KUAT GESER TANAH

Kuat Geser Tanah

- Tanah pada umumnya mempunyai kekasaran

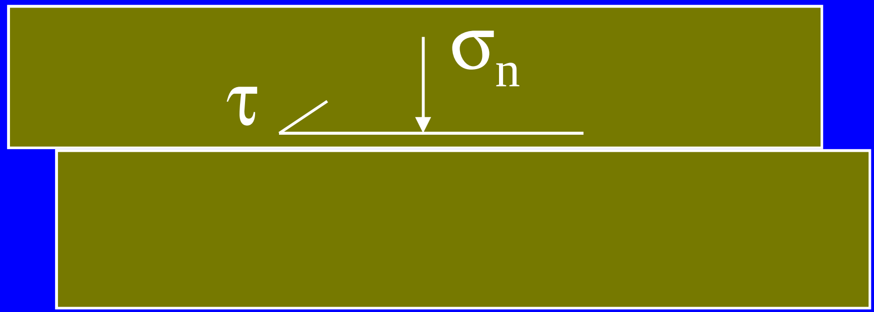
  Kuat gesernya, tergantung kepada tegangan yang diberikan.
- Kuat geser dipengaruhi oleh tegangan effektifnya

  tekanan air akan punya peran
- Tegangan geser tergantung pada drainase

  pengukuran tegangan dilakukan pada kondisi

1. Deformasi pada volume constan (undrained)
2. Deformasi tanpa menimbulkan excess pore pressures (drained)

Kriteria Keruntuhan Mohr-Coulomb



Hubungan antara tegangan geser dan tegangan normal :

$$\tau = c + \sigma_n \tan \phi$$

Dimana c = kohesi

ϕ = sudut geser

Kriteria Keruntuhan pada tegangan efektif

Jika tanah dalam kondisi runtuh , kriteria keruntuhan pada tegangan efektif akan memenuhi persamaan sbb;

$$\tau = c' + \sigma'_n \tan\phi'$$

c' and ϕ' Adalah parameter kuat geser dalam kondisi terdrainase

Kriteria keruntuhan pada tegangan total

Jika tanah dibebani pada kondisi volume konstan (undrained) persamaan kriteria keruntuhan dapat dirumuskan ;

$$\tau = c_u + \sigma_n \tan\phi_u$$

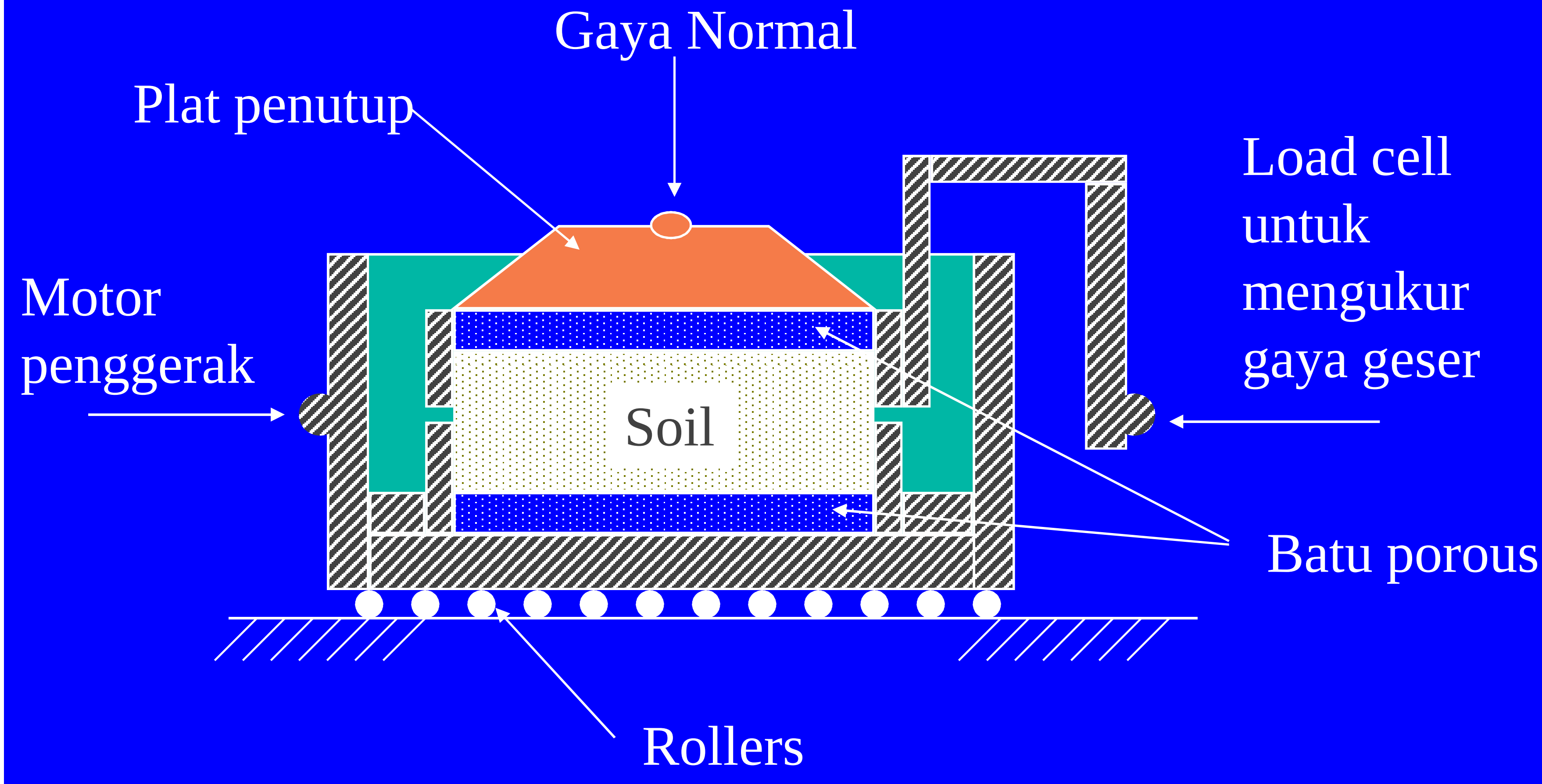
c_u dan ϕ_u adalah parameter undrained strength

Dalam praktek , undrained strength diterapkan pada tanah lempung pada jangka waktu singkat tidak terdrainase.

Jadi jika pore pressures tidak dapat diukur , kriteria tegangan efektif tidak bisa dipakai

