Comparing the RQD and the C values

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ABSTRACT:. The bore holes are usually analyzed by RQD method in the rock engineering practice. The limitation of this method mentioned by several authors: for example, RQD = 0 % (where the joint intercept (distance between the joint in the drill cores) is 10 cm or less), or RQD = 100 %, the RQD gives no information of the core pieces. It does not matter whether the discarded pieces are earth-like materials or fresh rock pieces up to 10 cm length. At the beginning of 2003, more than 3,000 meter long boreholes were analyzed parallel by two different methods: the traditional RQD and the C-method, introduced by Hansági. According to the results, in case of very good or very poor core drill, the C method shows the jointing patterns better than the RQD method. The goal of this paper is to present the C-method and their advandages/disadvandages. Linear regression was found between the values between 10 % < RQD < 90 %, but the C value is much more sensitive, than the RQD.

1 INTRODUCTION

In geotechnical engineering it is very important to know the surrounding soil and rock masses. In rocks the most useful are the rock mechanic properties. To get these drills should be made and the core should be gained from it intact. By getting a piece of the rock as it was in the original stat we can examine the jointing, the in fills, the weathering and a lot more. For the strength of the rock and deciding about the level of support the knowledge of the jointing is the most relevant. The RQD and the C methods are to make this property numerical.

After presenting the two methods, the comparison is based on the drill data of preliminary exploration of the site of the Radioactive Repository at Bátaapáti. The data was given by Mecsekérc Ltd. RQD and C was always calculated at every drill. The calculations were made by the same person therefore the subjective mistake can be regarded as constant.

After several investigations the Central Hungarian Mórágy basin was chosen for low and medium radioactive wastefinal disposal facility. The average high of the hilly land, which is covered by mostly forest, is around 260-280 above sea level while the deepest points of the valleys are approximately 160-170 m above sea level.

The strata of the area can be easily described although highly jointed by tectonic influenced. The main stratum is the Palaeozoic granite from the carbon time. The upper part of this stratum (more than 10 meters) is differently weathered. Above this about 50-60 m thick Pleistocene loess can be found (Gálos et al. 2002)

The allocated area (approximately 300x600 m) firstly was investigated with geophysical methods before the bores were carried out till different depth (300-500 m).

In this comparison more than 3,000 meters of core from 20 drills are used to make the statistics to show the relation of them clearly.

2 THEORETICAL BACKGROUNG

The RQD method is one of the mostly used methods for borehole investigations. In Hungary, parallel with the RQD-method, the C-method is also applied. In this chapter these two methods are presented.

2.1 RQD-method – calculation and limitations

RQD is the most often used method for measuring the degree of jointing of rock masses. This value is used to calculate the RMR and Q rock mass classifications. In 1964 Deere developed RQD calculating by the core with a diameter bigger than 54.7 mm (2.15”), but later it was converted to be able to calculate on the rock surfaces as well. The appropriate definition of it is “the percentage of intact core pieces longer than 100 mm in the total length of core”.

$$RQD = \frac{\Sigma h_{10}}{h_b - h_a} 100\,[\%] \tag{1}$$

An example is shown on Figure 1. (Deere, 1989). The lengths between two joints should be measured along the axis of the core. By dividing with the whole examined length we get an average value therefore it is not imprecise to give a single number as a result.

Based on the RQD result Eurocode 7-1 categorizes rocks and gives a rock engineering description. The categories are listed in Table 1.

