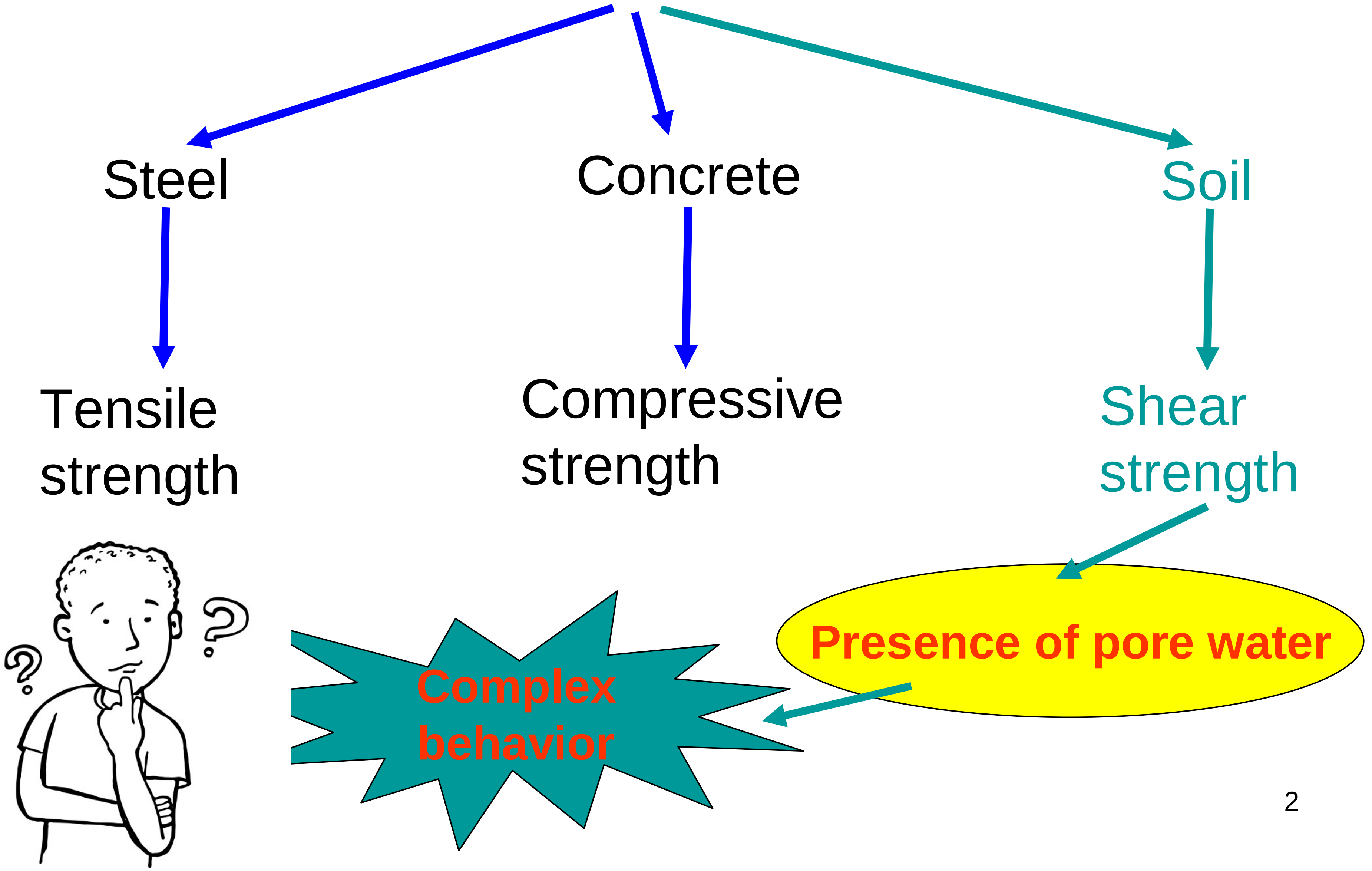
SHEAR STRENGTH OF SOILS

Strength of different materials



Shear Strength of Soil

- ***What is shear strength?***

  The shear strength of a soil mass is the resistance to deformation/movement along any plane inside the soil mass.

- *It is combination of:*

  a. Particle interlocking

  b. Friction from grain to grain contact

  c. Chemical bonds (cementation) between particles such as crystallized calcium carbonate

a & b is known as frictional resistance and c is known as cohesion.

Influencing Factors on Shear Strength

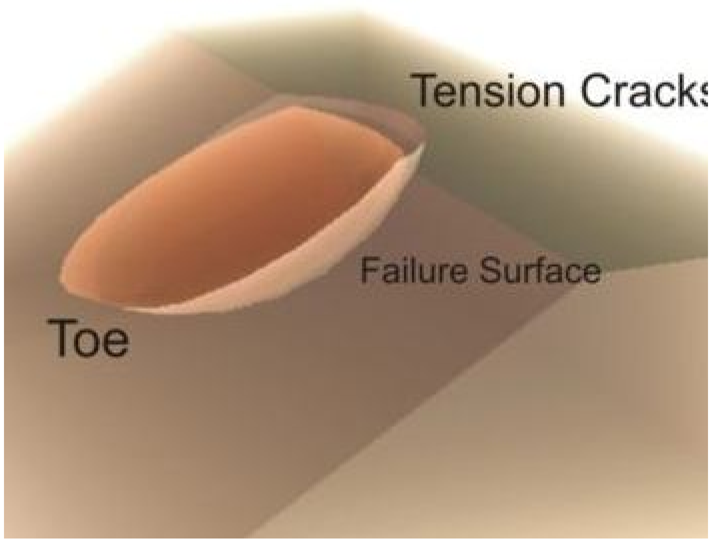
- The shearing strength, is affected by:
  - *soil composition*: mineralogy, grain size and grain size distribution, shape of particles, pore fluid type and content, ions on grain and in pore fluid.
  - *Initial state*: State can be describe by terms such as: loose, dense, over-consolidated, normally consolidated, stiff, soft, etc.
  - *Structure*: Refers to the arrangement of particles within the soil mass; the manner in which the particles are packed or distributed. Features such as layers, voids, pockets, cementation, etc, are part of the structure.

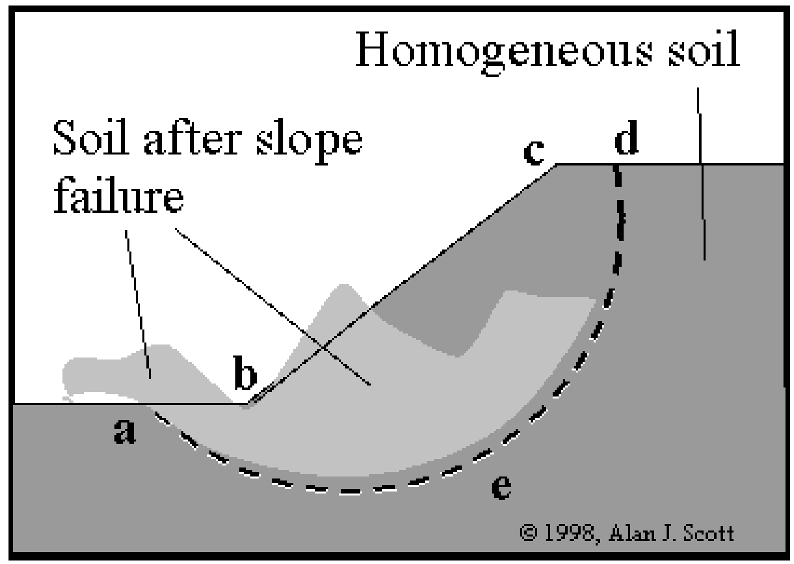
Soil Failure and shear strength.

- Soil failure usually occurs in the form of “shearing” along internal surface within the soil.
- Thus, structural strength is primarily a function of shear strength.
- Shear strength is a soils’ ability to resist sliding along internal surfaces within the soil mass.