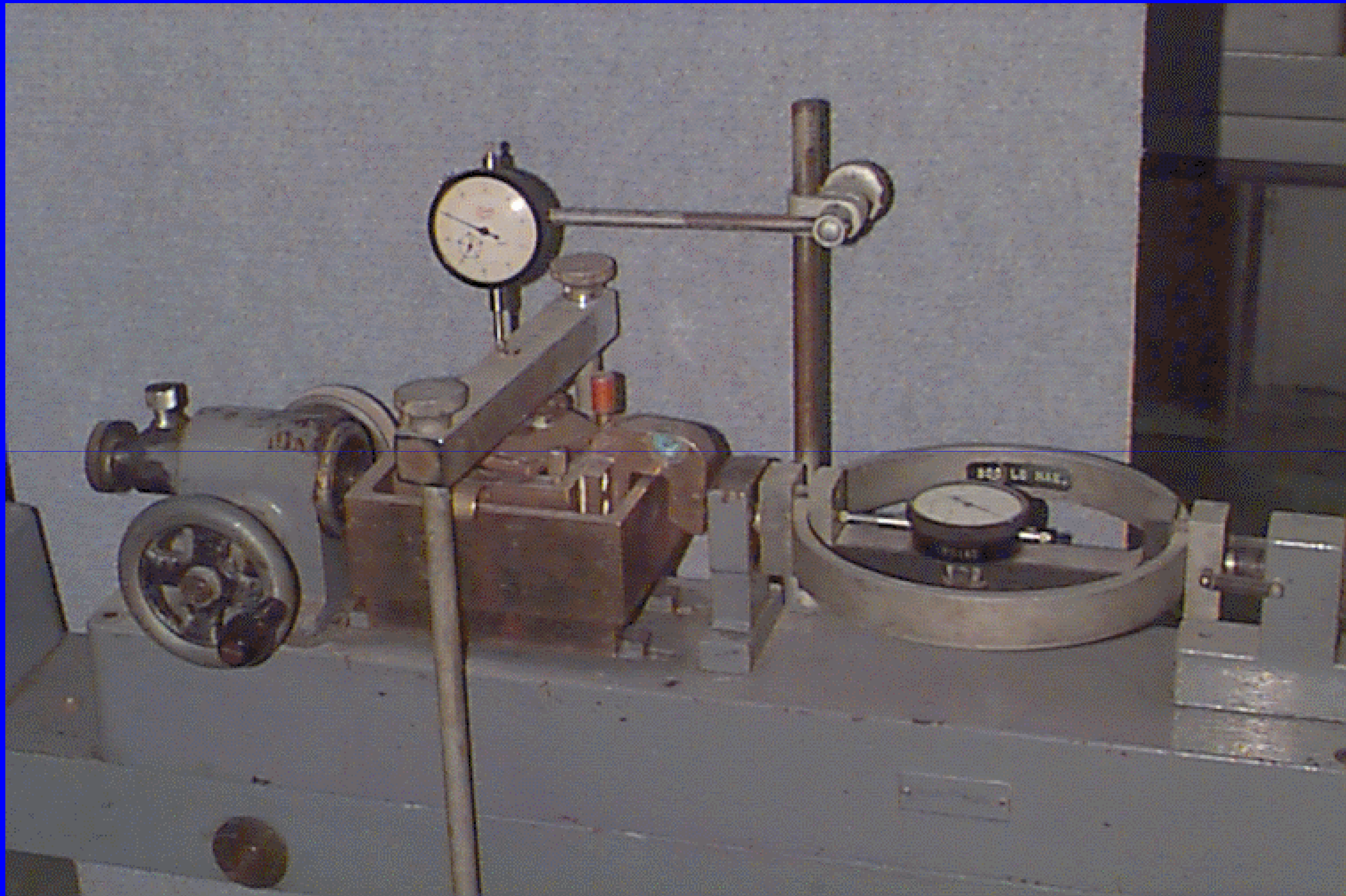
Percobaan Geser Langsung

1. Shear Box Test



Yang diukur pergerakan horisontal relatif dx

pergerakan vertikal, dy

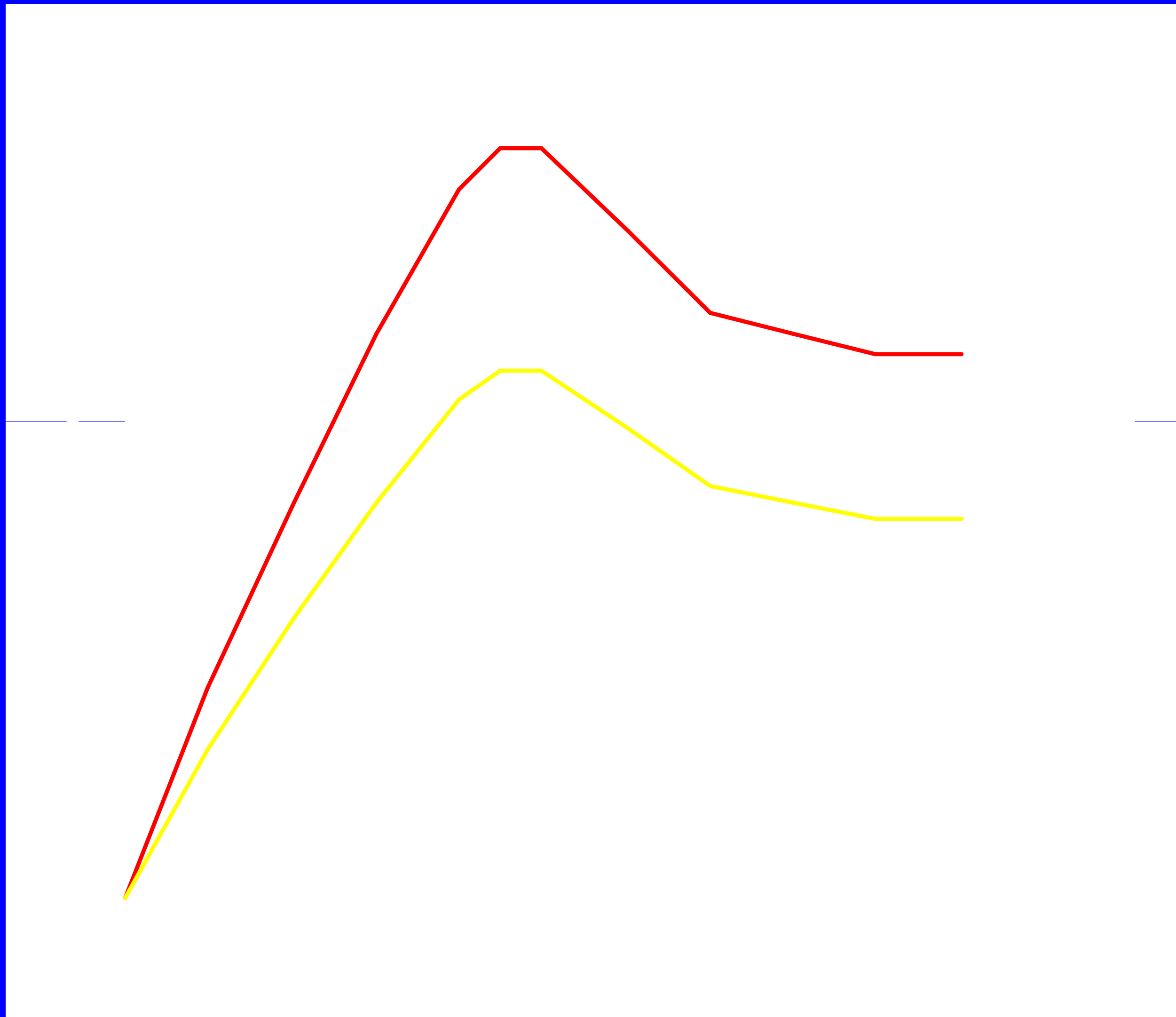


Shear box test

- Percobaan pada tanah lempung, kecepatan pembebanan harus rendah, untuk menghindari pengaruh pore pressure

