Geological Masses

ROCK DISCONTINUTIES

- Discontinuity is a general term that denotes any separation in a rock mass having zero or low tensile strength
- It is a collective term for most types of joints, weak bedding planes, weak schistocity planes, weakness zones, and faults

"The engineering properties of a rock mass often depend far more on the system of *geological defects* within the rock mass than on the strength of the rock itself. Thus, from an engineering point of view, a knowledge of the type and frequency of the joints and fissures are often more important than the types of rock involved. The observations and characterization of the joints should therefore be done carefully."

It affects

- Shear strength,
- stiffness,
- Influencing the deformation
- permeability of the ground

Types of Discontinuities

(1) *Integral discontinuities* – yet to be opened by movement or weathering

- they have tensile strength and, a true cohesion.
- Intact bedding planes, foliation planes, and strongly cemented joints

(2) *Mechanical discontinuities* – which have been opened as a response to stress or weathering

- they have little or no tensile strength
- generate shear strength.

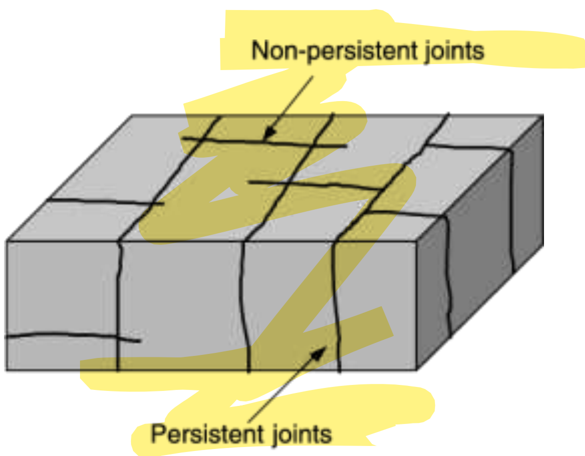
- Faults
- Bedding planes
- Joints
- Foliation
- Fracture

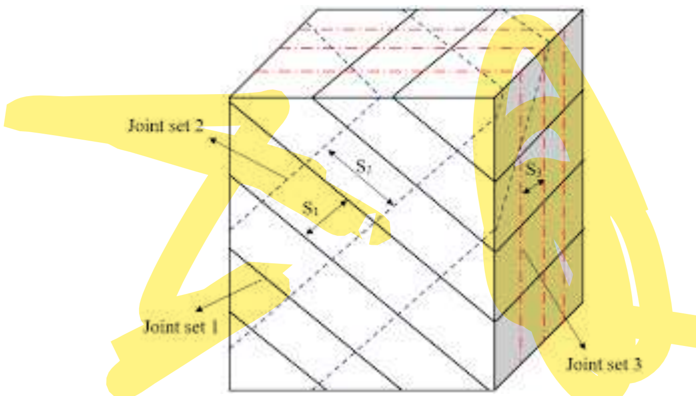
Description of Discontinuities

- Orientation

- Spacing: the perpendicular distance between adjacent discontinuities. It normally refers to the mean or modal spacing of a set of discontinuities

- Persistence: Discontinuity trace length as observed in an exposure.





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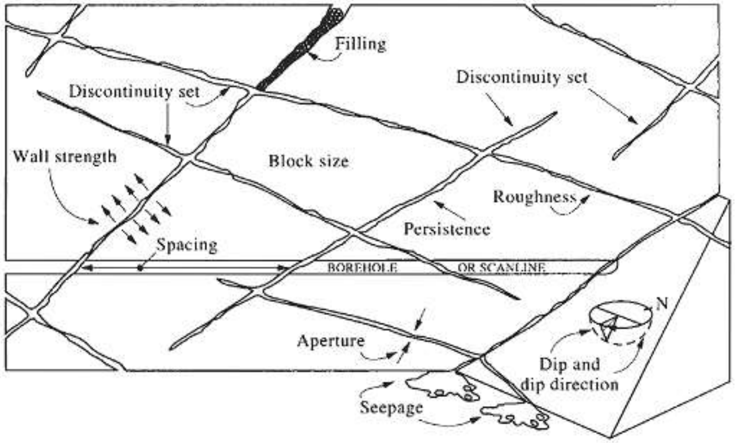
- Roughness: the inherent surface roughness and waviness relative to the mean plane of a discontinuity. Both roughness and waviness contribute to the shear strength.
- Aperture: the perpendicular distance between adjacent rock walls of a discontinuity, in which the intervening space is air or water filled.
- Filling: the material that separates the adjacent rock walls of a discontinuity and that is usually weaker than the parent rock. Filling materials are sand, silt, clay, breccia, gouge, and mylonite. Healed discontinuities such as quartz and calcite veins



