Factors affecting strength of Rocks in Engineering Practice

Introduction

Rock's involved in many civil and engg projects.

Introduction.....(2)

Rock is divided into:

- **Intact rock,**

- **Rock mass**

Intact Rock

An intact specimen may be described by std geologic terms:

- Texture
- Mineralogy
- grain size

Thus, geologic terminology is:

- Informative, but....
  - Does NOT provide Enggr with quantitative DESIGN DATA, e.g.;

Intact Rock strength

- Its fundamental & quantitative engg prop.
- Defined as amount of applied stress @ rock failure/rupture.

Applied stress may be:

- Compressive → *Compressive Strength*
- Tensile → *Tensile Strength*
- Shear → *Shear Strength*

Intact Rock strength

Uniaxial Compressive Strength (UCS) of intact rock:

- most commonly measured & used strength
- usually obtained by testing cylindrical rock specimen.
- dependent upon:
  - rate of loading
  - core size, and length-to-diameter ratios
    - (ratio range of 2.5-3 & core diameter no less than NX size (approx. 54 mm).

Deformation of Intact Rock

- When load is applied to intact rock sample, **STRAINS** are produced.
- Summation of these strains over stressed length is the **DEFORMATION,** which:
  - Normally leads to change in **SHAPE** and/or **VOLM**
  - Generates Data used to calculate **ELASTIC MODULI**;
    - Modulus of Elasticity or Young's Modulus (E)
    - Poisson's ratio (ν)

Types of Deformation

1) **Elastic** – where:

- when load is removed, deform^n instantly & completely disappears.
- Relationship between **STRESS** & **STRAIN** is more or less linear

2) **Plastic** – where:

- **STRAIN** resulting from **STRESS** is **NON-UNIFORM.**

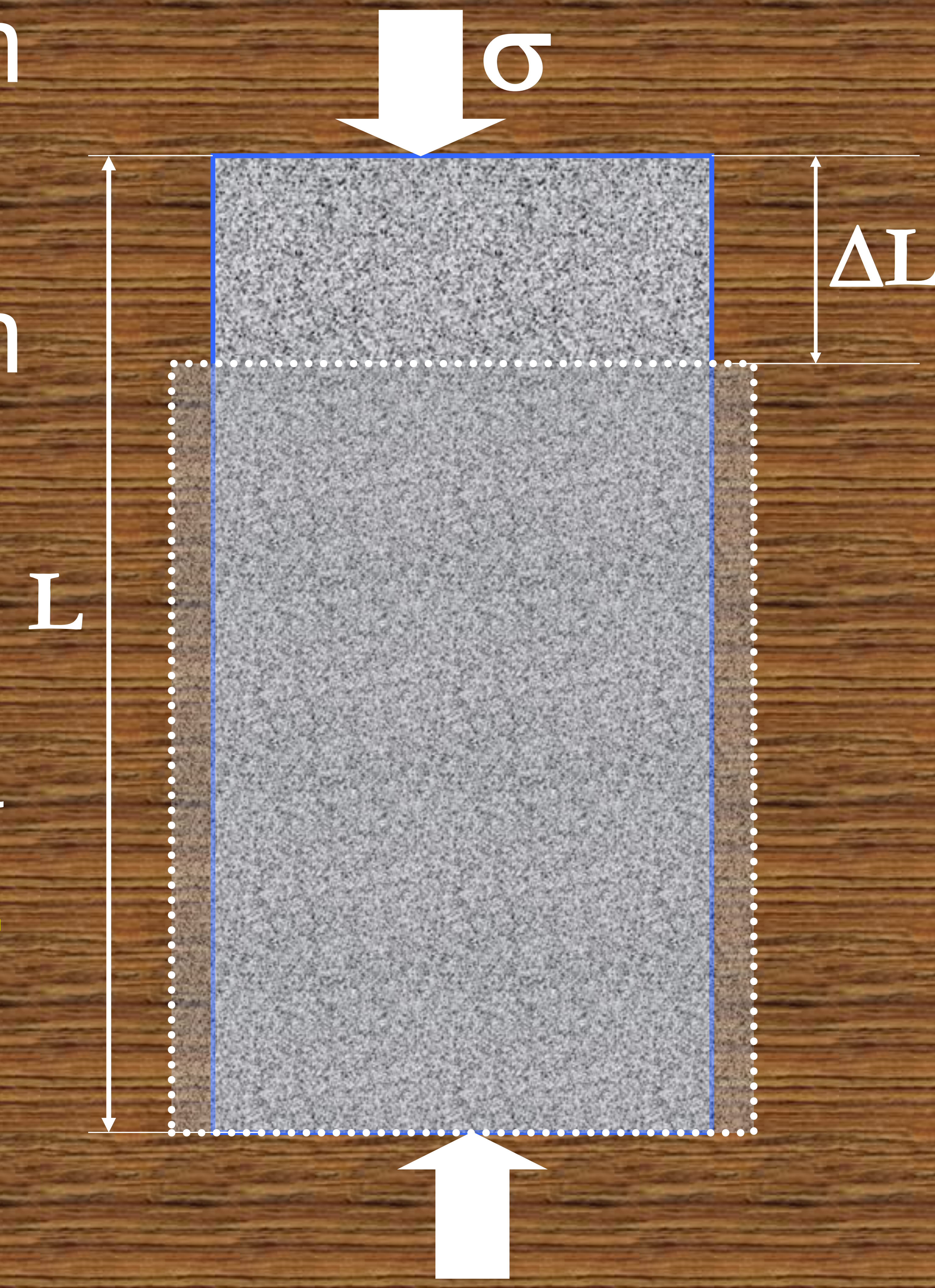
Elastic Deformation

- Shown by stress-strain relationship
- Represented by linear portion of curve for material testing

Example:

Cylinder of length L is loaded by a stress, σ. Shortening in length, ΔL gives the strain:

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



If, when stress is removed, deformation instantly disappears, material is said to be **ELASTIC.**

Elastic Deformation…..(2)

1. Modulus of Elasticity (E) is determined by:

$$E = \text{Stress} / \text{Strain} = \sigma/\varepsilon$$

E = Modulus of elasticity or Young's modulus (kN m^{-2})

σ = axial compressive stress (Uniaxial tests), or deviator stress (σ_1-σ_3) for triaxial tests (kN m^{-2})

ε = Axial Strain (expressed in mm/mm)

