Use Fullness of Rock Quality Designation for Determination of Rock Quality

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Abstract— The rock quality designation (RQD) is a commonly used index for the description of rock mass fractured state. The RQD was initially introduced for civil engineering applications, and it has been quickly adopted in mining, engineering geology as well as geotechnical engineering. The success of the RQD is in great part, due to its simplicity. The determination of rock mass strength using the technique of RQD can be performed in field or in the laboratory. When properly carried out, RQD forms a basic element in most used rock mass classification systems in engineering geology and geotechnical engineering. The report illustrates concepts used in determining the strength rock mass using the RQD technique. The determination of rock mass strength using the technique of RQD can be performed in field or in the laboratory. The RQD had done on rock mass gives different results ranging from very poor to excellent rock.

Key words: Rock Quality Designation (RQD)

I. INTRODUCTION

The rock quality designation, RQD, was initially proposed by Deere (1963) as an index of assessing rock quality quantitatively, and it has since then been the topic of various assessments (e.g., Deere et al. 1967, 1988; Deere 1989), mainly for civil engineering projects. Its application has also been quickly extended to other areas of rock mechanics, and it has become a fundamental parameter in geotechnical engineering (e.g. Hoekand Brown 1980; Hoek and Bray 1981). The success of the RQD is due, in large part, to its simple definition, which is the ratio (percentage) of intact core pieces longer than 10 cm over the total drilling length. However, this index is affected by a number of known limitations. For instance, its value can be different for a given location when obtained from cores with different drilling orientations

II. OBJECTIVE/PURPOSE

The objective of this paper is to show the wide application of RQD in the determination of rock mass strength. RQD has considerable value in estimating supports of rock tunnels. RQD forms a basic element in some of the most used rock mass classification systems such as Rock mass Rating (RMR), Extension of RMR – Slope Mass Rating (SMR), Rock Tunnel Quality Q-System, Extension of Q-System – QTBM for Mechanized Tunneling, Geological Strength Index GSI System, Rock Mass Number- N Classification System and corrected definition of rock quality designation, RQDc. Both of these methods utilize the RQD as their basic elements.

III. THE ROCK QUALITY DESIGNATION (RQD)

Rock-quality designation (RQD) Rough is the measure of the degree of jointing or fractures in a rock mass, measured as a percentage of the drill core in lengths of 10 cm or more. High-quality rock has an RQD of more than 75%, low quality of less than 50% (Table 1). Rock quality designation (RQD) has several definitions. The most widely used definition was developed in 1967 by D. U. Deere to provide a quantitative estimate of rock mass quality from drill core logs. It is the borehole core recovery percentage incorporating only pieces of solid core that are longer than 100 mm in length measured along the centerline of the core. In this respect pieces of core that are not hard and sound should not be counted though they are 100 mm in length. RQD was originally introduced for use with core diameters of 54.7 mm (NX-size core) drilled with a double-tube core barrel. Figure 1 indicates the correct procedures for measurement of the length of core pieces and the calculation of RQD.

This column is used for recording Rock Quality Designation, RQD, as proposed by Deere. Measurement of the RQD provides a method of assessing the quality of a rock mass, based on the size of individual core sticks obtained when drilling NX (54 mm diameter) size core. This method yields a numerical figure between 0 and 100. RQD is measured per drill run and is defined as the total length of the individual core sticks greater than 100 mm in length divided by the length of the drill run and expressed as a percentage.

$$\mathrm{RQD} = \frac{\sum \text{Length of Core Pieces } > 100\text{ mm}}{\text{Total Lenght of Core Run}} \times 100\ \%$$

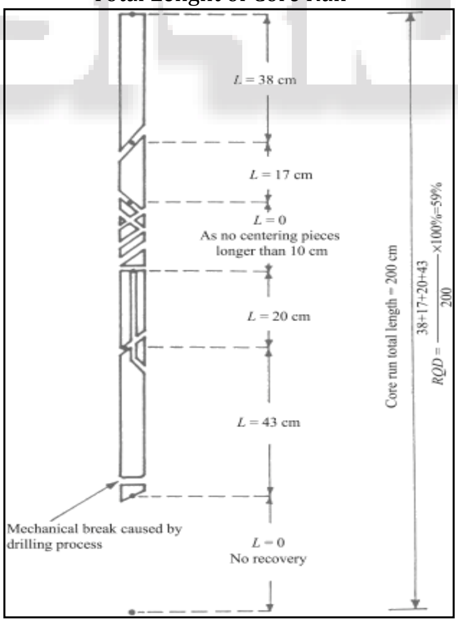

Fig. 1: Procedure for Measurement

RQD	Rock Mass Quality
<25%	completely weathered rock
25-50%	weathered rock
51-75%	moderately weathered rock
76-90%	Hard rock
91-100%	Fresh rock