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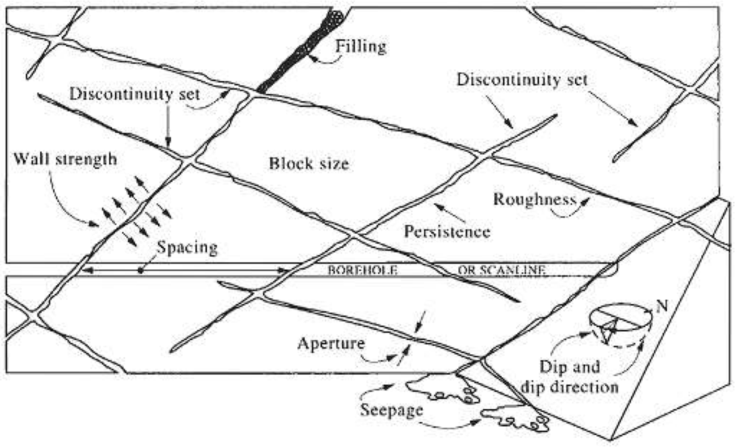
- Seepage: the water flow and free moisture visible in individual discontinuities or in the rock mass as a whole

- Number of Sets: the number of discontinuity sets comprising the intersecting discontinuity system

- Block Size: the rock block dimensions resulting from the mutual orientation of intersecting discontinuity sets, and resulting from the spacing of the individual sets



Shear Strength

- Main concern regarding discontinuities in engineering geology is their resistance to shear stress

$$\tau = c + \sigma\ \mu\tan\phi$$

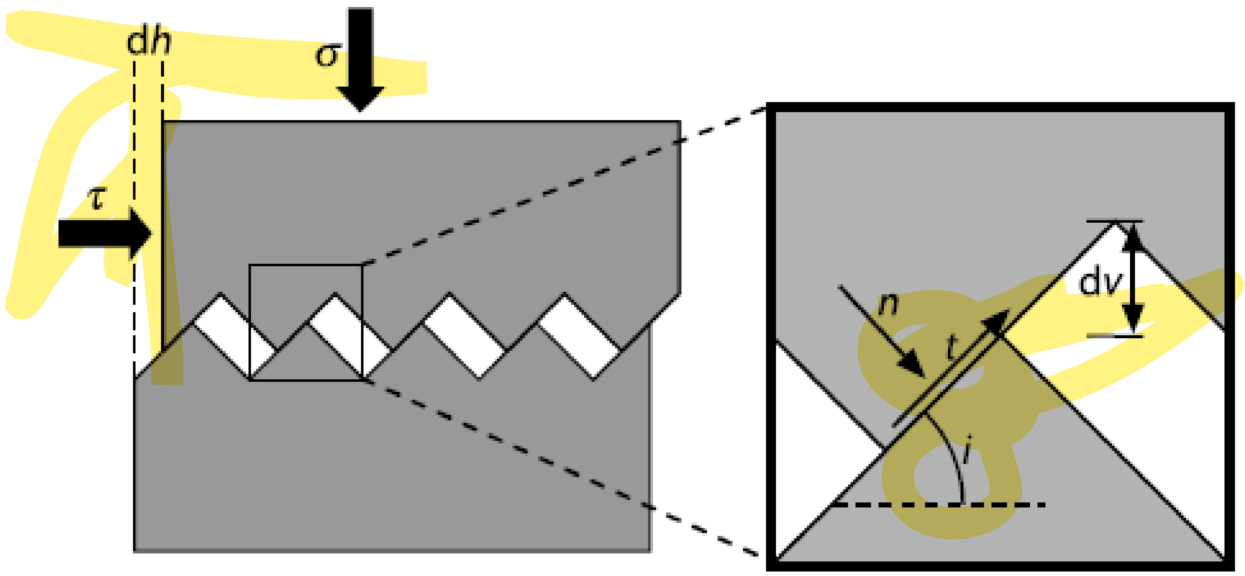
where τ = shear strength, c = cohesion, σn= normal stress on the sliding plane, and ϕ = angle of sliding resistance

True cohesion', e.g. there is tensile strength between the two discontinuity surfaces,

or

'Apparent cohesion' caused by irregularities

- The surfaces of mechanical discontinuities may be
  - smooth and planar or
  - exhibit varying degrees of roughness.
- Greater the roughness of the surface the greater the resistance of the discontinuity to shearing

