**UNIVERSITY OF ZAMBIA**

# Factors affecting strength of Rocks in Engineering Practice

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## Introduction

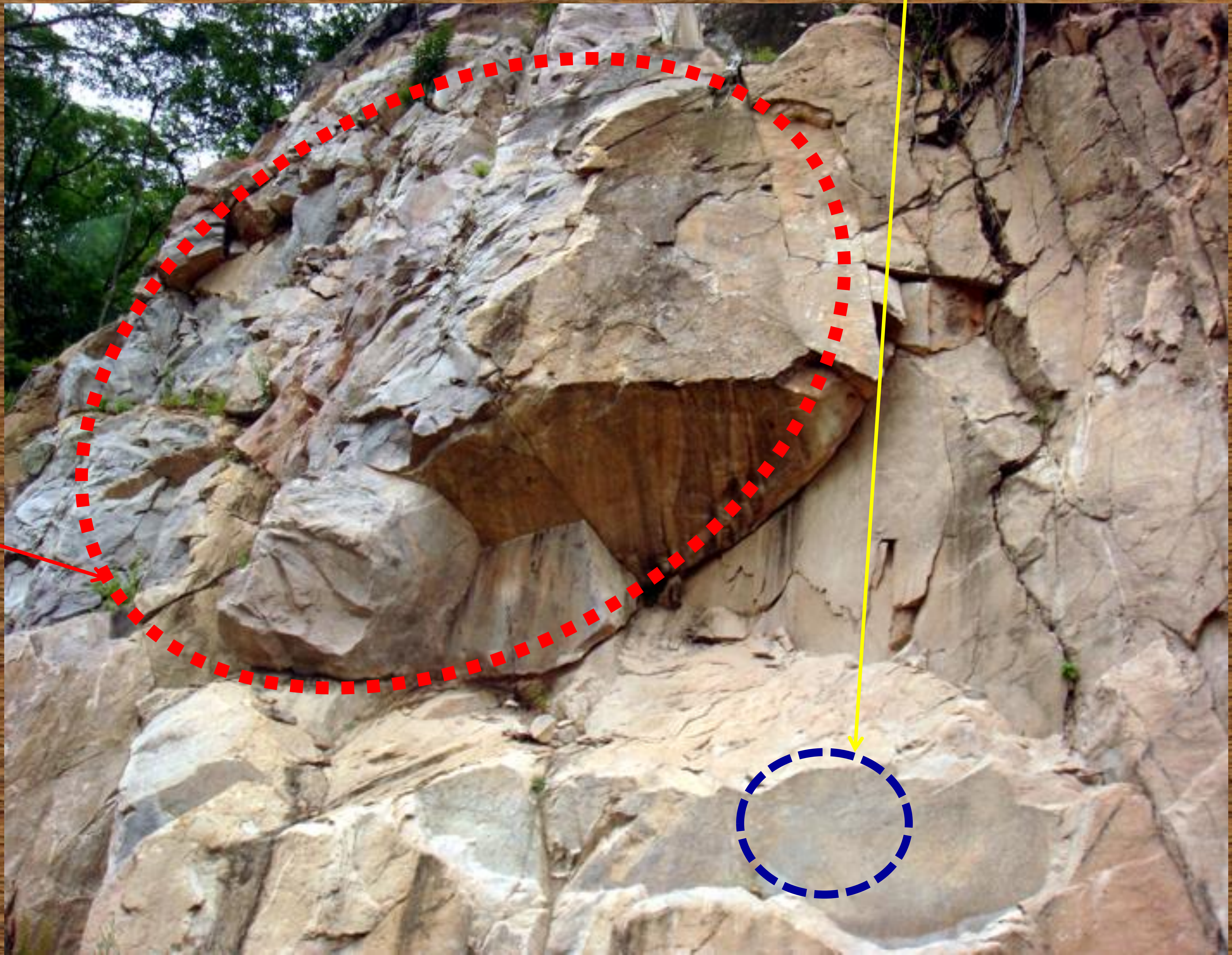
Rock's area involved in many civil and engineering geology projects.

# Introduction.....(2)

Rock is divided into:

➢ Intact rock,

➢ Rock mass



## Intact Rock

An **intact rock** 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, such as;

# Intact Rock Strength

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

The applied stress may be:

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

# Intact Rock strength

**Uniaxial Compressive Strength (UCS)** of intact rock is:

- most commonly measured & used strength
- usually obtained by testing cylindrical rock specimen and is
- dependent upon:
  - ✓ rate of loading
  - ✓ core size, and length-to-diameter ratios
    - ➢ (aspect 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.
- ✓ <u>Summation</u> of these strains over stressed length is the **DEFORMATION,** which:
  - ➢ Normally leads to change in **SHAPE** and/or **VOLUME** **and**
  - ➢ Generates Data used to calculate **ELASTIC MODULI;**
    - ➢ Modulus of Elasticity or Young's Modulus (E)
    - ➢ Poisson's Ratio ($\nu$)