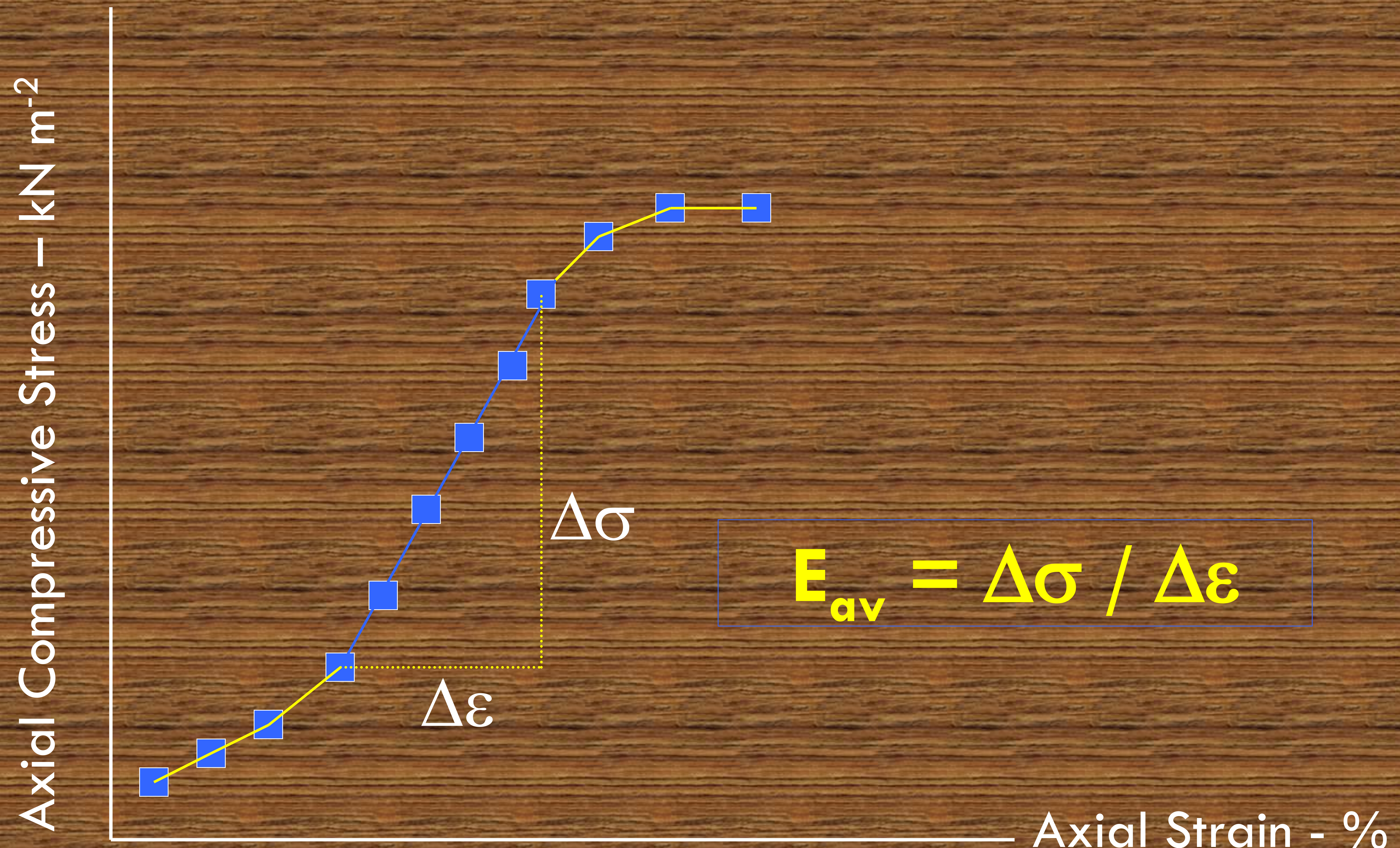
Value for E may be obtained from stress-strain diag.

E_{av} is obtained from best fit to linear or elastic part of curve.

Elastic Deformation…..(3)

Plot of unconfined compressive test stress-strain data

Axial Strain (%)	**1**	**1.3**	**1.6**	**1.9**	**2.5**	**3.2**	**4.7**	**5.8**	**7.4**	**7.8**	**8.3**	**8.5**
Compressive stress (kN m^{-2})	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**



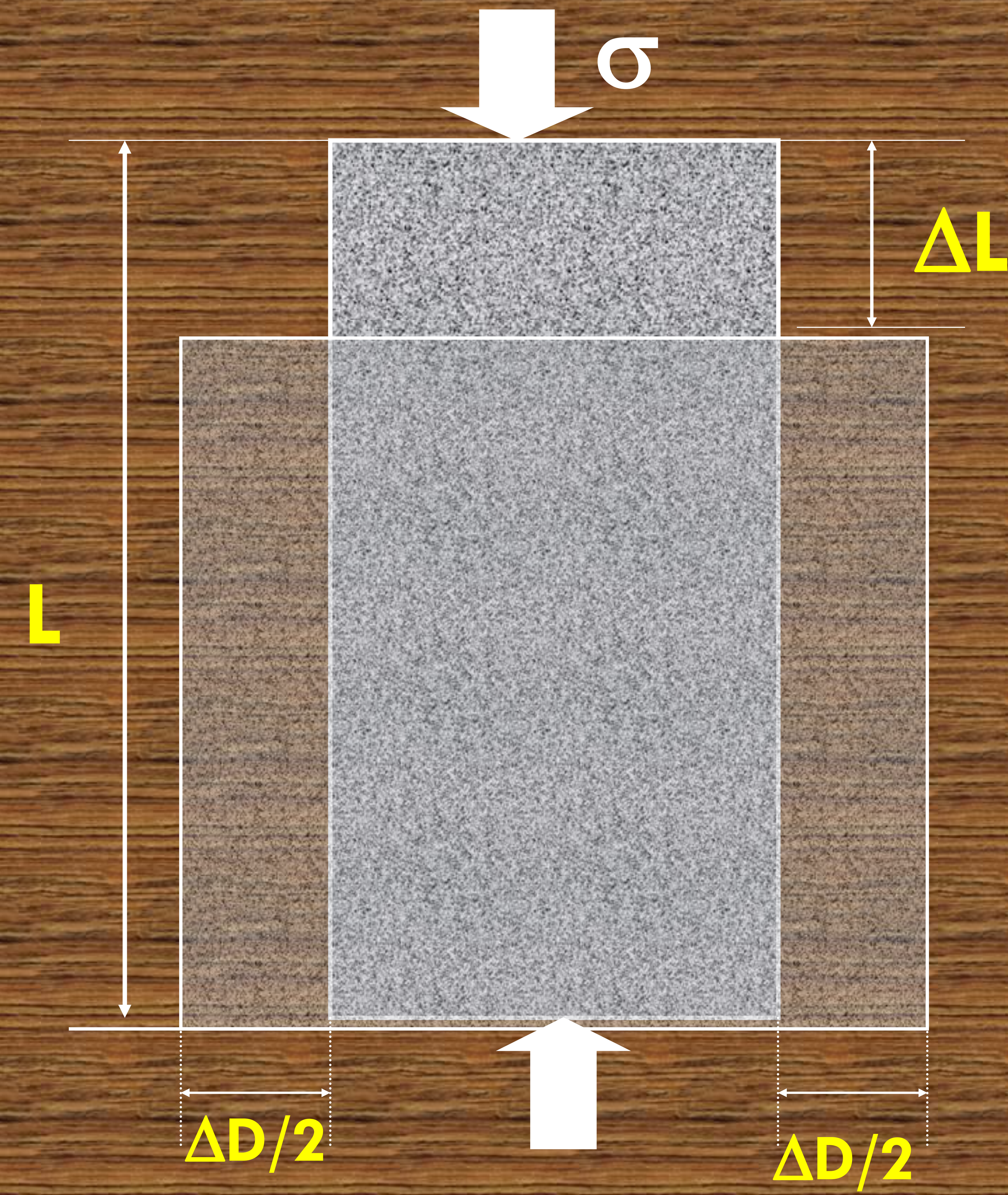
$$E_{av} = \Delta\sigma / \Delta\varepsilon$$

