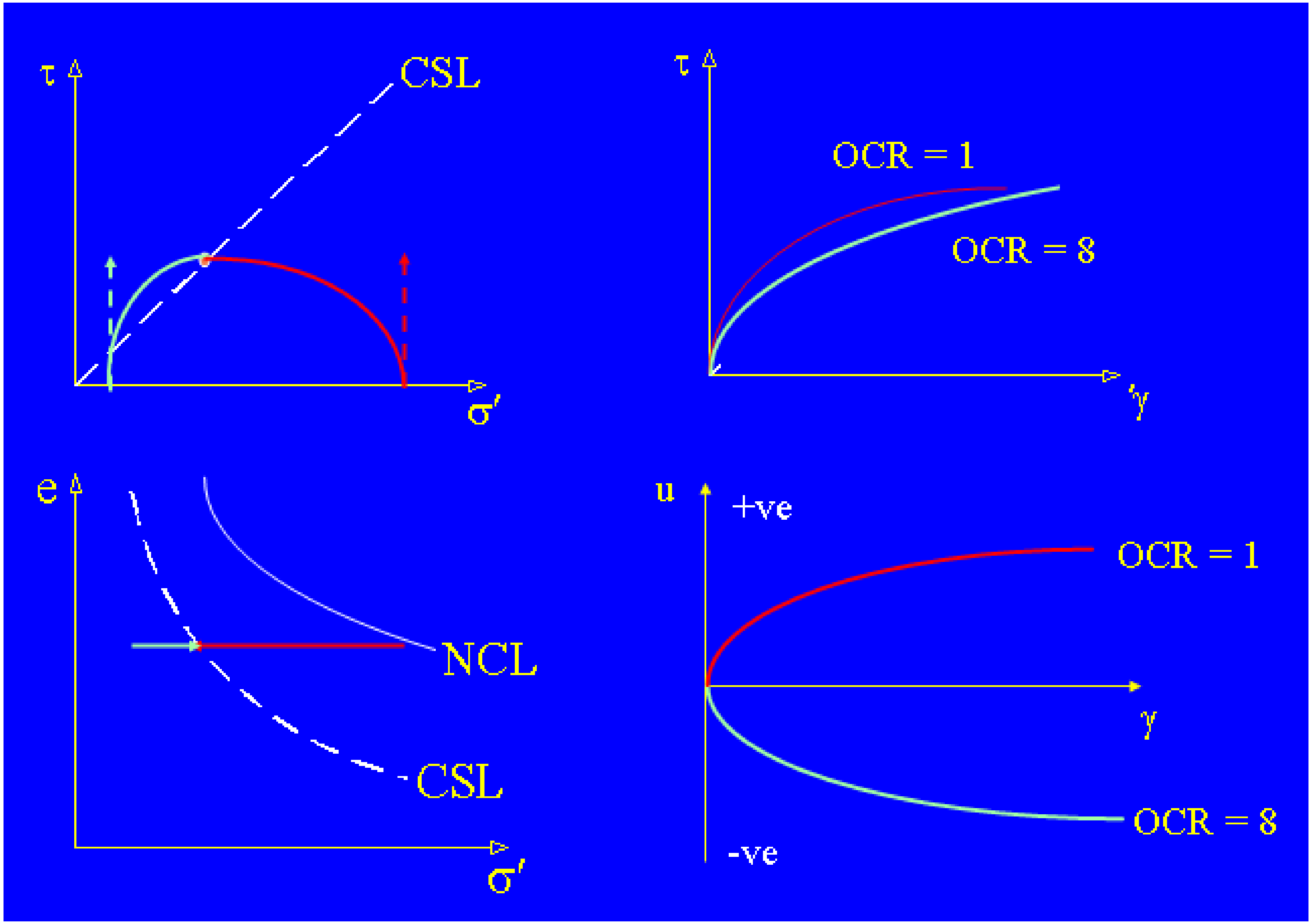
- In drained loading the change in effective stress is identical to the change in total stress. In a shear box (or simple shear) test the normal stress is usually kept constant, and hence the response is fixed in the t, s’ plot.

