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THE VOLUMETRIC JOINT COUNT - A USEFUL AND SIMPLE MEASURE OF THE DEGREE OF ROCK MASS JOINTING

LE COMPTE VOLUMETRIQUE DE FISSURES - SIMPLE MESURE UTILE DU DEGRE DE LA FISURATION DES MASSIFS ROCHEUX

ARILD PALMSTRØM

Engineering Geologist

Ing. A.B. Berdal A/S

Partner of Norconsult A.S.
Norway

ABSTRACT

In many cases the degree of jointing is the most important factor for the stability of rock masses. The volumetric joint count (Jv) is a simple measure of the degree of jointing. It takes into account all the occurring joints and fractures and is easily calculated from standard joint descriptions.

The (Jv) has been used by engineering geologists in Norway for several years and it has been a useful tool in the description and classification of rock masses. The paper describes the procedure for the calculation of the (Jv) and it shows how the joint spacings are included in the measure.

A classification of the (Jv) is shown and its relation to the RQD-system and the Q-system. From the (Jv) it is also shown how the inter-block size can easily be evaluated.

ABSTRAIT

Dans bien des cas, le degrè de la fissuration est le facteur le plus important pour la stability des massifs rocheux. Le compte volumétrique des fissures (Jv) est une simple mesure du degre de la fissuration. Le (Jv) comporte toutes les fissures et les fractures existantes, et on peut facilement l'évaluer au moyen de descriptions standard des fissures.

En Norvege, les ingénieurs géologues utilisent depuis des années le (Jv), qui se montre un instrument utile pour la description et la classification de massifs rocheux. Le document décrit le procédé du calcul du (Jv) et montre comment les caractéristiques des fissures sont incluses dans la mesure.

On montre une classification du (Jv) et les relations de ce systeme aux systemes RQD et Q. Le (Jv) montre aussi comment on peut facilement évaluer les dimensions des blocs encaissés.

1. Introduction

Joints are defects or discontinuities universally present in all rock masses. They have strength, permeability and deformation characteristics different from those of the intact rock. Depending upon origin and nature of the joint sets, their characteristics and structure can vary a lot. Both the single joint itself, its orientation, its size and properties have a great range of variations, Ref. (3),(7). In addition the jointing pattern made up of the different joint sets form the complexity of the rock mass jointing.

This makes description and classification of the different rock masses important, Ref. (2).

The importance of the joints and jointing upon the rock mass quality has been documented in the, two main rock mass classification systems, namely Bieniawski's Geomechanical Classification (Ref. 4) and Barton's Q-factor Classification System (Ref. 1). Both systems use joint and jointing characteristics as a main input.

A simple way to measure and describe joints and the jointing which take into account the most important joint properties is, therefore, very useful. The volumetric joint count is a measure for the degree of jointing or the inter block size and it can be used as an input in the description of rock mass jointing.

One of the difficulties in working out a system for characterizing the jointing, is its three-dimensional structure. The mostly used systems, namely joint spacing or joint frequency are rough, inaccurate measures based upon spacings of the dominating joint set. There do not exist rules how to correct the measure where several joint sets are present. Also the RQD measure (Rock Quality Designation, Ref. 5) give varying results whether the borehole is made perpendicular or parallel to the dominating joint set, causing that also this measure in many cases gives an inaccurate parameter of the degree of jointing.

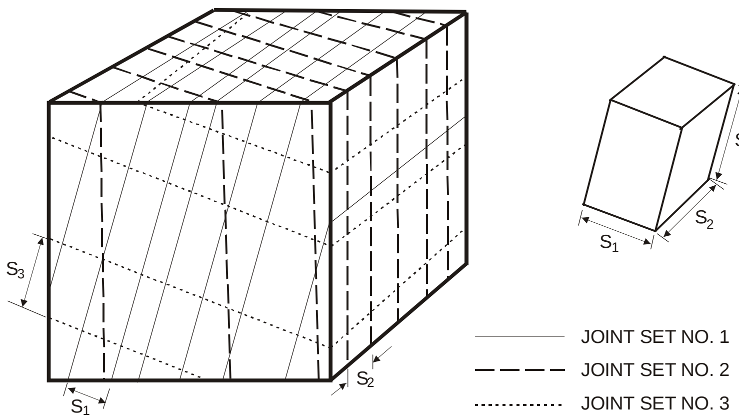


Fig. 1 BLOCK DIAGRAM CONTAINING 3 JOINT SETS

2. The volumetric joint count (Jv)

Fig. 1 shows a block diagram with three joint sets having spacings S1, S2 and S3. The joint frequency (number of joints per unit length) for each set will be 1/S1, 1/S2 and 1/S3 respectively.