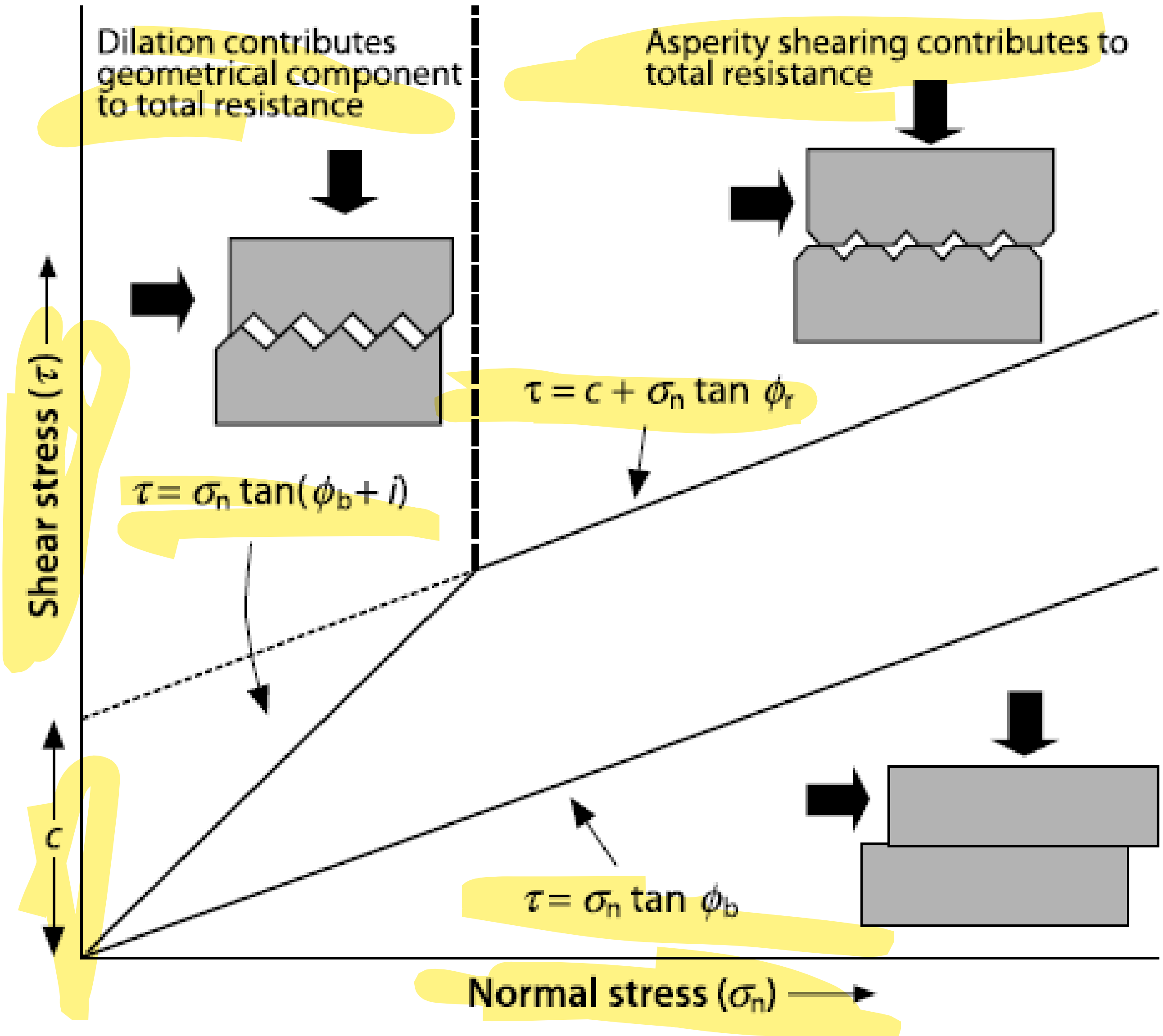


n is the normal and *t* the shear stress on the contact plane, resulting from the applied stresses *σ* and *τ*