Table 1. Rock mechanic categorization of RQD based on EUROCODE 7-1

RQD %	Rock classification based on EUROCODE 7-1	Rock engineering description
>25	Very poor	should be regarded as soil
25–50	Poor	highly fractured
50–75	Good	fractured
75–90	Very good	slightly fractured
90–100	Excellent	intact

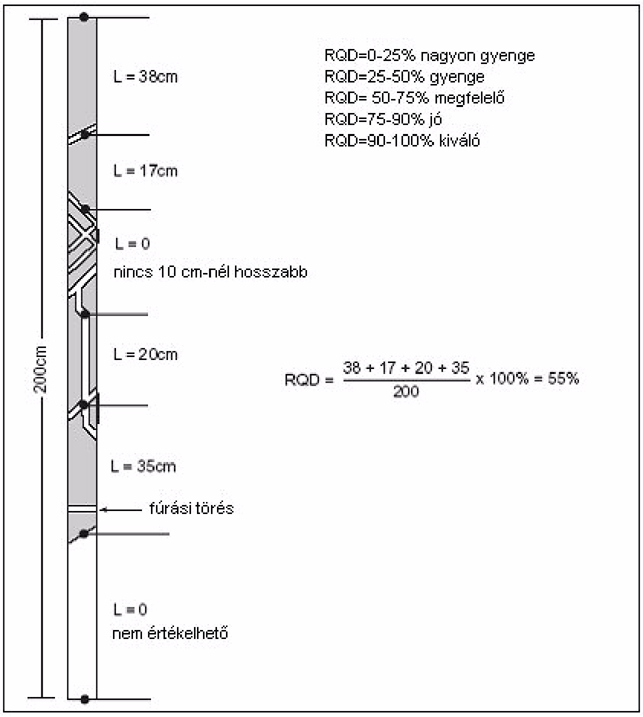

Figure 1. Calculating RQD (Deere, 1989)

On the recommendation of Eurocode 7-1 the fractures caused during the drilling or the extraction of the core should not be counted as a fracture as they are not present in the rock mass in their natural stage. In case of slate rock types the measurements must be carried out immediately after the drilling in order to get a true idea of the degree of jointing in the rock mass. By not letting the core to relax further on we can prevent the development of more cracks in the core.

One limitation of this method is that we do not get any information about the pieces shorter than 10 cm. Those parts could be soil like, full of fractures therefore appropriately resulted as RQD = 0 %, just as the first core sample in Figure 2. However those parts can be almost 10 cm long sound pieces – second core in Figure 2, with almost the same strength as other parts of the rock mass that are about RQD = 20-30 % or even 100 %. The middle two core samples are seemingly the same. The upper one contains only 9 cm long bits, while the lower consists of exactly 10 cm or little longer pieces. The difference between them, is the one with the slightly shorter bits is RQD = 0 %, while the other one is RQD = 100 %. The fourth core sample shows the limitation of RQD on the other extreme. Comparing it to the one with 10 long pieces it must have much favorable rock mechanic and water conductive properties. However RQD does not make difference between them, both are considered as intact.

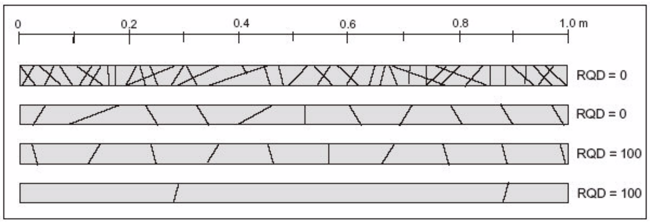

Figure 2. Examples of minimum and maximum values of RQD for various joints densities along drill cores (Palmström, 2005)

The value of RQD depends on the direction of the borehole in the rock mass as every one-dimensional measurement. Therefore it does not give a realistic picture of the jointing of the whole volume, not just the core itself. One cause of this is that Deere does not count the fractures parallel to the axis of the core as a joint. As Figure 1. shows with the 20 cm long piece in the middle of the examined section it is to be considered as an intact piece.

The directional property of the method can cause very different results even for one block. Figure 3. is an extreme example for this. In the example the rock has three perpendicular joint systems. The joint spacing of two sets is 11 and 15 centimeters, but the third is spaced by only 9 cm. If boreholes are drilled at a right angle to the first two joint sets RQD will be 100 %. In the third direction the intact pieces will be shorter than 10 cm therefore RQD result will be 0 %.