- The soil heads towards a critical state when sheared, and this ultimate (or critical) state can be determined from the t, s’ plot.

- The change in void ratio can then be determined.

- Knowing the sign of the volume change enables the likely stress-strain response to be estimated.

CLAY BEHAVIOUR – UNDRAINED CONDITION



CLAY BEHAVIOUR – UNDRAINED CONDITION

- In undrained loading the void ratio (moisture content) must stay constant.

- The soil must head towards a critical state when sheared, and knowing e the critical state can be determined from the e, σ' plot.

- Once the critical state has been determined in the e, σ' plot the ultimate shear stress is also fixed. The ultimate shear stress is related to the undrained strength. This relation can be obtained by considering a Mohr's circle.

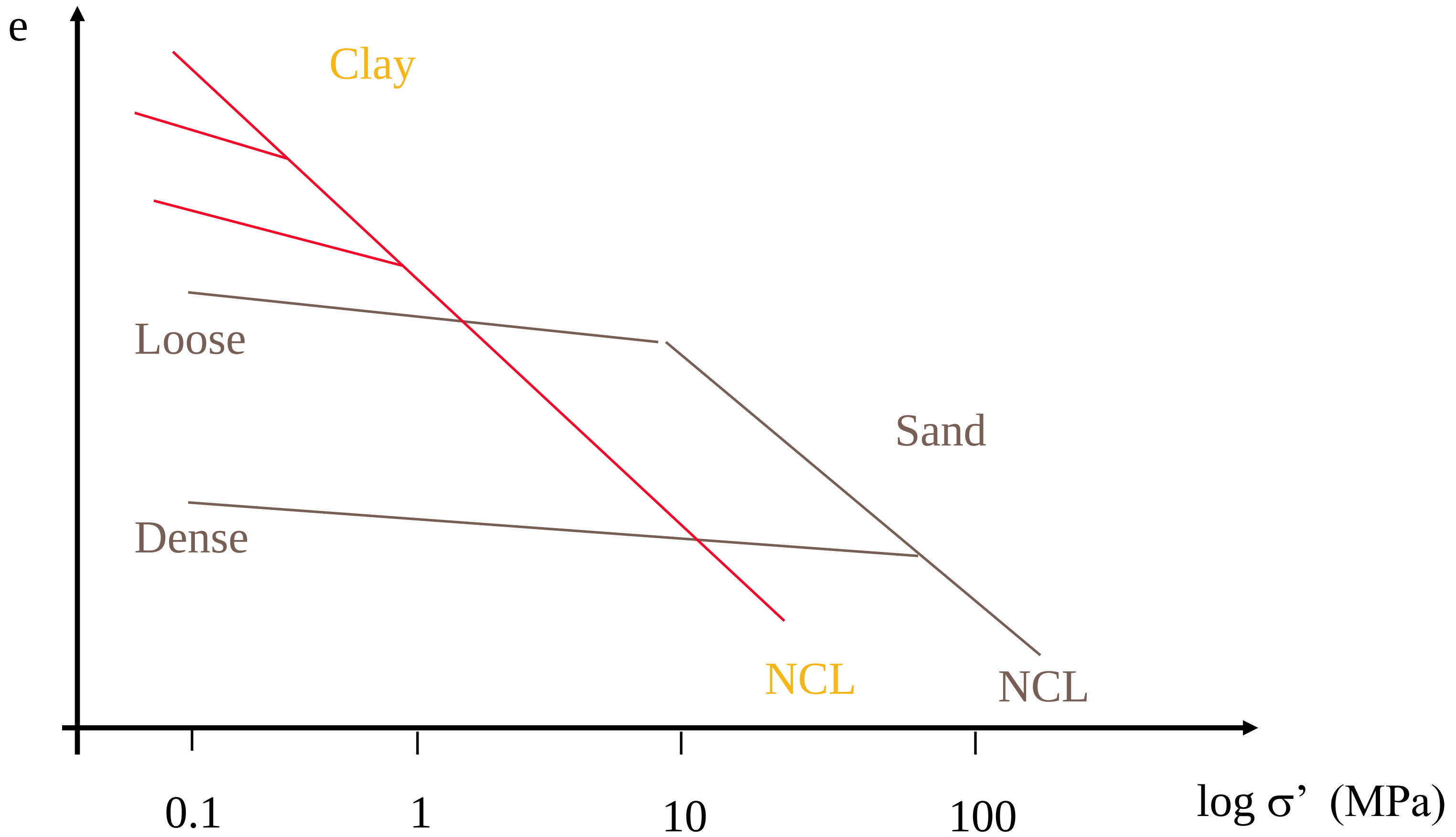
$$s_u = \frac{\tau_{ult}}{\cos\phi'_{ult}}$$