## ***Types of Deformation:***

1) **Elastic** – where*:*

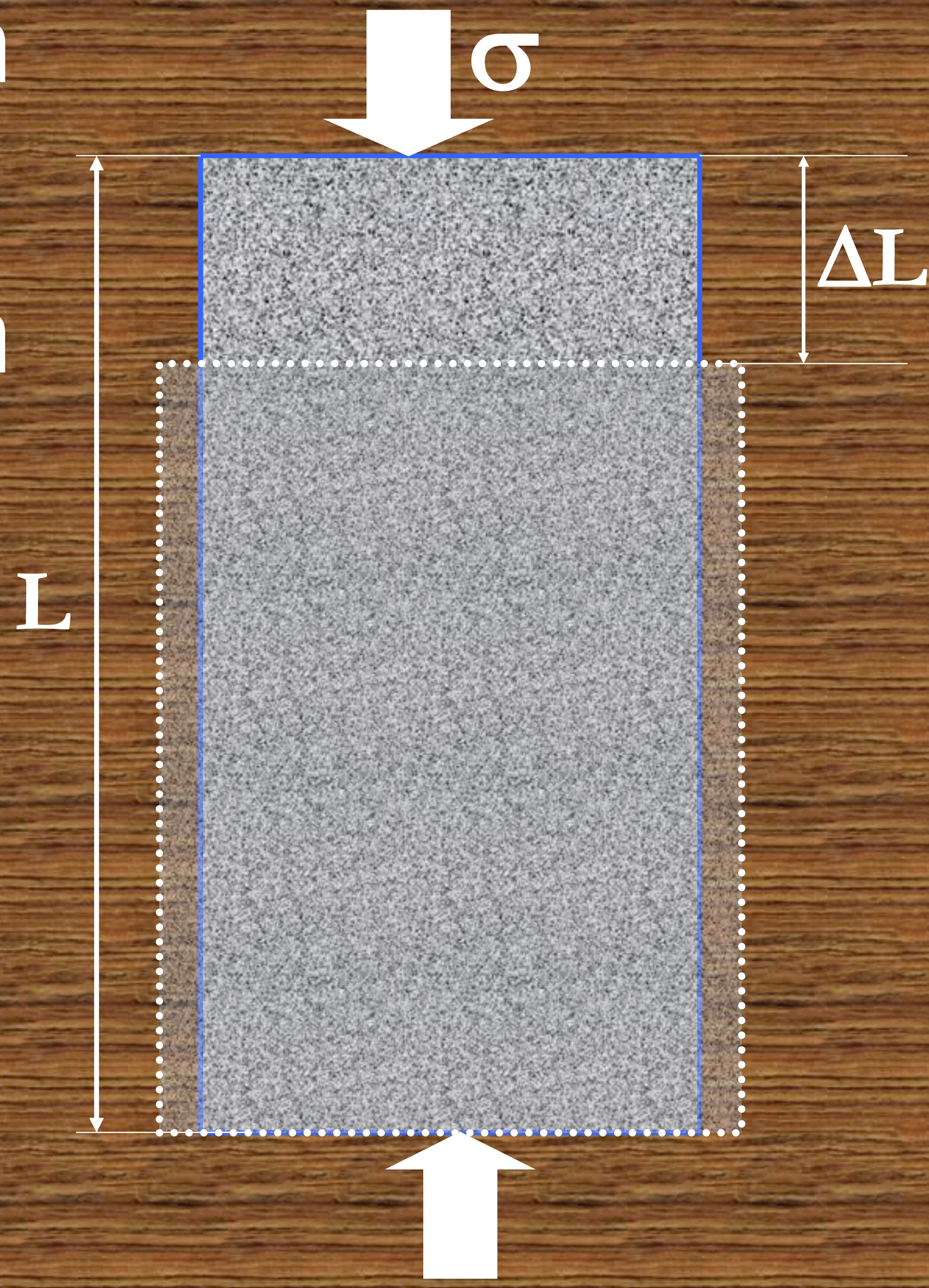
- ✓ When load is removed, deform$^n$ instantly & completely disappears.
- ✓ Relationship between **STRESS** & **STRAIN** is more or less linear

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 ($\sigma_1 - \sigma_3$) for triaxial tests ($kN\ m^{-2}$)

**ε** = Axial Strain (expressed in mm/mm)

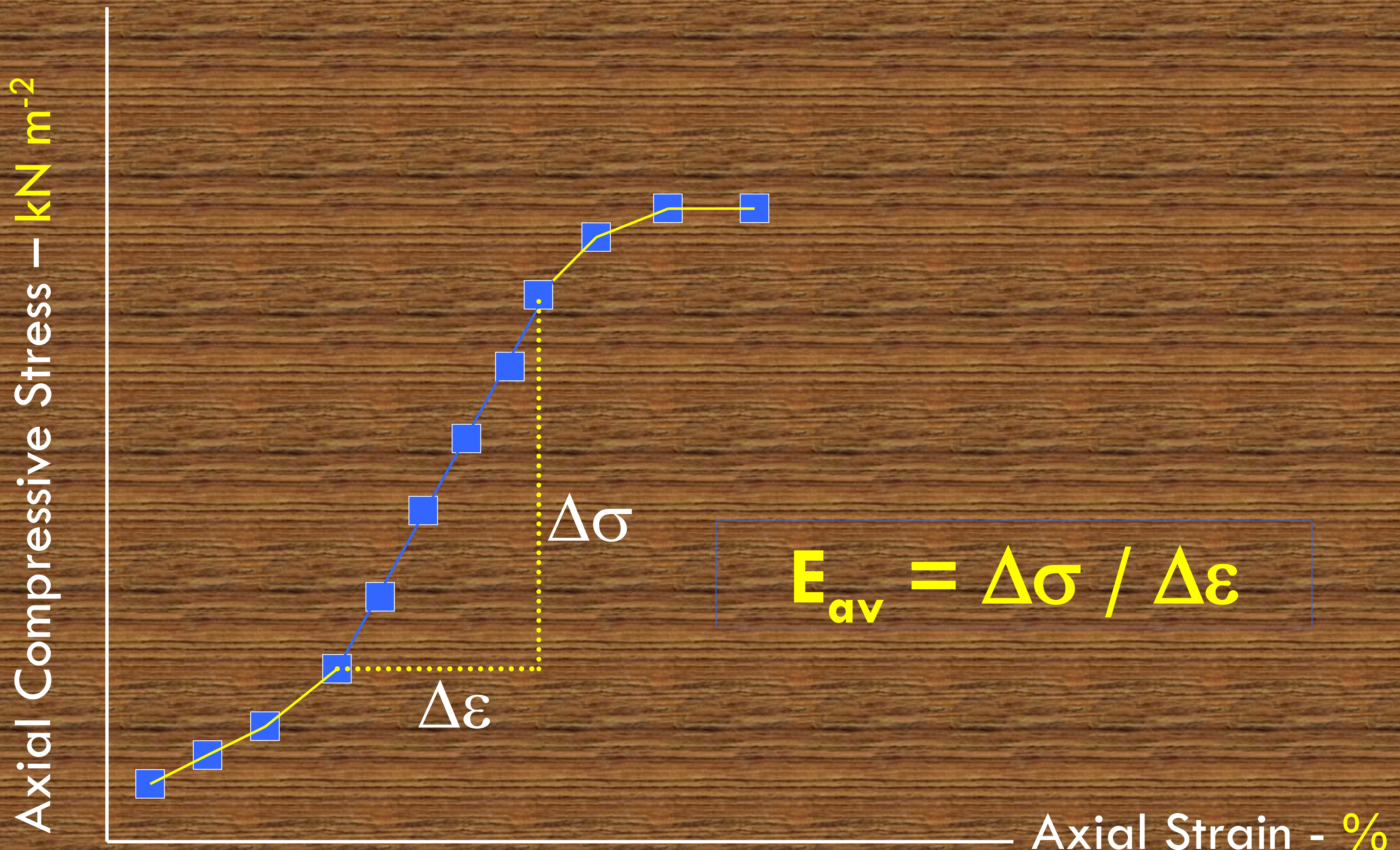
Value for E may be obtained from stress-strain diag.

