ENGINEERING GEOLOGY AND ROCK MECHANICS

SKAA 2712
ENGINEERING PROPERTIES OF ROCK MASSES

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ENGINEERING PROPERTIES OF ROCK MASSES

- Rock masses can be considered to be a function of a number of measurable parameters, with respect to their geomechanical properties display in massive and actual form.
- The properties are determined based on weathering, material strength, stratification of lithologies, frequency of jointing, discontinuities, bedding, orientation of joints, infill material and faults.
- Whereas material properties refer to the nature of rock in a relatively smaller scale such as mineral composition, grain size, strength and hardness

Masai, Johor

Batu Pahat, Johor

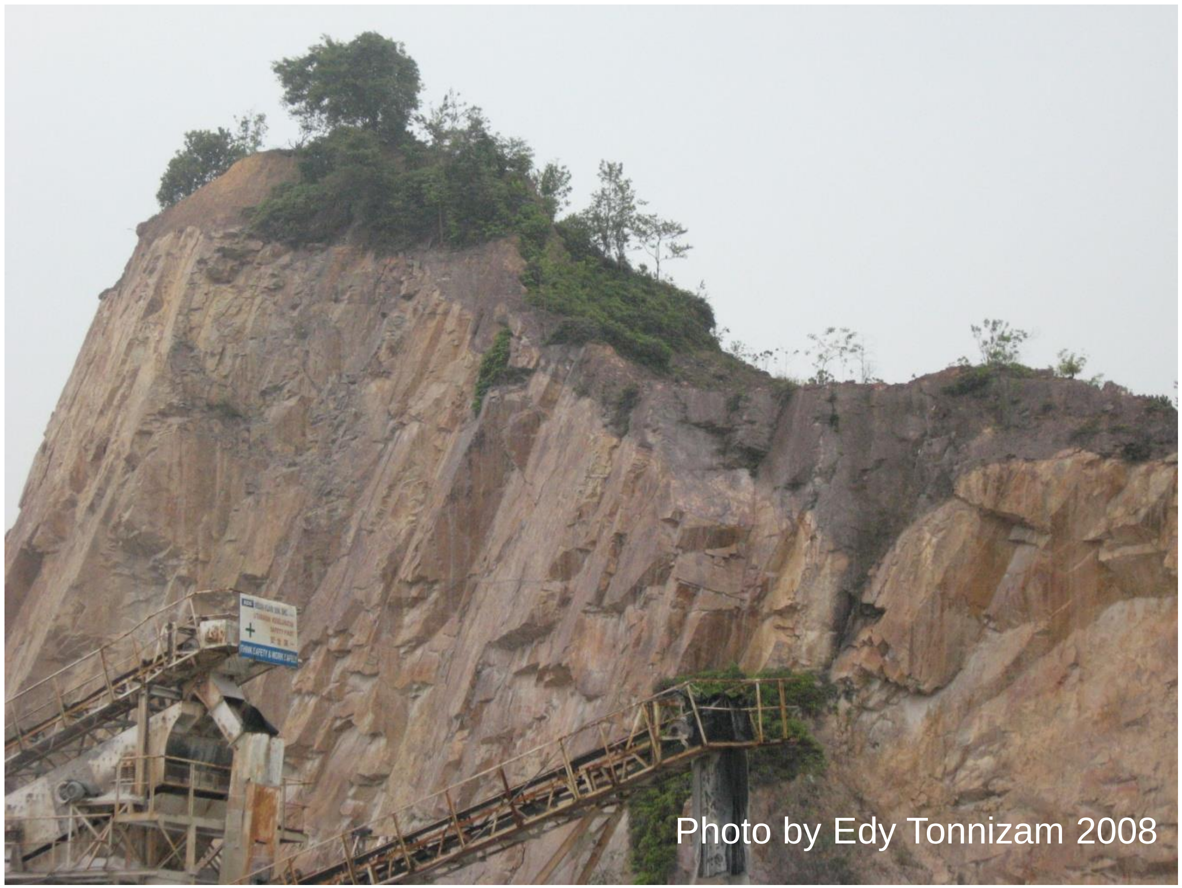

Photo by Edy Tonnizam 2008

Q-system (Barton et al., 1974)