Table 1: Classification of RQD Index of Rock Mass

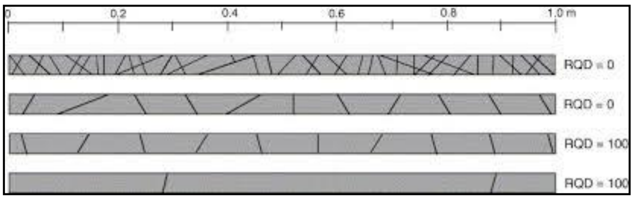

Fig. 2: RQD Values for Various Joint Densities along Drill Cores (Deere, 1989)

A. Limitations of the RQD

- RQD gives no information of the core pieces < 10cm excluded, i.e. it does not matter whether the discarded pieces are earth-like materials or fresh rock pieces up to 10cm length
- Gives wrong values where joints contain thin clay fillings or weathered material
- Does not take direct account of joint orientation
- RQD = 0 where the joint intercept (distance between the joints in the drill cores) is 10cm or less, while RQD = 100 where the distance is 11cm or more

B. Preparation of Litholog of Core

1) The Borehole Log

The borehole log serves to describe not only the rock core produced by drilling but also any other relevant information which may be obtained from the drilling process, and from tests on cores or in boreholes.

Data relative to the borehole, the tools and materials used to form it, the casing installed for sidewall support and the tests conducted in it are significant in as much as they greatly influence the condition of the core recovered, or provide indications of rock or soil mass properties. Such information is obtained from the drillers record and forms an integral part of the borehole log.

In the description of the borehole core it is usually advantageous to include a number of other parameters or indices. These indices, for example "Rock Quality Designation" (RQD) and "Standard Penetration Blow Count" (N), have been correlated with rock and soil behavioral characteristics and are indicative of certain rock and soil mass properties.

2) Layout of Log Sheet

The information recorded on such a log is as follows:

1) Borehole Number - This number should be used only once on any site and kept as simple as possible.
2) Location
a) Project - Name of Project e.g. Alrode Brewery
b) Site - Particular site e.g. Workshops
c) Location - Grid reference or chainage
d) Elevation given above M.S.L. and orientation if not vertical.
3) Drilling Technique
a) Machine - Make of machine with model number
b) Drilling method and size; including type of flush, core barrel and bit.
4) Contract Details
a) Contractor
b) Driller
c) Project Number - Consultants reference
d) Name of Logger
e) Date of logging
f) Date drilling started and drilling completed.

3) Drilling Method & Size

This column is to be used for recording the drilling technique, flush type, drilling or sampling tool and bit. Where casing is used, the type and size should be indicated. The use of conventional symbols such as NXM as defined by the Diamond Core Drill Manufacturers Association (DCDMA) or Swedish Method.

4) Percentage Core Recovery

This is the measured core recovery per drill run expressed as a percentage. This value may exceed 100% if core drilled during the previous run is recovered in the run described. As it is only possible to describe the core seen in the core box it is necessary to know on what proportion of the rock mass, intersected by the borehole, the description in the log is based. It may generally be anticipated that weak rock and fracture zones are most likely to be present in the sections of core not recovered. Poor core recovery is therefore indicative of poor rock mass strength. This parameter is considerably affected by the quality of drilling and drilling tools used. When recording the core recovery in any drill run, the core should be reassembled as far as is possible, as many drillers tend to spread the core out in the core box which gives a misleading impression of the recovery.

5) Fracture Frequency

The fracture frequency is obtained by counting the number of natural fractures (complete separations) that occur per metre length of core recorded over the actual length of core over which that frequency occurs. Unlike RQD, this parameter is not based on a specific size of core. The fracture frequency is recorded as a number. It has been found that where the number of fractures is greater than 20 the specific number is not significant and therefore only numbers for 0 to 20 and >20 need be recorded. The fracture spacing can readily be recorded as a histogram in order to illustrate graphically.

6) Test or Sample

The location and nature of any tests conducted in the borehole or on the core taken from the borehole should be indicated in this column. Tests commonly conducted in the borehole include standard penetration, shear vane, point load, permeability, pressure meter and geophysical tests. Tests on selected core samples may include index, shear strength, consolidation or permeability tests. Where symbols are used to indicate test types, these should be defined in the key.

7) Value

Where appropriate, the value obtained in the various tests conducted can be shown in this column. The nature of the value and the units in which it is quoted must be apparent from the manner in which it is recorded or the definitions given in the key. For example standard penetration test blow counts may be recorded in this column following the symbol N = with the appropriate definition in the key indicating that the number following N = indicates the number of blows per 300 mm advance in a Standard Penetration Test.

8) Depth

This column records depth to a definite scale. All other records on the borehole log should be referenced to this scale according to the depth in the borehole at which the data or description applies.

9) Water Rest Level

The level at which the water comes to rest in the borehole and the date at which this level is reached must be recorded on the log sheet in the test and value columns.

10) Description

This column is used for recording the core log in accordance with the proposals in this paper. The proposed borehole log sheet can be used in the field as a field sheet or alternatively, specially constructed field sheets can be used from which the final log is completed in the office.