$E_{av}$ 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** |



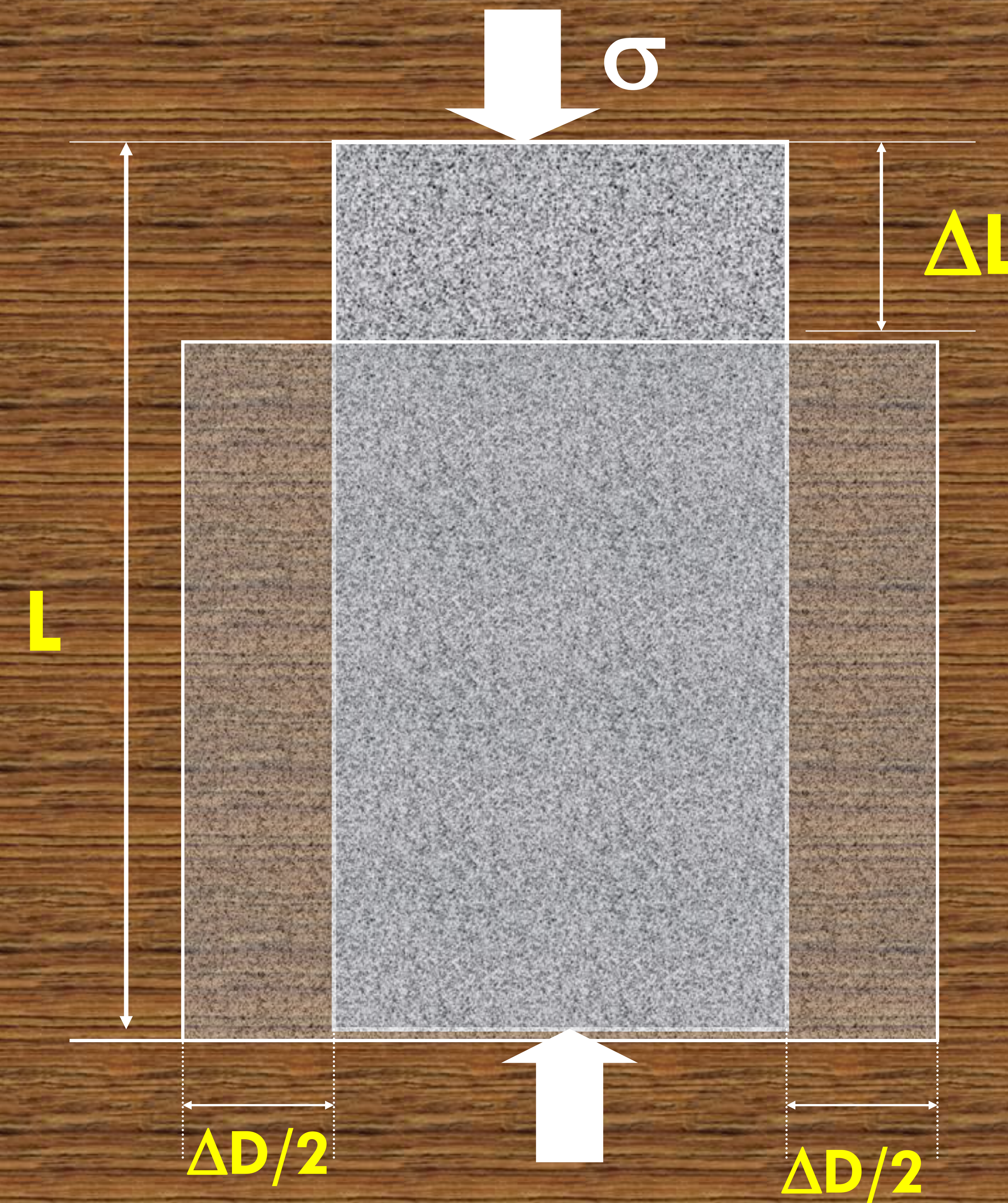

$$E_{av} = \Delta\sigma / \Delta\varepsilon$$

# *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:

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



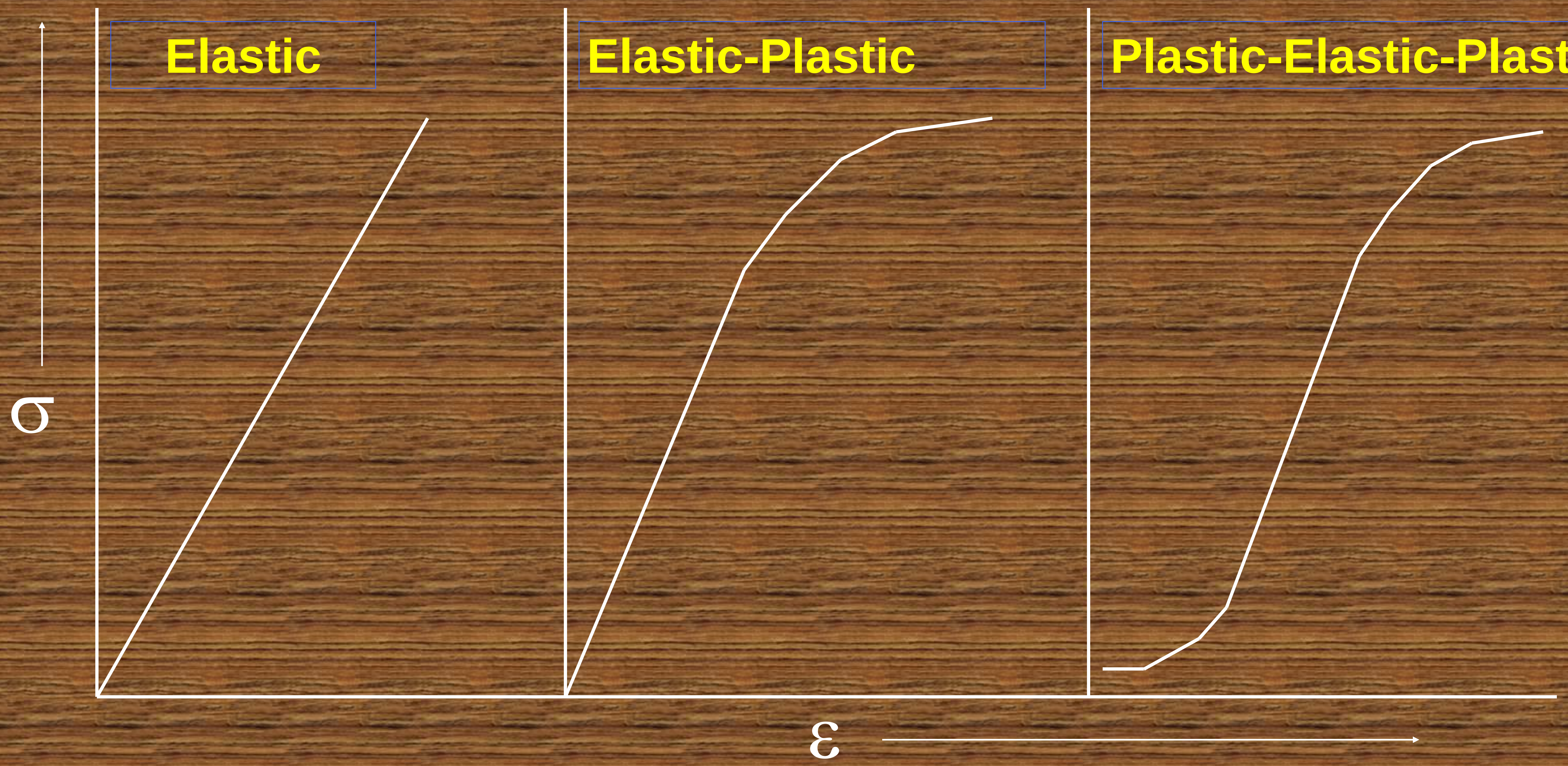

**$\Rightarrow \nu = (\Delta D/D)/(\Delta L/L)$** And Max value of ν is 0.5

# 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)

Some 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 