Application of Shear Strength

(i) Slope Stability: Failure is an Example of Shearing Along Internal Surface



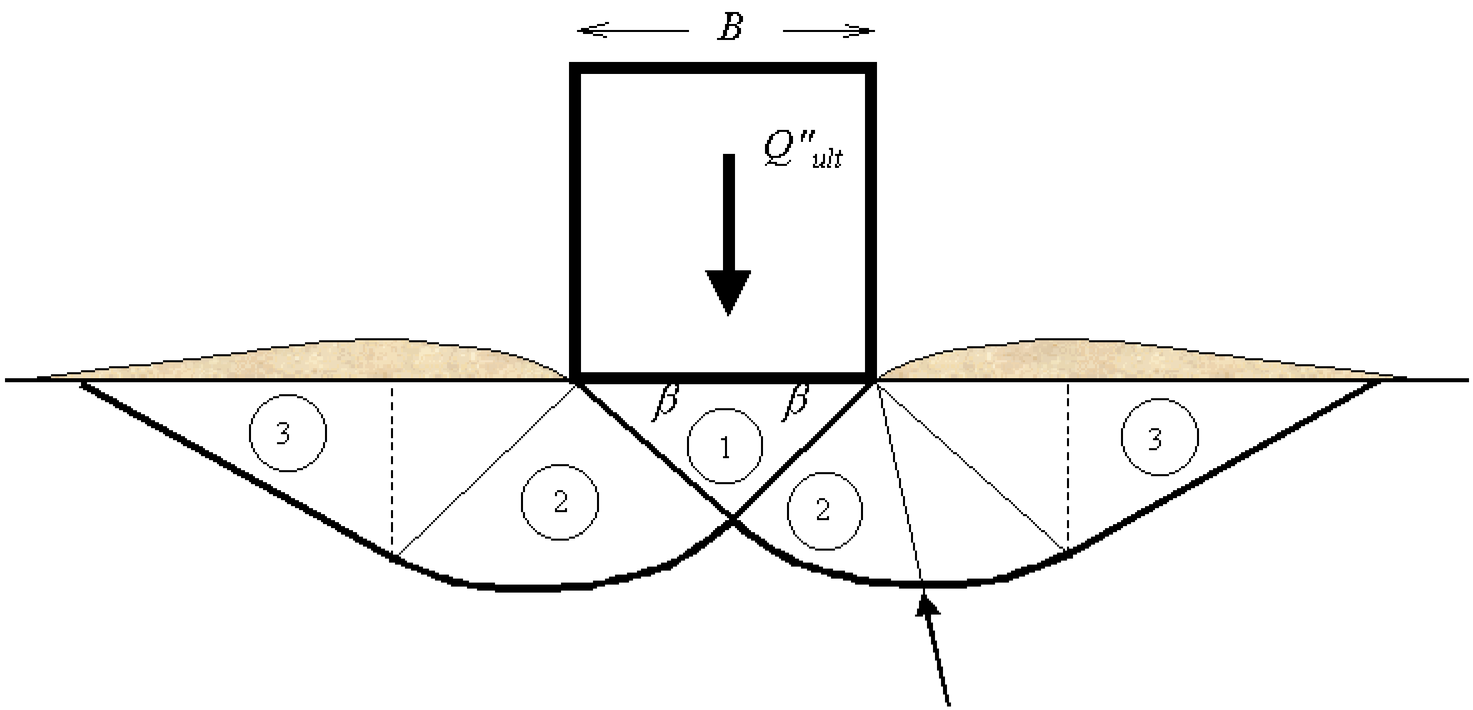


Application of Shear Strength

Land sliding: Shear Failure

Application of Shear Strength

(ii) Shear Failure Under Foundation Load



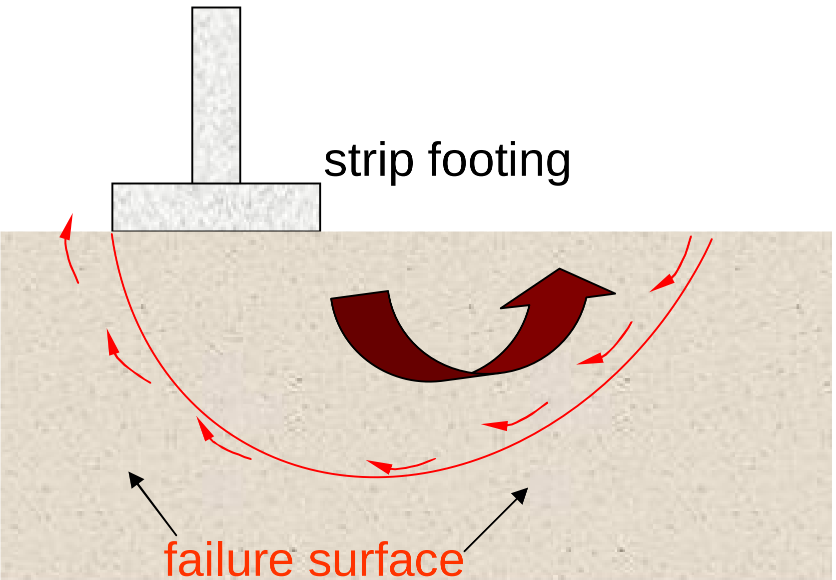
Application of Shear Strength

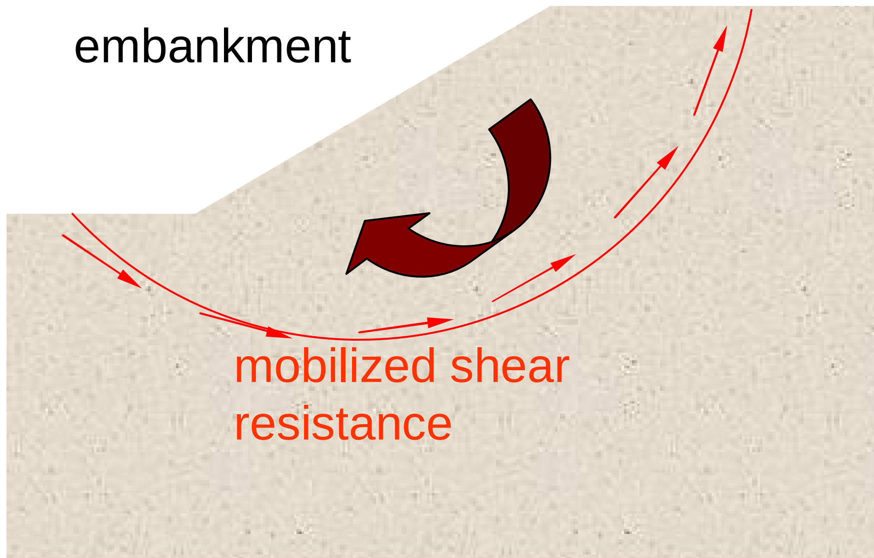
(iii) Earth pressure against retaining structures

Soils generally fail in <u>shear</u>

Shear failure

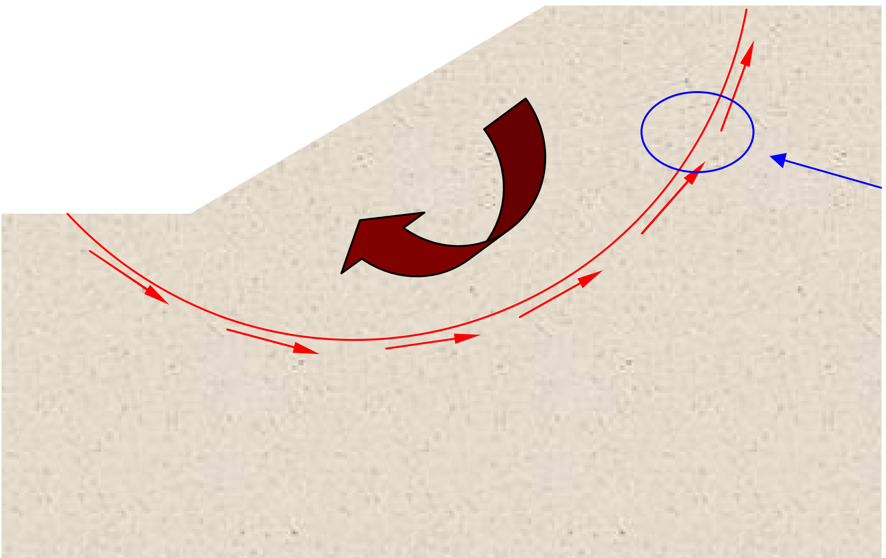
Soils generally fail in <u>shear</u>





At failure, shear stress along the failure surface reaches the shear strength.