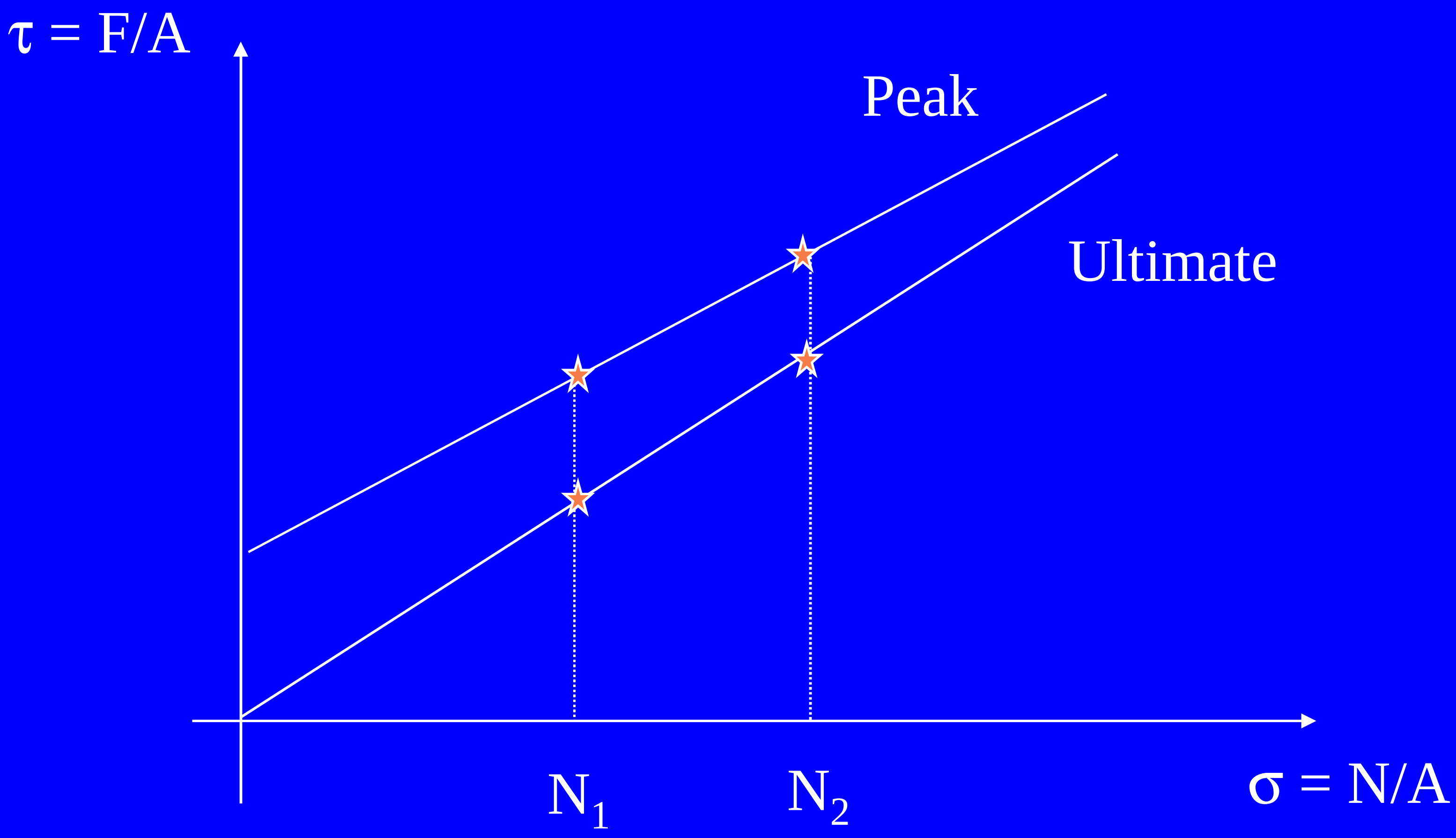
  Untuk jenis pasir dan kerikil dapat dilakukan pembebanan dengan kecepatan yang lebih tinggi

Contoh hasil percobaan geser



Normal load increasing

Contoh pembebanan dengan drained



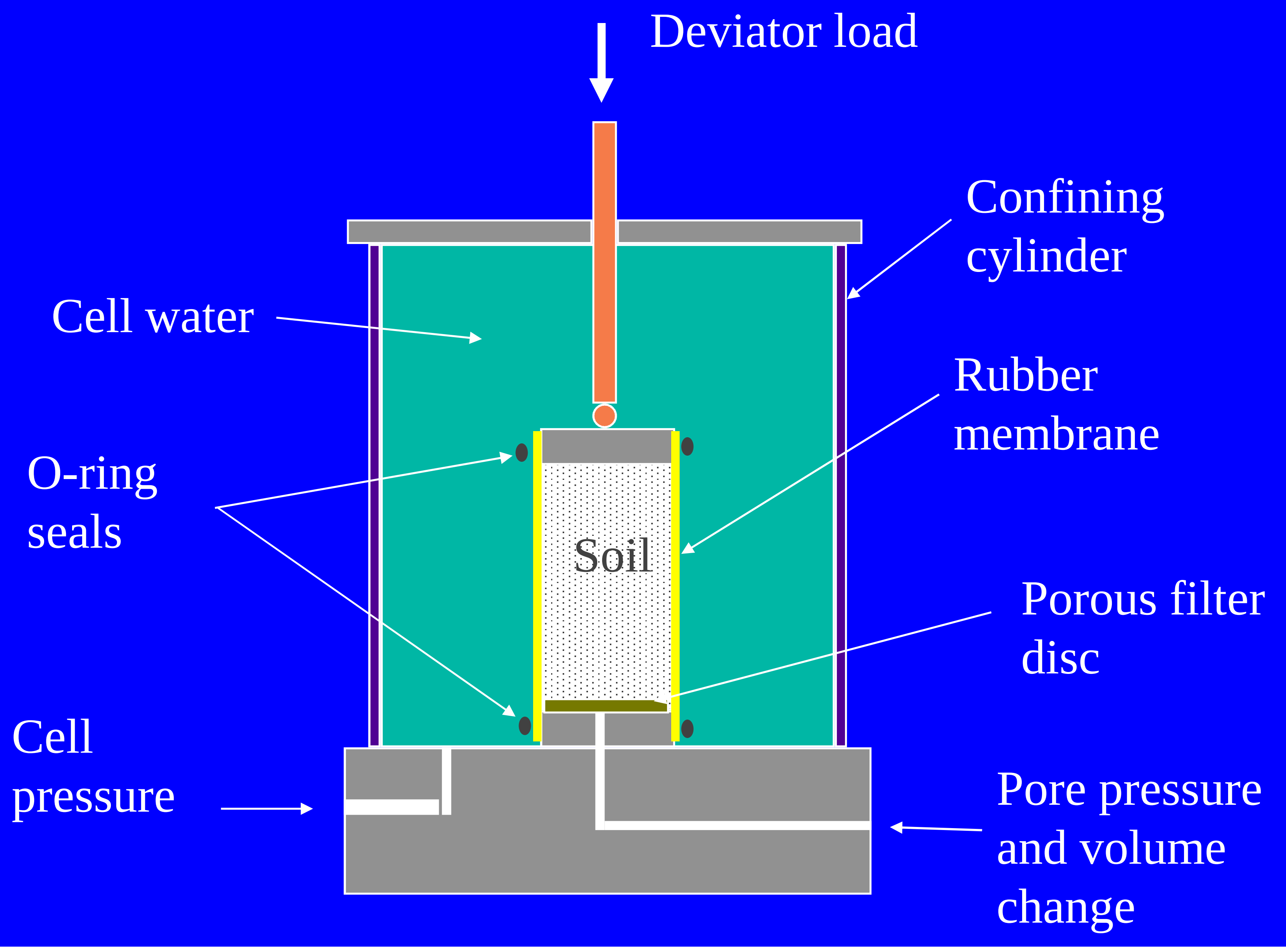
Keuntungan dengan percobaan Geser Langsung