CLAY BEHAVIOUR – UNDRAINED CONDITION

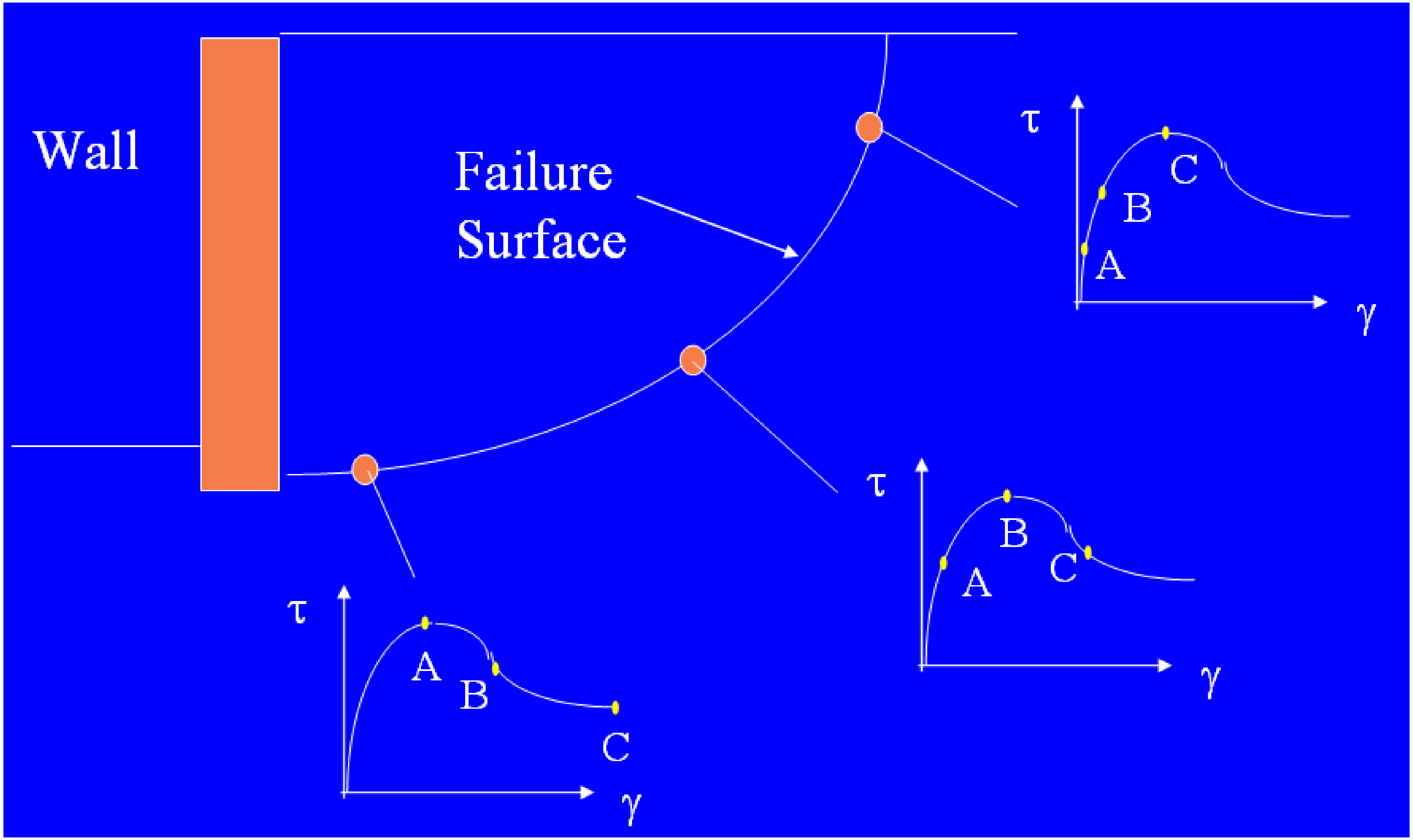
- In undrained loading the effective stresses are fixed because void ratio (moisture content) must stay constant.
- The total stresses are controlled by the external loads, and the pore pressure is simply the difference between the total stress and effective stress.
- The CSL provides an explanation for the existence of cohesion (undrained strength) in frictional soils
- From the CSL it can also be seen that changes in moisture content (void ratio) will lead to different undrained strengths

