Slope Stability Analysis

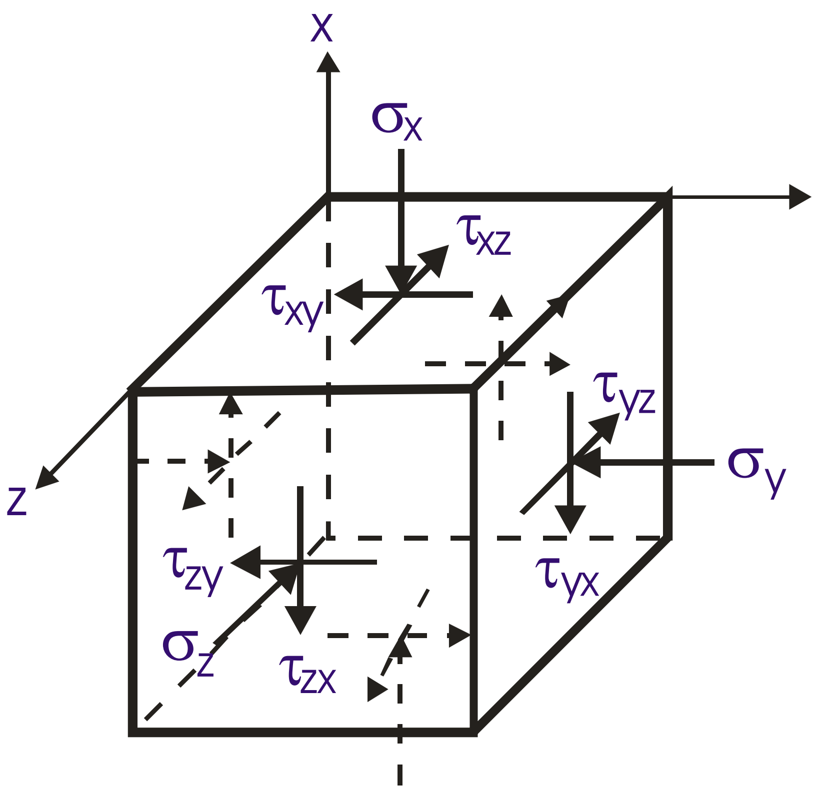
Requirements of a theoretical solution

- Equilibrium

$$\frac{\partial \sigma_x}{\partial x} + \frac{\partial \tau_{yx}}{\partial y} + \frac{\partial \tau_{zx}}{\partial z} + \gamma = 0$$

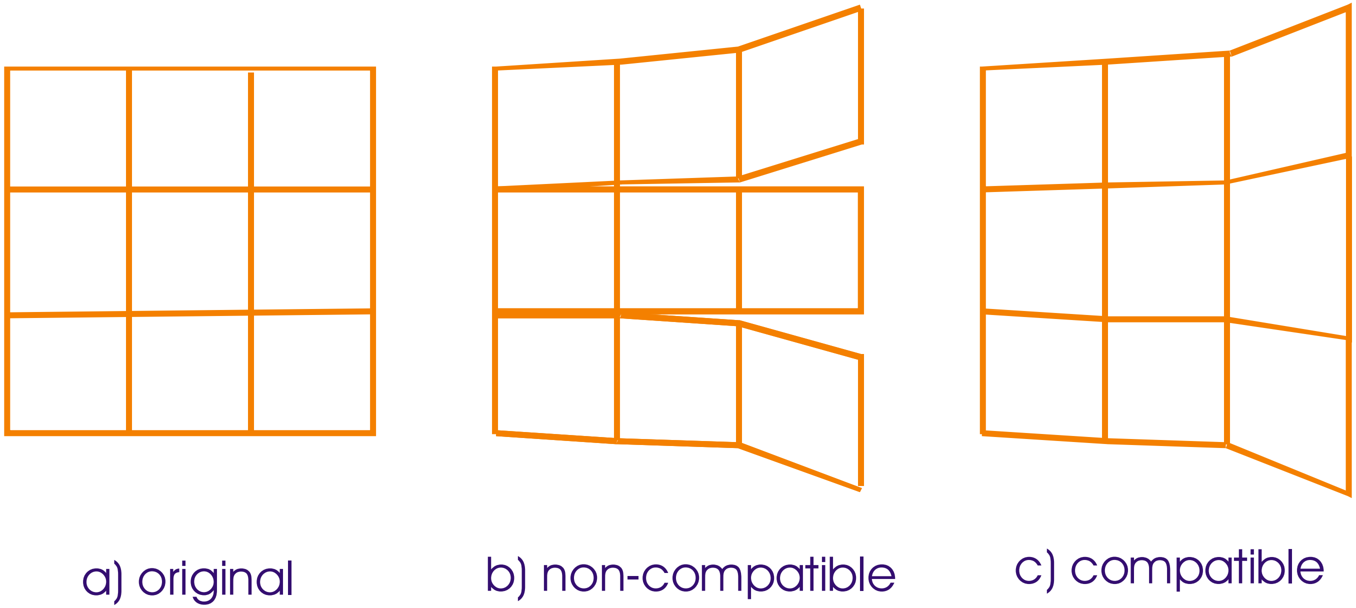
$$\frac{\partial \sigma_y}{\partial y} + \frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \tau_{xz}}{\partial z} = 0$$