(If set no.1 is the dominating set, the fracture frequency would be 1/S1, or roughly adjusted if the two other sets are taken into consideration).

The number of joints intersecting a unit rock mass defined as the volumetric count, will then be:

$$(Jv) = \frac{1}{S1} + \frac{1}{S2} + \frac{1}{S3}$$

This definition of degree of jointing (Jv) takes into account in an unambiguous way all the occurring joints in the rock mass.

From common joint observations the volumetric joint count can easily be calculated since it is based upon normal observations of the joint spacing, refer to Example 1 and 2. In the cases when mostly random or irregular joints occur the (Jv) can be found by counting all the observed joint within a known area. By assuming that the jointing has a uniform distribution, the (Jv) can be found by calculating the number of joints per unit area and multiplying this with a factor K. The factor K will vary with the distribution of the joints. With an equal distribution in all three directions K will be 1.15 - 1.5 depending upon the orientation of the surface with respect to joint planes. For unequal distributions the K will have greater variations. Under normal conditions, however, it has been found that K = 1.25 - 1.35. In this way the two-dimensional measurements are converted to three-dimensional, refer to Example 3.

The individual spacing for a joint set will normally vary within certain limits. By calculating the (Jv) from the closer and wider spacing for each set, the maximum and minimum degree of jointing can be found. This is further shown on Examples 1 and 2.

3. Classification of the (Jv)

Classification of the volumetric joint count (Jv) is partly based on the existing classifications of joint spacing and joint frequency. As these are measures of the dominating joint set, it is estimated that the (Jv) is between 1.5 and 2 times bigger than the joint frequency, as indicated on Fig. 2 where the correlation between the (Jv) and the existing jointing classification is shown.

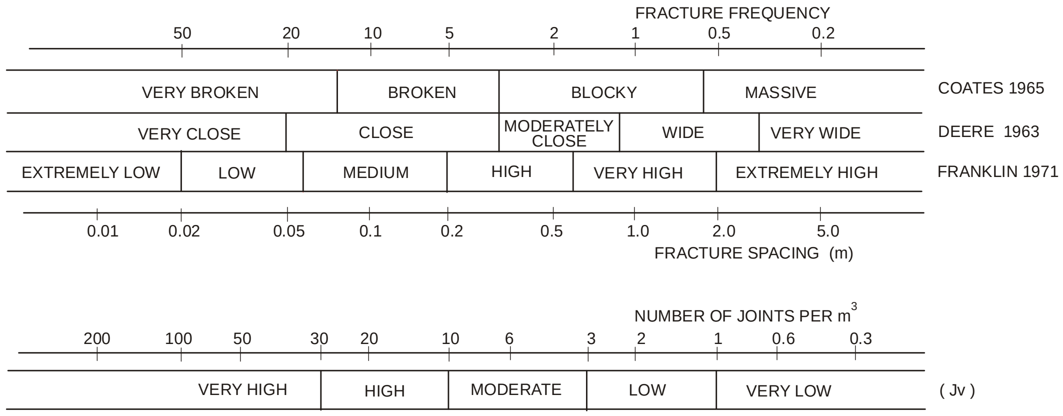


Fig. 2 CLASSIFICATION OF JOINT SPACING AND (Jv)

The volumetric joint count (Jv) is based upon mapping either in a tunnel, in a cavern or on the earth surface. In cases where no surface observations are available the (Jv) can be found using core observations either as RQD or as the joint frequency (number of joints per meter borehole). Transition from one-dimensional (in a borehole) to three-dimensional indicate a multiplying factor K = 1.65 – 3.0 for equally distributed joints. A factor K = 2.0 has been found to cover normal jointing distribution. If the borehole is orientated parallel or perpendicular to a dominating joint set, the factor K must be adjusted up or down respectively for the actual situation, Refer to Example 4.

Between the RQD and the (Jv) there is a theoretical correlation:

RQD = 115 - 3.3 (Jv) (RQD = 100 for Jv < 4.5)
or
Jv) = 35 – RQD/3.3 (RQD = 0 for Jv > 35)

as shown in Fig. 3.