Parameter	**Description**
Rock Quality Designation (RQD)	RQD is based on the percentage of core pieces that are 100mm long or more divided with the total length of the core. A higher RQD value indicates the rock is better quality.
Joint Set Number	This is a measure of the number joint sets within the rock mass. It has a range between 1 (massive) and 20 (crushed).
Joint Roughness Number	This describes the roughness of the joint surface. It ranges from 0.5 for a planar slickensided joint to 4 for a rough and undulating joint.
Joint Alteration Number	This is indicative of the nature of any joint infill. The extremes are 0.75 for a tight joint with no infill, to 15 for a wide joint with substantial clay infill.
Joint Water Reduction Number	This factor account for the strength reducing the nature of water.
Stress Reduction Factor	Stress reduction Factor: This accounts for the stress conditions found in the rock surrounding the excavation.

RMR (Bieniawski, 1989)

Parameter			Ranges of values						
1	Strength of intact rock	PLI (MPa)	> 10	4 -10	2 - 4	1 -2	For this low range UCS Test is preferred		
		UCS (MPa)	> 250	100 -250	50-100	25 - 50	5 - 25	1 - 5	< 1
	Rating		15	12	7	4	2	1	0
2	RQD (%)		90 -100	75 - 90	50 -75	25 - 50	< 25		
	Rating		20	17	13	8	3		
	Spacing of discontinuities		> 2m	0.6 - 2m	0.2 - 0.6m	0.06 - 0.2m	< 0.06m		
	Rating		20	15	10	8	5		
4	Condition of discontinuities		Very rough surfaces, not continuous, no separation, unweathered wall rock	Slightly rough surface, separation <1 mm, slightly weathered wall	Slightly rough surface, separation <1 mm, highly weathered wall	Slickensided surface or, gouge < 5mm thick or, separation 1 -5 mm, continuous	Soft gouge > 5mm thick or separation > 5mm, continuous		
	Rating		30	25	20	10	0		
5	Ground water	Inflow per 10m tunnel length (Lt/min)	None	< 10	10 - 25	25 -125	> 125		
		Joint water pressure/Major principal stress	0	< 0.1	0.1- 0.2	0.2 - 0.5	> 0.5		
		General conditions	Completely dry	Damp	Wet	Dripping	Flowing		
	Rating		15	10	7	4	0		

- Rock slopes form part of the components in many highway
- or roadway constructions in hilly terrain.

- The key question with regard to rock slopes along highways is their long-term stability since failure of a rock slope can have serious consequences.

- The stability of a particular rock slope is
- governed by three main engineering geologic factors,
- namely: lithology, structure and weathering grade.

- **Different lithologies, such as granite versus shale, can have**
- **very different instability problems not only due to their**
- **different material strengths, but also because of the**
- **different geologic structures associated with the different**
- **rock types. Hence, for example, the stability of granitic rock**
- **slopes is controlled by-and-large by the major sets of joints**
- **in the rock mass, while bedding planes control the stability**
- **of shale slopes.**

Rock Type

- There are three rock types by origin, which are igneous, sedimentary and metamorphic rock.
- Igneous rock are formed by cooling of molten magma or lava originated within the earth such as granite and basalt. This type of rock is known to be very hard due to the lack of stratification and weakness planes.
- Sedimentary rock consists of material derived from destruction of previously existing rocks. Their most prominent characteristic is bedding or stratification. Once deposited, the sediments are then lithified or turned into rock mass through processes such as compaction and cementation. Compaction is a process where the overlaying of sediment causes decreases in rock volume and compaction is a chemical precipitation process in pores spaces between grains and gluing the rock particles together.

Rock Type

- On the other hand, metamorphic rock can be of either igneous or sedimentary origin, which has undergone severe changes in pressure, stresses or temperature. The changes of this

  extreme condition may change the original minerals, texture or both, producing different types of rock, namely gneiss (originated from granite), shale, slate and quartzite (from sedimentary origins).

LITHOLOGY

- Lithology refers to rock type. Lithology is the basic consideration since different rock types would have different material properties and behaviour. (Edy Tonnizam et al., 2005) For example, granitic rocks differ from shales or schists.

- Limestone is yet another type of rock with its unique solution properties. Owing to the different nature and origin of the rock types mentioned above, the inherent geological structures associated with each rock type are also different.

- Thus, granitic rocks are often intersected by three or more sets of major joints that would control the stability of the rock slope at a particular location (Edy Tonnizam et al., 2013).