$$\frac{\partial \sigma_z}{\partial z} + \frac{\partial \tau_{zy}}{\partial y} + \frac{\partial \tau_{xz}}{\partial x} = 0$$



Requirements of a theoretical solution

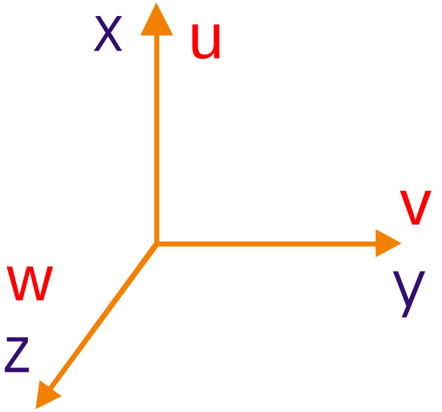
- Equilibrium
- Compatibility



No holes, no overlapping

Requirements of a theoretical solution

- Equilibrium
- Compatibility



$$\varepsilon_x = \frac{\partial u}{\partial x} \qquad \gamma_{xy} = \frac{\partial v}{\partial x} + \frac{\partial u}{\partial y}$$

$$\varepsilon_y = \frac{\partial v}{\partial y} \qquad \gamma_{yz} = \frac{\partial w}{\partial y} + \frac{\partial v}{\partial z}$$

$$\varepsilon_z = \frac{\partial w}{\partial z} \qquad \gamma_{xz} = \frac{\partial w}{\partial x} + \frac{\partial u}{\partial z}$$

Requirements of a theoretical solution

- Equilibrium
- Compatibility

So far we have:

Unknowns:6 stresses + 6 strains + 3 displacements
= 15 unknowns

Equations:3 equilibrium + 6 compatibility
= 9 equations

we therefore require 6 more equations

Requirements of a theoretical solution

- Equilibrium
- Compatibility
- Material's constitutive behaviour

$\Delta\sigma = [D]\ \Delta\varepsilon$

[D] is constant for linear elastic analysis

However, soil behaviour is nonlinear and thus it is more realistic for [D] to vary, depending on the current and past stress history

Requirements of a theoretical solution

- Equilibrium
- Compatibility
- Material's constitutive behaviour
- Boundary conditions
  - Force/Stress
  - Displacement

Methods of analysis

- Analytical solutions
- Stress field method
- Limit analysis
- Numerical analyses
- **Limit Equilibrium**

Limit Equilibrium

- A mechanism of collapse is assumed involving a failure surface that may be planar, curved or some combination of these
- A failure criterion (in terms of shear strength parameters, either total or effective) holds everywhere along the failure surface
- Only the global equilibrium of the rigid blocks of soil between the failure surfaces and the boundaries of the problem is considered
- The internal distribution within the blocks is not considered

Limit Equilibrium

Limitations:

- Solutions do not consider compatibility or any displacement boundary conditions
- No indication of the induced deformation is possible

However, Modern LE software deal with:

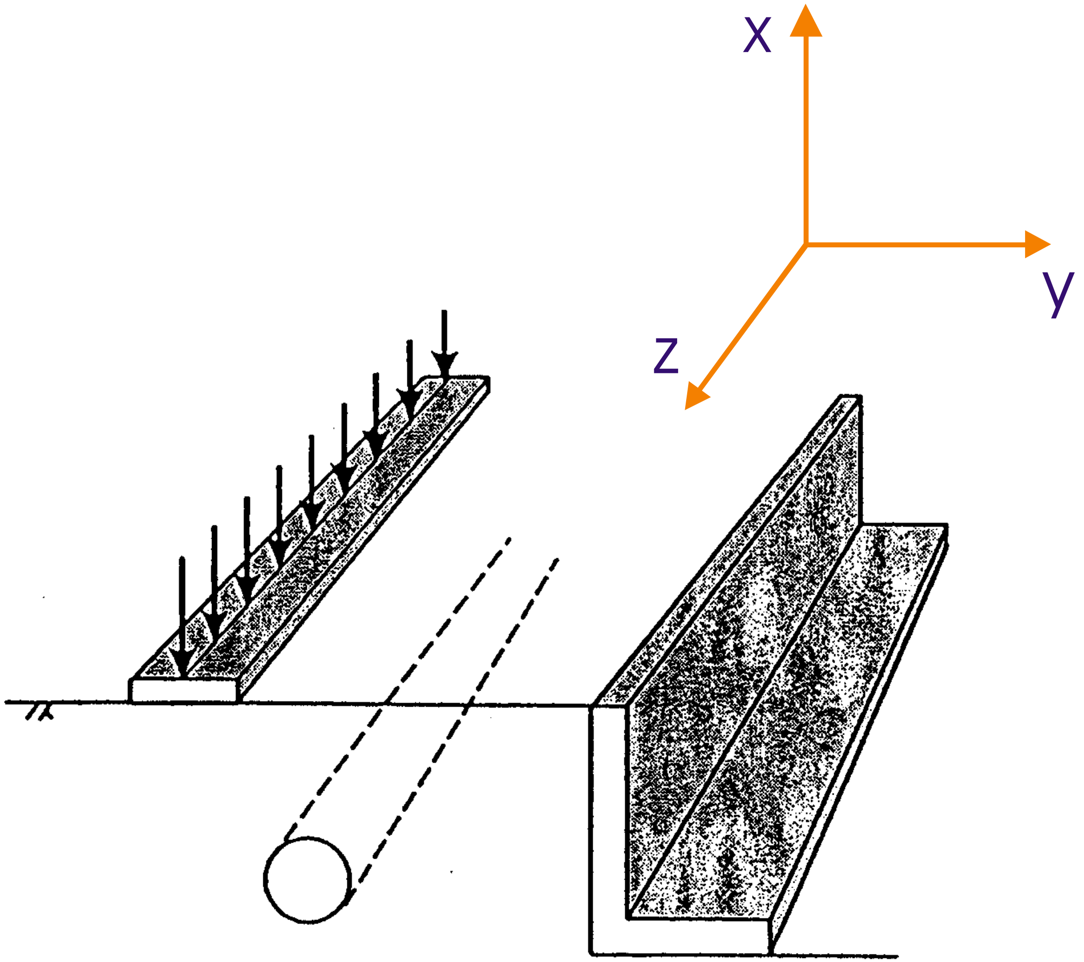
- Complex stratigraphy
- Irregular pwp conditions
- Almost any kind of slip surface
- Concentrated loads, structural reinforcement, etc

Plane strain approximation

$$\varepsilon_z = \frac{\partial w}{\partial z} = 0$$

$$\gamma_{yz} = \frac{\partial w}{\partial y} + \frac{\partial v}{\partial y} = 0$$

