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3 Stability of Slopes

- 3.1 Movement in slopes
- 3.2 The shear strength
- 3.3 Drained and undrained slopes
- 3.4 Failure mechanisms in cohesive soils

3.1 Movement in Slopes

- In all slopes there is a level of instability
- Are always trying to come to a horizontal state
- Forces in play are gravity and seepage
- Resisting forces are the shear strength and the mass of the soil itself
- Movement of slopes happen when;
 - The shear strength between particles is lost along an internal surface, or
 - The effective stress between particles is lost causing full or partial liquefaction
- Mainly three types of movements;
 - Falls
 - movement away from existing discontinuities – fissures and planes etc.
 - are mostly caused by water or ice pressures



- Flows
 - when the soil mass loses its friction (the shear strength) due to pore water pressure
 - usually happens on weak saturated soils

- no distinct failure surfaces
- acts almost as a fluid



- Slides – two main types
 - Translational slide
 - movements along planes
 - quite closer to the surface
 - mostly on sloping surfaces

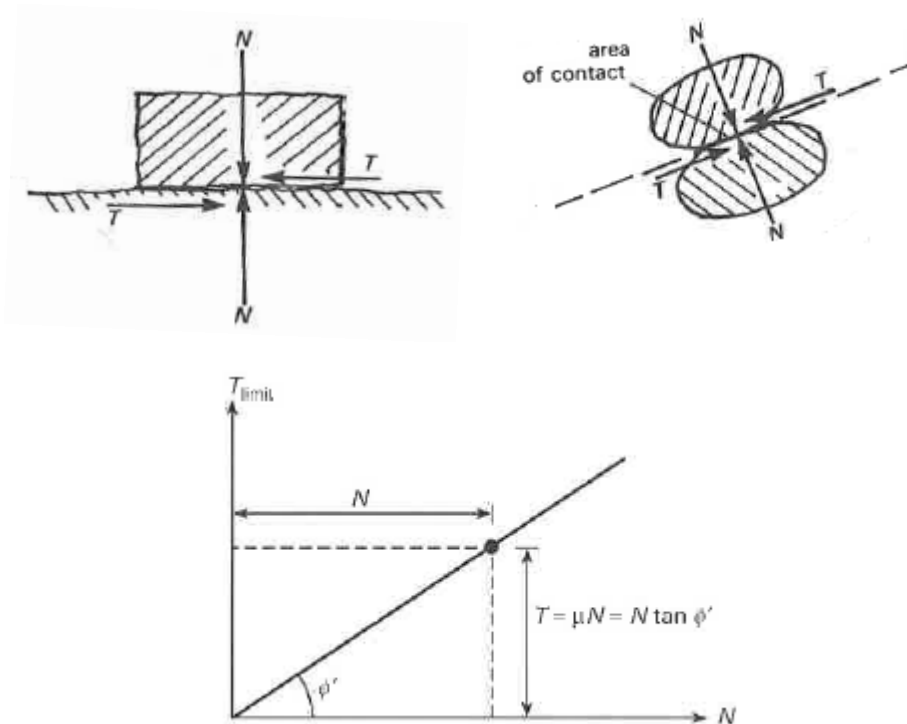


- Rotational slip
 - In soft rocks or cohesive soils
 - Takes place along curved surfaces
 - Slumps at the top and bulges at the toe

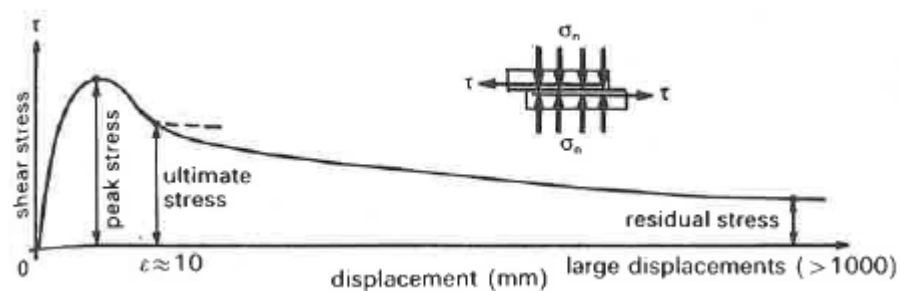


3.2 The Shear Strength

- Shear strength due to frictional resistance between adjacent particles
- The friction model
 - A normal force (N)
 - A tangential force (T)
 - When slip occurs, the ratio of T/N has reached the limiting value of “coefficient of friction”
 - Coefficient of friction is a measure of the roughness of the surfaces in contact
 - Is also defined as the tangent of the angle of friction (ϕ')

