ROCK MASS CHARACTERISATION

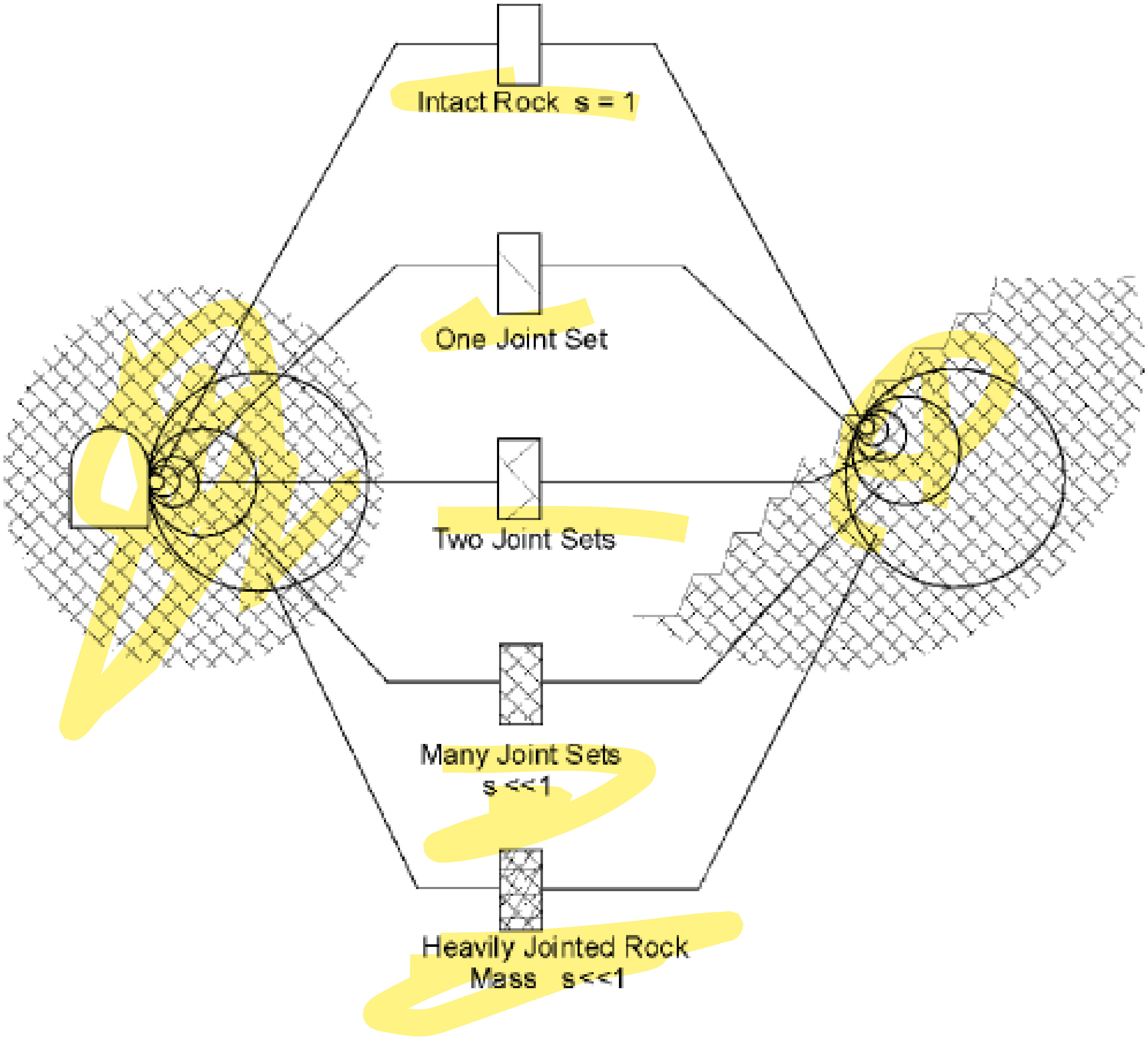
ROCK MATERIAL Vs ROCK MASS

- The term "rock material" refers to the intact rock within the framework of discontinuities.

- In other words, this is the smallest element of rock block not cut by any fracture.

- There are always some micro-fractures in the rock material, but these should not be treated as fractures.

- Rock material differs from "rock mass," which refers to in situ rock together with its discontinuities and weathering profile. Rock material has the characteristics


Intact Rock s = 1
One Joint Set
Two Joint Sets
Many Joint Sets
s <<1
Heavily Jointed Rock
Mass s<<1

HOMOGENEITY AND INHOMOGENEITY

- Bray (1967) demonstrated that if a rock contains ten or more sets of discontinuities (joints), then its behaviour can be approximated to the behaviour of a homogeneous and isotropic mass with only 5% error due to assumed homogeneity and isotropic condition.
- Also, if a rock is massive and contains very little discontinuity, it could ideally behave as a homogeneous medium.
- If the sample size is considerably reduced, the most heterogeneous rock will become a homogeneous rock.
- An inhomogeneous rock is more predictable than a homogeneous rock because the weakest rock gives distress signals before final collapse of the rock structure

CLASSIFICATION OF ROCK MATERIAL

- Ancient Shilpshastra in India classified rocks on the basis of color, sound, and heaviness.
- ISO14689-1 (2003) proposed classification of rock material based on uniaxial compressive strength (UCS).
- Rock material may show a large scatter in strength, say of the order of 10 times; hence, the need for a classification system based on strength and not mineral content.

