Joint characteristics

Introduction

There is a difficulty in giving a concise definition of what constitutes a joint. Over the years there have been several discussions whether 'joint', 'fracture' or other terms should be preferred in rock mechanics, engineering geology and rock engineering. ISRM (1975) has chosen 'joint' defined as: *"Joint is a discontinuity plane of natural origin along which there has been no visible displacement."*

There is a great variety of joints, from small cracks to long shears or seams, as seen in Figure 1.

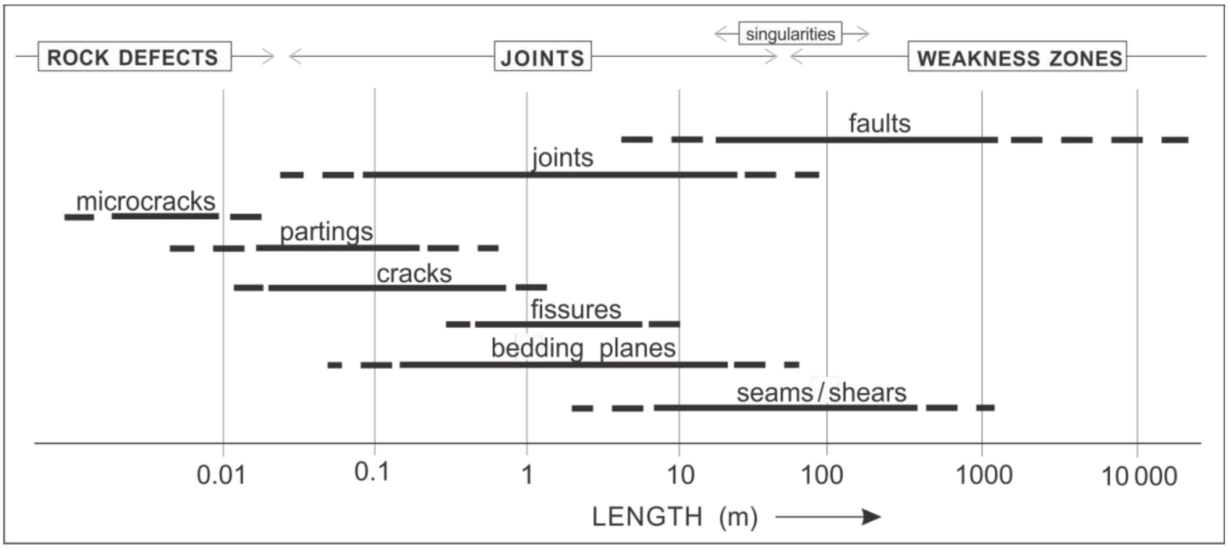

Figure 1: .The size span of different types of discontinuities (revised from Palmström, 1995)

The terms for the various types of joints in Figure 1 are generally chosen from their size and composition. Some supplementary definitions of these and some others are given as follows:

Crack is a small, partial or incomplete discontinuity. (ISRM, 1975)

Fracture is a discontinuity in rock due to intense folding or faulting. (Dictionary of geological terms, 1962). Fracture is a general term used in *geology* for all kinds of discontinuities caused by mechanical stresses in the bedrock. Fractures include joints and cracks and faults. It is suggested not to use this term in rock engineering and engineering geology.

Parting is a plane or surface along which a rock is readily separated or is naturally divided into layers, e.g. bedding-plane parting. (Glossary of geology, 1980).[1]

Rupture is a fracture or discontinuity caused by excavation works or other human activities.

Seam

1) a minor, often clay-filled zone with a thickness of a few centimetres.

   When occurring as weak clay zone in a sedimentary sequence, a seam can be considerably thicker. Otherwise, seams may represent very minor faults or altered zones along joints, dikes, beds or foliation. (Brekke and Howard, 1972).

2) a plane in a coal bed at which the different layers of coal are easily separated. (Dictionary of geological terms, 1962)

[1] Partings which often occur as bedding plane and foliation partings, are separations parallel to a mineralogically defined structural weakness in the rock. They are most often tight and rough except where flaky minerals (mica, chlorite) occur.

Shear is a seam of sheared and crushed rock usually spaced more widely than joints and is marked by several millimetres to as much as a metre thickness of soft or friable rock or soil.

Singularity is used as a general term for seams, filled joints, shears or other persistent discontinuities which are not considered as belonging to the general or *detailed jointing*.

The main joint characteristics are indicated in the Figure 2.