Elastic Deformation.....(4)

2. Poisson's Ratio (ν)

- Useful engg prop → measure of change in diameter with change in length under axial compressional stress.
- Is a unit-less modulus obtained from following equation:

$$\nu = \frac{\text{diametric strain}}{\text{longitudinal strain}}$$



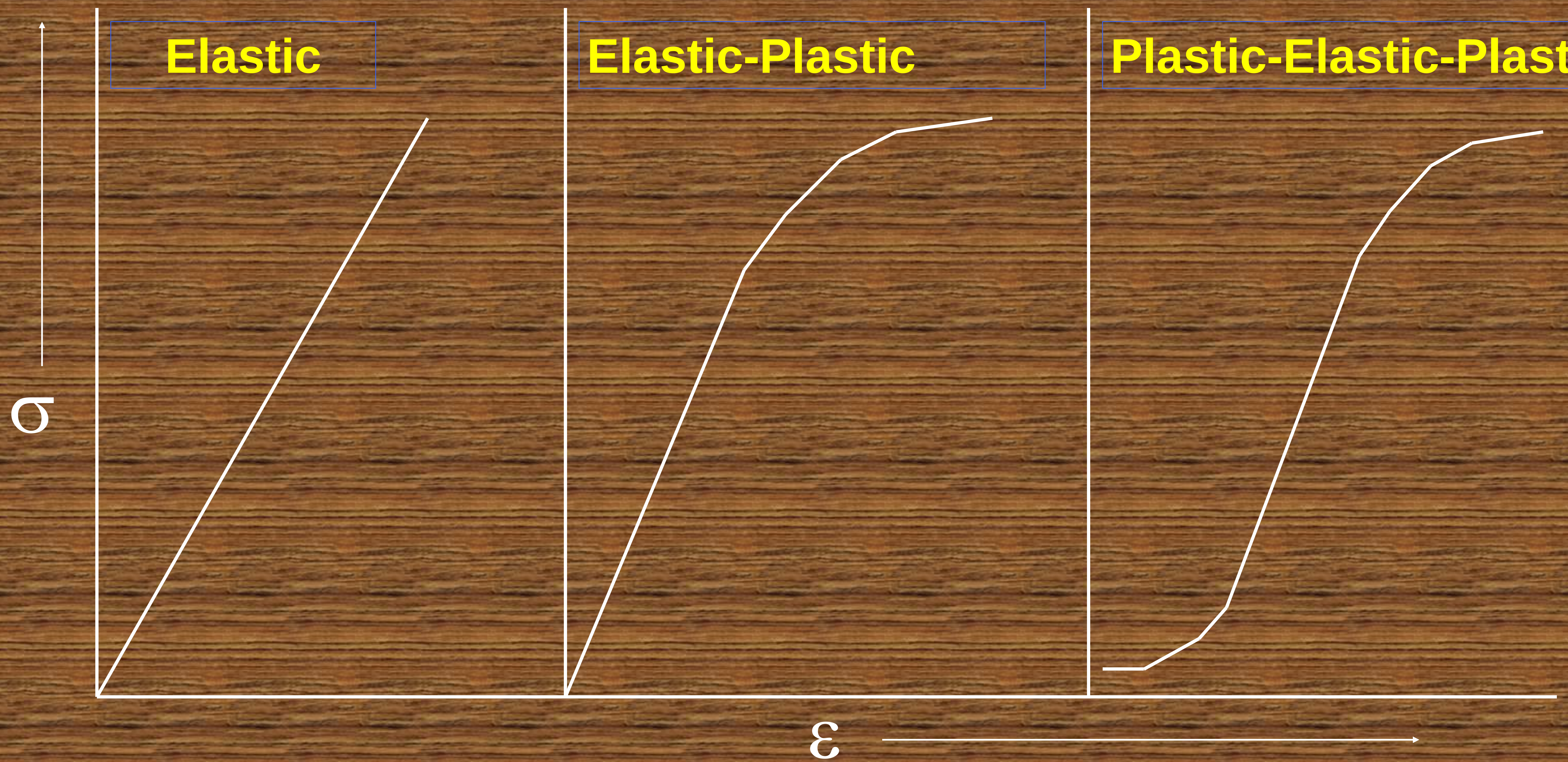
⇒ ν = (ΔD/D)/(ΔL/L) And has Max value of ν is 0.5

Example of Poisson's Ratio

Material	*Poisson's ratio*
rubber	≈0.5
gold	0.42
saturated clay	0.40 0.50
magnesium	0.35
titanium	0.34
copper	0.33
aluminium-alloy	0.33
clay	0.30 0.45

Elastic Deformation.....(5)

Rocks exhibit **ELASTIC** behaviour, some **ELASTIC – PLASTIC** others **PLASTIC – ELASTIC** behaviour



This behaviour forms basis for rockmass classifications

Rock Masses

Engg use of rock – as foundation materials, in *excavations & tunnels, or in maintaining slopes* – involves ROCK MASSES, in which presence of **DISCONTINUITIES** often has greater influence on engg character than *physical props* of intact rock.

Rock Masses.....*(2)*

⇒Design on/in rock **MUST** be based on:

- Intact rock props, &
- Those of the heterogeneous & anisotropic rock mass.