Shear failure

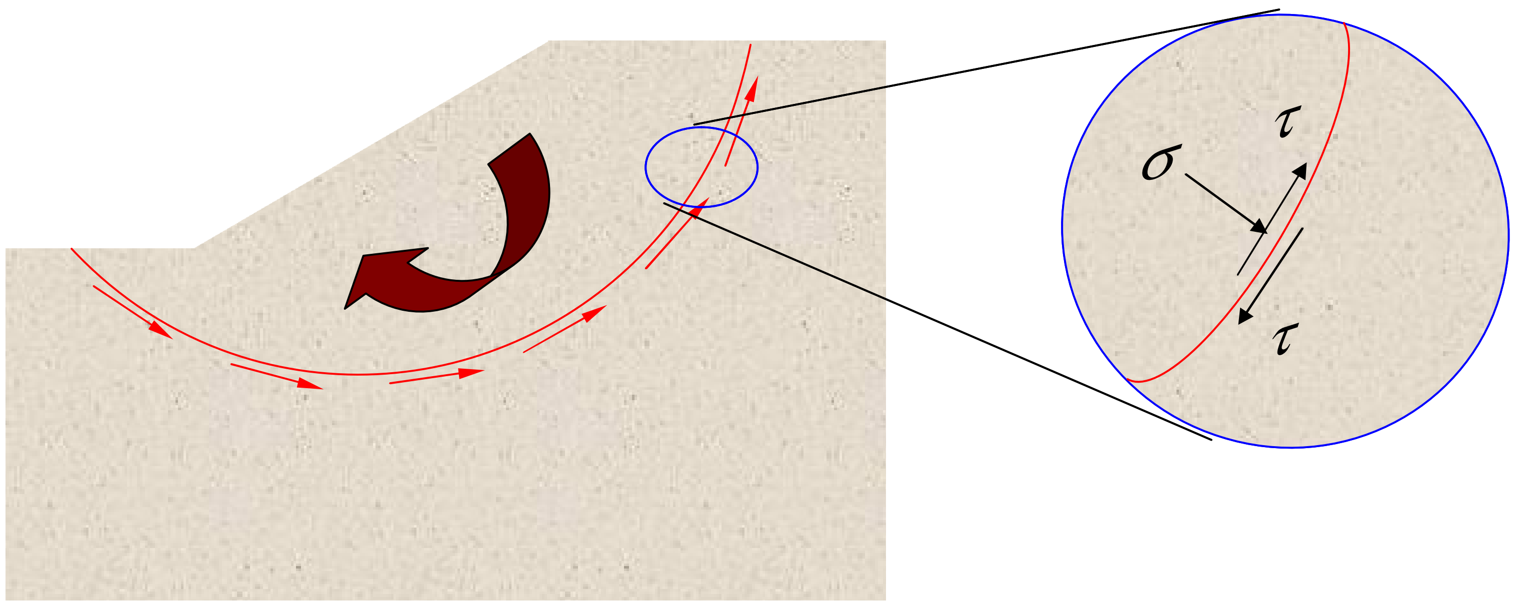


failure surface

The soil grains slide over each other along the failure surface.

No crushing of individual grains.

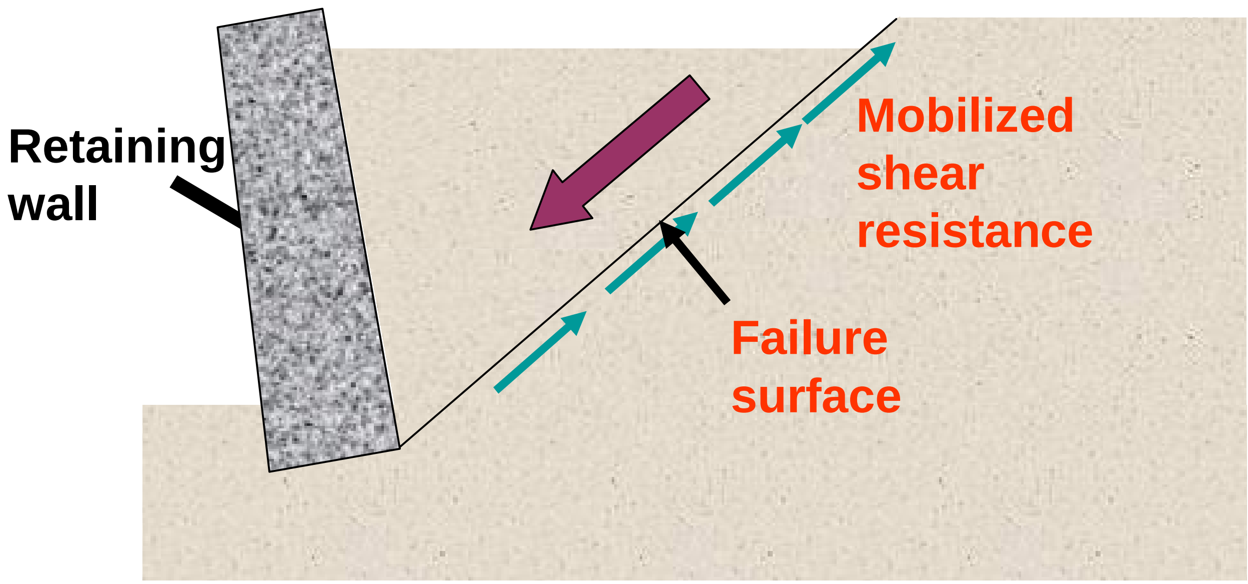
Shear failure mechanism



At failure, shear stress along the failure surface (τ) reaches the shear strength (τ_f).