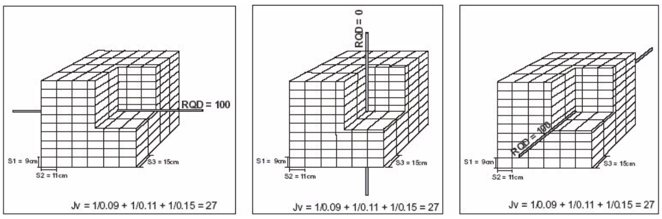

Figure 3. Example to show that RQD is directional dependency (Palmström, 2005)

2.2 C (Kiruna) method

Hansági developed the C method in 1965 in order to eliminate the restriction of the diameter in calculating RQD. C factor can be used at any diameters.

C factor is the average of two other factors, the C_p sample factor and the C_m core length factor.

$$C = \frac{C_p + C_m}{2} \tag{2}$$

C_p factor is similar to RQD. It gives the number of samples that can be saw out of the intact pieces of the core that is, how many times does the full diameter of the core fit to the length of the piece. We get the sample factor by multiplying the number of samples that can be gained with the actual diameter and dividing it with the length of the examined section.

$$C_p = \frac{pD}{h_b - h_a} \qquad (3)$$

C_m is calculated from the average lengths of the intact pieces from the examined core. While determining the core length factor one should be careful to measure all the pieces. By simply dividing the whole length with the number of fractures we do not get any information of the aperture or the highly fractured zones.

$$C_m = \frac{\overline{m}}{h_b - h_a} \qquad (4)$$

where:

$$\overline{m} = \frac{\sum_{i=1}^{n} m_i}{n} = \frac{M}{n} \qquad (5)$$

As C_m is the ratio of the average length and the full length it is a much smaller value than the C_p. By this it indicates the joints of the rock mass. For example C_p can be falsely high if the core consists of about diameter long sound parts. In this case the C_m will be much smaller to correct the final value of Kiruna.

Kiruna can be calculated with one equation that is the combination of the (3) and (4).

$$C = \frac{1}{2(h_b - h_a)}\left(pD + \frac{M}{n}\right) \qquad (6)$$

While calculating C it is important to divide the core into sections with similar rock mechanic properties in order to get a clear view of every significant portion of the rock it self. We can get values for the state of the blocks and the fault zones as well.

The value of Kiruna can vary between 1 and 0.C = 0 is the outcome when the intact parts are shorter than the diameter of the core. C = 1 is rare; it is possible only when the rock is sound and has no discontinuities in it. The difference between the block and the rock mass is not obvious in this case; the core comes out in one long piece.

3 COMPARING THE RQD AND THE C METHODS

The comparison of the two methods is based on the data from Bátaapáti Repository. All the calculations were made by one person to eliminate differences in subjective mistakes. Another problem is the fractures caused by the methodology of the drilling or the lack of experience of the people. It was assessed that the maximum number of this kind of fractures are only 11 % of all the joints in a core. This way all mistake possibilities are made constant to make no great differences in the values.

3.1 *Comparison* of C_p and RQD

Figure 4. shows the similarity of the two factors. Both measures the sound pieces that are longer than a certain length. Clearly a linear relation can be determined between them.

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$$C_p = 0.0087\ \mathrm{RQD} + 0.0357 \qquad (7)$$

$R^2 = 0.9606$

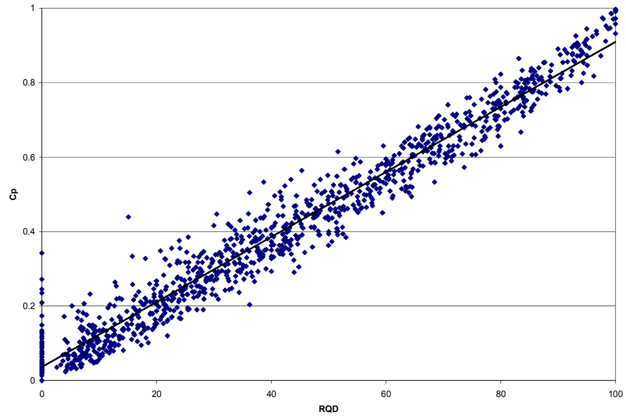

Figure 4. Relation between C_p and RQD factors

3.2 *Comparing* C and RQD

To examine the relation of two sets of data it is important to know the enveloping curves. This way we can see the extreme cases and the standard deviation from the exact relation given between them (see Figure 5).