DIFFERENCES BETWEEN SAND AND CLAY

All soils are essentially frictional materials but different parameters are used for sands (Id) and clays (OCR)



APPLICATION



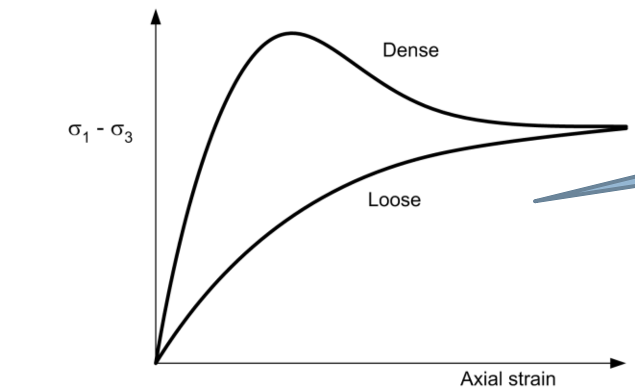
QUESTION 1

An understanding of the stress-strain response of soils is useful in interpreting the results of laboratory tests. With the aid of diagrams (*i.e.* $\sigma_1 - \sigma_3$ *vs* ε_a; *volumetric strain vs* ε_a), discuss the stress-strain response to soils (both dense and loose sands) based on drained test.

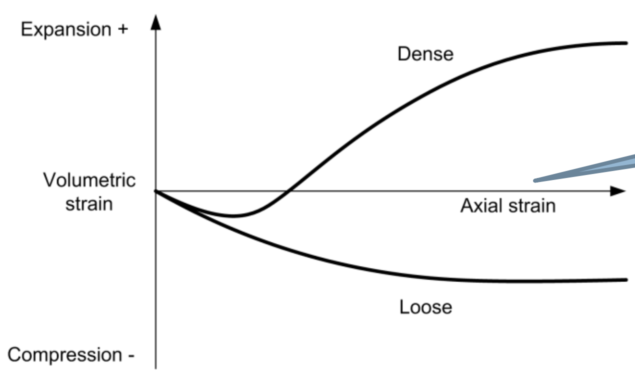
(10 marks)

ANSWER

- Typical stress-strain curves from triaxial shear tests on dense and loose sands are shown below:



Based on axial stress-strain curve



Based on volumetric strain vs. axial strain curve:

ANSWER

- **Based on axial stress-strain curve:**

- For loose sand, the axial stress may increase with increasing strain up to 20 or 25 percent axial strain or even more. Specimen normally does not have a significant peak point ($\sigma 1 - \sigma 3$ max). However, if large strains are required to reach a peak axial stress, or if the test data show no peak, it is appropriate to use some value of strain as the failure criterion (i.e. 15 percent axial strain should be taken as the stress at failure).

- In dense sands, peak load is reached at much smaller strains than for loose sands, and the stress may then decrease significantly as strains are further increased.