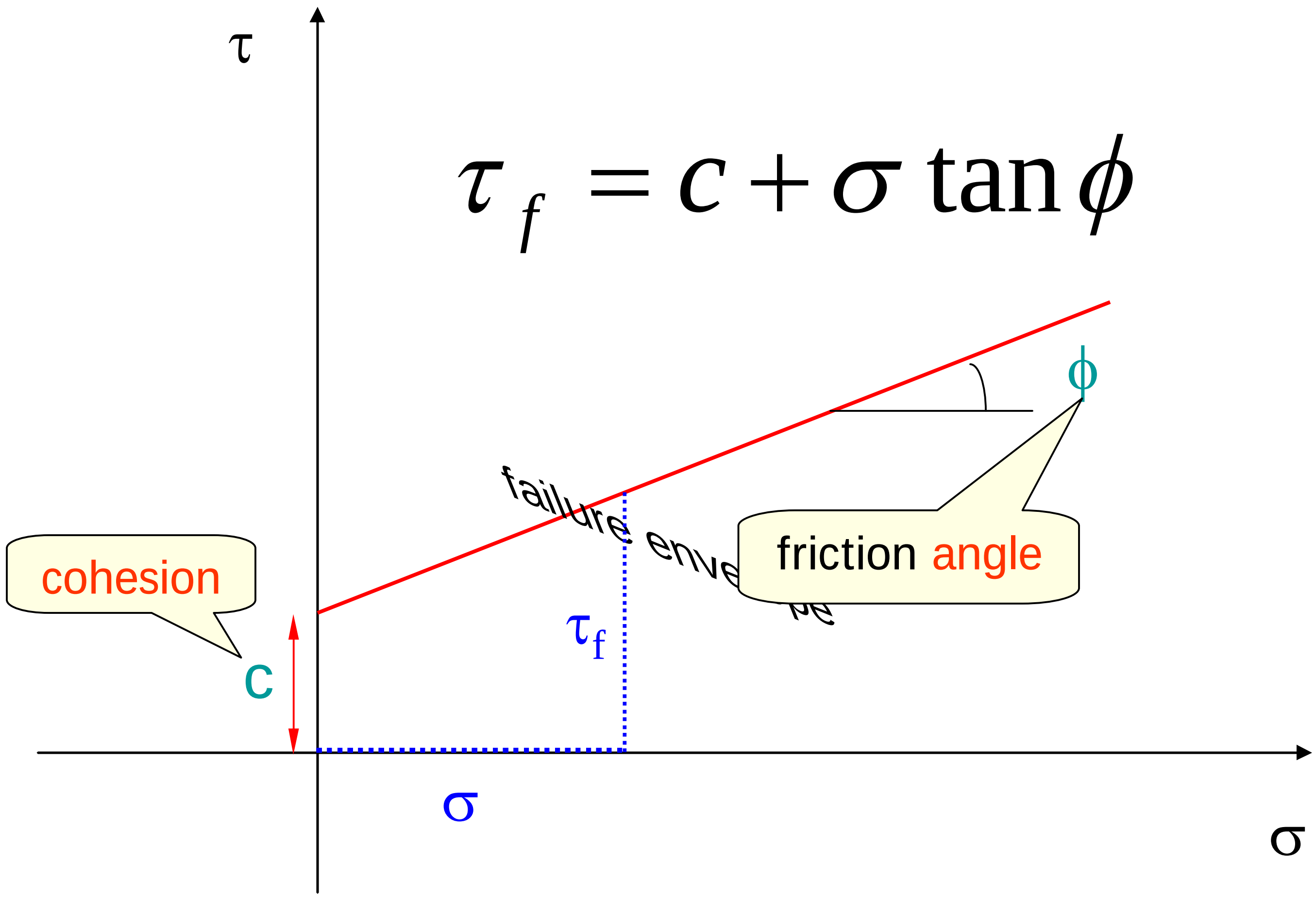
Shear failure of soils

Soils generally fail in shear



At failure, shear stress along the failure surface (mobilized shear resistance) reaches the shear strength.

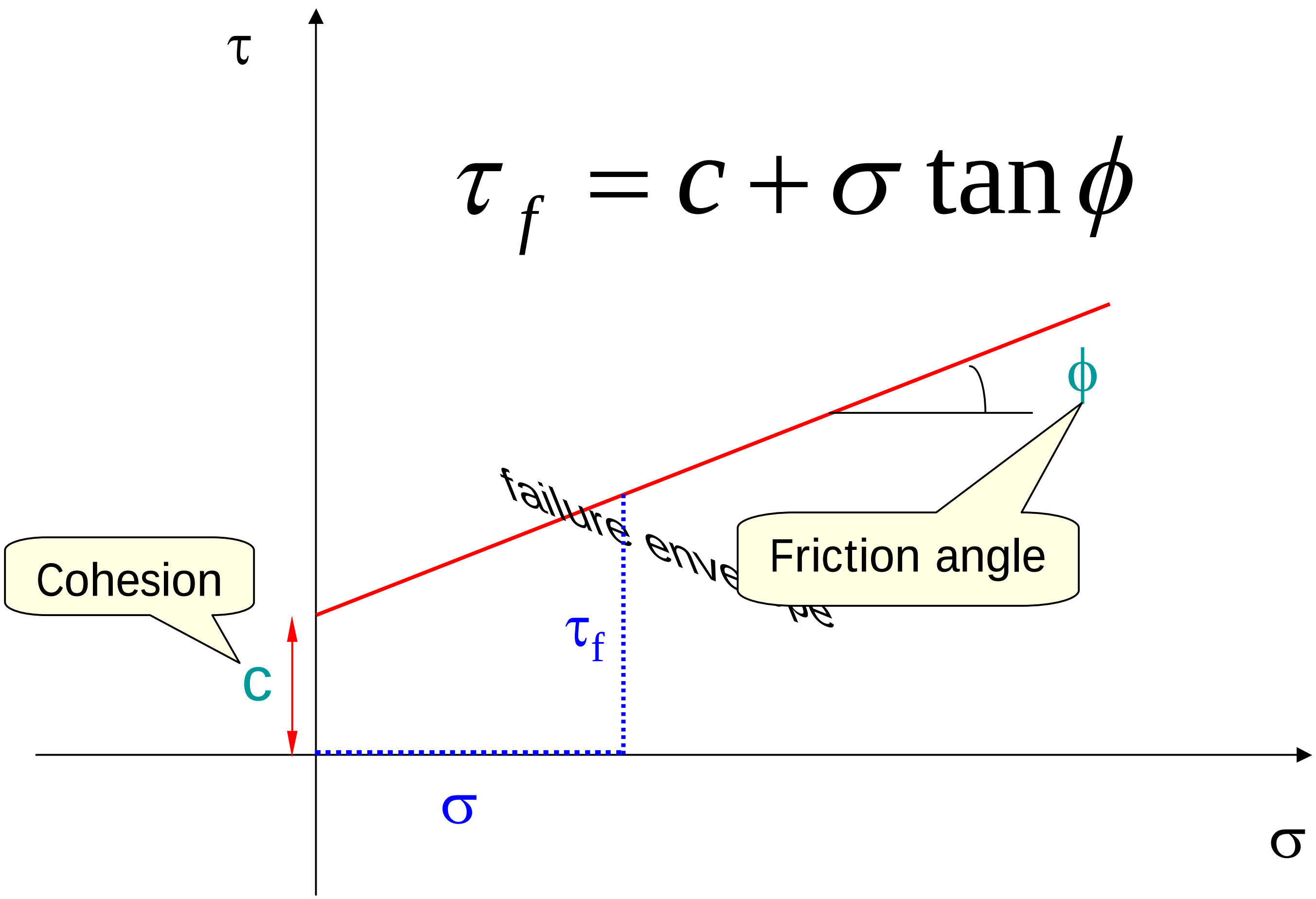
Mohr-Coulomb Failure Criterion



τ_f is the maximum shear stress the soil can take without failure, under normal stress of σ.