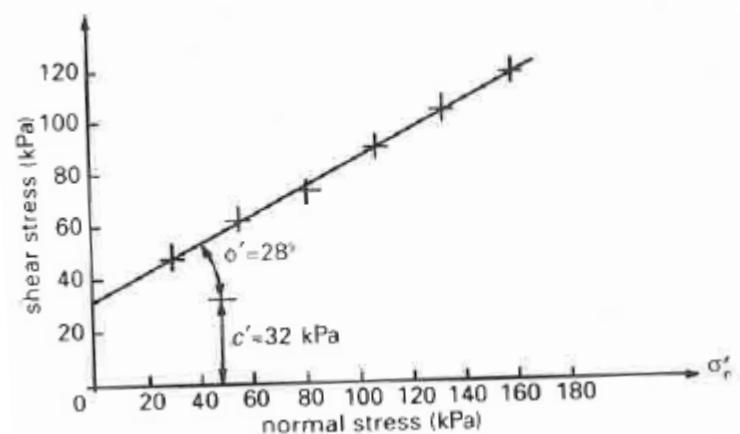
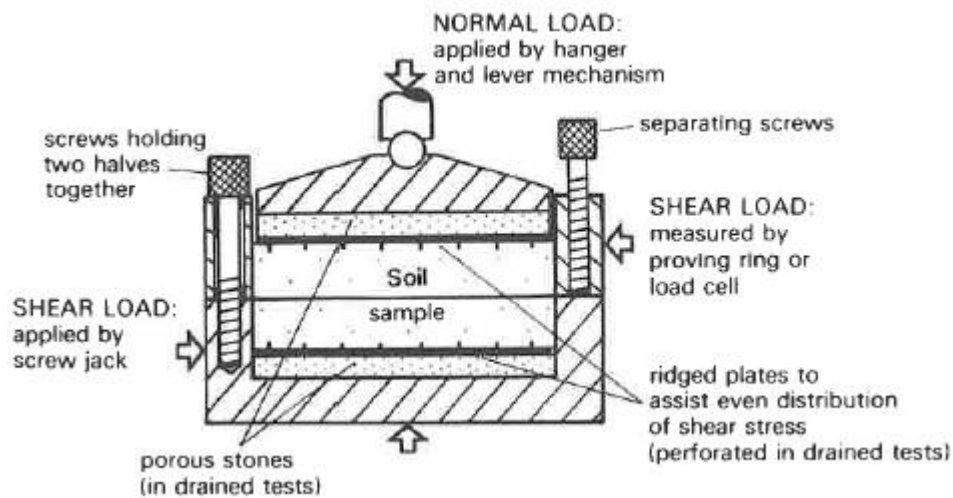


- The friction model is also valid for soils, but with the limitations that;
 - Loading a soil mass changes the volume and the pore pressure
 - Water may seep out depending on the permeability
 - Permeability of soils are vastly different between different types
 - The stress history of the soil can play a part