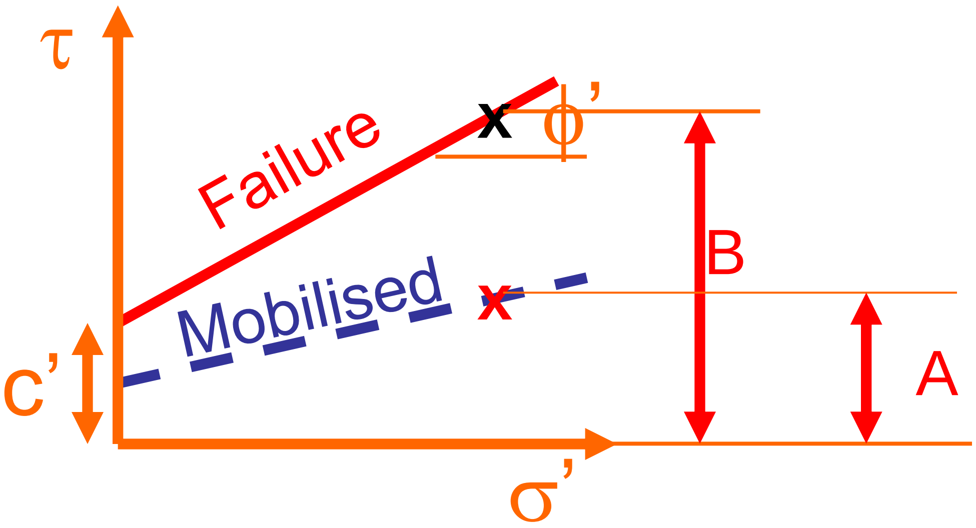
$$\gamma_{xz} = \frac{\partial w}{\partial x} + \frac{\partial u}{\partial z} = 0$$



Factor of Safety

- Accounts for uncertainty related to
  - strength parameters
  - pore pressure distribution
  - Stratigraphy
- Choice of FoS
  - experience
  - material type
  - performance requirements

Factor of Safety



Effective Stress Analysis

$F = B/A$

Shear strength at failure

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

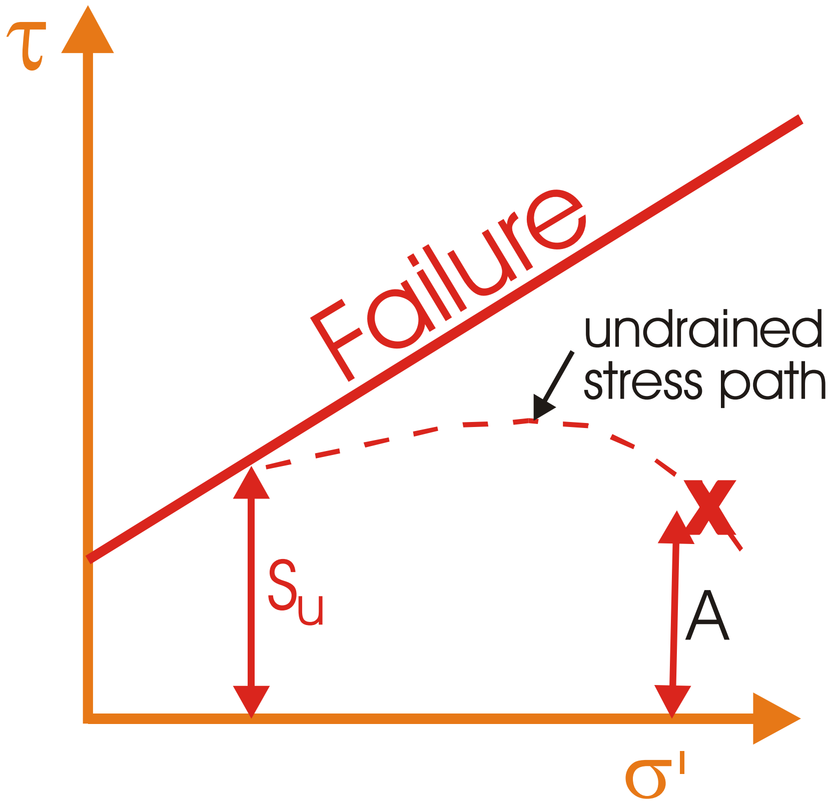
Mobilised Shear strength

$A = c'_m + \sigma' \tan \phi'_m$

$c'_m = c'/F$

$\tan \phi'_m = \tan \phi'/F$

Factor of Safety



Total Stress Analysis

$$F = S_u / A$$

$$\boxed{\tau_{mob} = S_u / F}$$

Important Assumption:
FoS assumed to be constant along the slip surface

Factor of Safety

Other definitions

$$F = \frac{\sum \text{Resisting forces}}{\sum \text{Disturbing forces}}$$

Planar failure surfaces

$$F = \frac{\sum \text{Resisting moments}}{\sum \text{Overturning moments}}$$

Rotational failure surfaces

In most cases the FoS on <u>shear strength</u> is adopted