both 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, such that:*

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

The resulting rockmass is:

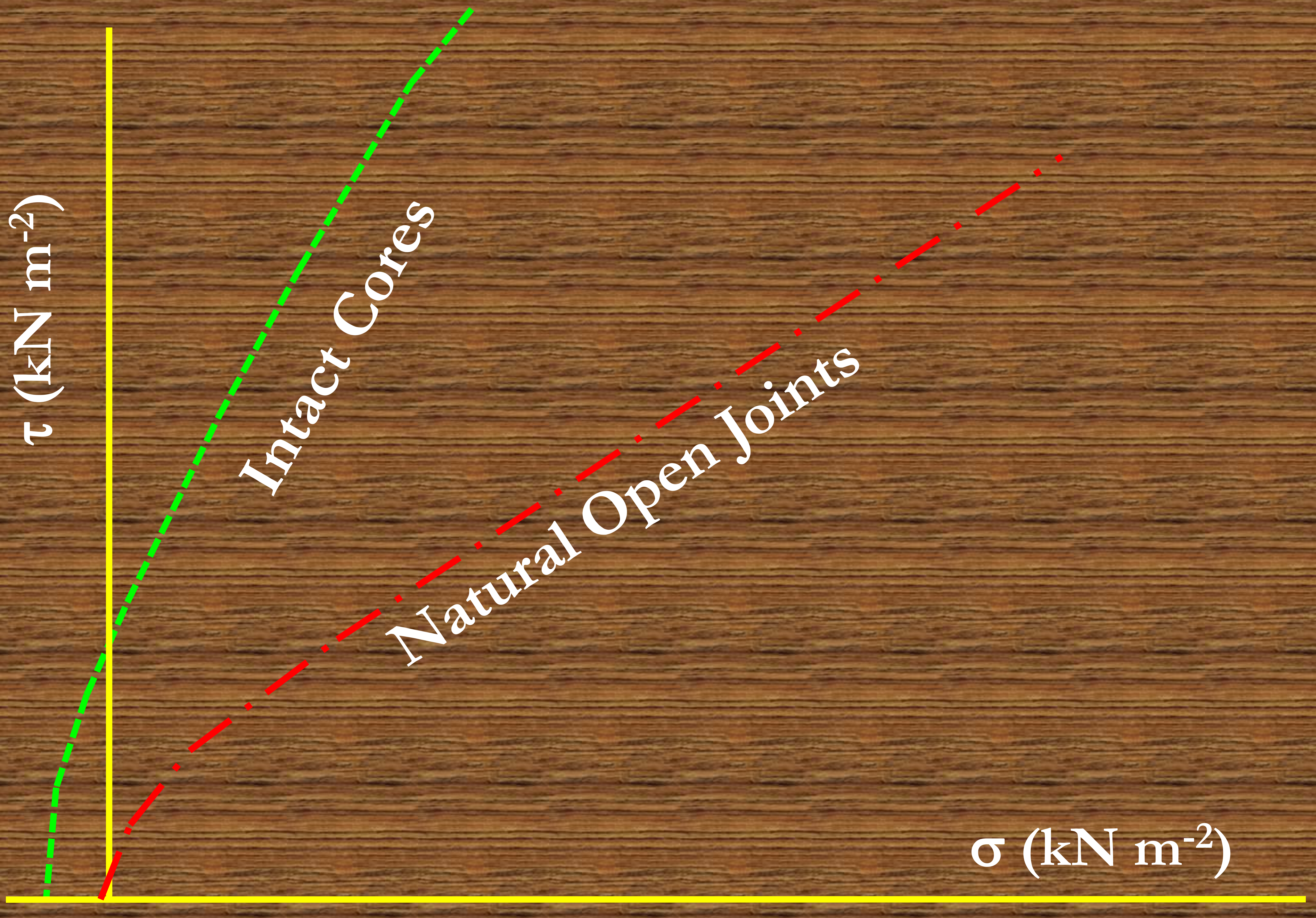
- ✓ An aggregation of **’blocks’** with significantly different physical props from intact rock samples...

⇒ Presence of discontinuities in rock mass → is primary the 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 are 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:*