TABLE 3.1 Classification of Rock Material Based on Unconfined Compressive Strength

Term for uniaxial compressive strength	Symbol	Strength (MPa)	Ranges for common rock materials: *Granite, basalt, gneiss, quartzite, marble*	*Schist, sandstone*	*Limestone, siltstone*	*Slate*	*Concrete*
Extremely weak*	EW	<1		**	**		
Very weak	VW	1–5		**	**	**	**
Weak	W	5–25		**	**	**	**
Medium strong	MS	25–50	**		**	**	
Strong	S	50–100	**				
Very strong	VS	100–250	**				
Extremely Strong	ES	>250	**				

*Some extremely weak rocks behave as soils and should be described as soils.
**Indicates the range of strength of rock material.

Source: ISO 14689-1, 2003.

- The UCS can be easily predicted from point load strength index tests on rock cores and rock lumps right at the drilling site because ends of rock specimens do not need to be cut and lapped
- UCS is also found from Schmidt's rebound hammer
- There are frequent legal disputes on soil-rock classification.
- The International Standard Organization (ISO) classifies geological material having a UCS less than 1.0 Mpa as soil.

STABILITY IN WATER

- In hydroelectric projects, rocks are charged with water. The potential for disintegration of rock material in water can be determined by immersing rock pieces in water.
- Ultrasonic pulse velocity in a saturated rock is higher than in a dry rock because it is easier for pulse to travel through water than in air voids.

TABLE 3.2 Rock Material Stability in Water

Term	Description (after 24 h in water)	Grade
Stable	No changes	1
Fairly stable	A few fissures are formed or specimen surface crumbles slightly	2
	Many fissures are formed and broken into small lumps or specimen surface crumbles	3
Unstable	Specimen disintegrates or nearly the whole specimen surface crumbles	4
	The whole specimen becomes muddy or disintegrates into sand	5

Source: ISO 14689-1, 2003.

SLAKE DURABILITY INDEX

- To assess wheatherability or inverse of durability
- Slake durability is defined as the resistance of a rock to wetting and drying cycles
- Based upon tests on representative shales and clay stones for two 10-minute cycles after drying, Gamble (1971) found the slake durability index varied from 0 to 100%.
- There are no visible connections between durability and geological age, but durability increased linearly with density and inversely with natural water content. Based on his results, Gamble proposed a classification of slake durability.
- The slake durability classification is useful when selecting rock aggregates for road, rail line, concrete, and shotcrete.

It consists of two drums 100 mm long and 140 mm in diameter, containing about 500g of rocks (10 lumps) in each drum.

Sieve mesh forms the walls of the drums with openings of 2 mm. The drums rotate at a speed of 20 rpm for a period of 10 minutes in a water bath.

The rock in the drums are subject to different cycles of wetting in the bath and drying in the oven.

- $I_d = ((C - D)/ (A - D)) * 100$

where I_d = Slake Durability Index in %

$A =$ Weight of sample plus drum

$C =$ Weight of drum plus retained portion of sample (2nd water cycle)

$D =$ Weight of only drum

TABLE 3.3 Slake Durability Classification

Group name	% retained after one 10-minute cycle (dry weight basis)	% retained after two 10-minute cycles (dry weight basis)
Very high durability	>99	>98
High durability	98–99	95–98
Medium high durability	95–98	85–95
Medium durability	85–95	60–85
Low durability	60–85	30–60
Very low durability	<60	<30

Source: Gamble, 1971, 2003.

Rock Quality Designation

- Rock quality designation (RQD) was introduced by Deere in 1964 as an index of assessing rock quality quantitatively.
- The RQD is a modified percent core recovery that incorporates only sound pieces of core that are 10 cm (4 in.) or greater in length along the core axis

$$RQD = \frac{\text{sum of core pieces} \geq 10\text{ cm}}{\text{total drill run}} \cdot 100,\ \%$$