Most universally occurring anisotropy in rocks is caused by presence of **DISCONTINUITIES** – *bedding surfaces, joints, faults, well-developed metamorphic foliation.*

Rock Masses.....*(3)*

Resulting rockmass is:

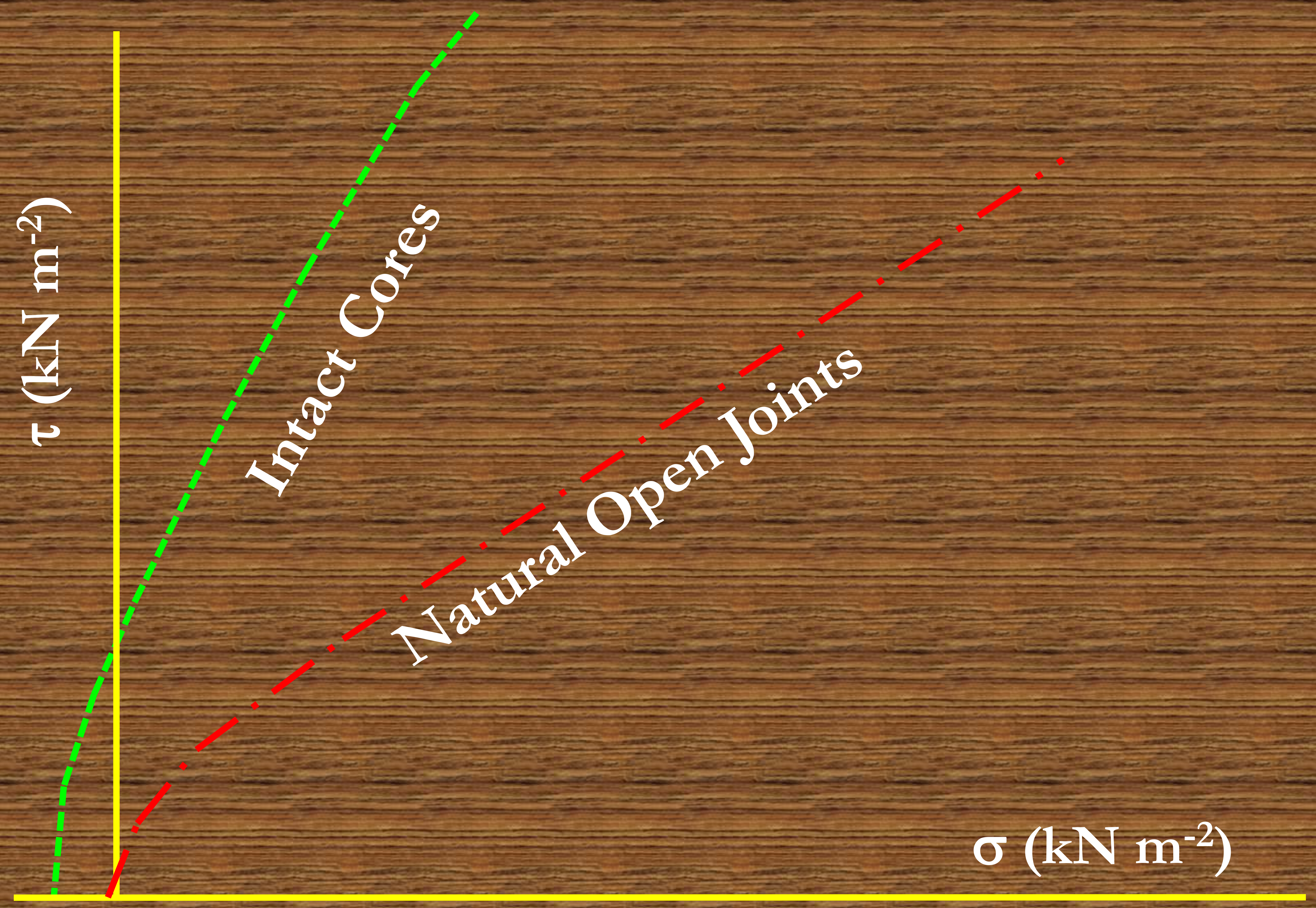
- An aggregation of **'blocks'** with significantly different physical props from intact rock samples...

⇒ Presence of discontinuities in rock mass → primary controlling factor of:

- rock mass strength &
- deformability of rock

Rock Masses.....*(4)*

Comparison of Mohr strength envelopes of intact cores and natural open-joints



Rock Masses.....*(5)*

⇒ Evaluation of engg props of rock mass includes:

- Knowledge of intact rock props
- Occurrence & nature of discontinuities
- Extent of weathering

Discontinuities in Rock Masses

Recap:

- Almost all rocks ramified by discontinuities of some kind.
- These discontinuities are of utmost importance to all engg works on rock.

⇒ shear strength of discontinuous rockmass is of primary importance.

Characteristics of Discontinuities

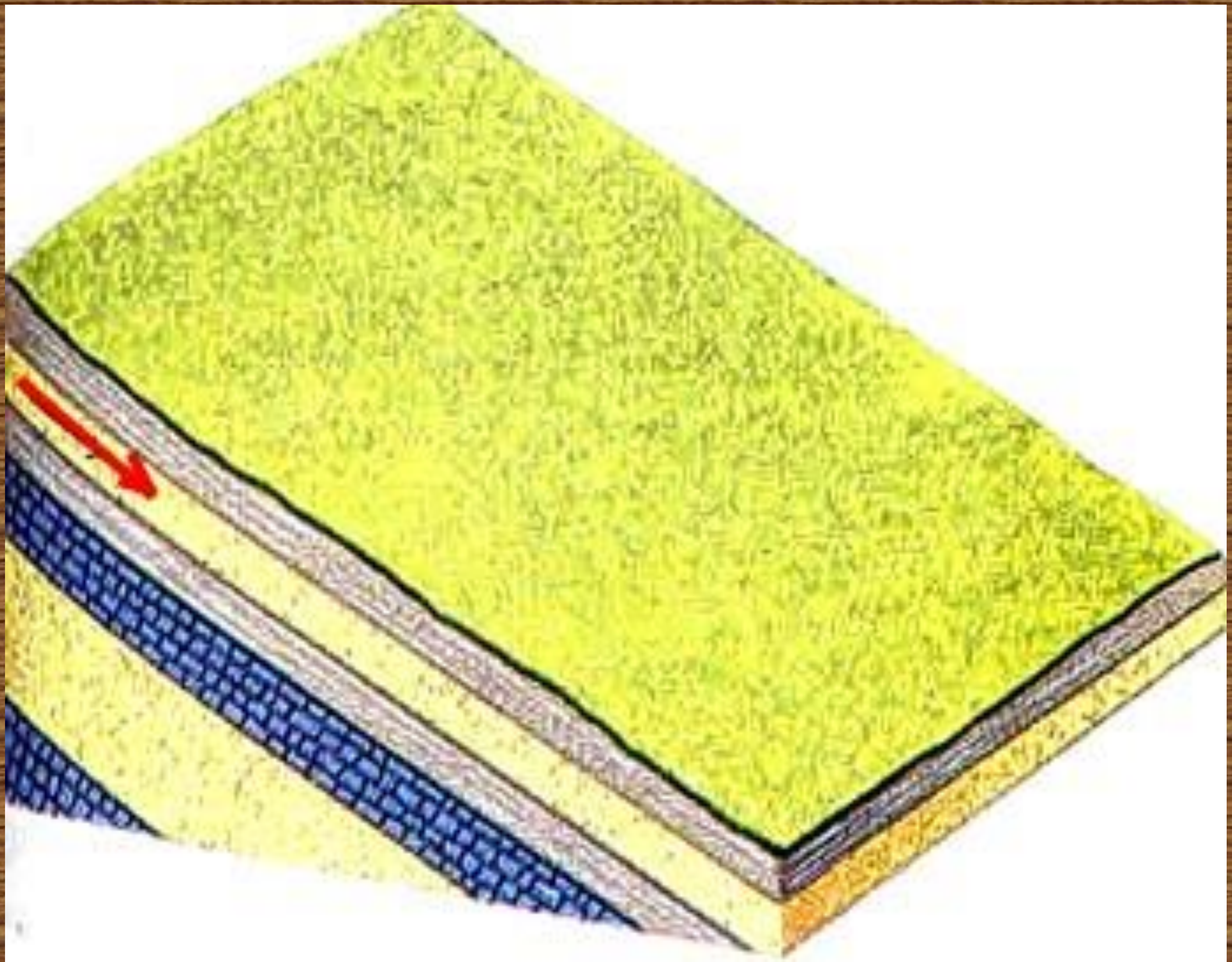
Influence of discontinuities on ***strength*** & ***deformability*** of rockmasses arising from engg construction on/within them is affected by their:

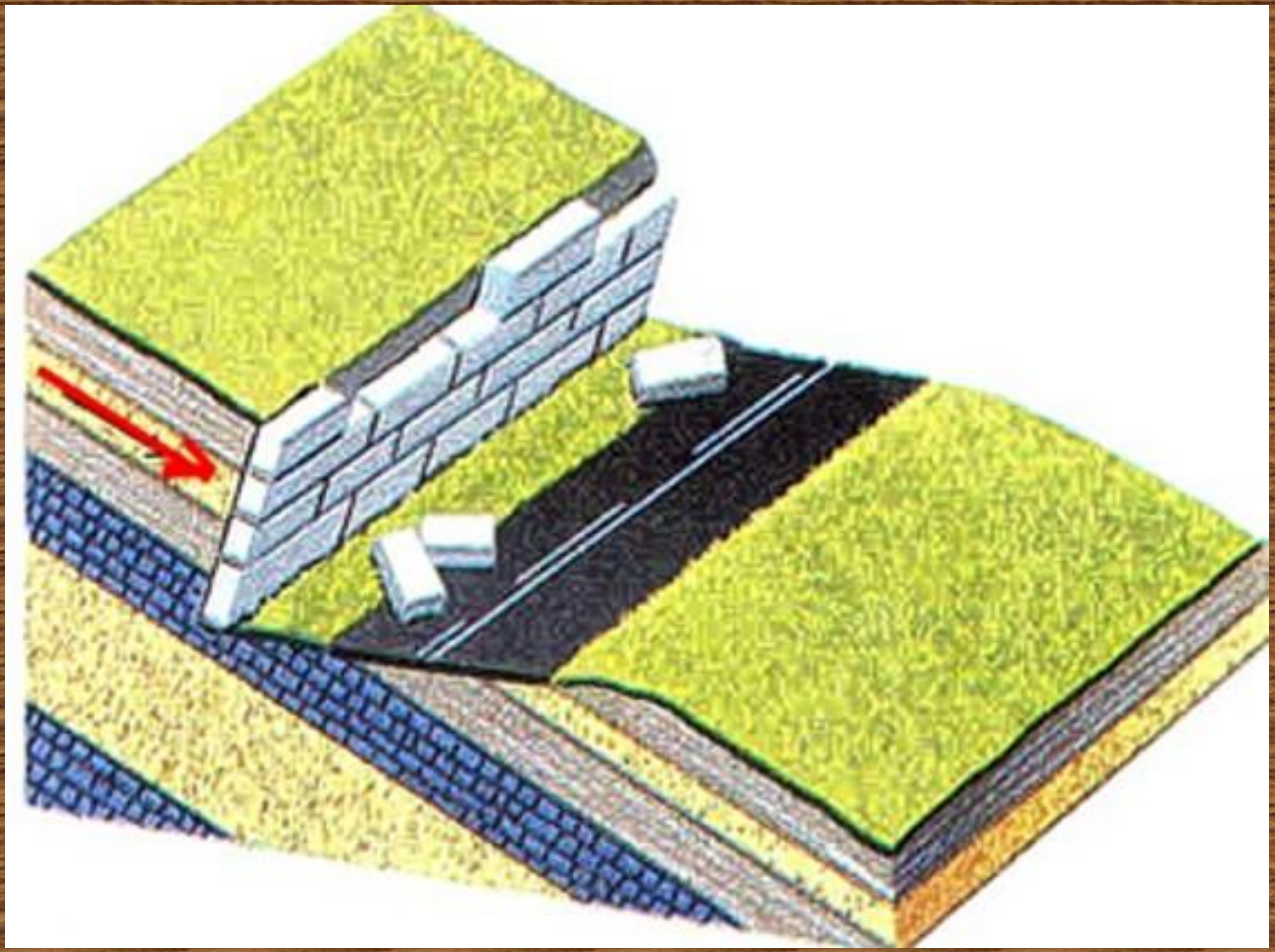
- Orientation
- Spacing
- Continuity
- Surface characteristics *(roughness, weathering / alteration)*
- Thickness & nature of filling material *(if present)*
- Presence of water

Orientation

- Importance of discontinuities in any project depends partly *on* their ***orientation relative to directions of imposed stresses.***