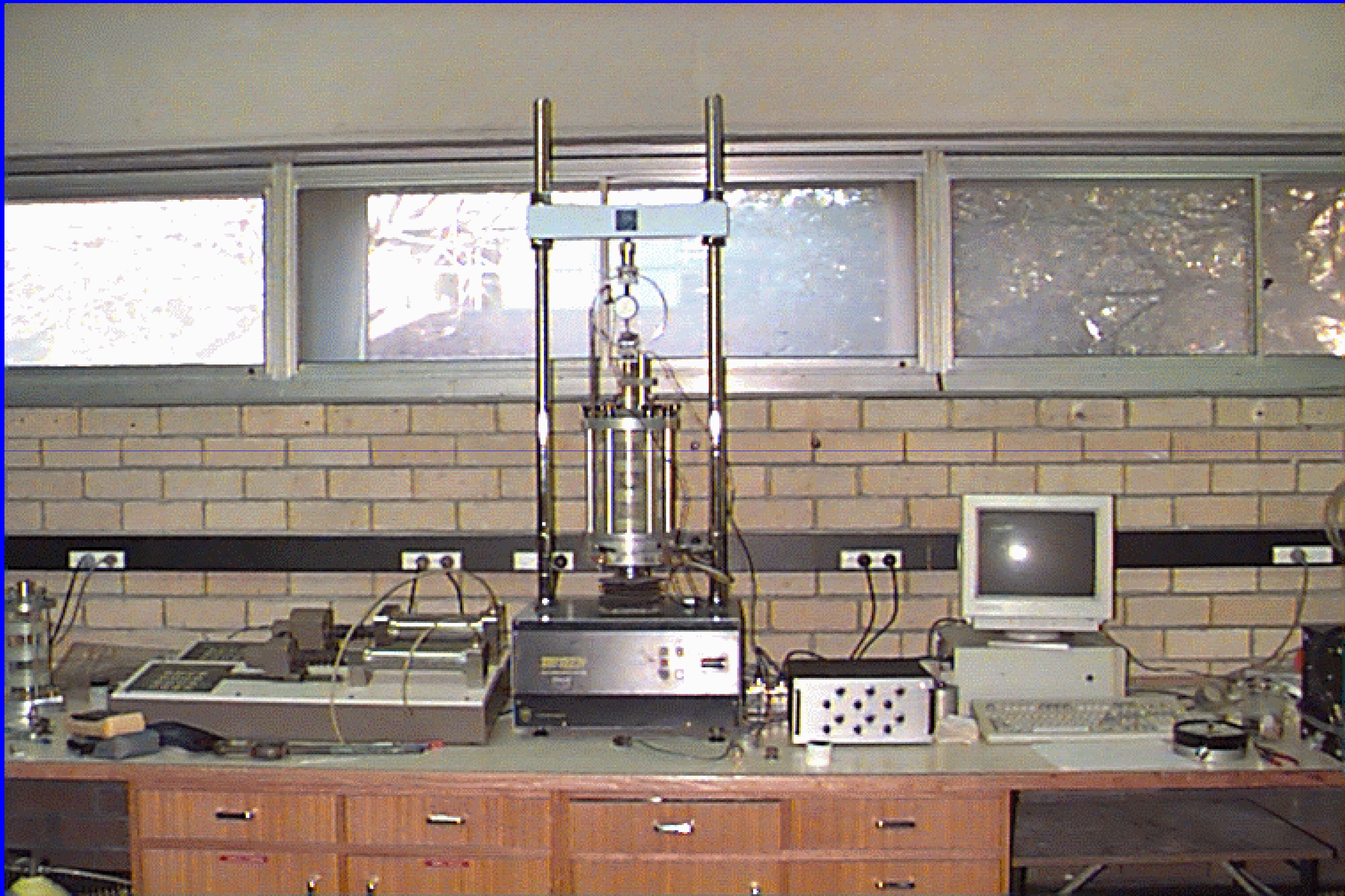
- Mudah dan cepat untuk tes pada pasir dan gravel
- Percobaan dengan deformasi yang besar dapat dilakukan untuk mengetahui kuat geser residual
- Sampel ukuran besar dapat dilakukan pada box yang besar

Kerugian pada Tes Kuat Geser Langsung

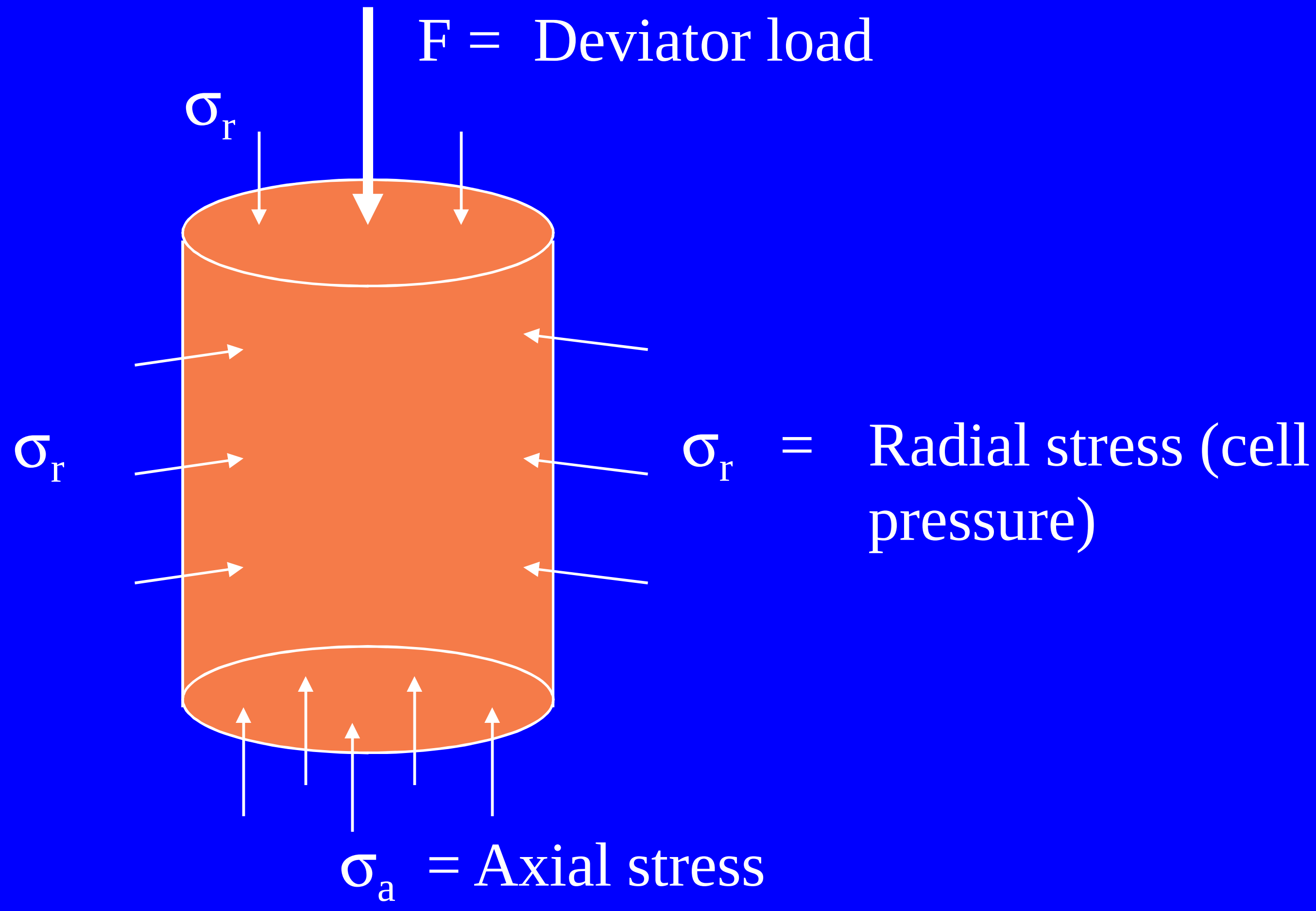
- Tegangan Efektif tidak bisa ditentukan dari undrained test
- Undrained strengths yang didapat tidak tepat , karena tidak mungkin menghindari drainasi tanpa menerapkan pembebanan dengan kecepatan tinggi