The best approximation of the upper curve is linear:

$$\mathrm{RQD} = 222\ C \qquad (8)$$

While the lower enveloping curve can be converged with a logarithmic equation:

$$\mathrm{RQD} = 65.28 \ln(C) + 98 \qquad (9)$$

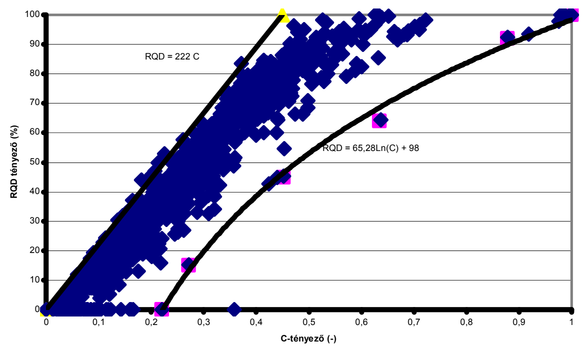

Figure 5. Enveloping curves of RQD – C diagram

From the curving lines we can see that the two methods greatly defer at the extreme values. At RQD = 100 % Kiruna varies between 1 and 0.62, while at RQD = 0 % it varies between 0 and 0.22. This kind of variation of Kiruna is general in the most jointed parts and the parts that are assumed closely intact by the RQD. These cases are when RQD is between 0 and 10 % or 90 and 100 %. Because of the great dispersion a relation can not be given with these in it. To get a more precise relation we examined only the values between RQD 10 % and 90 %. This way we got a linear relation between the two methods (Figure 6):

$$RQD = 175.75\, C + 2\ (\%) \quad R^2 = 0.9079 \tag{10}$$

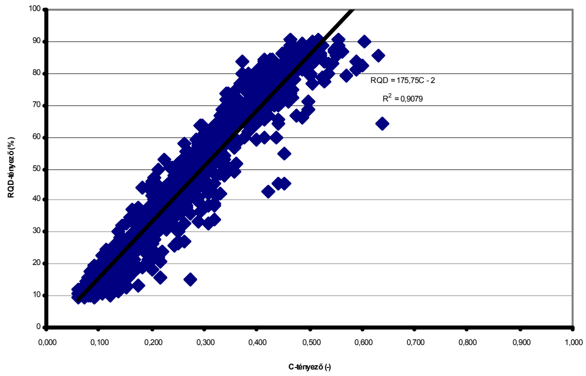

Figure 6. Relation between RQD and C values, in case of RQD between 10 and 90 %.

Even in the examined area the C shows the presence of the joint more precisely than the RQD. It is because of taking the average lengths of the intact pieces of the core into consideration which is C_m.

4 CONCLUSIONS

RQD and C methods are both simple to use and have a great importance in rock mechanic calculation in designing any kind of underground facilities.

While RQD is used much more often – only Sweden and Hungary use Kiruna – it has more limitations than C method. The first advantage of Hansági’s C factor is the elimination of the diameter restriction.

The most important innovation of the C method is the sensitivity in the extremes. With the average core length factor we get knowledge about the core pieces shorter than 10 centimeters, if it is soil like or intact pieces. This is how the fault zones can be found easier with it. The other extreme is between RQD 90 % and 100 %. With the same m factor Kiruna has more information about the state and length of the sound core. It is not subsidiary to know if the logged section consist of more smaller – but still minimum 10 centimeters long – intact parts or only of a few and much longer pieces.

Still leaving the extreme end data out a linear relation can be mentioned between the two methods. However both of them still have their limitation as the problem of directional property.

The safest way to get to determine the rock support is to use both methods and consider other thing as well to eliminate all limitations of each method or factor.

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