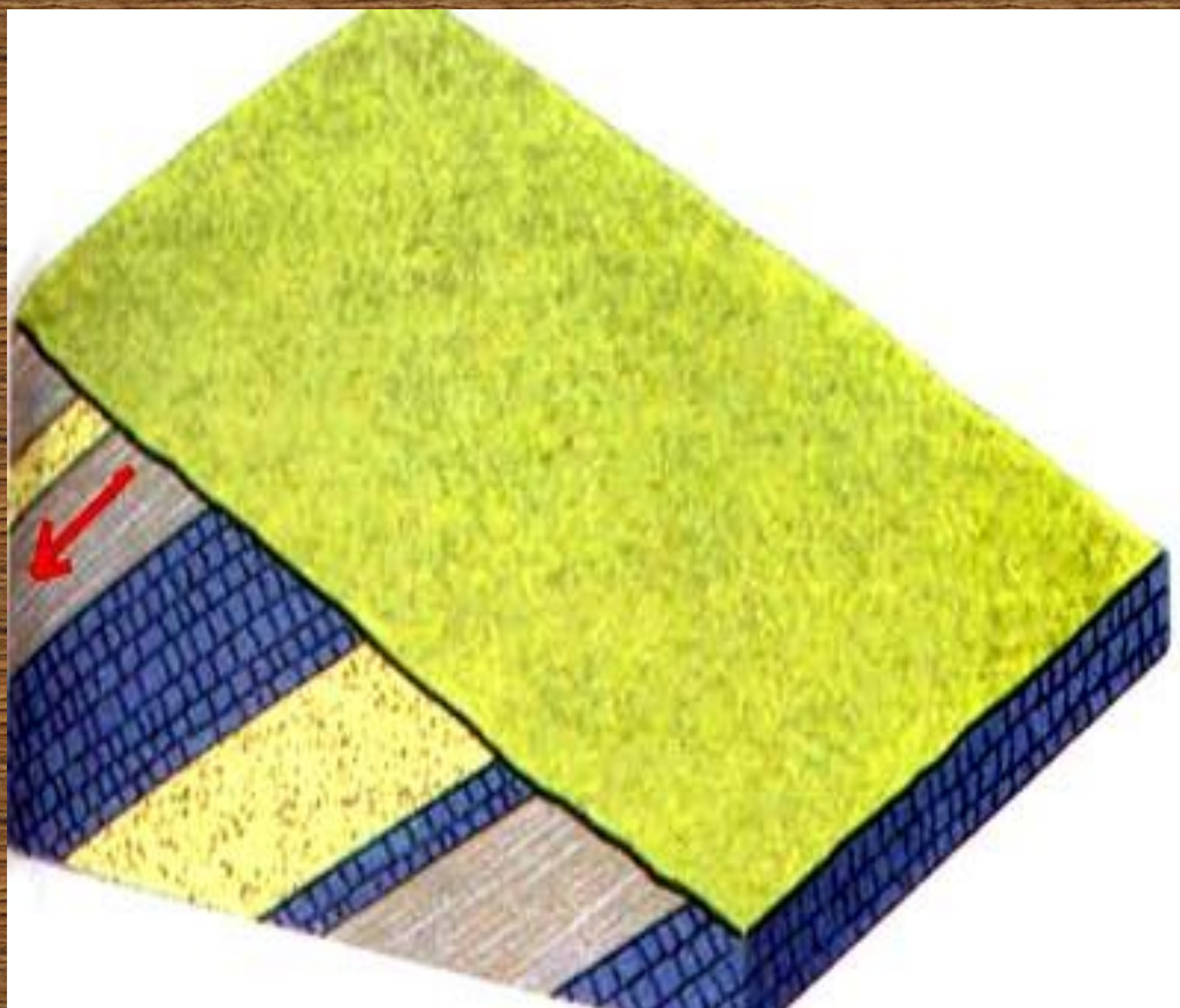
Example 1:

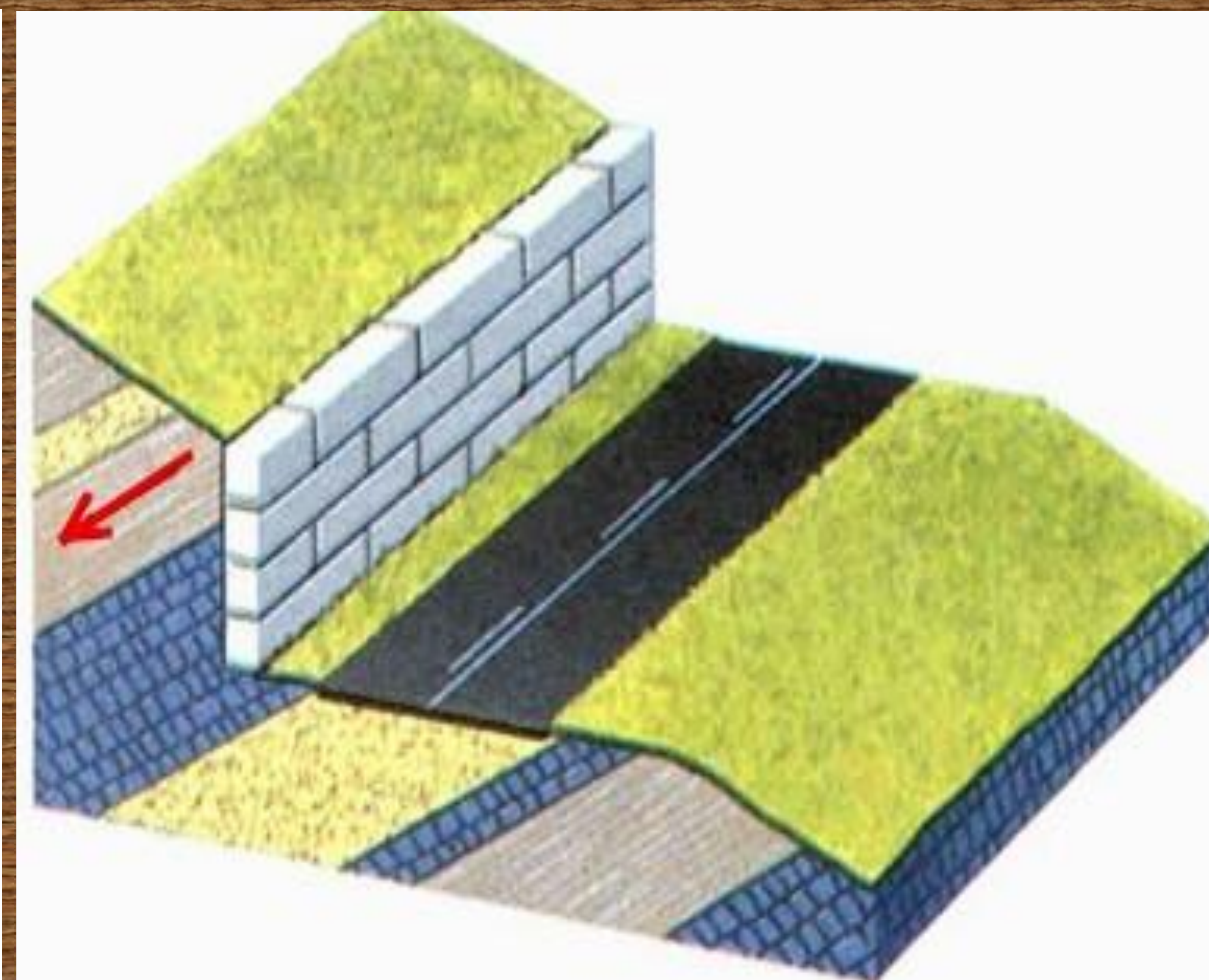




Orientation.....(2)

Example 2:





Stable scenario

Spacing of Discontinuities

- Affects overall rock mass strength and/or quality.
  - Even strongest intact rock is reduced to one of little strength, when closely spaced joints are encountered.