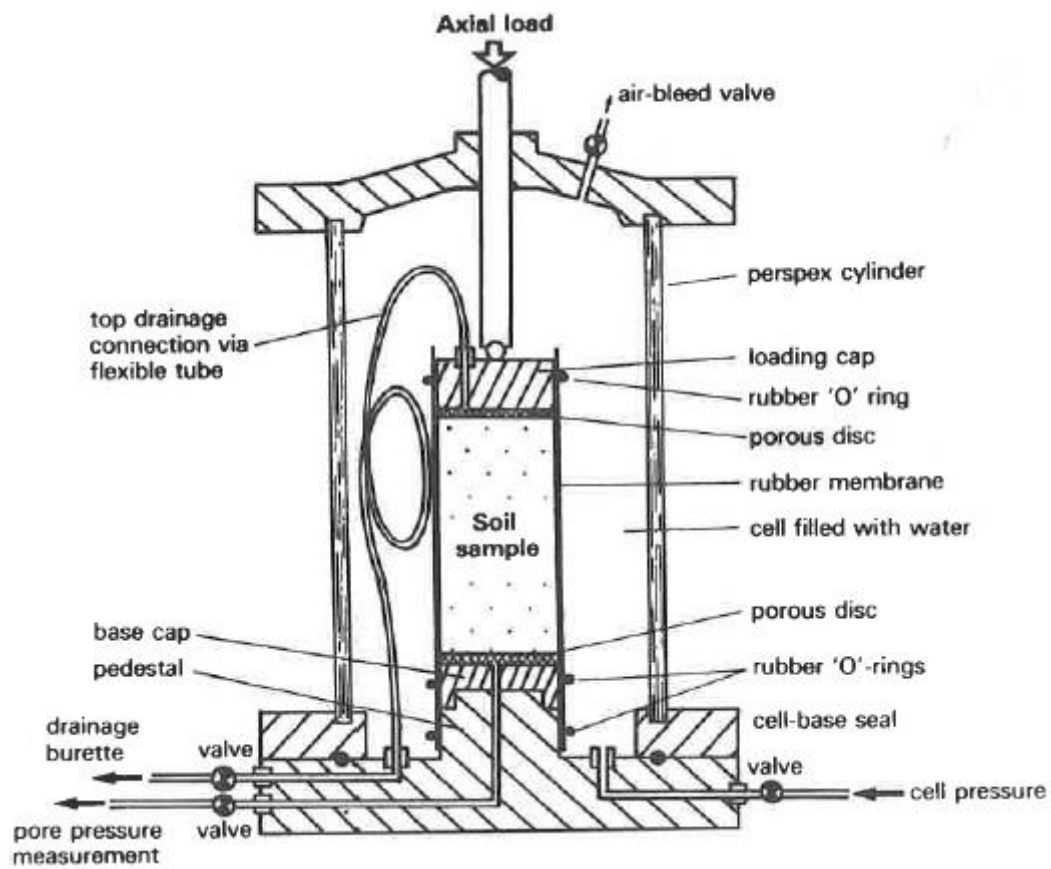
- Rate and amount of strain applied
- Shear strength tests
 - Influenced by the drainage conditions during tests
 - Two main parts to the test
 - Consolidation stage
 - One dimensionally or isotropically
 - Achieves an initial stress state or a full saturation state
 - Could be instant or hours for finer soils
 - Shearing or axial loading stage - Direct or triaxial
 - Un-drained tests
 - No drainage of water from the specimen is allowed
 - Un-drained shear strength (c_u is determined)

- Drained tests
- Test types:
 - Laboratory
 - Direct Shear test
 - Triaxial test
 - Field
 - Standard penetration test (SPT)
 - Cone penetration test (CPT)
 - Direct shear test (shear box test) – normally drained



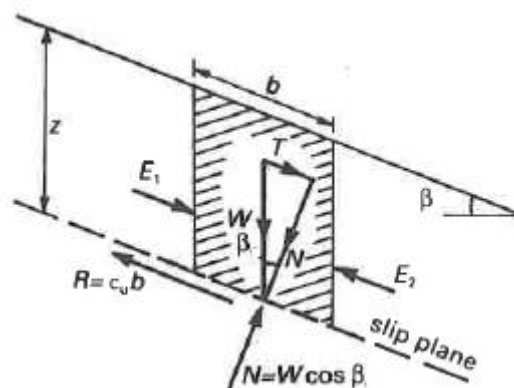
- Apparent cohesion (c')
- Angle of friction (ϕ')

- Triaxial test - can be both undrained as well as drained



3.3 Undrained and Drained Slopes

3.3.1 Undrained Slopes (assume infinite length)



Weight of the soil element

$$W = \gamma \times z \times b \times \cos \beta$$

Normal reaction on the slip plane

$$N = W \times \cos \beta$$

Tangential force down the slope

$$T = W \times \sin \beta$$

Shear resistance force up the slope

$$R = c_u \times b$$

For equilibrium

$$R = T$$

$$c_u \times b = W \times \sin \beta$$

$$c_u \times b = \gamma \times z \times b \times \cos \beta \times \sin \beta$$

$$c_u \times b = \gamma \times z \times b \times \frac{1}{2} \times \sin 2\beta$$

$$z = \frac{2 \times c_u}{\gamma \times \sin 2\beta}$$

Example:

Soil in a long undrained slope has shear strength of 50 kN/m² and a unit weight of 18 kN/m³. Estimate the depth at which a shear slip may occur when the slope angle is 22°.

Example:

An undrained slope is 1 vertical: 1.5 horizontal. At 1.8 m deep there is a weak layer of cohesive soil, for which undrained shear strength is 24 kN/m² and the overburden has a unit weight of 18.5 kN/m³. Calculate the factor of safety against collapse.

Disturbing moment

$$W \times d$$

Mobilised shear strength along the arc length of AB

$$c_u \times R \times \theta$$

Where θ is in radians

Moment generated by the shear strength

$$c_u \times R \times R \times \theta$$

The factor of safety

$$F = \frac{c_u \times R^2 \times \theta}{W \times d}$$

References Used:

Whitlow, R. (2001), "Basic Soil Mechanics", Pearson Education Ltd, ISBN:0582-38109-6