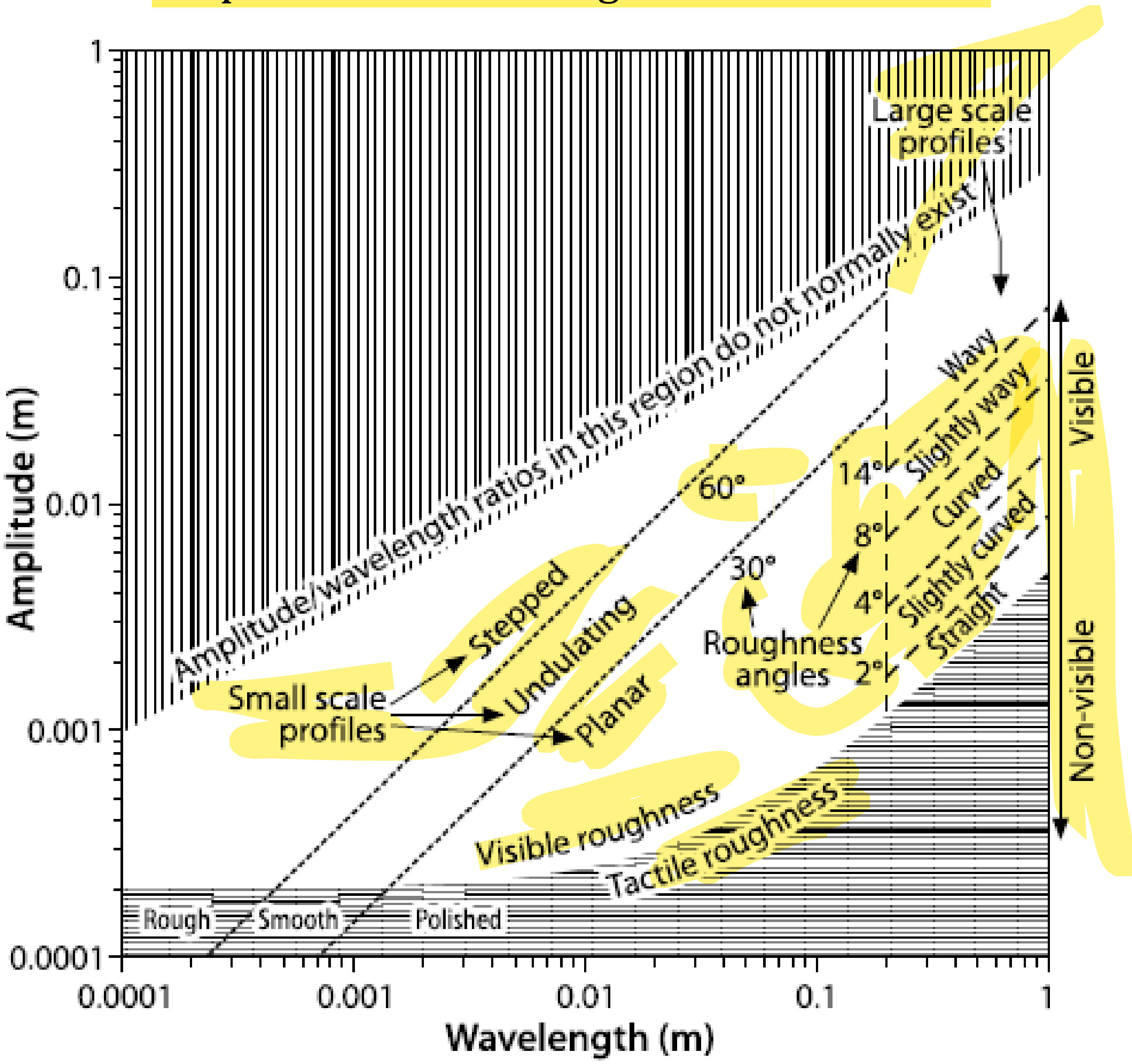
$$\tau = \sigma_n \tan(\varphi_b + i)$$

φ_b, the basic friction angle, plus *i*,

Asperity failure of a discontinuity will give an '*apparent cohesion*'



Amplitude Vs Wavelength for discontinuities



Hack, 1998

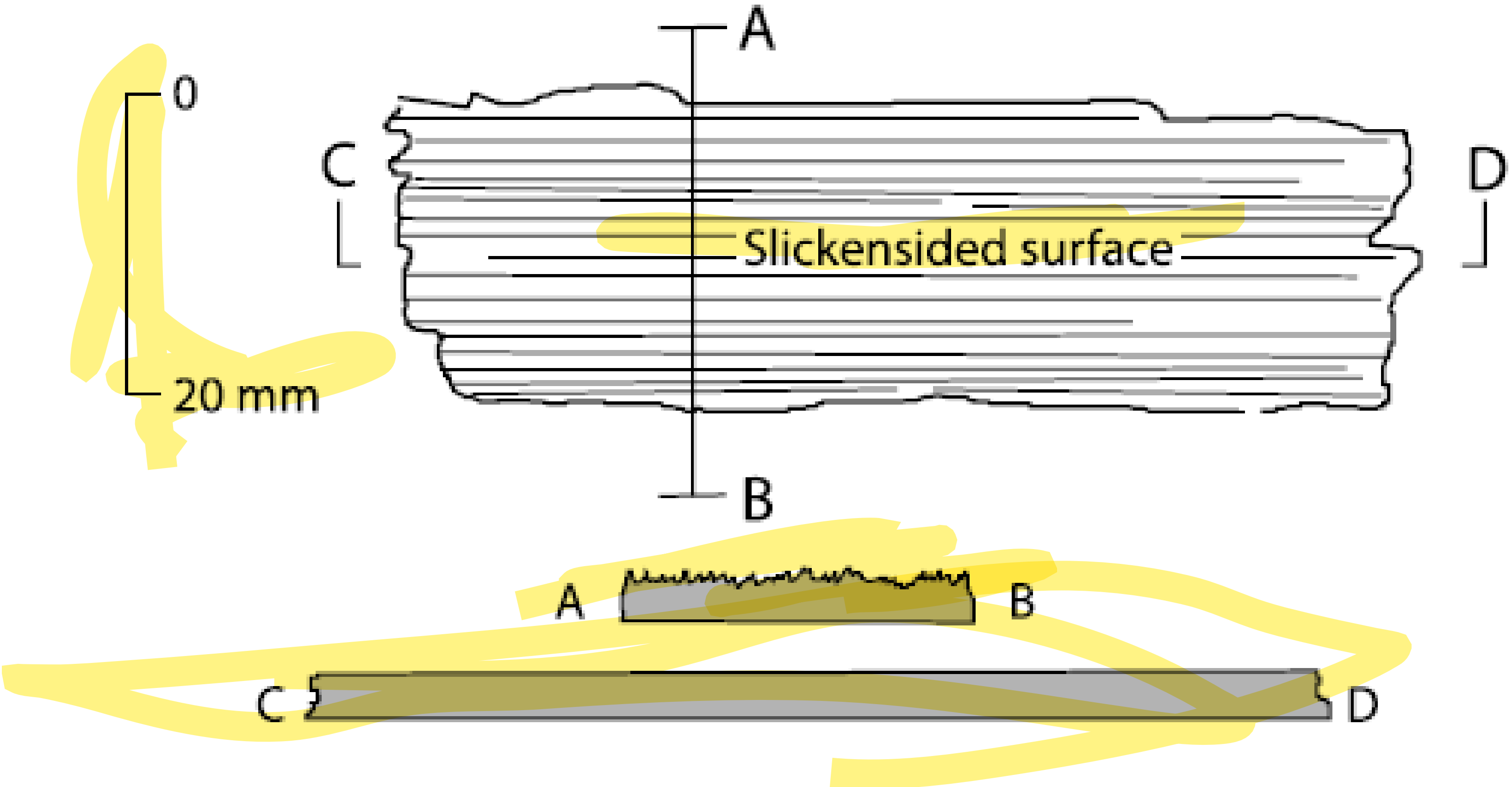
Scale of Roughness and Anisotropy

- Roughness may be seen on different scales.