Tes Triaksial

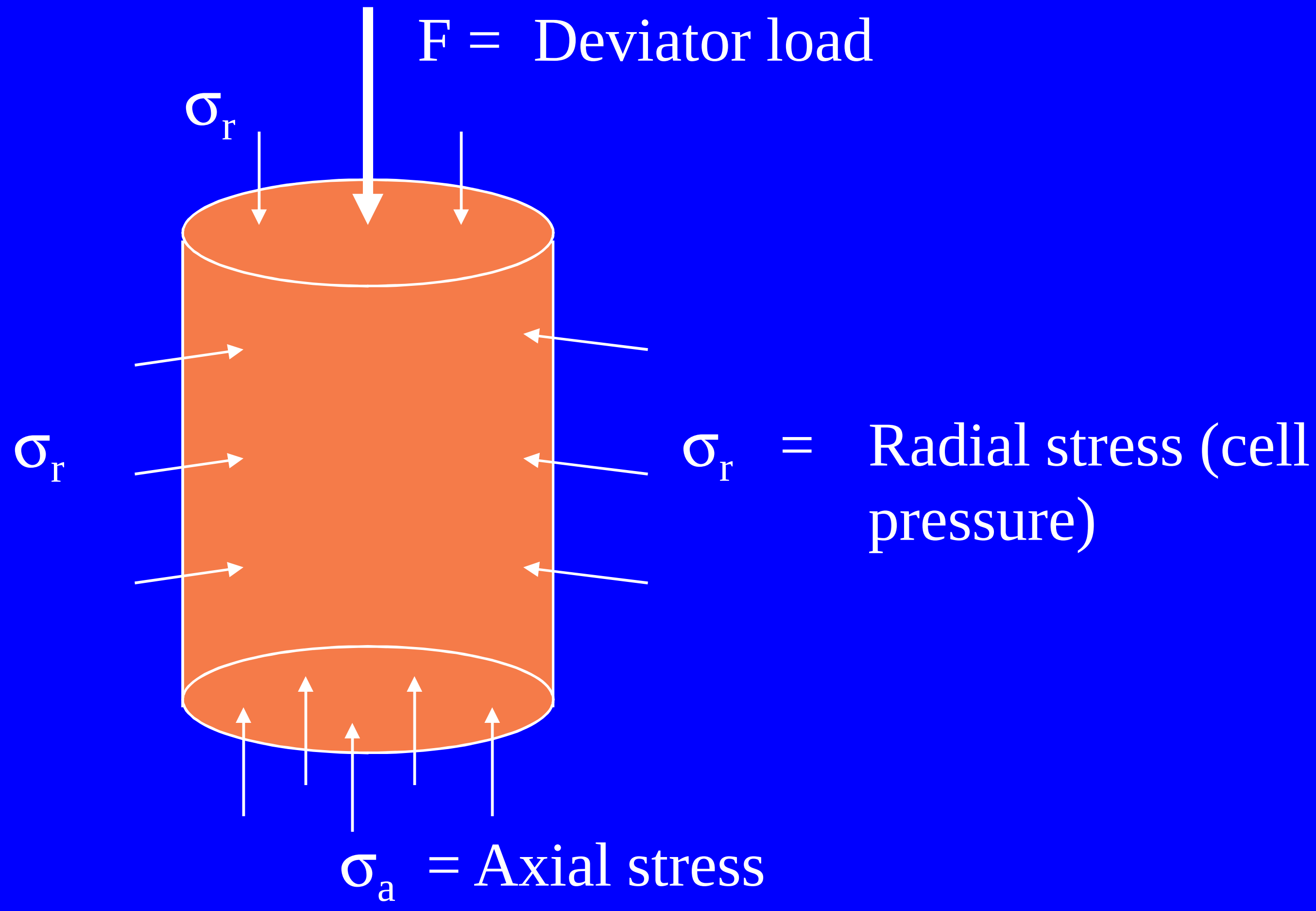




Tegangan yang bekerja pada contoh tanah



Tegangan yang terjadi pada contoh tanah



Strains in triaxial specimens

Dari pengukuran tinggi dh, dan perubahan volume dV didapatkan

Axial strain $$\varepsilon_a = -\frac{dh}{h_0}$$

Volume strain $$\varepsilon_V = -\frac{dV}{V_0}$$

Dimana h_0 adalah tinggi awal , dan Vo adalah volume awal

Dengan anggapan bahwa deformasi terjadi dengan bentuk silinder
Sehingga luas penampang melintang A dapat dihitung dari

$$A = A_o \left(\frac{1 + \frac{dV}{V_0}}{1 + \frac{dh}{h_0}} \right) = A_o \left(\frac{1 - \varepsilon_v}{1 - \varepsilon_a} \right)$$

Jenis Percobaan Triaxial

Beberapa Jenis Variasi percobaan

- UU (unconsolidated undrained) test.

  Cell pressure applied without allowing drainage. Then keeping cell pressure constant increase deviator load to failure without drainage.

- CIU (isotropically consolidated undrained) test.

  Drainage allowed during cell pressure application. Then without allowing further drainage increase q keeping σ_r constant as for UU test.

- CID (isotropically consolidated drained) test

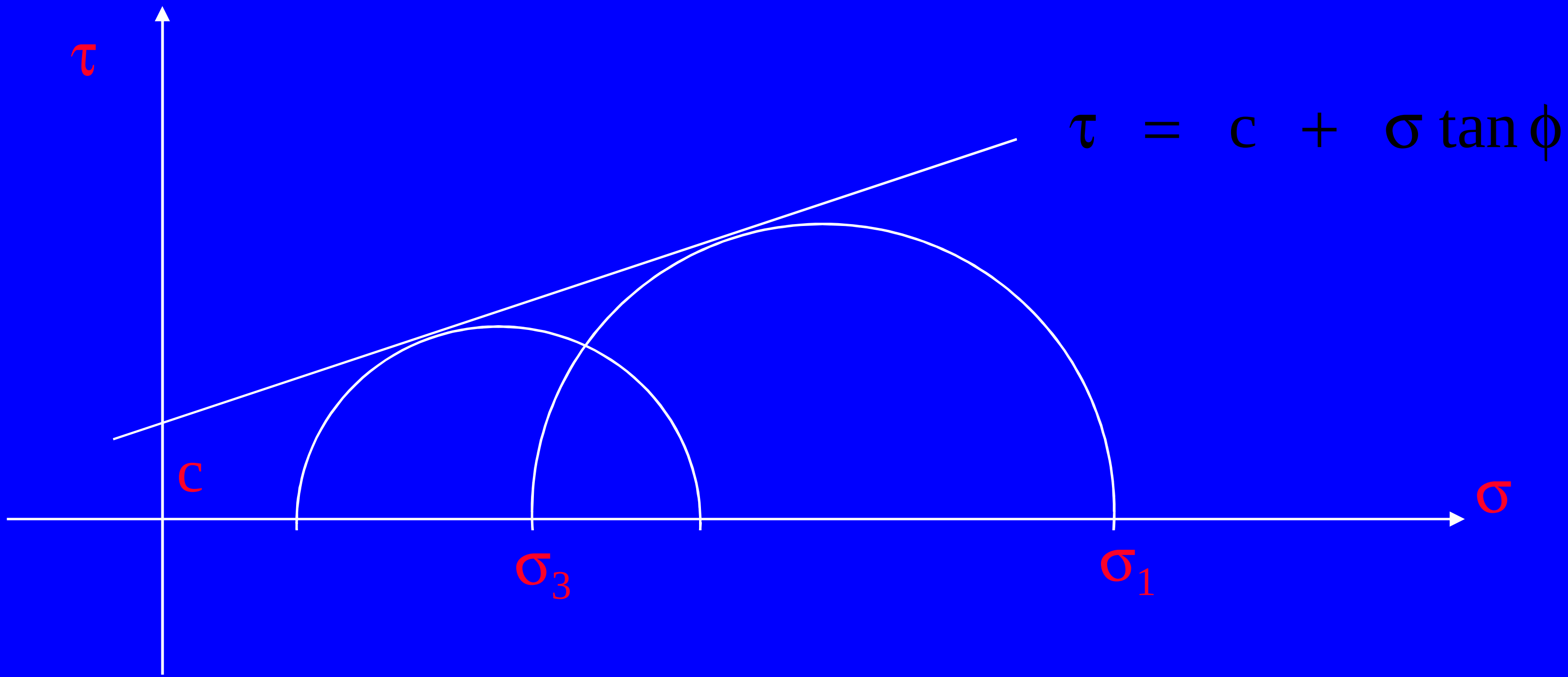
  Similar to CIU except that as deviator stress is increased drainage is permitted.