Mohr-Coulomb Failure Criterion

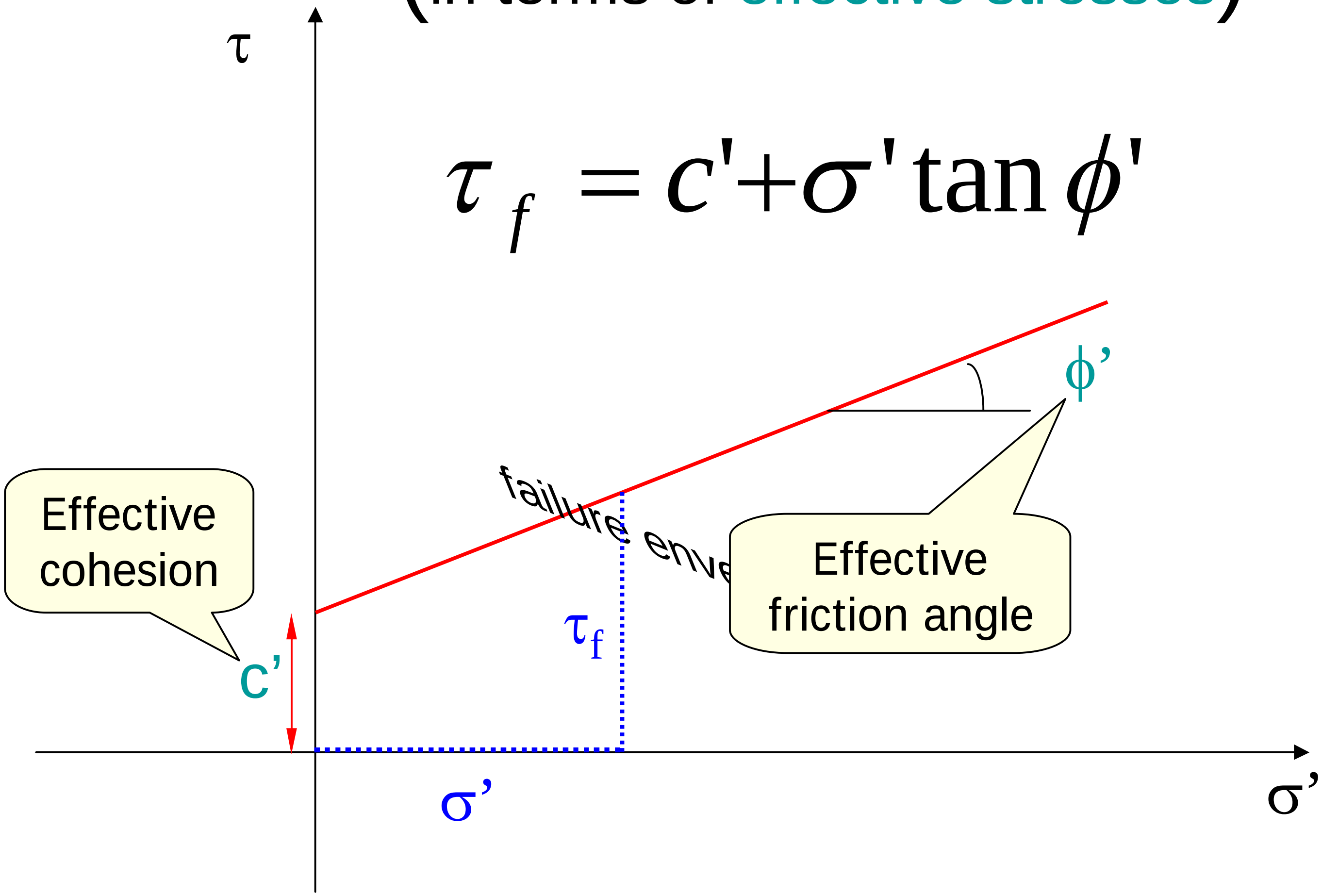
(in terms of total stresses)



τ_f is the maximum shear stress the soil can take without failure, under normal stress of σ.

Mohr-Coulomb Failure Criterion

(in terms of effective stresses)



$$\tau_f = c' + \sigma' \tan\phi'$$

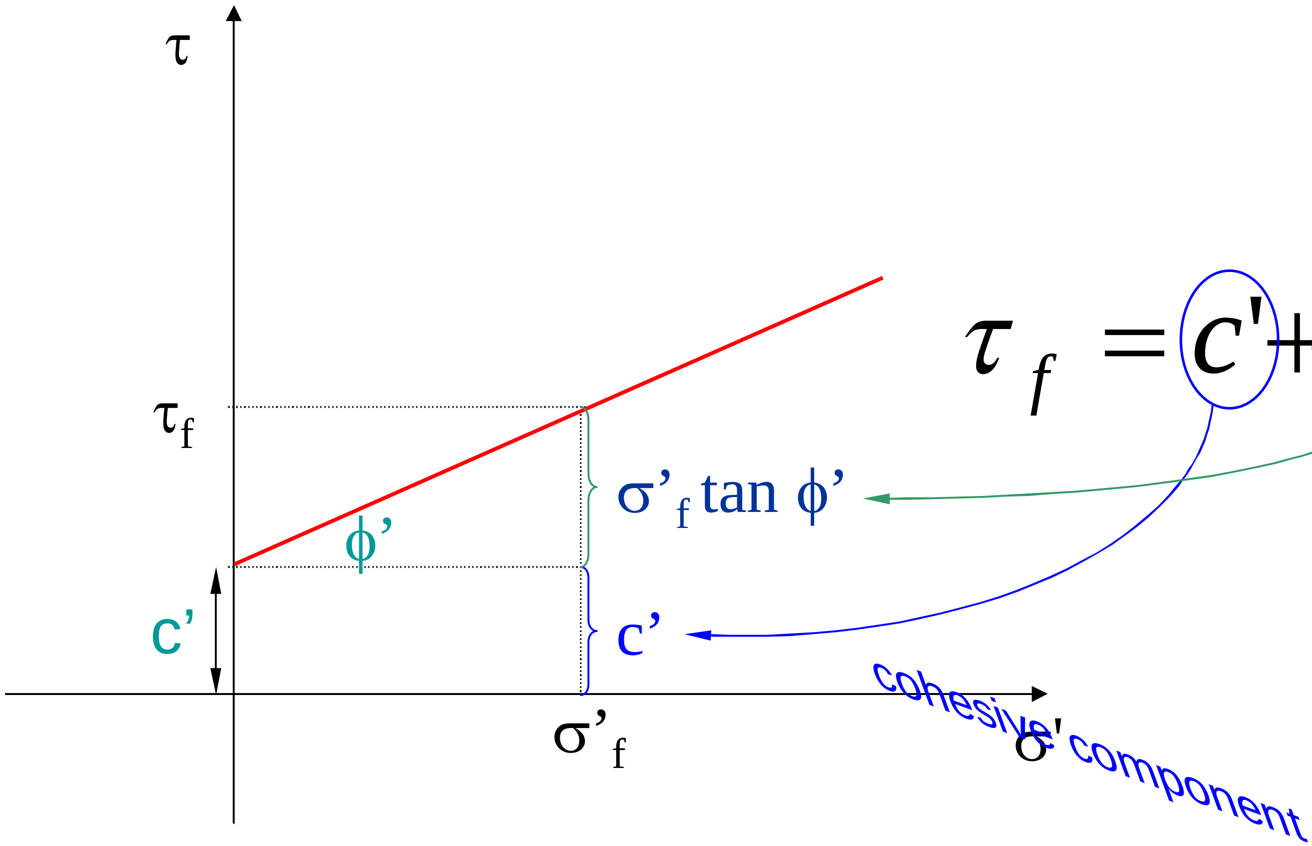
$$\sigma' = \sigma - u$$

u = pore water pressure

τ_f is the maximum shear stress the soil can take without failure, under normal effective stress of σ'.