- Up to mm scale the roughness is normally formed by grains or crystals in the rock, as, say, might be found in shrinkage joints in granite.

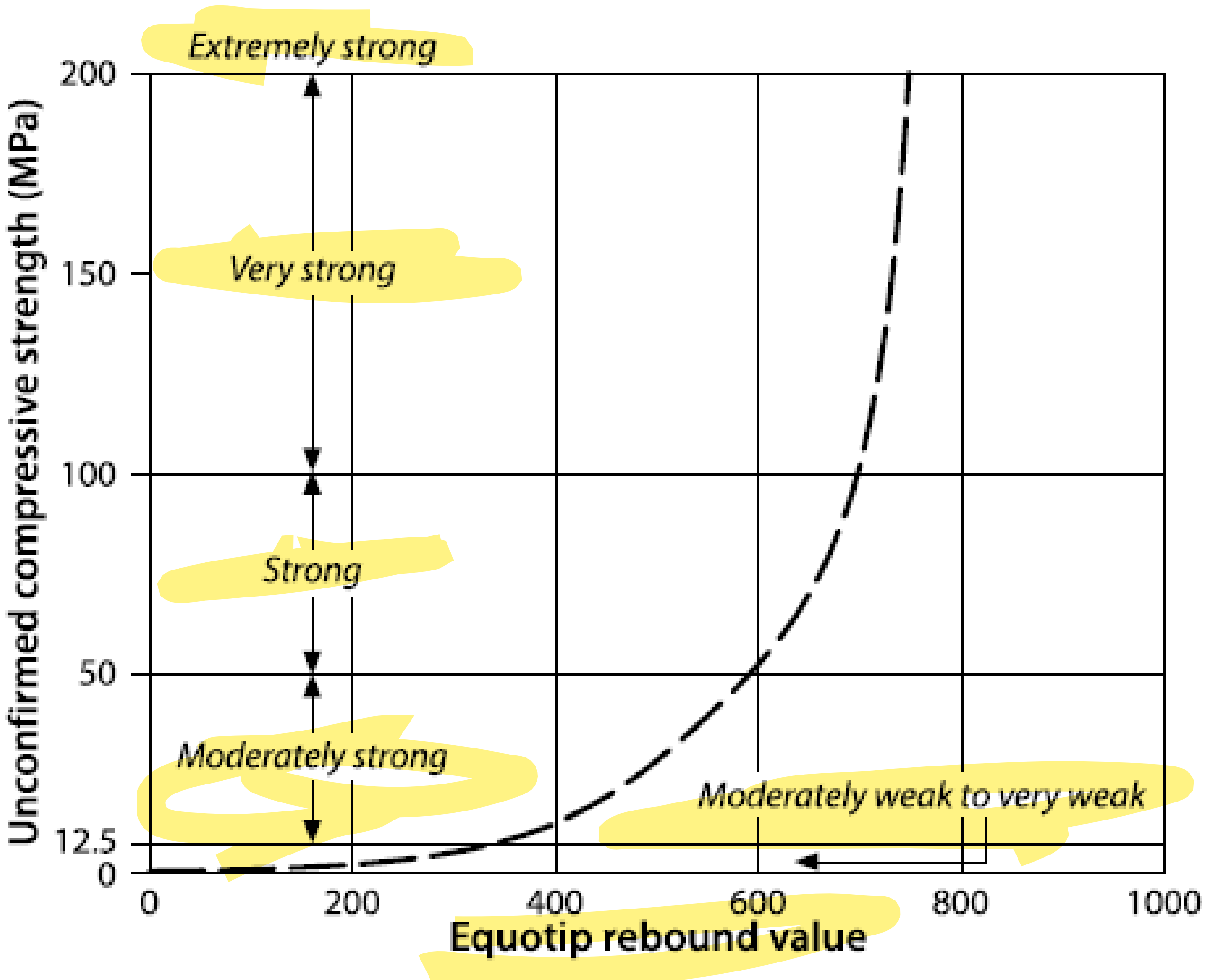
- On the 0.01 to 1 m scale, roughness is normally due to depositional features in sedimentary rock or foliation undulations in metamorphic rock.