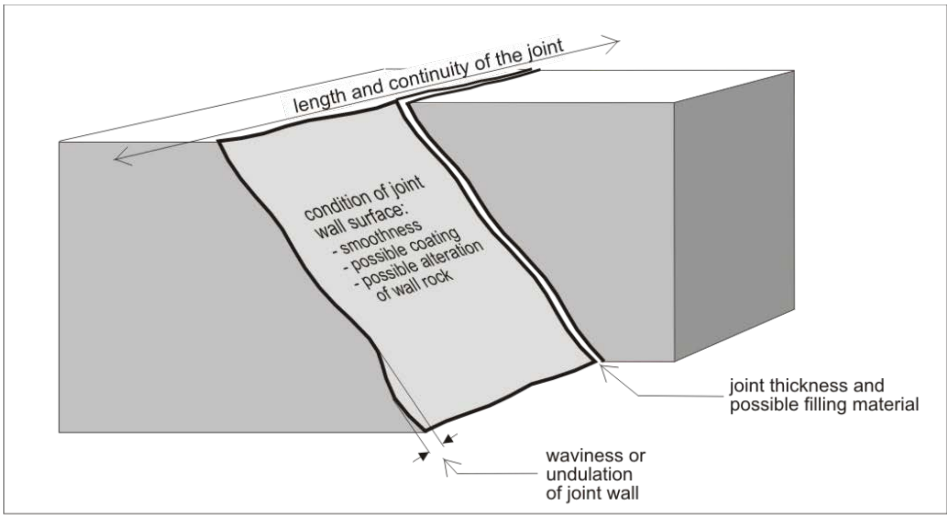

Figure 2: Main characteristics of a joint. Also orientation is an important characteristic

A joint is a three-dimensional discontinuity composed of two matching surfaces called *joint walls*. It is composed of several *characteristics* of which the main are, see Figure 3.2:

A. Length (size) and continuity of the joint
B. Separation
C. Joint surface characteristics (smoothness and waviness)
D. Condition (alteration) of the discontinuity, i.e. whether the wall is fresh or weathered/altered and/or presence of possible filling.

There are two main groups of discontinuities: Firstly feature characteristics of the origin of the rock such as bedding, foliations and flow bands, and secondly features occurring as a result of tectonic rupture (fractures) such as joints, fractures, faults and shears.

A. Joint size and continuity

Discontinuities constitute a tremendous range, from structures of up to several kilometres in extent down to a few centimetres, see Figure 1. *Discontinuous joints* terminate in massive rock. Such joints can be foliation partings, *en echelon joints* in addition to many of the smaller joints (less than 1 metre long). *Continuous joints* terminate at other joints.

Table 1: Classification of joint size (based on Bieniawski, 1984)

SIZE	JOINT LENGTH
Very short	< 1 m
Short	1 - 3 m
Medium long	3 - 10 m
Very long	> 10 m

Very long joints and seams or shears occur often as singularities (see Figure 1).

The size of a joint may vary within the same joint set. This is specially the case for foliation joints where small joints or partings often occur between longer, continuous joints. The length (size) can be crudely quantified by observing the joint trace lengths on the surface exposures. Often, rock exposures are small compared to the area or length of persistent joints, and in such cases the real persistence can only be guessed.

B. Separation

Separation is the maximum distance between two joint walls. It is generally small, mainly less than a millimetre, except for filled joints, seams or shears. The size of the joint is often proportional to the thickness or separation of the joint.

Aperture is the perpendicular distance separating the adjacent rock walls of an <u>open</u> discontinuity, in which the intervening space is air or water filled. Aperture is thereby distinguished from the width of a filled discontinuity (ISRM, 1978).)

Table 2: Classification of the separation of joints (from Bieniawski 1984)

TERM	SEPARATION
Very tight	< 0.1 mm
Tight	0.1 - 0.5 mm
Moderately open	0.5 - 2.5 mm
Open	2.5 - 10 mm
Very open	10 - 25 mm

C. Description of the joint surfaces

<u>Waviness</u>

Large, low angle asperities that cannot be sheared off are termed waviness, see Figure 3. They cannot be reliably measured in a drill core.

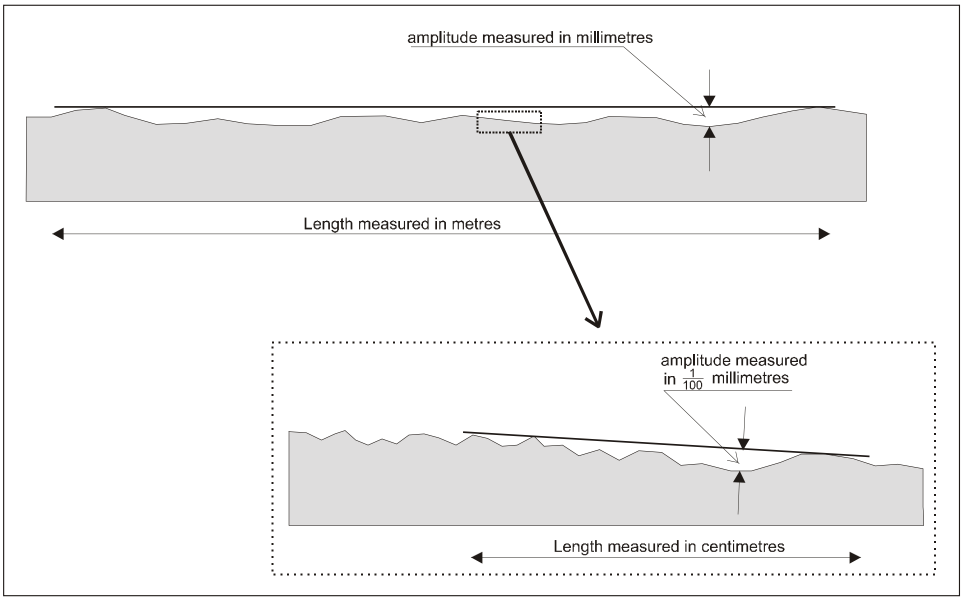

Figure 3: The joint wall features can be characterised by the large scale waviness (top) and the small scale smoothness (or unevenness) (from Palmström, 1995).

