Rock Mass

Observation of jointing features

Joints are often found in certain, preferred directions. One to three prominent sets and one or more minor sets often occur; in addition several individual or random joints may be present. Jointing is the occurrence of joint sets forming the system or pattern of joints as well as the amount or intensity of joints. The network of joints in the massifs between weakness zones is often referred to as the 'detailed jointing'.

The jointing can be measured and characterized in different ways. The main ones are:

1. The degree or density of jointing, which can be measured as:
   A. joint spacing (S),
   B. volumetric joint count (Jv),
   C. block volume Vb), and/or
   D. rock quality designation (RQD)
2. Orientation of joints and joint sets
3. Jointing pattern and block shape,

This is further described in this paper.

A. Joint spacing

Where discontinuity surfaces are parallel or sub-parallel (joint set) the spacing is taken in the direction normal to the surface orientation. The proposed description of joint surface spacing is given in Table 1.

Table 1: Classification of spacing of discontinuities (from de Beer et al., 1976)

Description for structural features: bedding, foliation or flow banding	Spacing in mm	Description for joints, faults, or other fractures
Very thickly (bedded foliated or banded)	> 1 000	Very widely (jointed)
Thickly	300 – 1 000	Widely
Medium	100 - 300	Medium
Thinly	30 - 100	Closely
Very thinly	10 - 30	Very closely
Description for micro-structural features: lamination, foliations or cleavage		
Intensely laminated (foliated or cleaved)	3 - 10	
Very intensely	< 3	

In many cases one joint set is dominant, being both larger and/or more frequent than joints of other sets in the same locality. This set is often referred to as the main joint set (or by geologists as primary joints).

B. The volumetric joint count (Jv)

The volumetric joint count (Jv) is the number of joints intersecting a rock mass volume of 1 m³.
Where the jointing is formed only by joints sets it can be found from:

1. Measuring the spacing of each joint set:

   $Jv = \Sigma\ 1/S = 1/S1 + 1/S2 + 1/S3 + \ldots$ where S1, S2, S3, etc. are joint spacings for the various joint sets given in metre

2. Where joint sets and additional random joints occur, a 'spacing' of 5 m is applied for each random joint seen in 1 m³ volume:

   $Jv = \Sigma\ (1/S) + Nr/5) = (1/S1 + 1/S2 + 1/S3 + \ldots) + Nr/5$ where Nr = the number of random joints

The following papers deal with the Jv, which was first presented (in Norwegian) by Palmstrom in 1974, later presented in English in 1982, 1985, 1986 and 1996.

C. Block size (block volume)

The joints delineate *blocks*. Their dimensions and shapes are determined by the joint spacings, by the number of joint sets and by the random joints. *Block size* is a volumetric expression for the jointing density or the degree of jointing. It is a result of the *detailed jointing*. The block dimensions are determined by joint spacings and the number of joint sets. Individual or random joints and possible other planes of weakness may further influence on the size and shape of rock blocks, as well as impact from excavation works.

Direct measurement of the block volume can be made where the rock masses can be observed in surfaces, cuttings and underground excavations. The volumes will generally vary considerably at each site, and it is generally recommended to record also the variation in volumes in addition to the average volume.

Where the jointing is developed mainly from 3 joint sets, the block volumes can be estimated from the joint spacings of the 3 joint sets. Vb = S1 x S2 x S3 (when the sets occur approximately at right angles to each other).

Rock masses can be described by the following adjectives, to give an impression of block size and shape (joint geometry):

- massive = few joints or very wide spacing
- blocky = approximately equidimensional
- tabular = one dimension considerably smaller than the other two
- columnar = one dimension considerably larger than the other two
- irregular = wide variations of block size and shape
- crushed = heavily jointed to "sugar cube"

The paper Measurements of and correlations between block size and rock quality designation (RQD) shows the difficulties in establishing an acceptable comparison between RQD and Vb (block size).

D. RQD (Rock quality designation)

A measurement often used for the degree of jointing is the "Rock Quality Designation" (RQD). RQD is defined by the sum per metre of drill core pieces longer than 10cm in NX (54.7 mm) cores, see Figure 1 on next page. RQD can also be found from similar measurement along a scanline.

Table 1: Effect of discontinuity strike and dip orientation in tunnelling (from Bieniawski, 1984)

Strike perpendicular to tunnel axis			
Drive with dip		Drive against dip	
Dip 45° – 90°	Dip 20° – 45°	Dip 45° – 90°	Dip 20° – 45°
Very favourable	**Favourable**	**Fair**	**Unfavourable**
Strike parallel to tunnel axis			Irrespective of strike
Dip 20° – 45°	Dip 45° – 90°		Dip 0° – 20°
Fair	**Very unfavourable**		**Fair**