- If loose and dense specimens of the same sand are sheared to large strains at the same confining pressure, the strengths will become similar at large strains, regardless of the initial density.

ANSWER

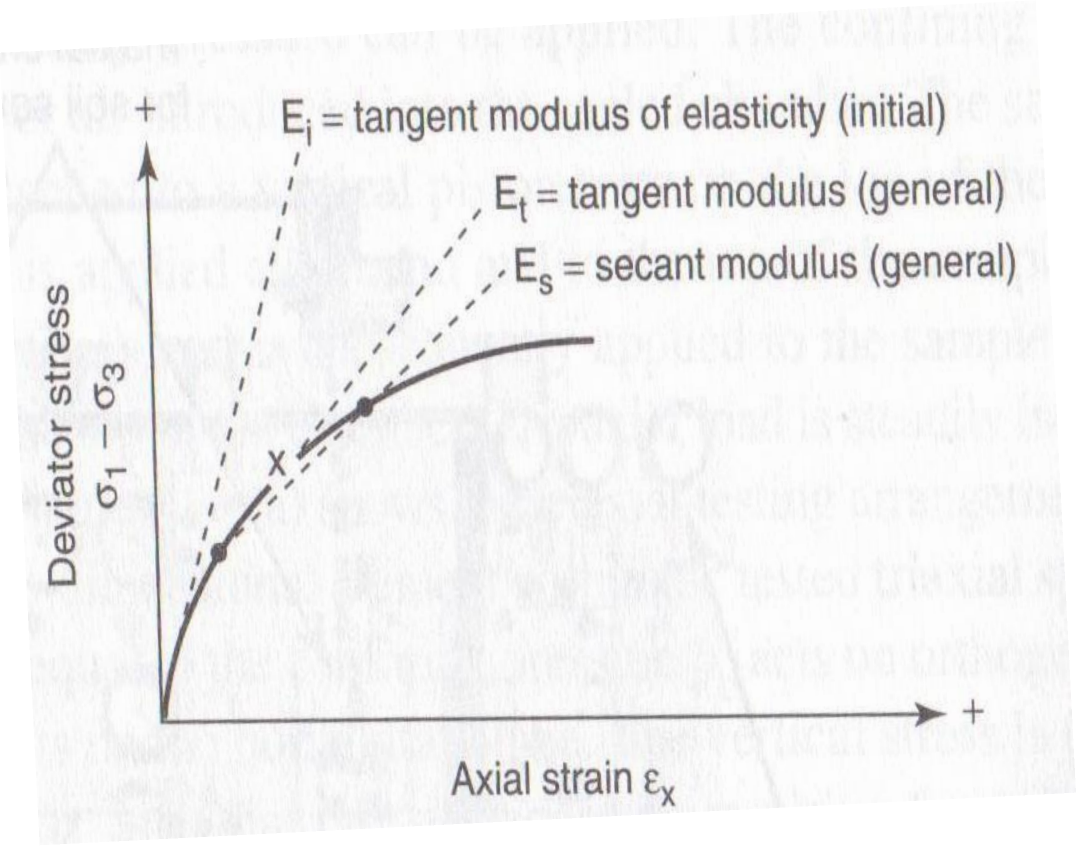
- **Based on volumetric strain vs. axial strain curve:**

- Loose sands tend to compress (volume decreases) during shear.

- Dense sands also tend to compress initially when sheared, but they then expand as they are sheared to larger strains.

QUESTION 2

- Figure shows the related stress-strain curve of the modulus of elasticity, *E*. Please fill in the blanks and explains the terms used to relate with the-stress-strain behaviour



ANSWER

- The higher the value of E, the stiffer or stronger the material.
- A tangent modulus is the slope of a line drawn tangent to a point on the stress-strain curve.
- A secant modulus is the slope of a line connecting 2 points on the stress-strain curve.
- Based on figure, it should be clear that a tangent modulus or a secant modulus will not be constant for all parts of the curve.

Ice breaking session ? ? ?