⇒ When discontinuity-spacing is large, ***behaviour of rockmass*** will be ***strongly influenced by intact rock props***.

Spacing of Discontinuities.....(2)

Spacing btwn discontinuities must be measured....

Discontinuity Surface Characteristics

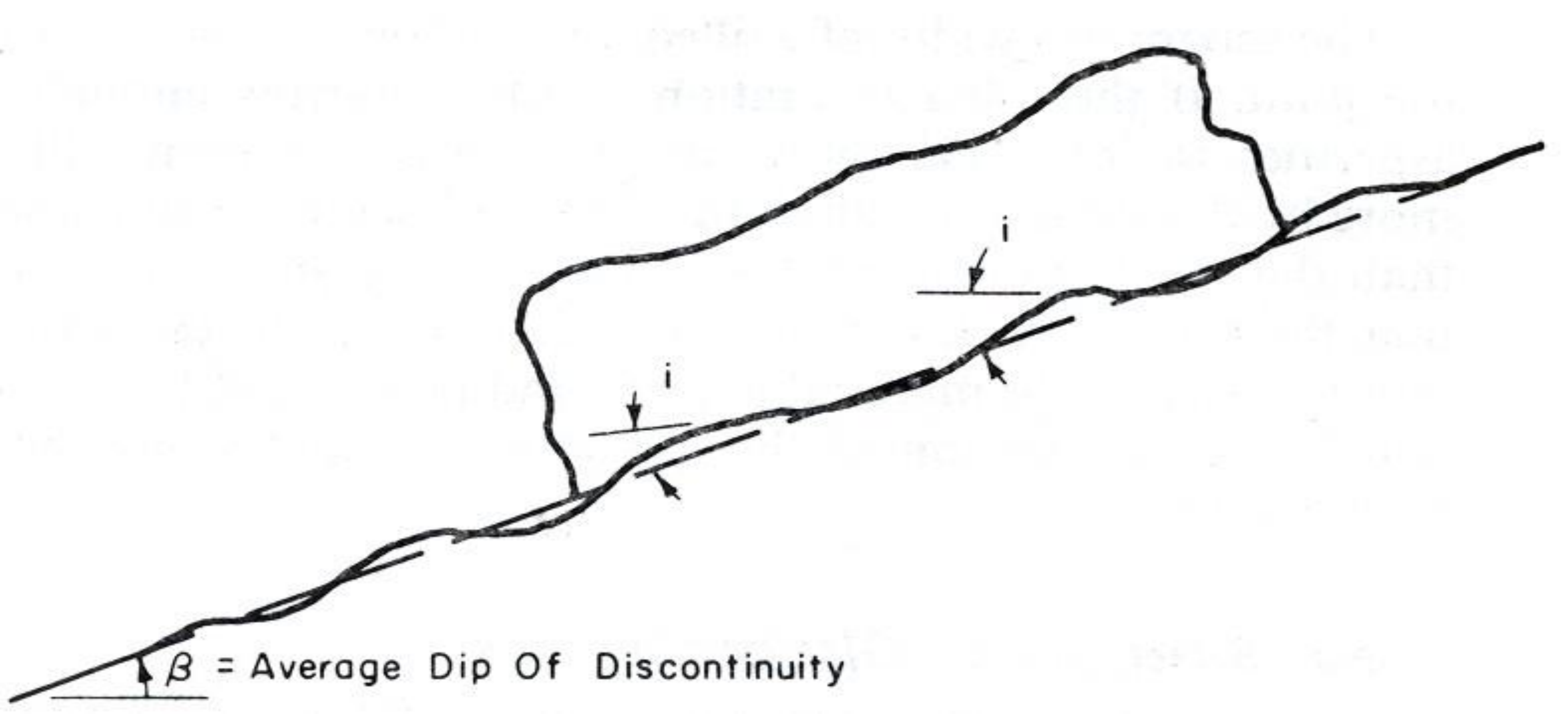
Factors involved in consideration of surface characteristics of discontinuities:

1. Roughness / waviness
2. Physical props of material filing space

Discontinuity Surface Characteristics…..(2)