Keuntungan penggunaan triaxial test

- Contoh tanah menerima tegangan dan regangan yang relatif merata
- Perilaku stress-strain-strength dapat diamati semua
- Dapat dilakukan drained dan undrained tests
- Pore water pressures dapat diukur pada undrained tests
- Dapat diterapkan cell pressure and axial stress yang berbeda besarnya

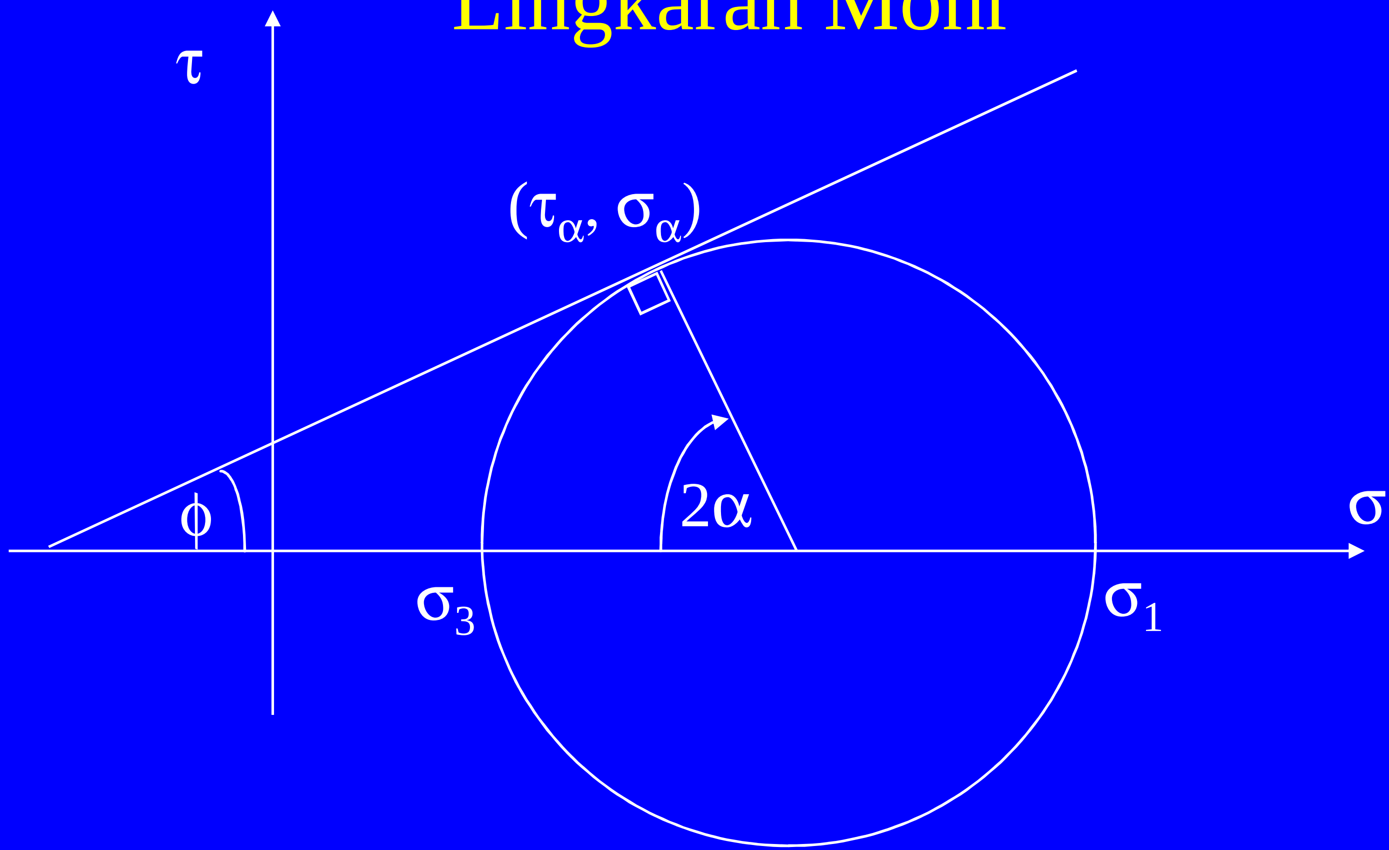
Mohr Circles

To relate strengths from different tests we need to use some results from the Mohr circle transformation of stress.



The Mohr-Coulomb failure locus is tangent to the Mohr circles at failure

Lingkaran Mohr



From the Mohr Circle geometry

$$\sigma_\alpha = \frac{(\sigma_1 + \sigma_3)}{2} - \frac{(\sigma_1 - \sigma_3)}{2}\cos 2\alpha$$

$$\tau_\alpha = \frac{(\sigma_1 - \sigma_3)}{2}\sin 2\alpha$$

$$\alpha = \left(\frac{\pi}{4} - \frac{\phi}{2}\right)$$

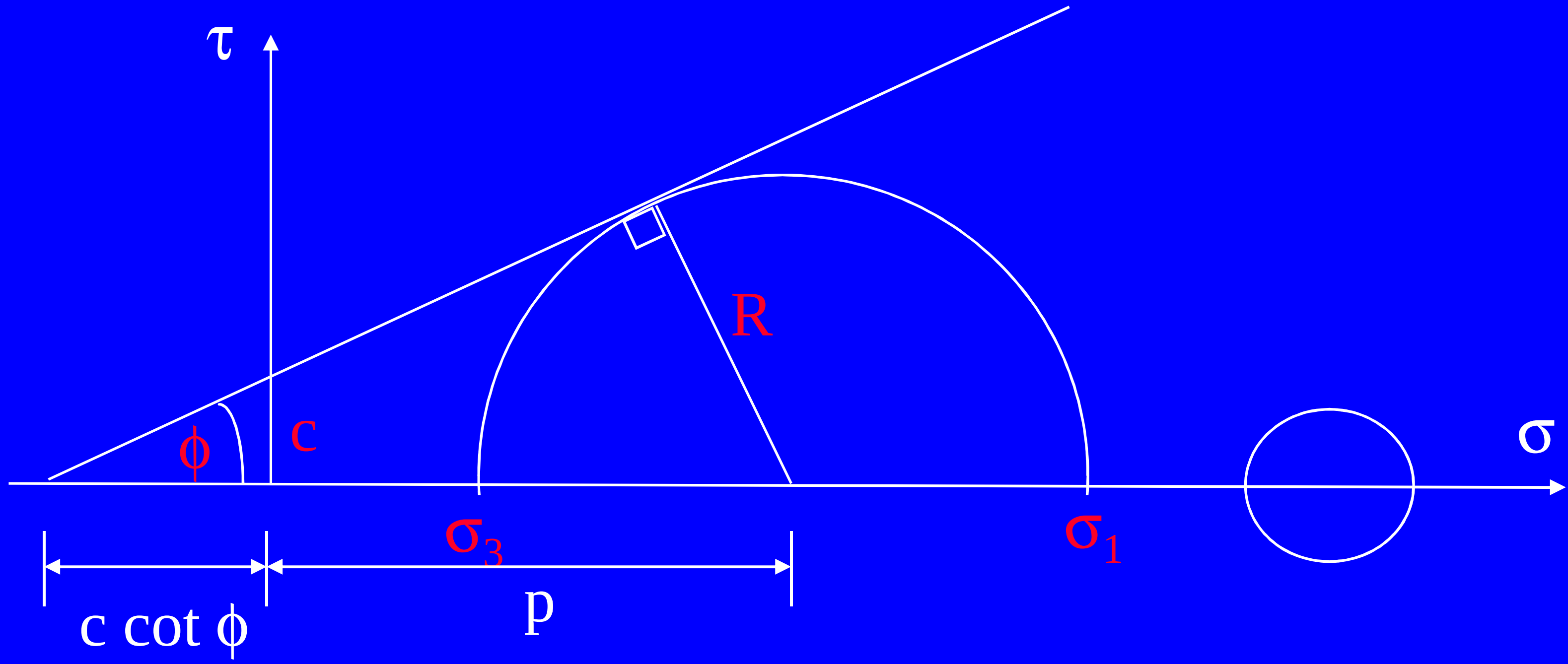
Mohr Circles

- The Mohr circle construction enables the stresses acting in different directions at a point on a plane to be determined, provided that the stress acting normal to the plane is a principal stress.
- The construction is useful in Soil Mechanics because many practical situations may be approximated as plane strain.
- The sign convention is different to that used in Structural analysis because it is conventional to take compressive stresses positive
- Sign convention: Compressive normal stresses positive

  Anti-clockwise shear stresses positive (from inside element)

  Angles measured clockwise are positive

Mohr-Coulomb criterion (Principal stresses)