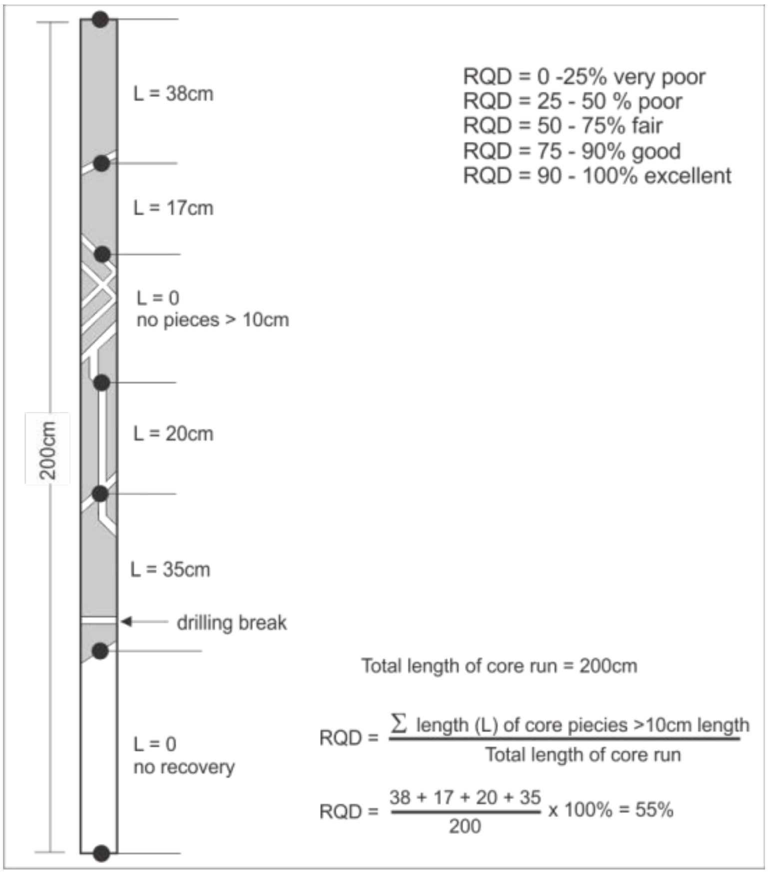

Figure 1: The definition of RQD (from Deere, 1963.)

3. Jointing pattern and block shape

The jointing pattern is determined by the joint spacings, by the number and orientations of joint sets and by the random joints.

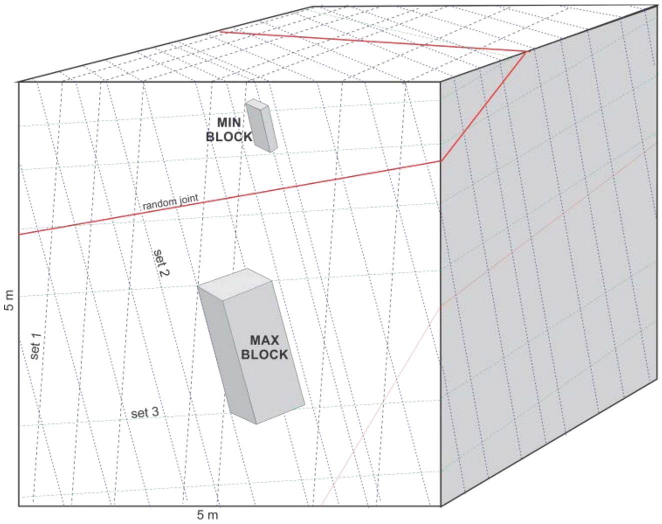

Figure 2: Three joint sets and two random joints with blocks (from Palmström and Nilsen, 2000)

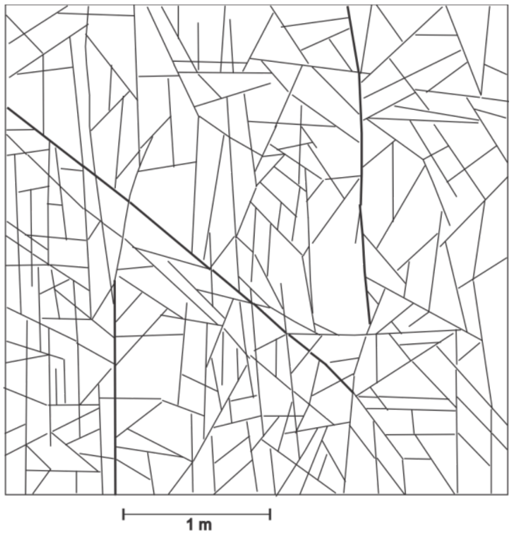

Figure 3: The jointing pattern can be quite irregular and difficult to characterize

The type of block is mainly determined by the difference in dimensions between the block faces.

A practical method to estimate the block shape factor β is from measurement of the longest (L_{max}) and shortest (L_{min}) dimension of the block in the equation $\beta = 20 + 7\ L_{max}/L_{min}$ The block shape factor β is used to characterize the shape of the different block types according to Table 2.

Table 2: Classification of the block shape factor β (from Palmström, 1995)

Value of β	Term for block type
27 - 32	cubical
32 - 50	slightly long or flat block
50 - 100	moderately long or flat block
100 - 500	very long or flat block
> 500	extremely long or flat block

The division into the block types above does not, however, include the impact of the angles between joints or joint sets. The angles between the block faces (or joint sets) delineate:

- right-angled or prismatic blocks;
- rhombohedral blocks; or
- obtuse-angled blocks (where more than 3 joint sets occur).

A very simple expression for the jointing pattern is applied in the Q-system and the RMi support method where the pattern is expressed as the number of joint sets with or without random joints.

References

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