Roughness dependent on direction for slickenside surfaces



Discontinuity Wall Strength

- Full evaluation of discontinuity shear strength requires not only assessment of roughness but also of wall strength
- Impossible by conventional laboratory testing
- The Schmidt hammer gives too strong a blow to be of use (for the *N*-value reflects both near surface and deeper rock properties)
- Equotip tester (Verwaal and Mulder 1993) gives a much lighter blow which rebound reflects rock properties at shallow depth



Equotip rebound values vs. unconfined compressive strength
(after Verwaal and Mulder 1993)

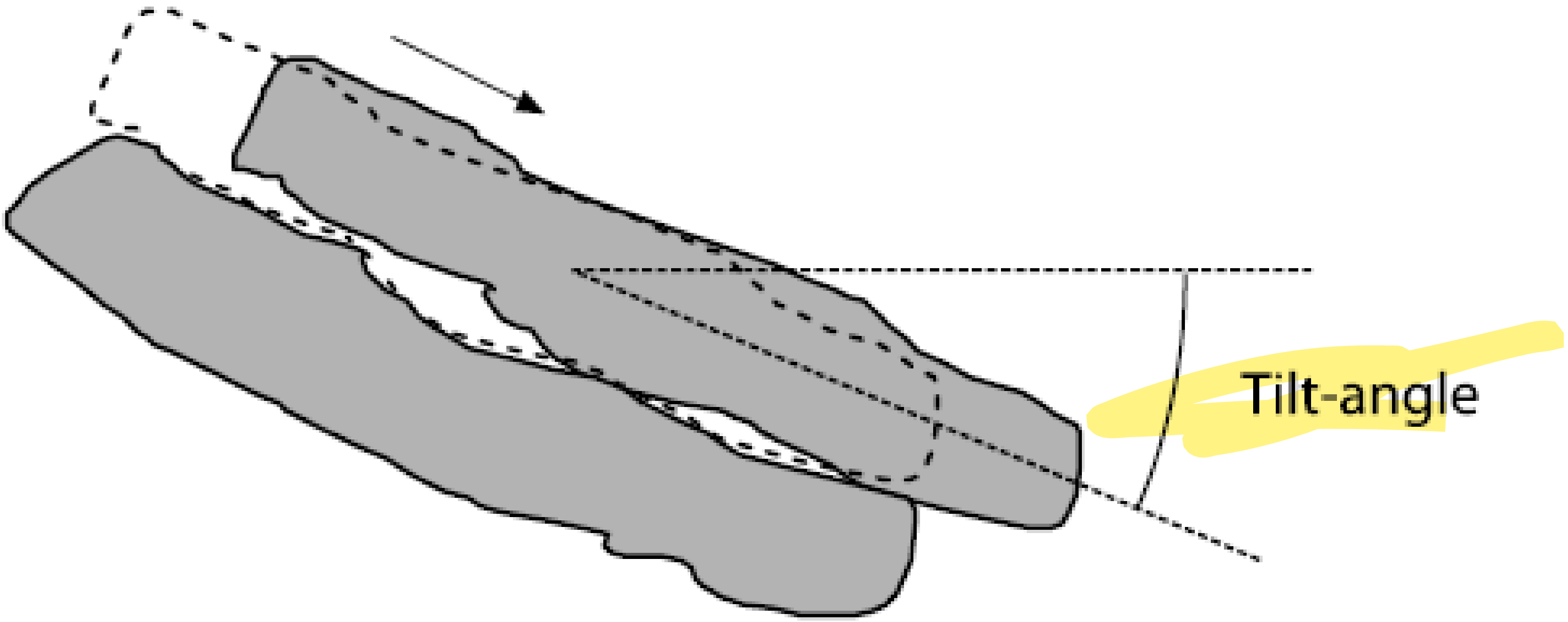
Aperture and Discontinuity Infill

- Openness of discontinuities in outcrops may have arisen from slope relaxation, near surface movement or plant root wedging
- If discontinuities are open, they may be either wholly or partially filled by material
- Bedding planes opened by weathering may be filled with clay or limestone solution cavities filled by washed in debris
- Infill results from mineralisation as, for example, quartz or calcite, the infill may be stronger than, and closely bonded to, the rock; the discontinuity may then be described as ‘healed

Descriptive terminology for aperture

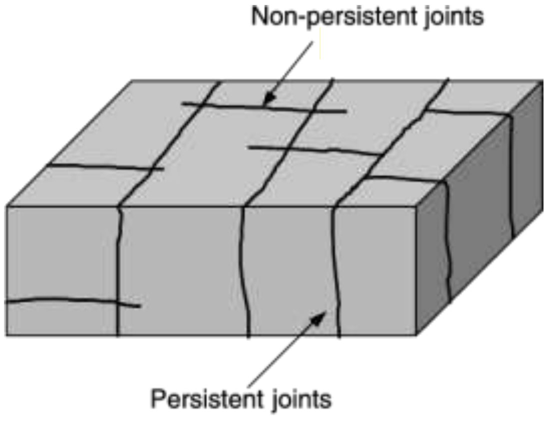
Class	Descriptor	Numeric value (mm)
Closed	Very tight	< 0.1
	Tight	0.1 – 0.25
	Partly open	0.25 – 0.5
Gapped	Open	0.5 – 2.5
	Moderately wide	2.5 – 10
	Wide	10 – 100
Open	Very wide	100 – 1000
	Extremely wide	> 1000