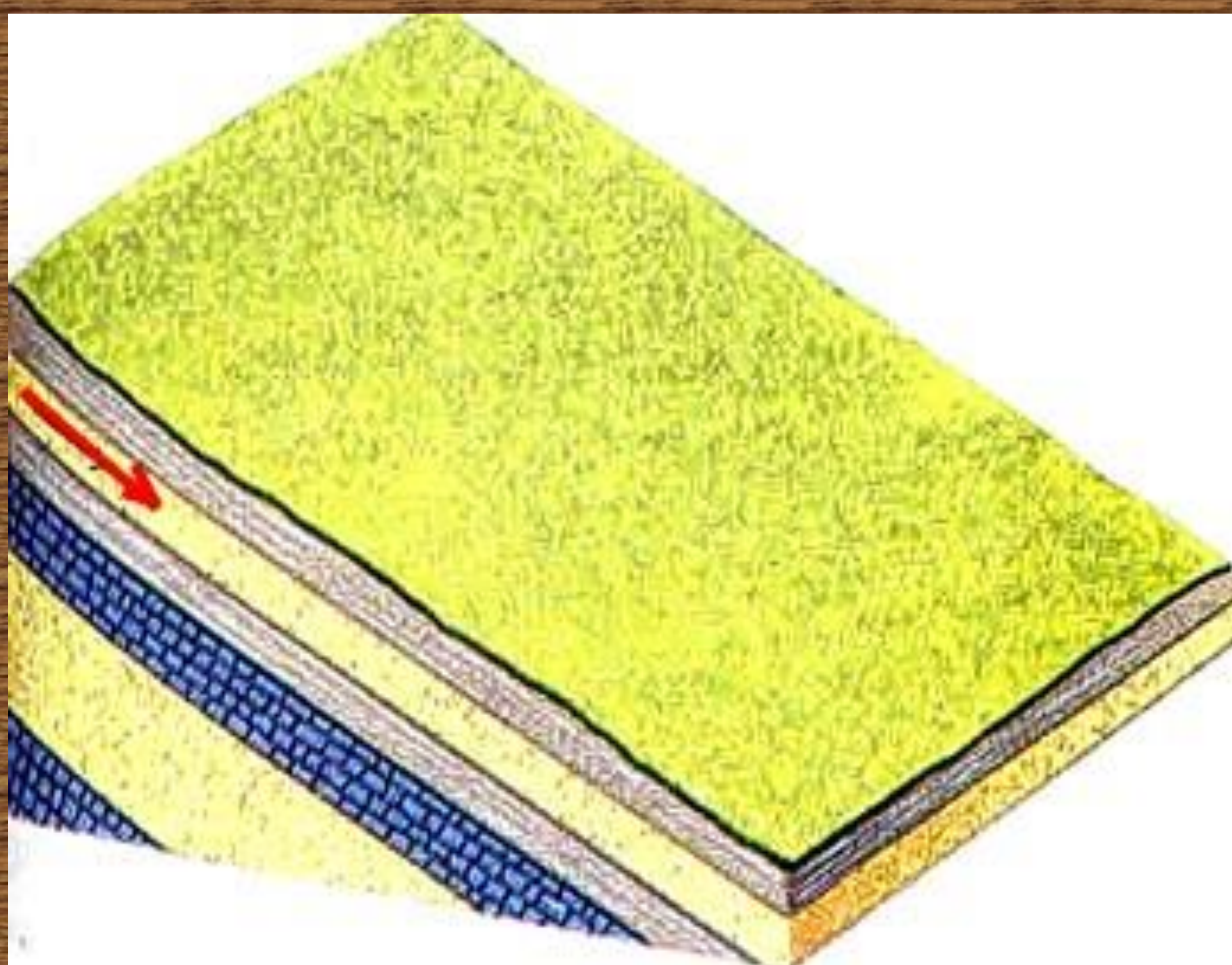
Influence of discontinuities on ***strength*** & ***deformability*** of rockmasses arising from engg construction on / within them is affected by their:

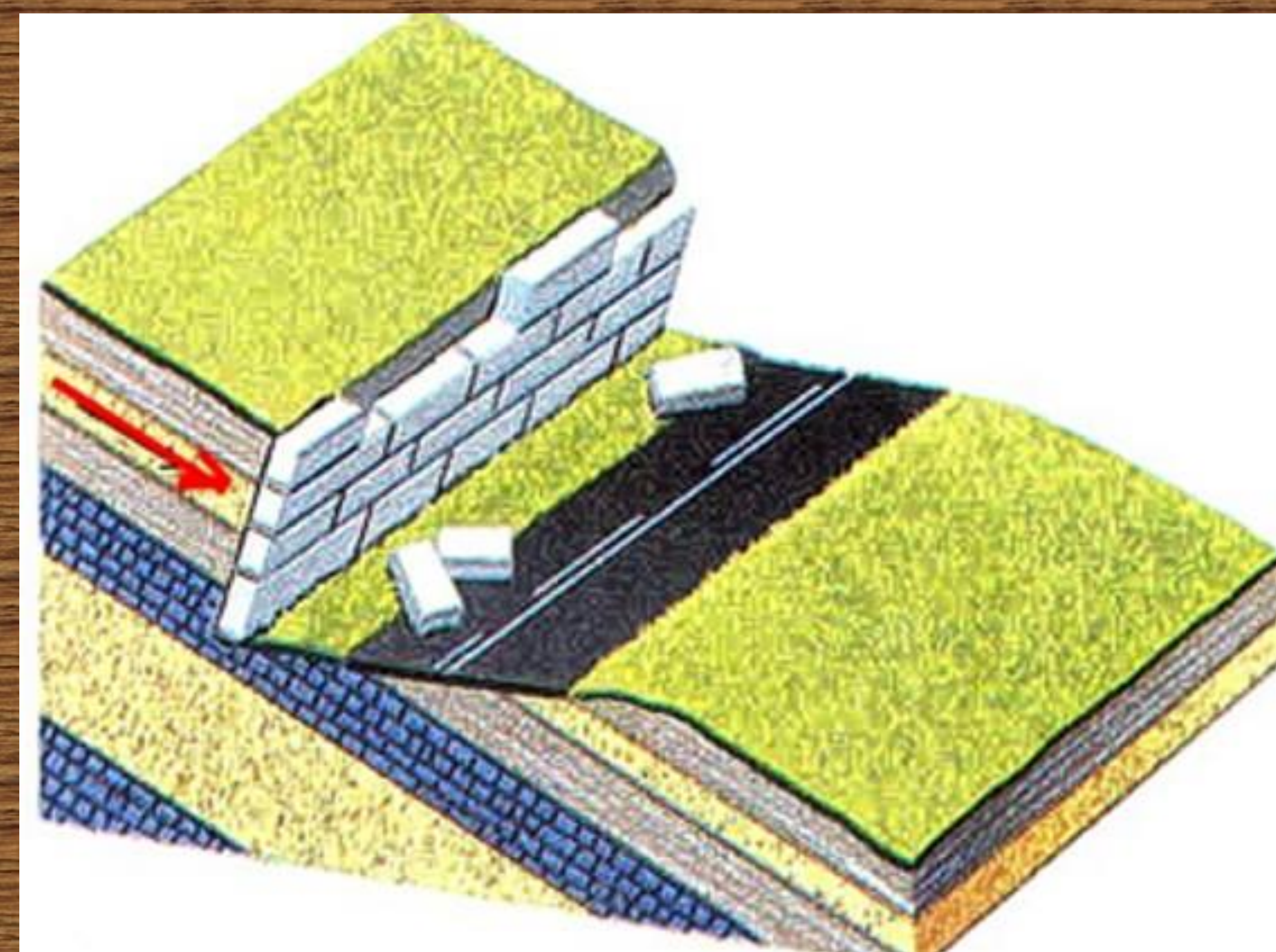
- ✓ Orientation [Geometry]
- ✓ Spacing
- ✓ Continuity
- ✓ Surface characteristics *(roughness, weathering / alteration)*
- ✓ Thickness & nature of filling material *(if present)*
- ✓ Physical Properties of adjacent rock
- ✓ Presence of water