Mohr-Coulomb Failure Criterion

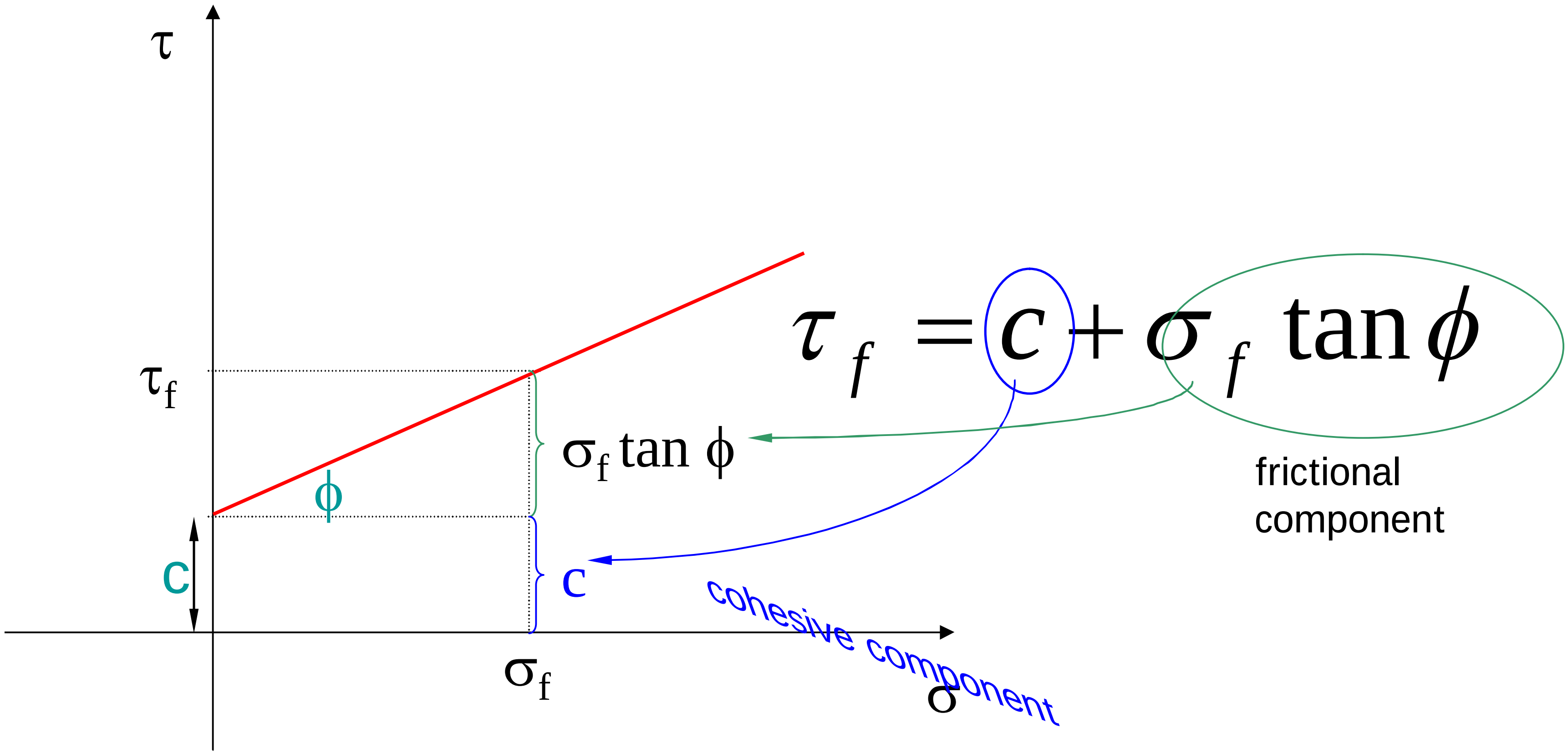
Shear strength consists of two components: cohesive and frictional.



$$\tau_f = c' + \sigma'_f \tan\phi'$$

Mohr-Coulomb Failure Criterion

Shear strength consists of two components: cohesive and frictional.



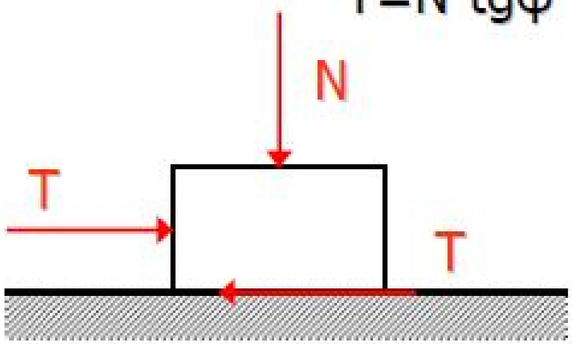
$$\tau_f = c + \sigma_f \tan\phi$$

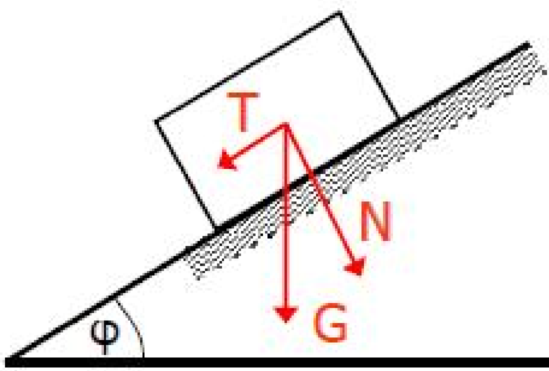
c and ϕ are measures of shear strength.

Higher the values, higher the shear strength.

Shear strength of soils

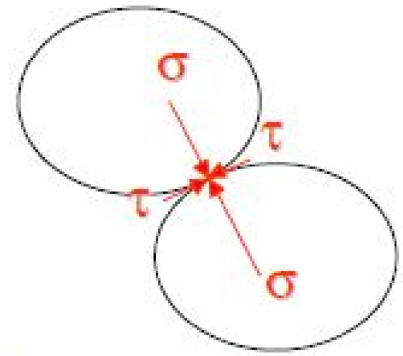
$T=N \cdot tg\varphi$





<u>Granular soils</u>

$\tau = \sigma \cdot \tan\varphi$

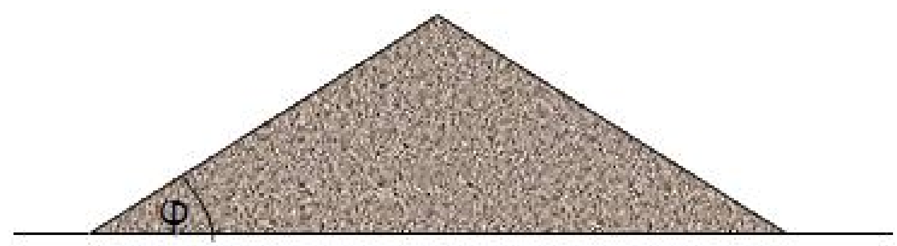


For soils this φ angle is called:

angle of internal friction or

friction angle

Angle of repose = φ



Shear strength of soils

<u>Fine grained soils:</u>

Their strength is, apart from from friction, due to internal forces holding the particles together

This propertiy is called cohesion, and soils possessing it are cohesive soils

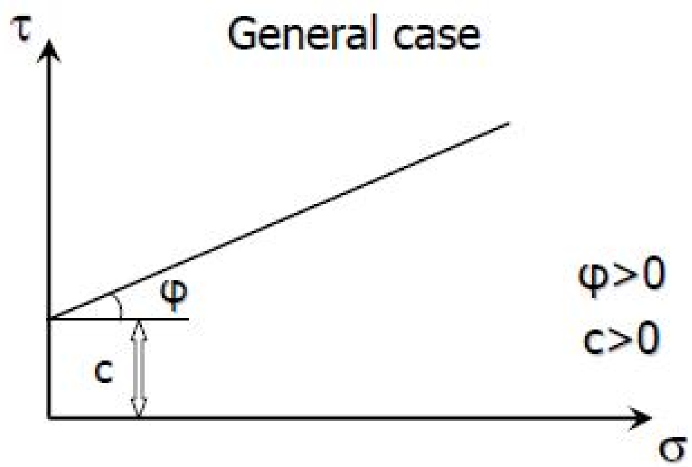
Coulomb's law extended to cohesive soils:

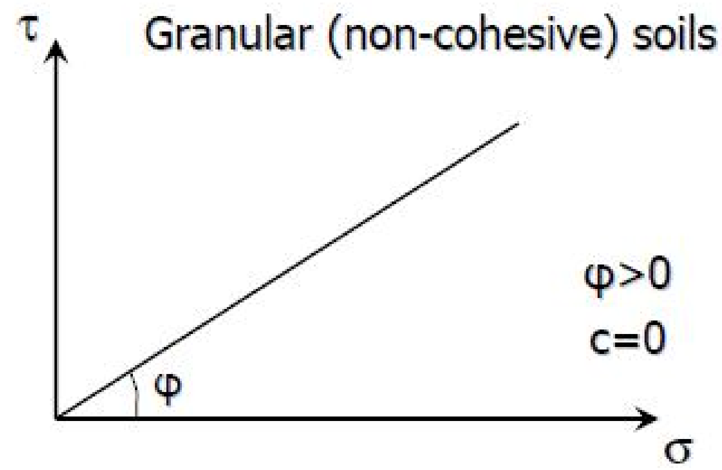
$$\tau = \sigma \cdot \tan\varphi + c$$

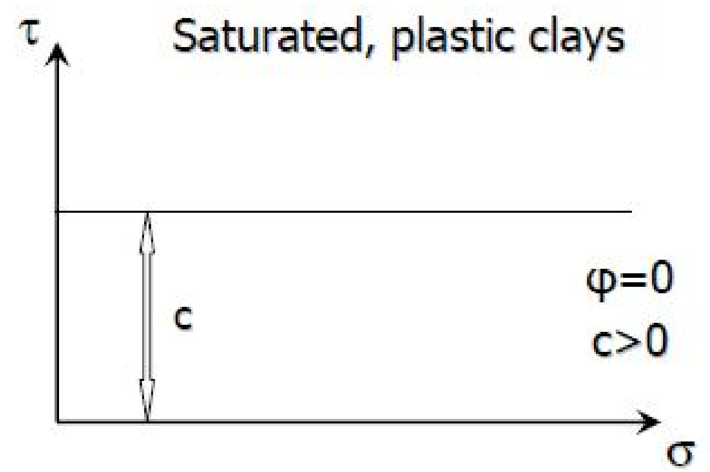
In case of saturated soils this can be expressed as:

$$\tau = (\sigma - u) \cdot \tan\varphi + c$$

Graphical represantation of Mohr Coulomb failure criteria







Mohr Stress Circle

Principal stresses and shear stress

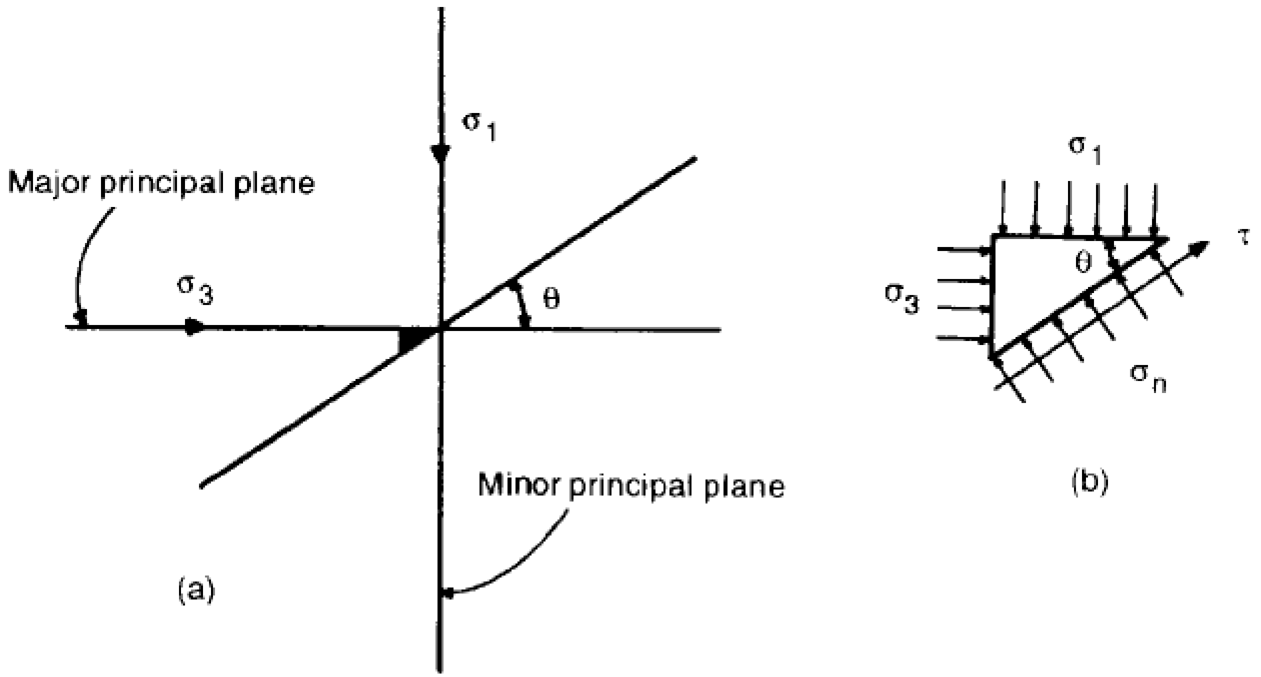


Fig. 3.3 Stress induced by two principal stresses, σ_1 and σ_3, on a plane inclined at θ to σ_3.

Stress Sign Convention

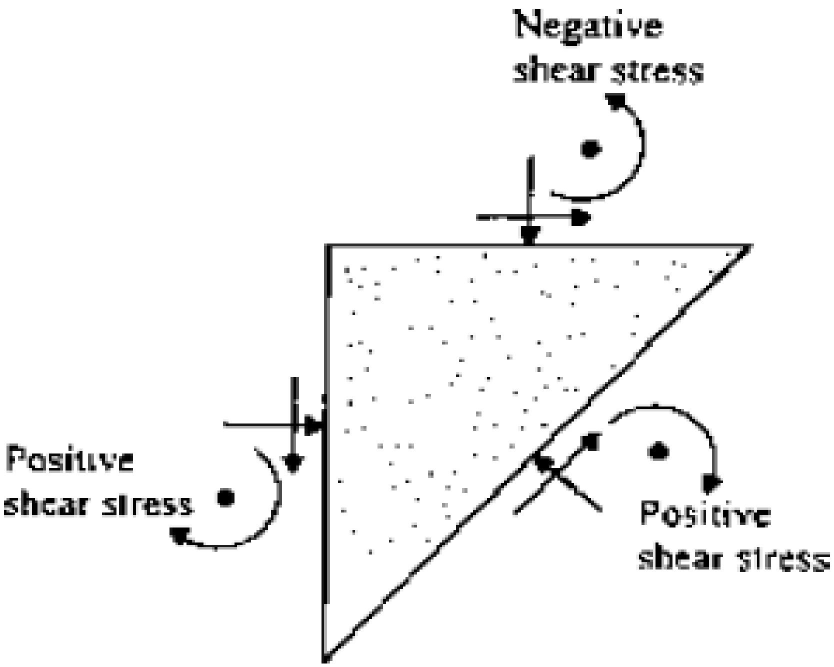
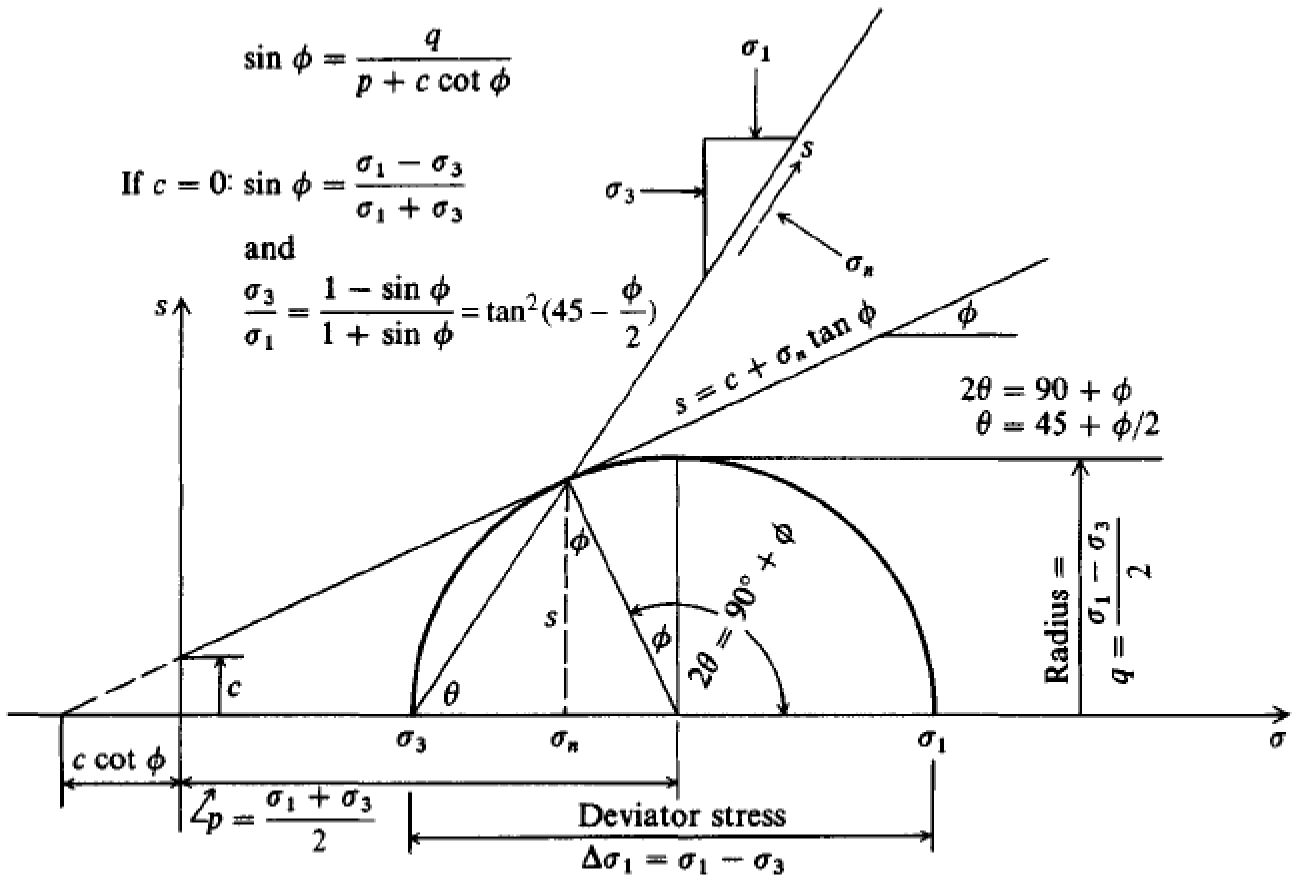