Failure occurs if a Mohr circle touches the failure criterion. Then

$$R = \sin\phi \,(\, p + c\cot\phi\,)$$

$$\frac{\sigma_1 + c\cot\phi}{\sigma_3 + c\cot\phi} = \frac{1 + \sin\phi}{1 - \sin\phi} = \tan^2\left[\frac{\pi}{4} + \frac{\phi}{2}\right] = N_\phi$$

$$\sigma_1 = N_\phi\,\sigma_3 + 2c\sqrt{N_\phi}$$

Effective stress Mohr-Coulomb criterion

As mentioned previously the effective strength parameters c' and ϕ' are the fundamental parameters. The Mohr-Coulomb criterion must be expressed in terms of effective stresses

$$\tau = c' + \sigma'_n \tan\phi'$$

$$\sigma'_1 = N_\phi \, \sigma'_3 + 2\,c' \sqrt{N_\phi}$$

where

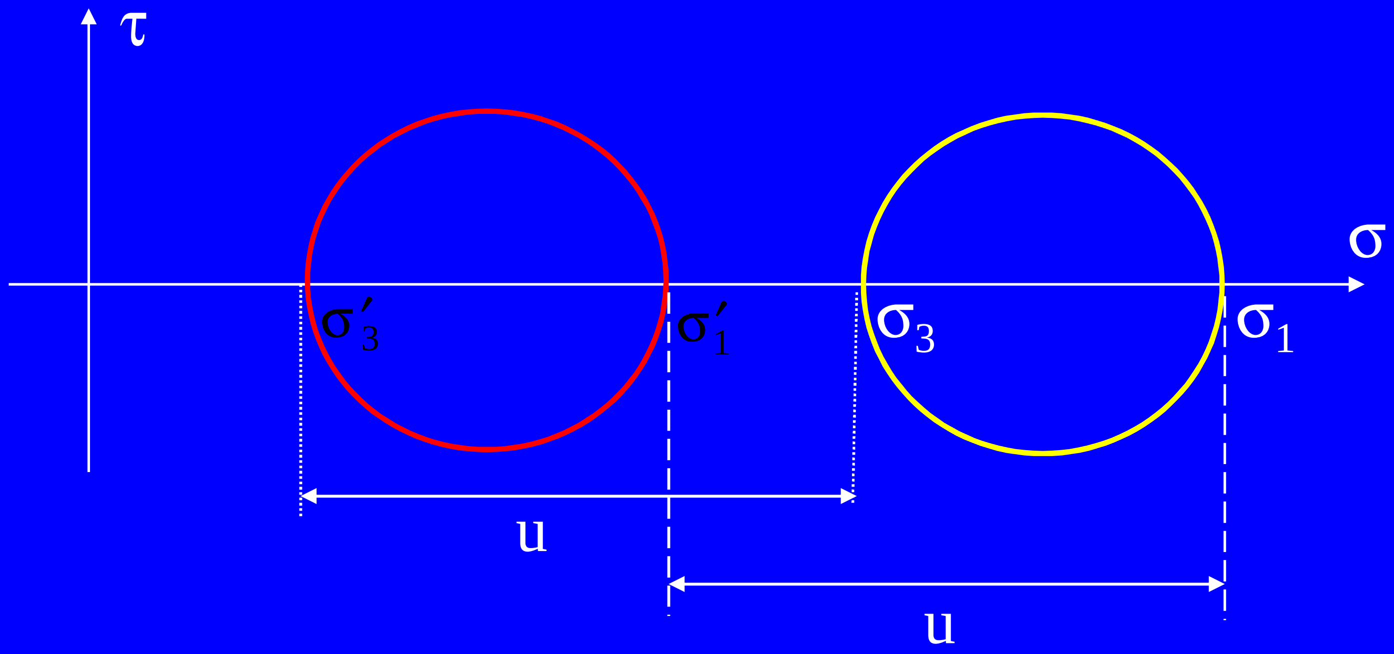
$$N_\phi = \frac{1 + \sin\phi'}{1 - \sin\phi'}$$

$$\sigma'_n = \sigma_n - u$$

$$\sigma'_1 = \sigma_1 - u$$

$$\sigma'_3 = \sigma_3 - u$$

Effective and total stress Mohr circles



For any point in the soil a total and an effective stress Mohr circle can be drawn. These are the same size with

$$\sigma'_1 - \sigma'_3 = \sigma_1 - \sigma_3$$

The two circles are displaced horizontally by the pore pressure, u.

Interpretation of Laboratory results

1. Drained shear loading

- In laboratory tests the loading rate is chosen so that no excess water pressures will be generated, and the specimens are free to drain. Effective stresses can be determined from the applied total stresses and the known pore water pressure.
- Only the effective strength parameters c’ and ϕ’have any relevance to drained tests.
- It is possible to construct a series of total stress Mohr circles but the inferred total stress (undrained) strength parameters are meaningless.

Interpretation of Laboratory results

- Effective strength parameters are generally used to check the long term stability (that is when all excess pore pressures have dissipated) of soil constructions.

- For sands and gravels pore pressures dissipate rapidly and the effective strength parameters can also be used to check the short term stability.

- In principle the effective strength parameters can be used to check the stability at any time for any soil type. However, to do this the pore pressures in the ground must be known and in general they are only known in the long term.

Interpretation of Laboratory results

2. Undrained loading

- In undrained laboratory tests no drainage from the sample must occur, nor should there be moisture redistribution within the sample.

- In the shear box this requires fast shear rates. In triaxial tests slower loading rates are possible because conditions are uniform and drainage from the sample is easily prevented.

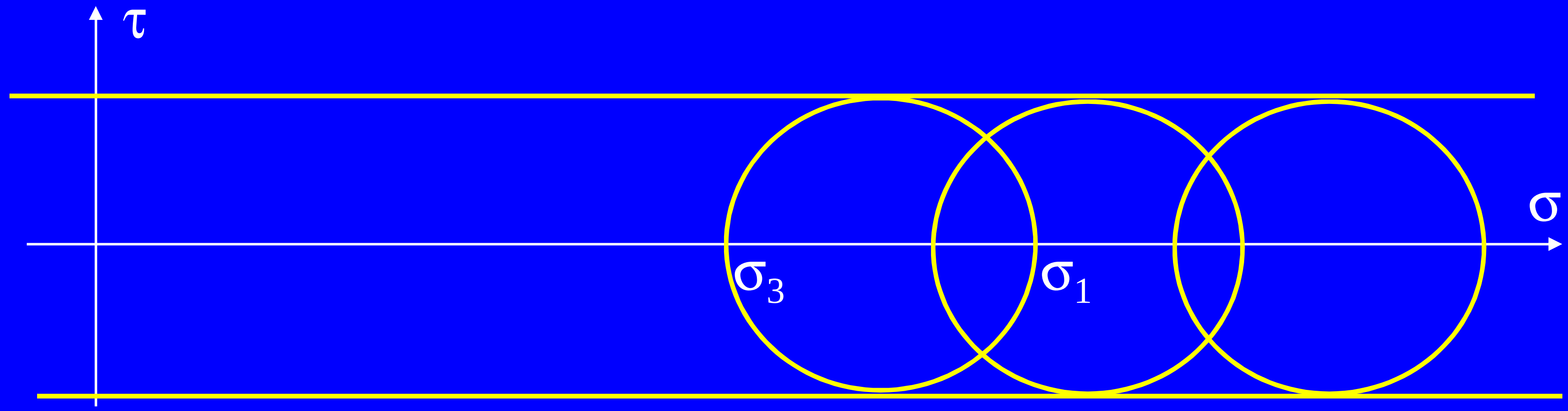
- In a triaxial test with pore pressure measurement the effective stresses can be determined and the effective strength parameters c', ϕ' evaluated. These can be used as discussed previously to evaluate long term stability.