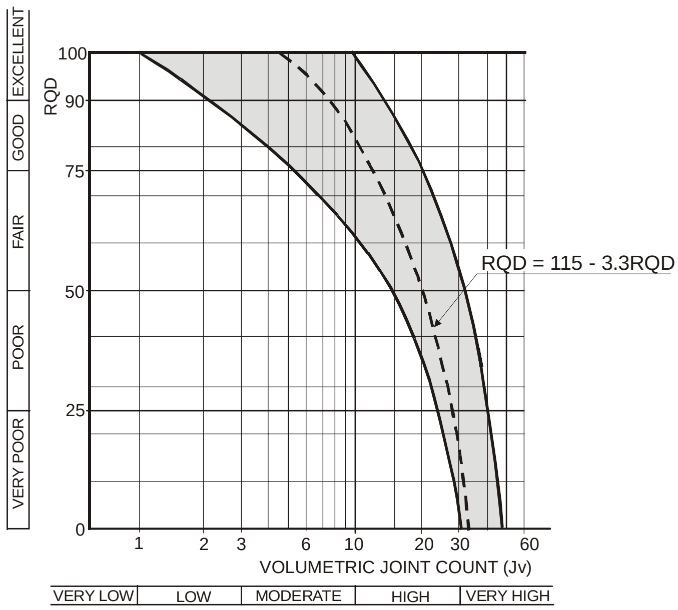


Fig. 3 CONNECTION BETWEEN RQD AND (Jv)

The limitations in the RQD assessment, (where for example the RQD = 100 if the core pieces are 11 cm long and 0 if they are 9 cm) causes often a rough correlation between the two parameters.

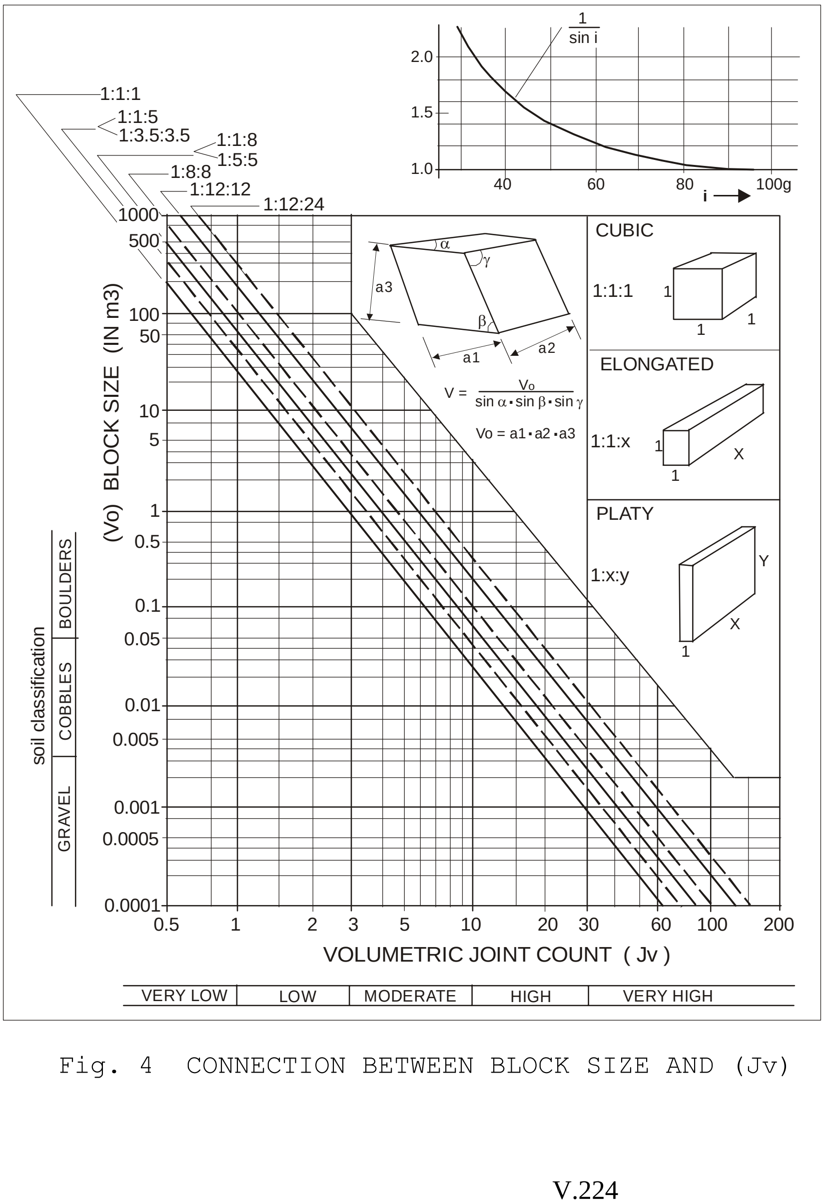


Fig. 4 CONNECTION BETWEEN BLOCK SIZE AND (Jv)