11) Core Handling, Logging & Storage Techniques

It is not the object of this section to prescribe standard methods for handling, logging and storage of core, but to provide a number of useful hints which make core logging easier, more accurate and consistent. It is assumed that the core has been obtained with due care and in accordance with current good practice. Most of the points mentioned under 1 and 2 below are the responsibility of the drilling contractor but the core logger must be aware of these requirements in order to ensure that they are met.

12) Extraction & Protection of Borehole Bore

Core drilling is an expensive and highly specialized operation aimed at the recovery of a core which is as complete and undisturbed as possible. It is therefore of utmost importance that great care be taken not only when drilling but also when extracting the core from the barrel to avoid the further breaking up and loss of material. Extraction under steady, carefully applied pressure or the use of split inner tubes is to be preferred. Hammering or jetting of the core barrel should not be allowed under any circumstances. Weathered cores or cores susceptible to weathering should be wrapped in thin plastic tubing, tied at either end to retain moisture conditions.

Cores of slaking material must not be exposed to the sun but foil-wrapped and waxed as soon as possible after recovery (within an hour). Logging should be done before waxing, if possible, or otherwise as soon as possible thereafter. Wax should be removed without heat and after logging, cores must be re-waxed.

13) Arrangement & Labelling of Core in Core Boxes

Core boxes should be of light but robust construction and of such a size that they can be handled with ease (maximum size recommended is 1,5 x 0,5 m). Wooden boxes are recommended. Boxes should be made to hold the particular size of core tightly, in rows separated by wooden slats. The lid of the core box may have a foam rubber lining to keep the core in position during transportation.

Core boxes should be clearly identified by painting the project number, site name, borehole number, core box number, top and bottom depths of core contained and the drilling contractor's name on the outside and inside of the lid as well as on at least one side of the core box.

Core must be laid out in the core box to read in book fashion that is with the shallowest cores in the left side of the top row next to the lid hinge and the next row of core starting again with its shallowest depth in the left side and deepening towards the right.

At the beginning and end of every core run, a wooden block of appropriate dimensions should be placed. On these blocks, and if possible also on the core, the direction of drilling and the depth must be written in well-spaced figures with a size of at least 20 mm. The marking of depths on the core box is not recommended.

Core loss should be indicated by placing a wooden block, with length equal to that of the loss, in the appropriate position and by writing the depths at both ends of the block. Blocks indicating core loss are often painted red. Where core samples are removed for laboratory testing, yellow blocks equal in length to the core removed, should be instituted in the box.

Before logging or photographing is undertaken, it is advisable to make sure that the core is properly packed and marked in a core box. It is usually necessary to turn cores around in order to orientate according to a known marker feature such as bedding, a major joint set and to fit pieces of core together in order to measure core recovery etc. At this stage it may be necessary to rewrite depths on the core or to add further depth marks.

14) Core Logging

Only persons trained and experienced in engineering geology or geotechnical engineering should be allowed to log borehole core. It is recommended that the method of description as presented in this paper be adopted.

Equipment that is considered essential for the logging of rock cores includes the drillers log, paper, pencil, metric tape, compass, clinorule, water, brush or cloth, knife, geological pick and magnifying glass. A labourer to assist in the moving of core boxes can be most helpful.

Useful additional equipment includes pre-printed logging forms, clip-board, geological compass, clinometer, annular protractor to fit core, orientation box, and insecticide type garden spray for wetting cores, table or stand for core box, point load apparatus, camera and accessories, and colour chart.

The best place to log core is at the borehole position which avoids unnecessary handling and disturbance of the core. The best time to log is as shortly after the core is removed from the core barrel as is possible, due to the rapid deterioration of cores (especially sedimentary rocks) and core boxes.

It is preferable that the driller be present while logging, in order to draw on his intimate knowledge of drilling and rock conditions and to obtain drilling information required on the core log. The following comments apply to the filling in of the log sheet:

- Drilling method and size: This information is obtained from the driller's log.
- Core recovery, RQD and fracture frequency: These measurements are normally carried out after the core has been properly arranged and before pieces are removed for laboratory testing. A 3 m retractable steel tape is a most useful tool and it is advisable to record information on a special sheet with space for calculations and the entering of percentages. Fracture frequency is measured by counting all fractures intersecting an imaginary line drawn along the top of the core.
- Color: Wetting of the core is best achieved by means of a garden insecticide type spray, filled with water. Otherwise a bucket with water and a soft brush or a cloth can be used.

- Weathering and fabric: A magnifying glass is useful. (v) Fracture spacing: The average spacing of all fractures intersecting an imaginary line drawn along the top of a core is determined.
- Hardness can be determined by using a knife (1-3 MPa), geological pick (3-25 MPa) and a portable point load apparatus (> 25 MPa).

IV. CONCLUSION

In this paper the rock quality designation, RQD has proved useful in logging rock core. The results of RQD in this paper have shown that the qualities of rock masses range from very bad to very good quality in a continuous and progressive manner, which gives a better representation of the actual quality of rock masses. The use of RQD lowers operating costs by simply employing simple tools to assess the quality of the rock masses.

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