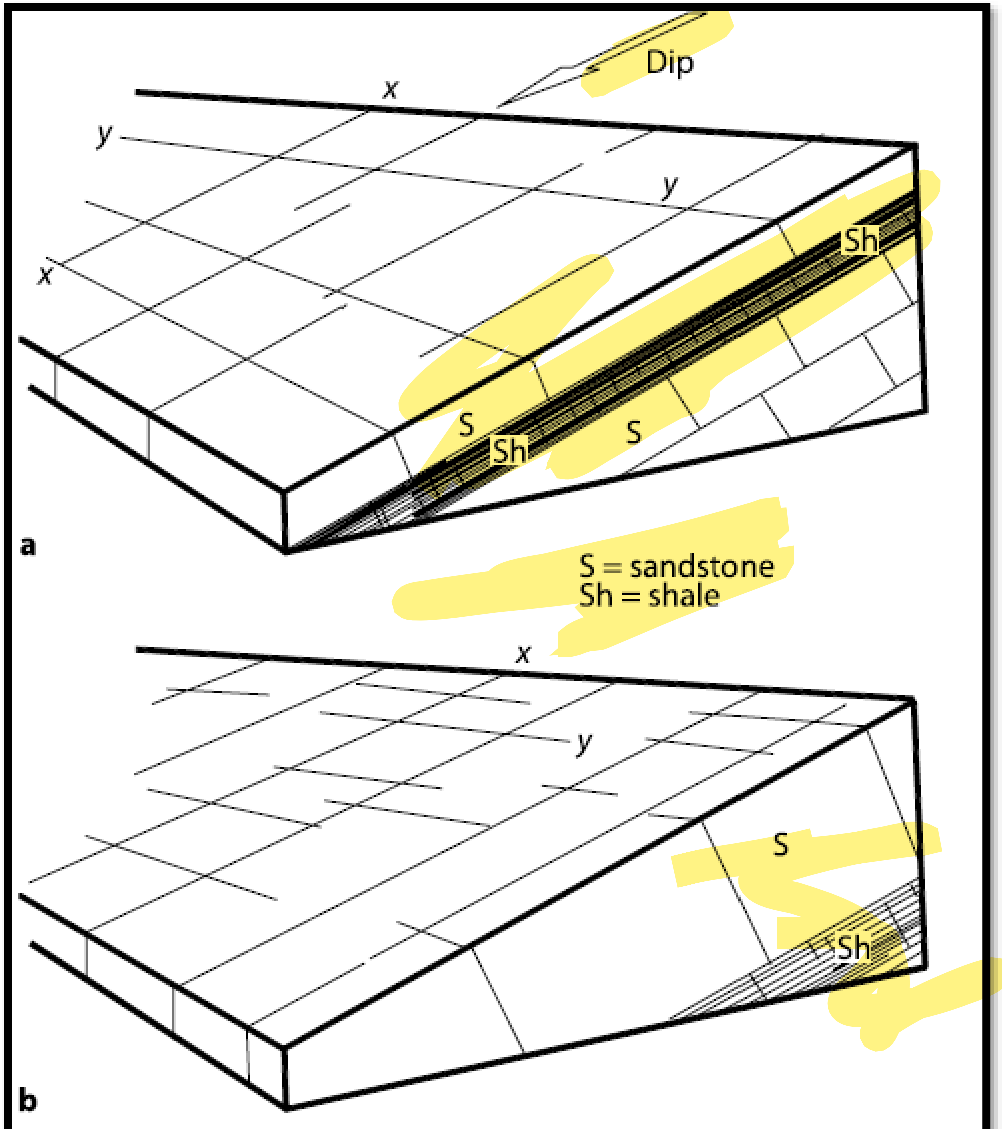
Tilt Test



Persistence (Continuity)

- The shear strength along the discontinuity is dependent on the persistence
- Intact rock has to be broken before displacement can take place if the discontinuity ends in intact rock
- Persistence cannot be measured from cores




Dip
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y
y
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S
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a
S = sandstone
Sh = shale
x
y
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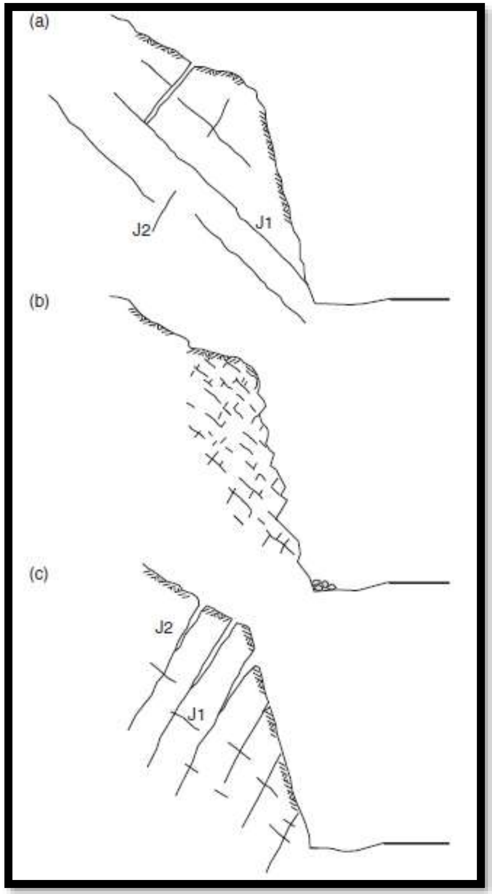
Effects of joint properties on slope stability:



(a) persistent J1 joints dipping out of face forms potentially unstable sliding blocks; (b) closely spaced, low persistence joints cause raveling of small blocks; (c) persistent J2 joints dipping into face form
potential toppling slabs

Persistence

Term	Numerical value (m)
Very low	< 1
Low	1 – 3
Medium	3 – 10
High	10 – 20
Very high	> 20

Spacing

Integral discontinuities	Spacing	Mechanical discontinuities
Very thickly bedded	> 6 m	Extremely widely spaced
Very thickly bedded	2 – 6 m	Very widely spaced
Thickly bedded	0.6 – 2 m	Widely spaced
Medium bedded	0.2 – 0.6 m	Medium spaced
Thinly bedded	60 mm – 0.2 m	Close spaced
Very thinly bedded	20 –60 mm	Very close spaced
Thickly laminated	6 –20 mm	Extremely close spaced
Thinly laminated	< 6 mm	Extremely close spaced

Block size

First term	Maximum dimension
Very large	> 2 m
Large	0.6 – 2 m
Medium	0.2 – 0.6 m
Small	60 – 200 mm
Very small	< 60 mm
Second term	**Shape of block**
Blocky or cubic	Equi-dimensional
Tabular	Thickness much less than length or width
Columnar	Height much greater than cross section

The shape and size of rock blocks depends upon the spacing of the discontinuities

Shear Strength along discontinuities

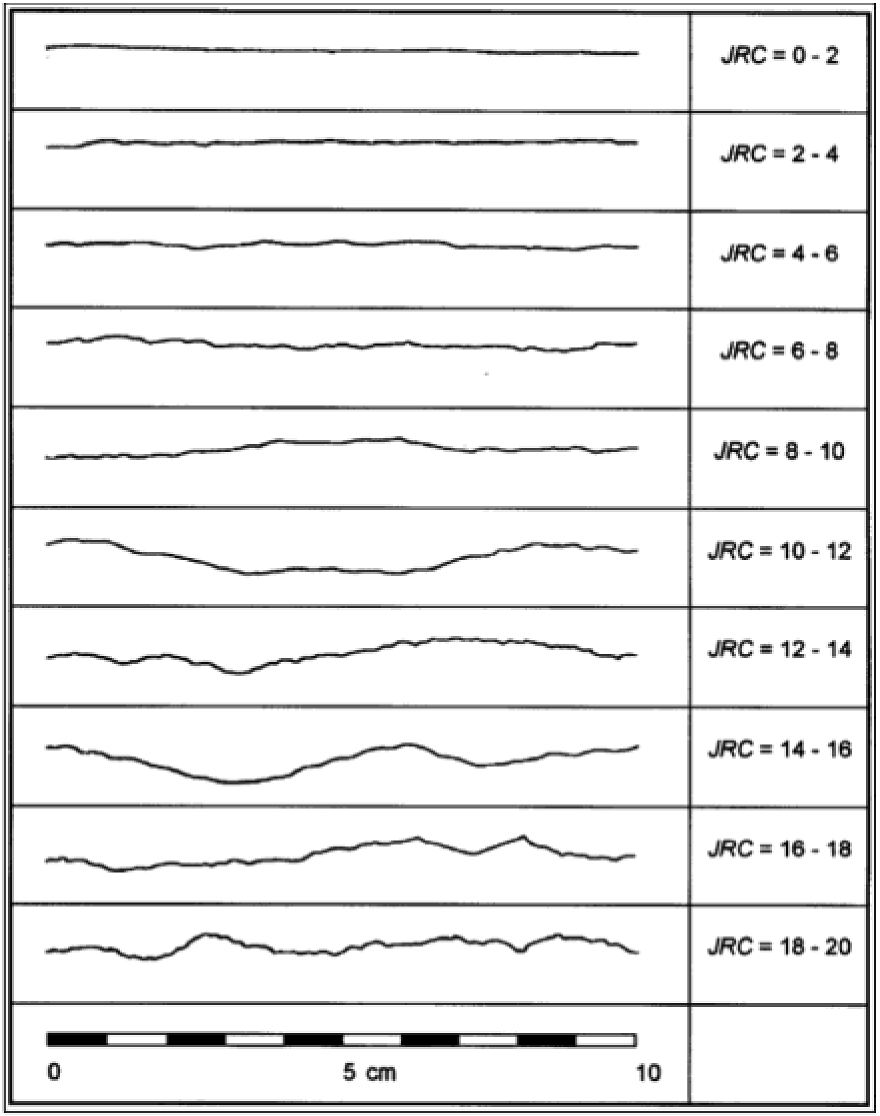
$$\tau = \sigma_n \tan\left[JRC \log_{10}\left(\frac{JCS}{\sigma_n}\right) + \varphi_r\right]$$

Barton, 1971

Where *JRC* - joint roughness coefficient
JCS - joint wall condition strength
σ*n* - normal stress on the discontinuity
φr - residual friction angle

JRC

JRC is the joint roughness coefficient : a number, low for smooth planar surfaces rising with increasing roughness, estimated by visual comparison of the discontinuity surface to standard roughness graphs



JCS: Joint wall compressive strength