4. Application of the (Jv)

Because both the (Jv) and the block size of the rock mass vary according to the degree of jointing, there exists a correlation between them. The (Jv) is, however, dependent upon the jointing pattern which means that it must be adjusted for both the angles between the different joint sets and the block shape. From the diagram in Fig. 4 the block size can be found for the three main different block shapes, namely the cubic, the elongated and the platy type. The diagram is based on joints intersecting each other at right angles. At other angles the volume must be adjusted by the formula

$$V = Vo \times \frac{1}{\sin \alpha} \times \frac{1}{\sin \beta} \times \frac{1}{\sin \gamma}$$

where α, β and γ are the angles between the joint sets, see Example 2.

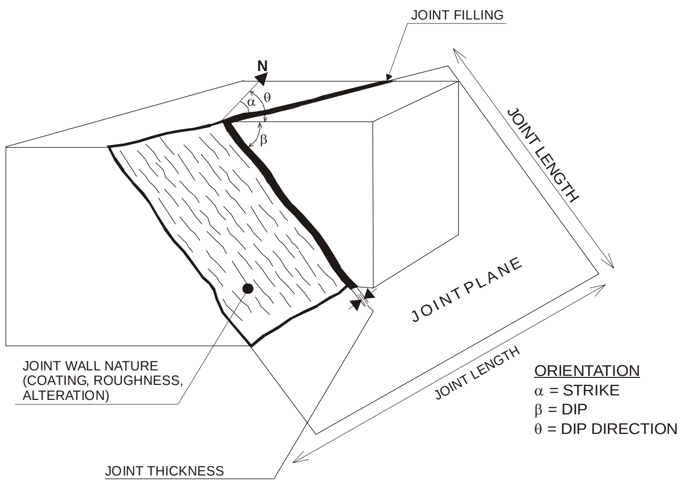


Fig. 5 THE STRUCTURE OF A JOINT

It is very seldom that the angles between joint sets, are less than 50^g. If all the three angles are 50^g the block size will be: V = 2.8 Vo
Mostly, however, the block size is: V = (1.0 to 1.5)Vo

Fig. 5 shows the main parts of a joint. A standard description of a joint should take into account all these, (Ref. 8) which are:

- joint orientation (strike and dip, or dip direction and dip)
- joint size (length, aperture/thickness)
- joint nature (roughness, character of joint walls, joint filling)
- joint course (planarity, persistence)
- joint spacing (or number of joints in an area)

The influence of these parameters upon jointing is indicated on Fig. 6 which also shows the importance of block size or volumetric joint count (Jv) upon jointing.

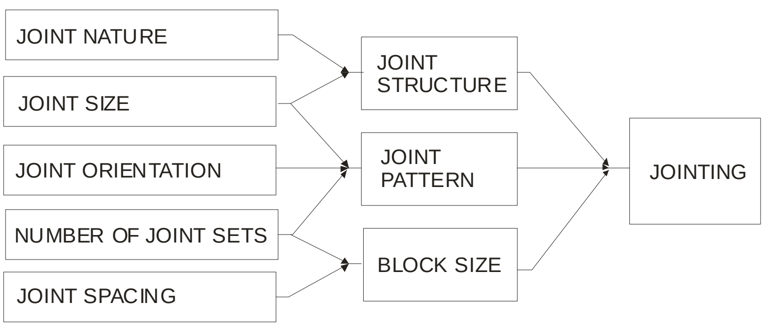


Fig. 6 THE INFLUENCE OF JOINT PROPERTIES UPON JOINTING

The volumetric joint count (JV) has been in use by the author for more than 10 years. It has been found very useful as an input both for the description of the rock mass jointing and for stability predictions. Also as input in the Q-system to assess the rock support in different rock excavations the (Jv) has successfully been used. (Ref. 1). Especially for tunnel mapping the (Jv) is suitable since it enables a quick, simple and accurate measure for the degree of jointing.