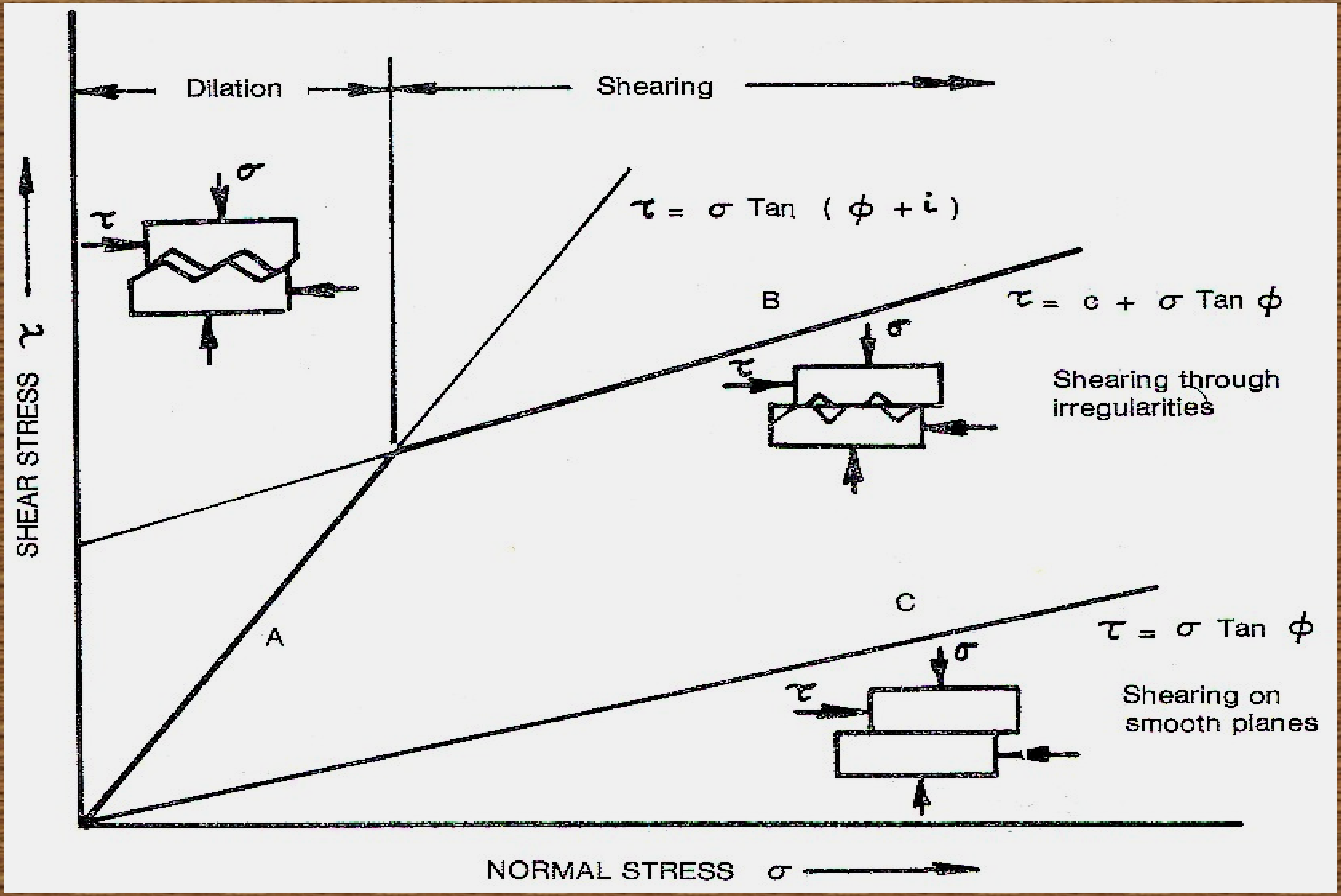
Roughness

- results in variations in orientation / attitude along given discontinuity.
- provides friction btwn two adjacent blocks.



Discontinuity Surface Characteristics…..(3)

Shear strength of discontinuities – expressed in terms of c & φ. Roughness has important influence on discontinuity strength, which varies depending on ***scale of roughness relative to discontinuity plane.***



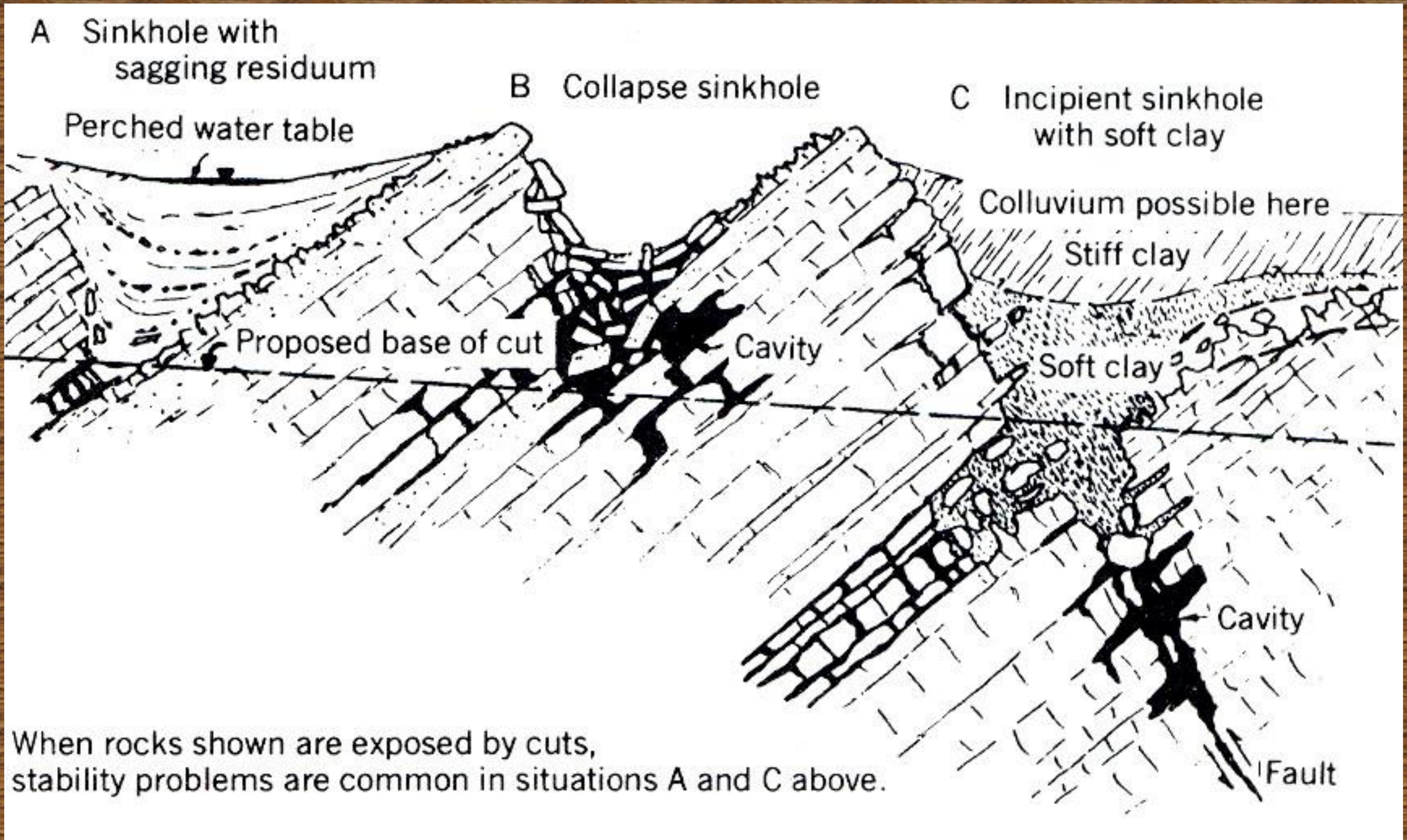
Weathering of Rockmass

Weathered state of rock has significant influence on engg props of rock mass:

- Physical weathering results in changes in SIZE & N$^{o.}$ of DISCONTINUITIES in rockmass.
- Chemical weathering of rock mass is enhanced by movement of grdwater thru network of discontinuities.

Weathering of Rockmass.....(2)

Control of water movement thru discontinuities may result in localised & often deeply penetrating zones of weathering.



Typical weathering feature of carbonate rocks.

Summary

- Geologic factors – *mineralogy, texture, grain size, and cementing material* – significantly affect intact rock strength.
- Rocks with interlocking textures are typically stronger than those with clastic textures.
- Chemical weathering alters engg props of all rocks.
- Strength & deformation props are primary factors in utilisation of both ***INTACT ROCK & ROCKMASSES*** in engg projects.

Summary.....*(2)*

- Geologic factors – *mineralogy, texture, grain size, cementing material* – significantly affect intact rock strength & deformability.
- Chemical weathering alters engg props of all rocks, thereby weakening rocks.
- Strength & deformability of rock masses and susceptibility to chemical weathering are controlled by presence of discontinuities.

Summary*.....(3)*

- Presence of intersecting discontinuity-sets greatly reduces rock mass strength compared to that of intact rock.
- Characteristics of discontinuities → *orientation, frequency of occurrence, continuity and surface characteristics* – have an important role in way rockmass deform.