- On the other hand, shales and sandstones are dominated by bedding planes, and it is the bedding planes that would control the stability of the cut-slopes.
- Similarly in phyllites and schists which are foliated, the foliations would be the controlling features.
- In the case of limestone cliffs which are characterised by their unique solution or karstic features, in particular sub-vertical or overhanging cliffs, the stability of the cliffs is controlled by major joints or faults and solutioning of the limestone.

Weathering

Strength

- Compressive and tensile failures of rock are both involved in the fracture mechanism
- Smart et al. (1982) have found a close correlation between the uniaxial strength and quartz content. They found that the increase of quartz in rock material would increase the strength.

Strength

- In addition to the mineral composition of the rock material, the strength is also considerably influenced by water content. This factor can be a great challenge in weak rocks in tropical area where some of the original minerals and fabric have undergone alteration.
- Most of the secondary minerals will absorb water easily and will reduce the original rock strength. Heavy rainfall will increase the moisture content of the rock material especially for those in highly weathered (Grade IV) and completely weathered (Grade V) materials. This is due to loose interaction between grains as weathering has taken place (Edy Tonnizam, 2005a).

Point load tester

Photo by Edy Tonnizam 2010

Decreasing in strength due to moisture content

Old Alluvium

Abrasiveness

- Abrasiveness of rock is a complex function of various properties including rock competency, hardness, mineralogical composition and proportions. The grain binding for quartz is an important factor that effects the abrasion of rock material.

- The parameters affecting abrasiveness are as follows (Singh et al., 1986): -

1. Mineral composition and proportions including hardness of constituent minerals, grain shape and size, harness and strength of matrix material. This is determined by petrographic examinations.
2. Physical properties of rocks including strength and hardness.

- Several studies were carried out to understand the geotechnical properties of weathered sedimentary rock in Peninsular Malaysia.
- The results showed that material properties deteriorate from the fresher material as more intense weathering takes place.
- The weathering effect can take place up to 100m down from the earth's surface in tropical areas (Ibrahim Komoo, 1995).

Rock Structure

- One of the main factors that affect the behaviour of the rock mass is the structural discontinuities such as joints, bedding planes, lamination, cleavages and faults.
- These factors will influence and control the rock mass behaviour.
- Discontinuity can be defined as a plane of weakness within the rock across which the rock material is structurally discontinuous and has zero or low tensile strength.
- In another words, discontinuity is used to describe any mechanical interruption of rock properties.

Orientation

- The dip and orientation of discontinuities together with joint spacing are critical factors in stability
- Excavation works may prove easier and more productive if carried out parallel to such planes of weakness
- The joint spacing and orientations will determine the dimensions and shape of rock mass blocks.
- Orientation of bedded structure can have a particularly adverse effect causing ripping behaviour similar to a massive rock structure for vertically inclined bedding or for horizontal bedding with wide spacing (Edy Tonnizam et al., 2005b).

Orientation

Spacing

- The presence of joints will reduce the shear strength of rock mass and their spacing governs the degree of such reduction.
- Even, in most of the rock mass classifications such as Rock Mass Rating (RMR) and Q-System used in tunnelling, this factor is treated as one of the main criteria in their assessments.

Closed spacing

Gouge

- The gouge characteristics present in joints also plays an outstanding role in stability of rock mass.
- Where chemical weathering is crucial in tropical climate, minerals in rock can be altered and accumulated at joints opening.
- Accumulation of iron pan is a good example of this secondary product.

Iron pan

Material Density

- The degree of cementation, sorting of sediment, packing of the grain and the shape of the grains can be assessed by knowing the density.
- Higher density may associates with lesser voids within the rock and strong bonding between the mineral grains, hence stronger material.

Rock Fabric

- Fabric is a term used to describe the micro structural and textural features of rock material.
- Researchers have found that rock fabric is another factor affecting the strength
- Coarse-grained rocks (grain size > 5mm) such as pegmatite and sandstone can be ripped easily than fine-grained rocks (grain size < 1 mm) such as quartzite, basalt and limestone.
- It can also be generally assumed that acidic rocks are weaker than basic rocks

- The small and larger scale of discontinuity that are always present in the sedimentary rock such as thickness of bedding, joints and foliation are also need to be assesed.
- The percentage of dominancy of low or high strength of rock need to be assessed in advance as it may cause problems in the assessment.

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