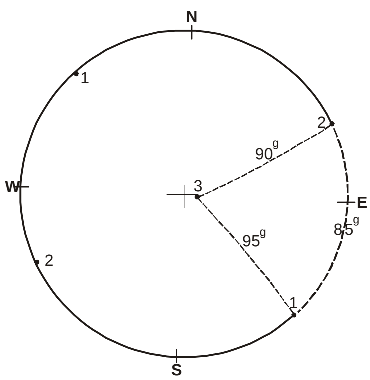
5. Examples

Example 1

In a granite three joint sets occur and a few random joints.

A mean (Jv) = 2.9 can be classified as low to moderate.

From the mean joint spacings the shape of the block is 1:2:2 (elongated) which from Fig. 4 gives a block size for a right angle block Vo = 1.5 m3.



The exact angles between the three joint sets can be found using Wulff's stereographical net. As shown on Fig. 7 they are 85^g, 90^g, 95^g which gives V = approx. Vo = 1.5 m3.

Fig. 7 THE POLES OF THE THREE JOINT SETS PLOTTED IN WULFF's STEREOGRAPHIC NET

Example 1

OBSERVATIONS					CALCULATIONS		
JOINT SET NO.	ORIENTATION (i^g)	JOINT SPACING (m)			JOINT FREQUENCY (joints/m)		
	strike/dip	max.	mean	min.	min.	mean	max.
1	30/100	2	0.75	0.3	0.5	1.3	3
2	150/100	3	1.5	1	0.3	0.7	1
3	190/10W	2	1.5	1.5	0.5	0.7	1
random	80/30NW	5*)	5*)	5*)	0.2	0.2	0.2
	Volumetric joint count (Jv) =				1.5	2.9	5.2

*) For random joints a spacing of 5 m is used when calculating the joint frequency

Example 2

A gneiss is cut by a dominating joint set parallel to the foliation, in addition two other joint sets occur.

The degree of jointing can be classified as high with a mean (Jv) = 23.9.

The shape of the block is platy (1:6:30) which from Fig. 4 gives Vo = approx. 0.03 m3 for right angles between the joint sets. From Wulff's stereographical net the angles between the three joint sets are found to be 115^g, 80^g and 80^g. The volume corrected for these angles are

$$V = Vo \times \frac{1}{\sin 115^g} \times \frac{1}{\sin 80^g} \times \frac{1}{\sin 80^g}$$

V = 0.03 × 1.03 × 1.05 × 1.05 = 0.34 m3.

Example 2

OBSERVATIONS					CALCULATIONS		
JOINT SET NO.	ORIENTATION (i^g)	JOINT SPACING (m)			JOINT FREQUENCY (joints/m)		
	strike/dip	max	mean	min	min.	mean	max.
1	80/60 NW	0.1	0.05	0.03	10	20	30
2	10/90 SE	0.5	0.3	0.2	2	3	5
3	80/20 SE	3	1.5	1	0.3	0.7	1
random	50/80 NE	5	5	5	0.2	0.2	0.2
				(Jv) =	12.5	23.9	36.2

Example 3

A hornfels is mostly cut by irregular, single or random joints, which means that it is difficult to find the joint spacings. The number of joints cutting a given area has been measured at 3 observation points.

It is here assumed that the joints are about equally distributed in all three dimensions. A factor K = 1.3 is therefore used in converting from two-dimensional to three-dimensional measurements.

By further assuming that the blocks mostly have a cubic shape (and right angles) the block size is V = 1.3 - 2.0 m3.

Example 3

OBSERVATIONS			CALCULATIONS	
OBSERVATION POINT		NUMBER OF JOINTS		Jv
number	area (m^2)	number	joints/m^2	joints/m^3
1	6	10	1.7	2.2
2	8	15	1.9	2.5
3	4	8	2	2.6

Example 4

The joint frequency has been measured from drill core logging.

The (Jv) has been calculated using a factor h = 2.0. It is assumed an even distribution of the joints in the rock mass and cubic blocks.

Example 4

OBSERVATIONS		CALCULATIONS		
DEPTH (m)	JOINT FREQUENCY	(Jv)	RQD	BLOCK SIZE (m^3)
0-10	15	30	16	0.001
10-20	12	24	36	0.02
20-30	8	16	62	0.06

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