Ideally, the *joint waviness* should be measured as the ratio between max. amplitude and joint length. As it is seldom possible to observe the whole joint plane, a simplified measurement is normally carried out the so-called undulation factor, representing the ratio between max. amplitude (A) and a reduced, measured length (L) along the joint plane:

$$u = \frac{\text{amplitude from planarity (A)}}{\text{measured length along joint (L)}}$$

A classification of the waviness of the joint plane is shown in Table 3.

Table 3: Classification of joint plane undulation based on measurements related to 1 m long profile length) (from Milne et al. (1992)

CLASSIFICATION	**UNDULATION**
Wavy joints	u > 2%
Planar to wavy joints	u = 1 - 2%
Planar joints	u < 1%

The longest possible ruler should be applied in measurement of waviness. In many cases, however, the determination of waviness is done from visual observations alone.

Smoothness

Small, high angle asperities that are sheared off during shear displacement are here termed smoothness[2]. A possible solution is to simply touch the surface with the finger and compare it with a reference surface of known roughness, for example sand papers of various abrasivities (mesh). The applicable descriptive terms are defined in Table 4.

Table 4: Joint smoothness description. The terms are based on Jr in the Q-system, the description partly on Bieniawski (1984).

TERM	DESCRIPTION
Slickensided	Polished and striated surface
Polished	Visual evidence of polishing exists, as often seen in chlorite and specially talc coatings
Smooth	Appears smooth and is essentially smooth to the touch. .
Slightly Rough	Asperities on the fracture surfaces are visible and can be distinctly felt
Medium Rough	Asperities are clearly visible and fracture surface feels abrasive
Rough	Large angular asperities can be seen. Some ridge and high side angle steps evident.
Very Rough	Near vertical steps and ridges occur on the joint wall surface

Where slickensides are observed the direction of the slickensides should be recorded

D. Condition of the joint

Joint filling

All materials occurring between the fracture walls are referred to as joint filling. The term includes in-situ weathered materials, fault zone materials (gouge) and foreign materials either deposited or intruded between the joint surfaces.

Only the presence or absence of joint filling is noted in the joint surface description. The suggested terminology is given in Table 5.

Table 5: Presence or absence of joint filling materials

Term	**Description**[1)]
Clean	No fracture filling material
Stained	Colouration of rock only. No recognisable filling material
Coated	A very thin layer (coating) occur on the joint wall (no filling)
Filled	THIN joint filled with recognisable filling material
	THICK filling of soft or hard materials(s) other than the surrounding rock [2)]

[1)] Possible alteration of the wall rock (other than the adjacent rock) should be noted (in addition to the term).

[2)] Thick filling is often connected to weakness zones (large faults, shears) and is described in Section B. Separation.

[2] Not to be confused with the term roughness used in the Q-system, where roughness is used both for small, high angle and large, low-angle asperities

A filling can consist of several different minerals and materials. The main groups are:
- *Hard and resistant minerals* (quartz, epidote and serpentine).
- *Soft minerals* (clay, chlorite, talc and graphite).
- *Soluble minerals* (calcite, gypsum).
- *Swelling minerals* (swelling clays (smectites), anhydrite).
- Loose materials (silt, sand and gravel).

Other features which may be described are:
- Moisture and consistency,
- Colour,
- hardness
- porosity, an estimate given; as a percentage.

More information can be found in the file on observation of weakness zones.

Joints, seams and sometimes even minor faults may be *healed* through precipitation from hydrothermal solutions of quartz, epidote or calcite. This may be the case for layered, igneous and metamorphic rocks in which the layers are strongly *welded* together; therefore such planes are not planes of weakness in the way bedding planes in sedimentary rocks are, but can be regarded more appropriately as planes of reduced strength.

E. Orientation of joints

The two necessary and sufficient conditions for the definition of the orientation of a particular plane are its dip and dip direction (also given as strike and dip).
The dip of a particular surface is the maximum angle between the plane containing the surface and the horizontal and is recorded in degrees from 0^o to 90^o.

F. On description

Recognition of discontinuity type in terms of its origin can be useful. For example bedding planes clearly have a much greater extent than cross joints in the same sedimentary rock.
Where individual, significant discontinuities are recognisable, such as faults, shear zones or narrow dykes, they may be described singly. Where they are observed to fall into distinct groups, that is, joint sets, with distinctly different group properties, each group may be described separately.

Sufficient detail should be included to enable a valid assessment of the rock mass behaviour to be made for the specific engineering problem at hand, but unnecessary and often costly detail should be avoided.

Major discontinuities (*singularities*), such as shears and seams, should be recorded on an individual basis, see weakness zones

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