Figure 2.14 Sign convention for shear stress used for the construction of Mohr's circle.

Typical Mohr Stress Circle



Shear Plane is not a plane of max shear stress

Limit conditions

It has been stated that the maximum shearing resistance is developed when the angle of obliquity equals its limiting value, ϕ. For this condition the line OD becomes a tangent to the stress circle, inclined at angle ϕ to axis OX (Fig. 3.5).

An interesting point that arises from Fig. 3.5 is that the failure plane is not the plane subjected to the maximum value of shear stress. The criterion of

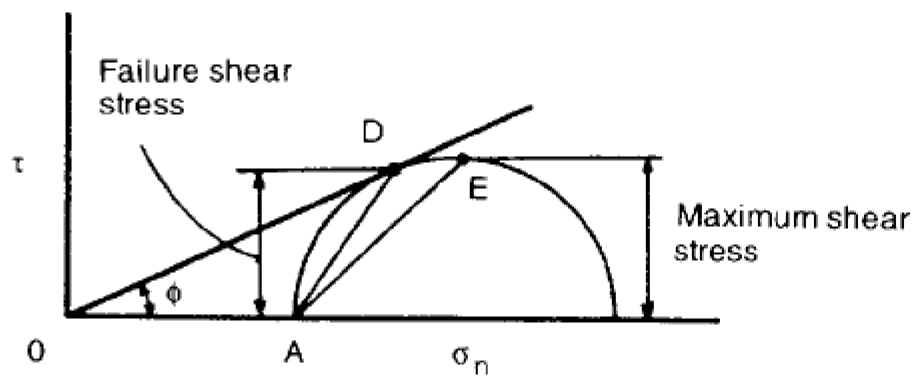
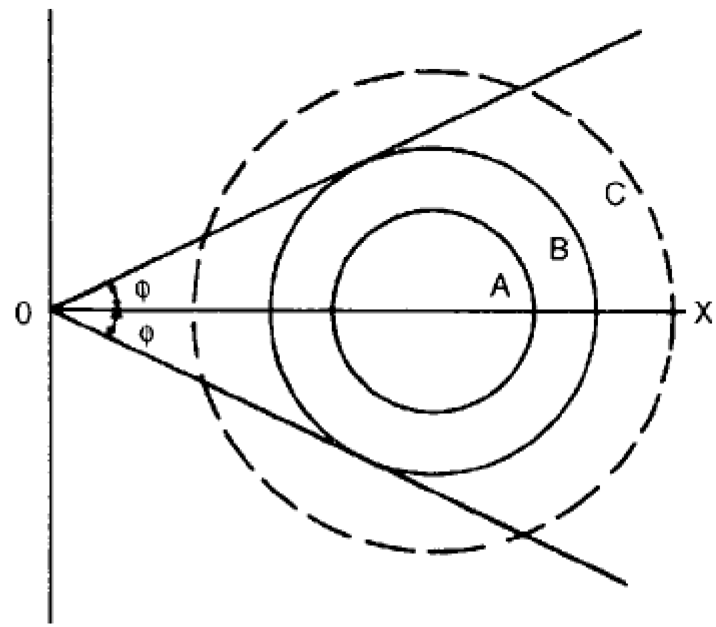


Fig. 3.5 Mohr circle diagram for limit shear resistance.

Failure Condition

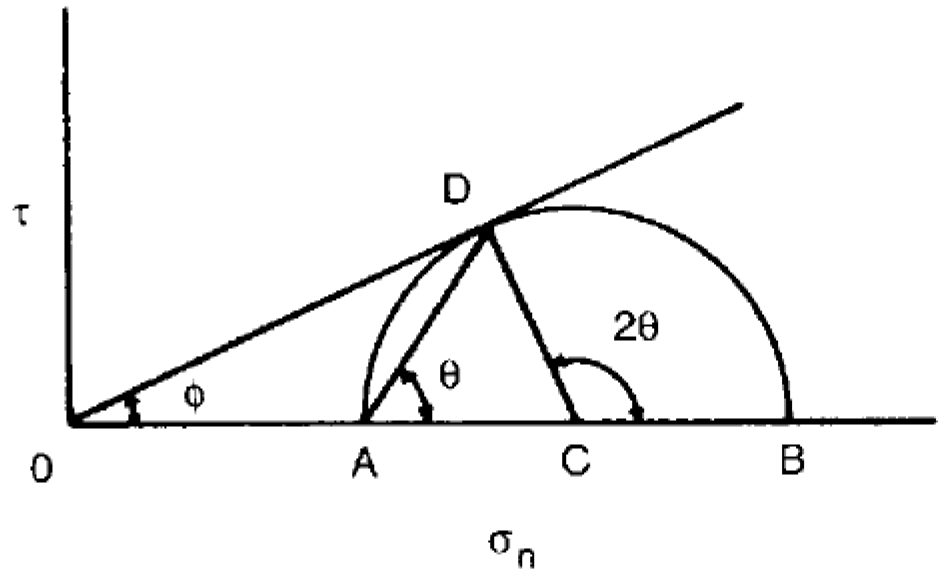


Circle-A -----no failure as it is much below failure line

Circle-B------shear failure as the circle touches the failure line

Circle-C------does not exists, its hypothetical condition

Relation b/w ϕ and failure plane, φ



3.7 Relationship between ϕ and θ.

$\varphi = 45 + \phi/2$