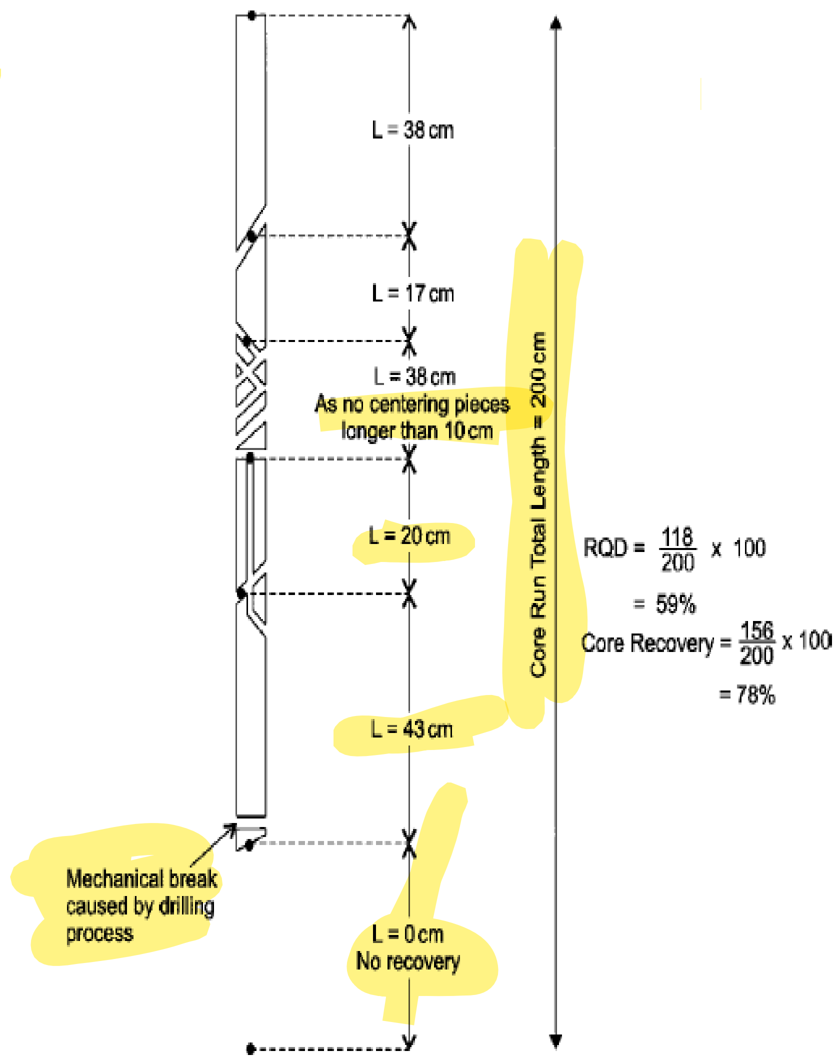
- RQD is found to be a practical parameter for core logging, but it is not sufficient on its own to provide an adequate description of rock mass (Bieniawski, 1984).

DIRECT METHOD

- For RQD determination, the International Society for Rock Mechanics (ISRM) recommends a core size of at least NX (54.7 mm)
- Artificial fractures can be identified by close fitting cores and unstained surfaces.
- All of the artificial fractures should be ignored while counting the core length for RQD.
- A slow rate of drilling will also give better RQD.
- The relationship between RQD and the engineering quality of the rock mass as proposed by Deere (1968)

TABLE 4.1 Correlation between RQD and Rock Quality

S. No.	RQD (%)	Rock quality
1	<25	Very poor
2	25–50	Poor
3	50–75	Fair
4	75–90	Good
5	90–100	Excellent



INDIRECT METHODS

- Seismic Method

$$RQD = (V_F/V_L)^2 * 100$$

V_F - in situ compressional wave velocity

V_L - compressional wave velocity in intact rock core

- Volumetric Joint Count
  - $RQD = 115 – 3.3\ J_v$ (Palmstrom, 1982)
  - $RQD = 110 – 2.5\ J_v$ (Palmstrom, 2005)
    - J_v represents the total number of joints per cubic meter or the volumetric joint count
  - It is a measure for the number of joints within a unit volume of rock mass defined by

- $Jv = \sum_{i=1}^{j}(\frac{1}{Si})$

S_i is the average joint spacing in meters for the i_{th} joint set and J is the total number of joint sets except the random joint set

- Random joints may also be considered by assuming a "random spacing." Palmstrom (1982) presented an approximate rule of thumb correction for this with a spacing of 5 m for each random joint (Palmstrom, 2005)

- $Jv = \sum_{i=1}^{j}(\frac{1}{Si})+ \mathrm{Nr}/5\sqrt{A}$

Nr is the number of random joints in the actual location and A is the area in m2.

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- RQD is a directionally dependent parameter and its value may change significantly, depending upon the borehole orientation. The use of the volumetric joint count can be useful in reducing this directional dependence

- The limiting length of 10 cm is arbitrary
- The limiting length of 10 cm is an "abrupt boundary." A simple yet insightful example: A core in a rock mass that includes an ideally uniformly distributed joint spacing of 9 cm shows an RQD of 0% (drilled perpendicular to the joints); if the spacing is just above 10 cm RQD is 100%. The limit of 10 cm is based on extensive experience.
- RQD is biased by orientation of measurement. Some approximate corrections are available to remove these effects.
- RQD is influenced by drilling equipment, size of equipment, handling of core, experience of the personnel, and so forth.