# *Orientation [Geometry] of discontinuity:*

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

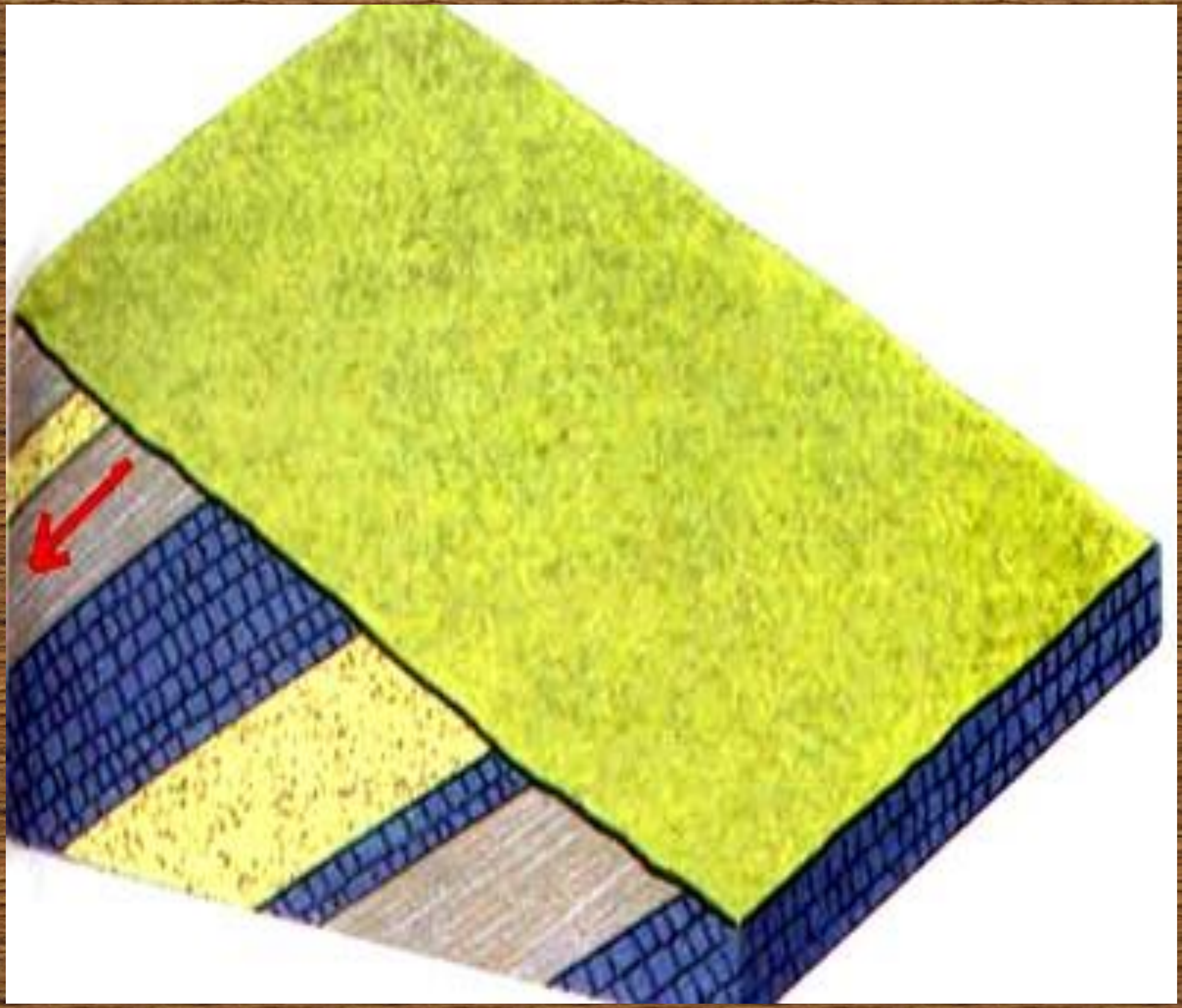
Example 1:

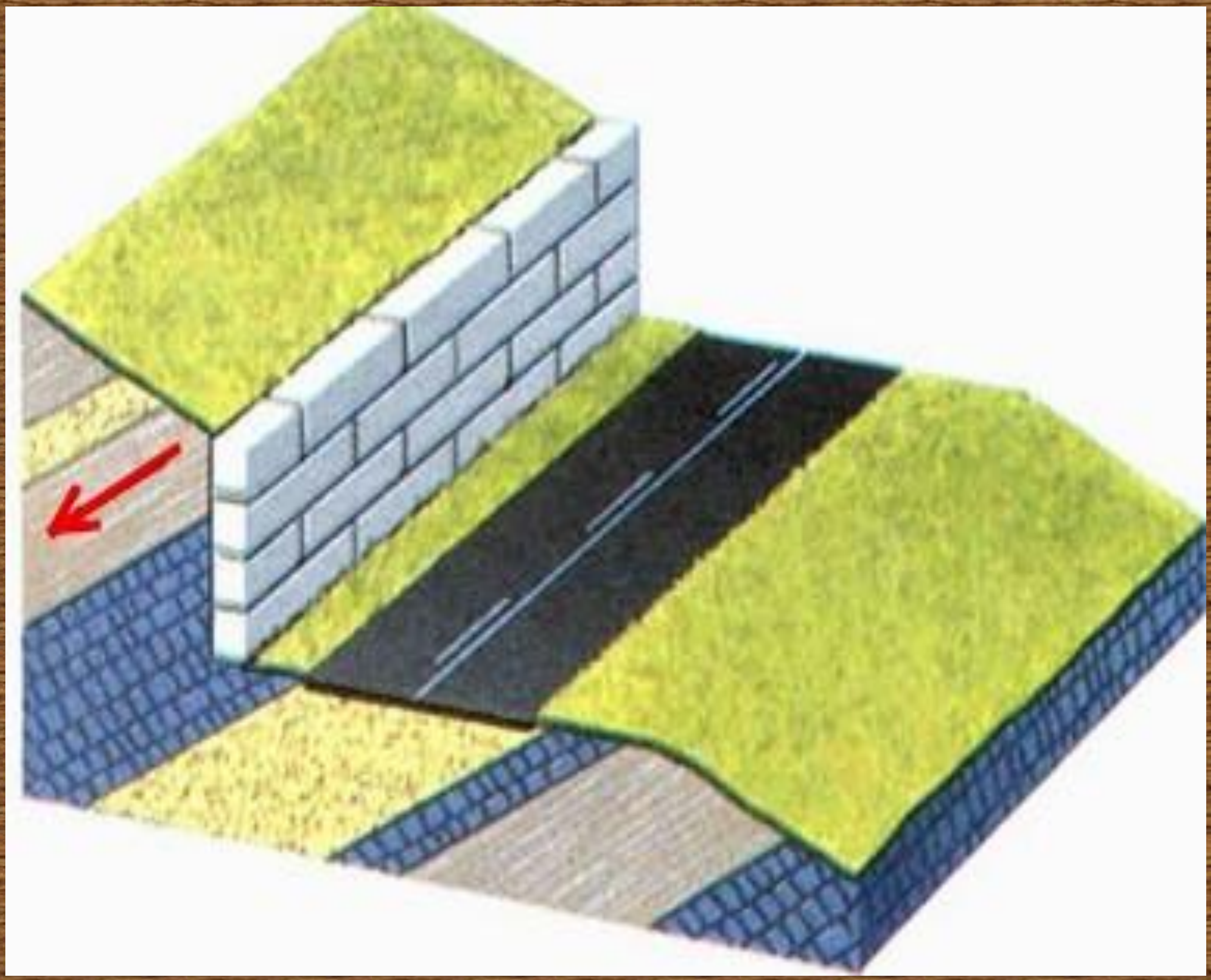




# *Orientation…..(2)*

Example 2:





Stable scenario

## ***Spacing of Discontinuities:***

- ✓ Affects overall rock mass strength and/or quality:
  - ✓ Even the 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:*

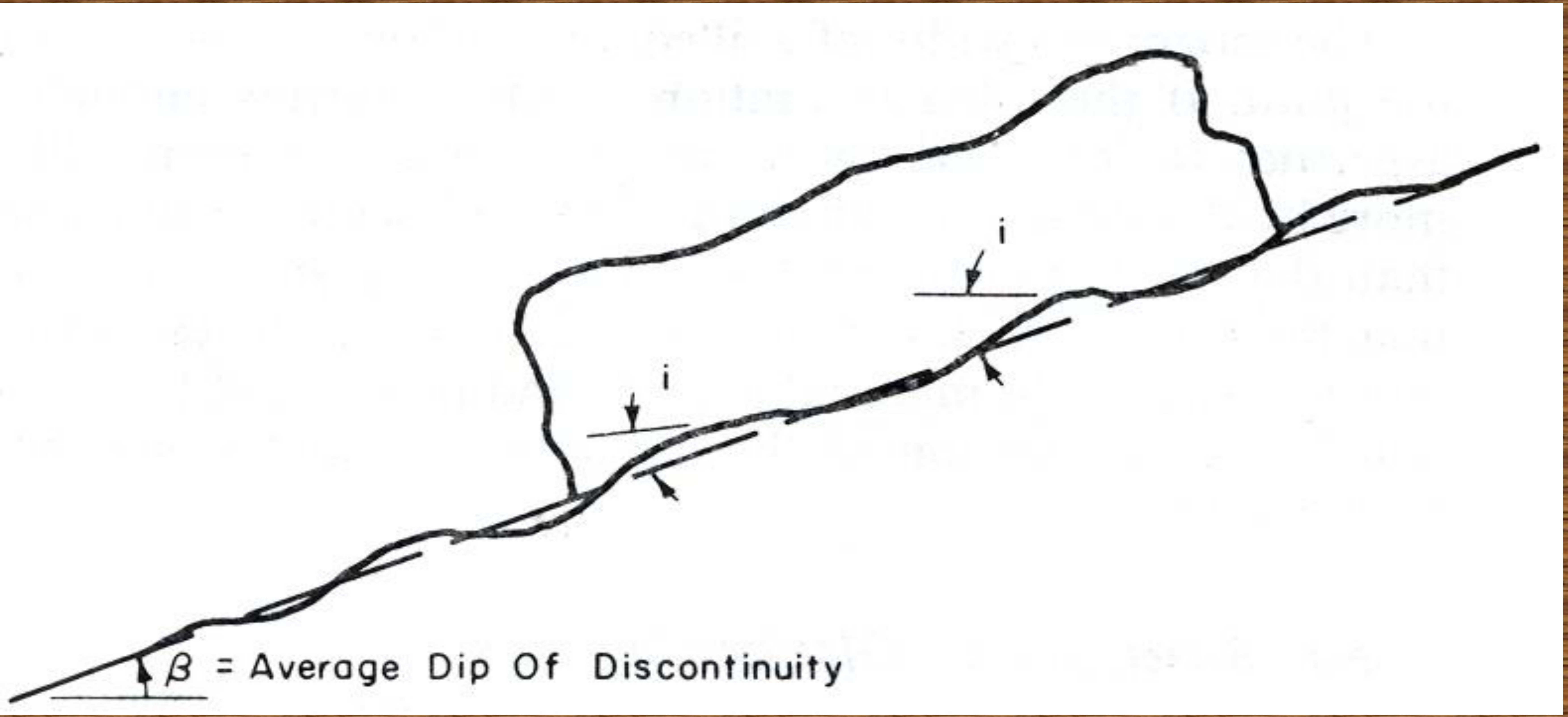
Factors involved in consideration of surface characteristics of discontinuities:

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

# *Discontinuity Surface Characteristics.....(2)*

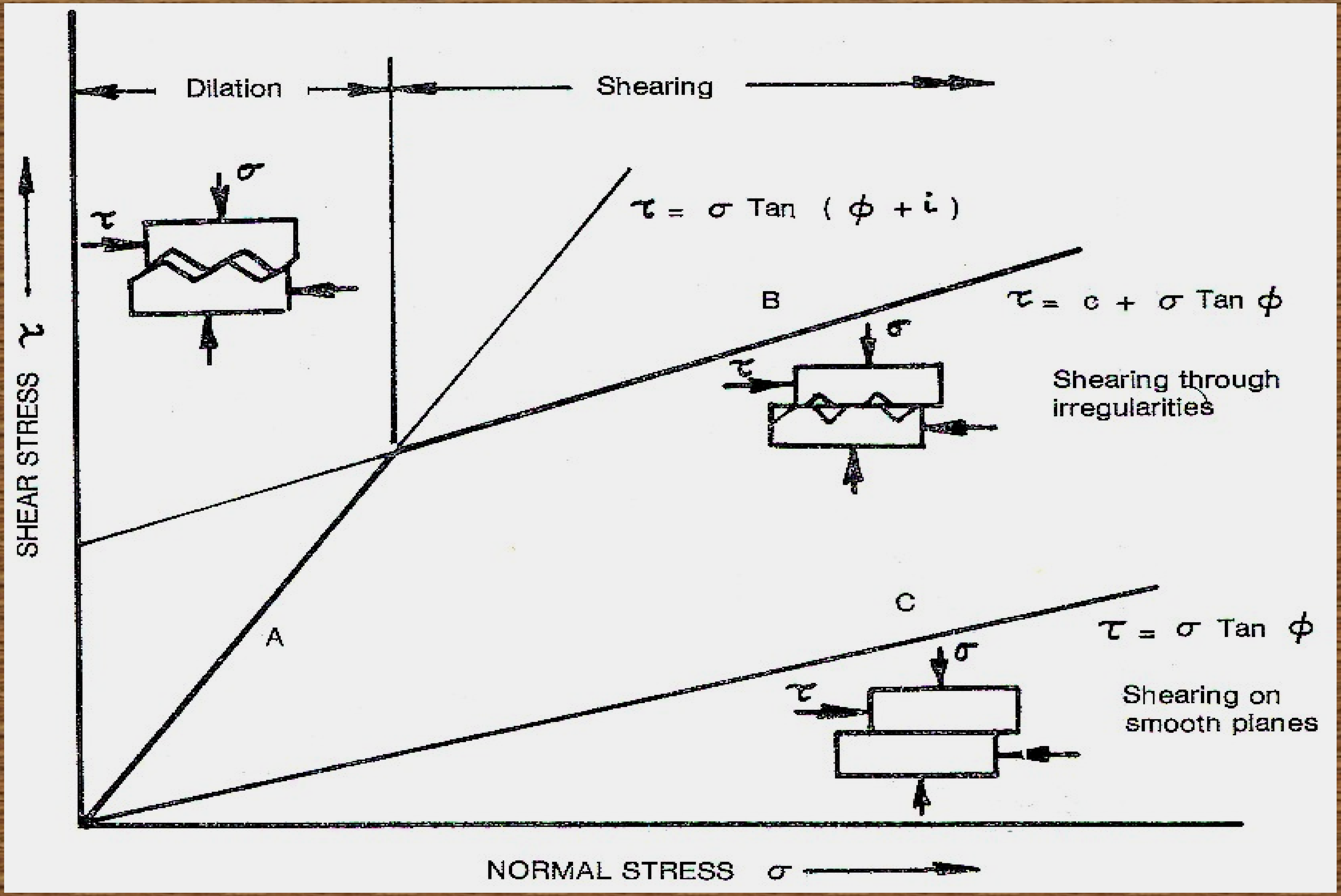
## Roughness:

- ✓ 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.***



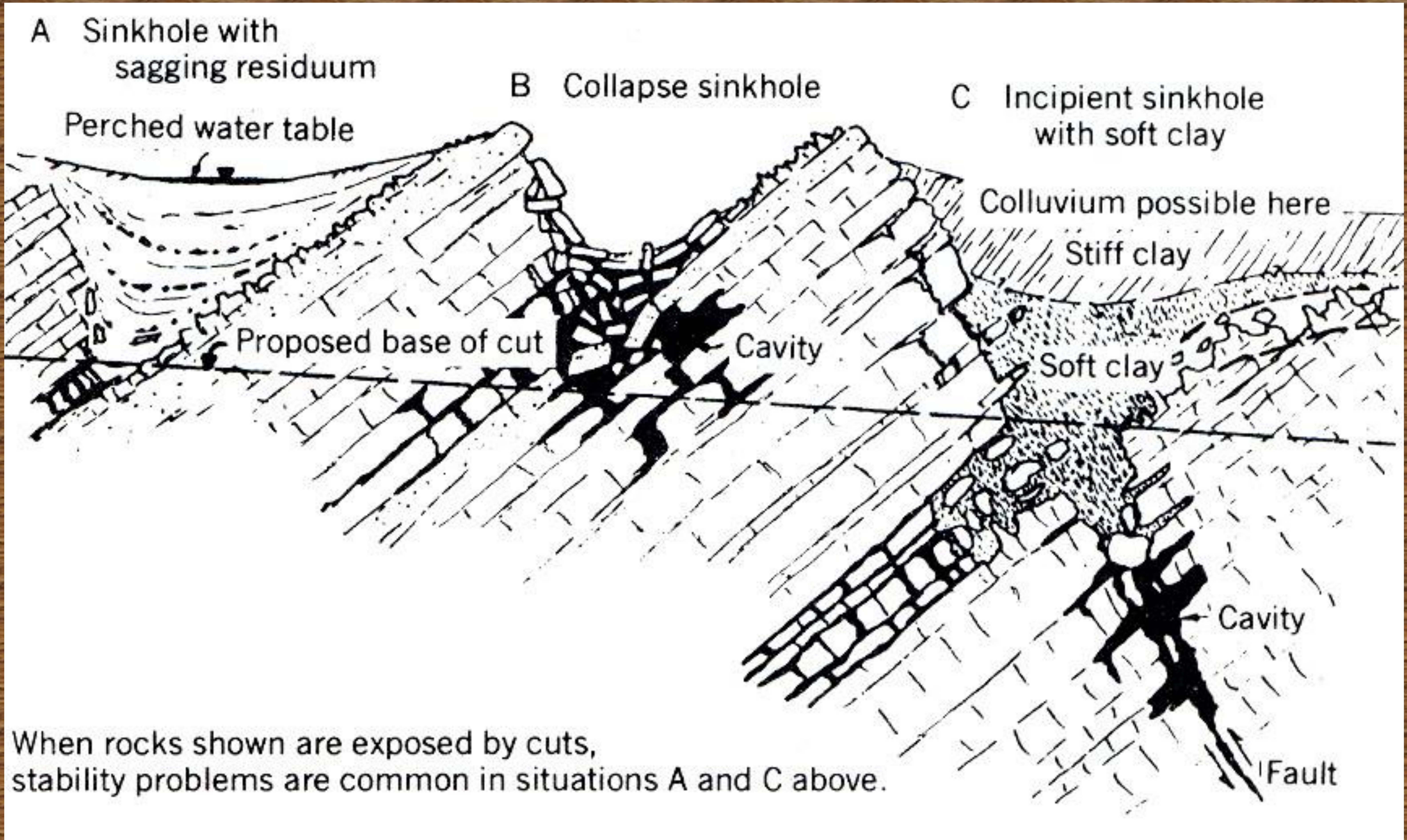
## *Weathering of Rockmass:*

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

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

## Summary.....*(2)*

- ✓ **Chemical weathering** alters engg props of all rocks, thereby weakening them.
- ✓ **Strength & deformability** of rock masses and susceptibility to chemical weathering are controlled by **presence of discontinuities**.
- ✓ Presence of intersecting discontinuity-sets greatly reduces rock mass strength compared to that of intact rock.

## **Summary***.....(3)*

- ✓ Characteristics of discontinuities → *orientation, frequency of occurrence, continuity, surface characteristics nature of host rock and presence or absence of filling* – have an important role in way rockmass deform.

END OF LECTURE