Interpretation of Laboratory results

- The undrained tests can also be used to determine the total (or undrained) strength parameters c_u, ϕ_u. If these parameters are to be relevant to the ground the moisture content must be the same. This can be achieved either by performing UU tests or by using CIU tests and consolidating to the in-situ stresses.
- The total (undrained) strength parameters are used to assess the short term stability of soil constructions. It is important that no drainage should occur if this approach is to be valid. For example, a total stress analysis would not be appropriate for sands and gravels.
- For clayey soils a total stress analysis is the only simple way to assess stability
- Note that undrained strengths can be determined for any soil, but they may not be relevant in practice

Relation between effective and total stress criteria

Three identical saturated soil samples are sheared to failure in UU triaxial tests. Each sample is subjected to a different cell pressure. No water can drain at any stage. At failure the Mohr circles are found to be as shown

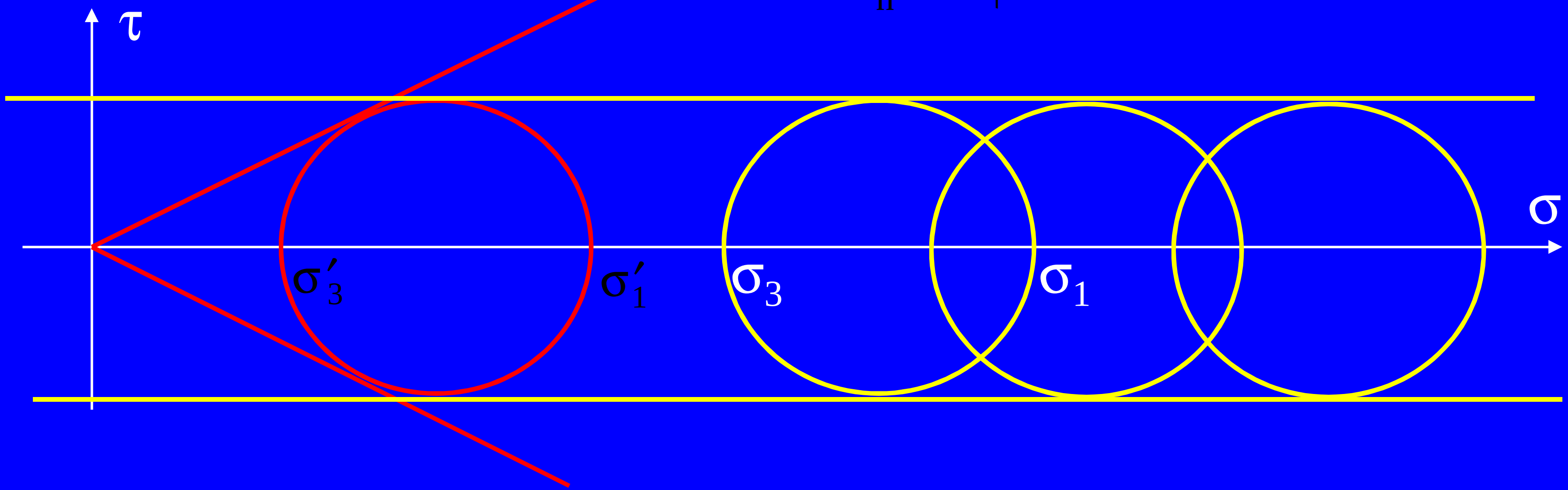


We find that all the total stress Mohr circles are the same size, and therefore $\phi_u = 0$ and $\tau = s_u = c_u =$ constant

Relation between effective and total stress criteria

Because each sample is at failure, the fundamental effective stress failure condition must also be satisfied. As all the circles have the same size there must be only one effective stress Mohr circle

$$\tau = c' + \sigma'_n \tan\phi'$$



We have the following relations

$$\sigma'_1 - \sigma'_3 = \sigma_1 - \sigma_3 = 2c_u$$

$$\sigma'_1 = N_\phi \sigma'_3 + 2c'\sqrt{N_\phi}$$

Relation between effective and total stress criteria

- The different total stress Mohr circles with a single effective stress Mohr circle indicate that the pore pressure is different for each sample.
- As discussed previously increasing the cell pressure without allowing drainage has the effect of increasing the pore pressure by the same amount ($\Delta u = \Delta\sigma_r$) with no change in effective stress.
- The change in pore pressure during shearing is a function of the initial effective stress and the moisture content. As these are identical for the three samples an identical strength is obtained.

Significance of undrained strength parameters

- It is often found that a series of undrained tests from a particular site give a value of ϕ_u that is not zero (c_u not constant). If this happens either
  - the samples are not saturated, or
  - the samples have different moisture contents
- If the samples are not saturated analyses based on undrained behaviour will not be correct
- The undrained strength c_u is not a fundamental soil property. If the moisture content changes so will the undrained strength.

Example

In an unconsolidated undrained triaxial test the undrained strength is measured as 17.5 kPa. Determine the cell pressure used in the test if the effective strength parameters are c’ = 0, ϕ’ = 26^o and the pore pressure at failure is 43 kPa.

Analytical solution

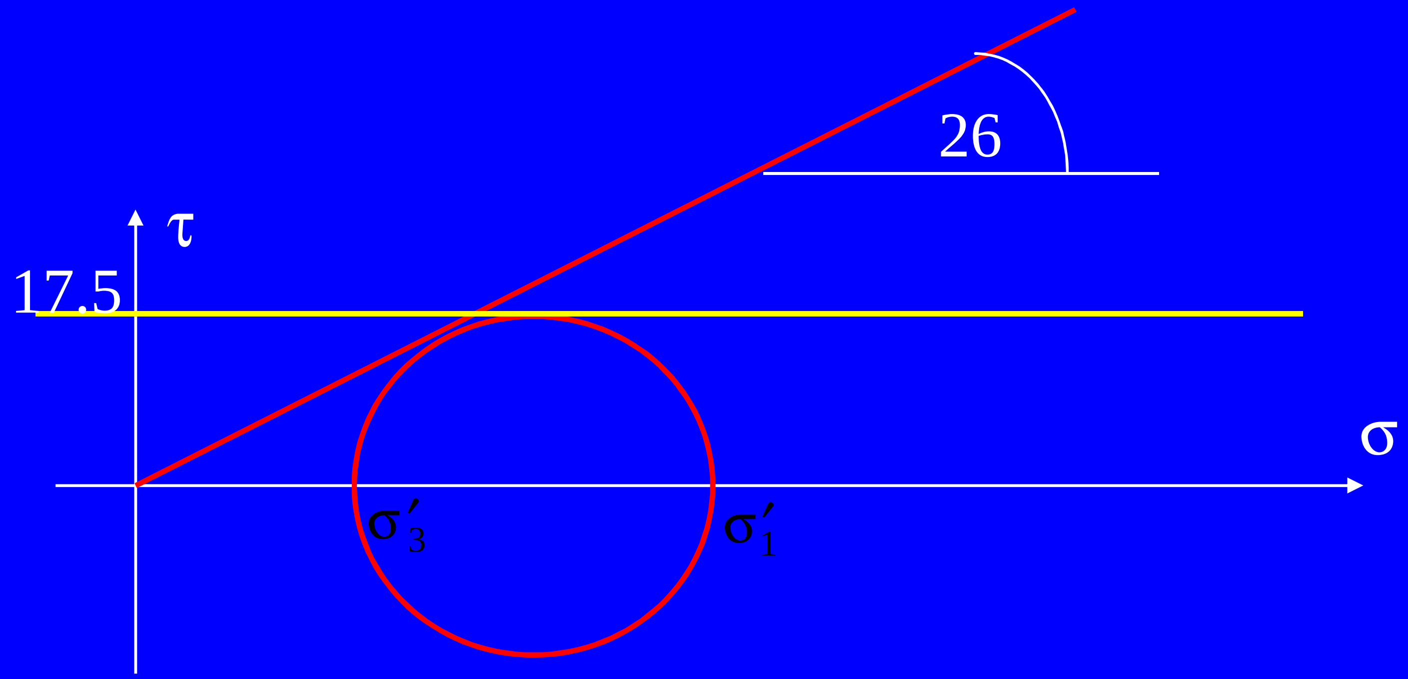
Undrained strength = 17.5 = $\dfrac{(\sigma_1 - \sigma_3)}{2} = \dfrac{(\sigma'_1 - \sigma'_3)}{2}$

Failure criterion $\sigma'_1 = N_\phi \, \sigma'_3 + 2\, c' \sqrt{N_\phi}$

Hence σ_1’ = 57.4 kPa, σ_3’ = 22.4 kPa

and cell pressure (total stress) = σ_3’ + u = 65.4 kPa

Graphical solution



Graphical solution