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The Usefulness of Rock Quality Designation (RQD) in Determining Strength of the Rock

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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. This paper investigates the usefulness of rock quality designation (RQD) on determination of the rock mass strength. 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 done on rock mass in Nyarukunguru Gold Mines in Musoma, Tanzania gave different results ranging from very poor to excellent rock. When properly carried out, RQD forms a basic element in most used rock mass classification systems in engineering geology and geotechnical engineering.

Keywords:- RQD, borehore, rock mass strength

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. Hoek& 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. In addition, the RQD may be affected by the rock strength and core size.

Other neglected influence factors include water conditions, and joints aperture, alteration and roughness. Although these limitations have been addressed in rock mass classifications, such as the Rock Mass Rating (RMR; Bieniawski 1973, 1976, 1979), the Norwegian Geotechnical Institute's Q system (Barton et al. 1974), and the cumulative core index (Sen, 1990), the RQD is still used on its own, without correction, in many geotechnical engineering applications (Kulhawy& Goodman, 1980). Another significant limitation of the RQD definition is its dependency on the selected threshold length of unbroken rocks (Terzaghi 1965; Priest & Hudson 1976; Harrison 1999; Hack 2002; Choi & Park 2004; Chen et al. 2005). This signifies that the RQD value would typically vary with different threshold length for the same core.

In practice, a familiar observation associated with this drawback is that the RQD values tend to be either high or low (often above 70% or below 10 to 20 %) in most rock engineering projects. Some values (e.g., between 40% and 60%) are less frequently encountered, due to the customarily and universally adopted, but very arbitrarily selected threshold value of 10 cm (for NX cores) in the assessment of RQD (Harrison 1999). This phenomenon can be illustrated using the example with fictive cores shown in Figure 1; this aspect is further discussed below. To obtain a wider range of RQD values, Harrison (1999) proposed a technique for determining an optimal threshold length. However, this approach is only appropriate for a particular rock mass. Besides, this technique requires the determination of the minimum and maximum values of discontinuity frequency in the rock mass, which generally means that the original RQD's simplicity is lost. In this paper, the application of rock quality designation (RQD) for the determination of rock mass quality is emphasized so as to encourage the engineering community to show great interest in its use.

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 – Q_{TBM} 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.

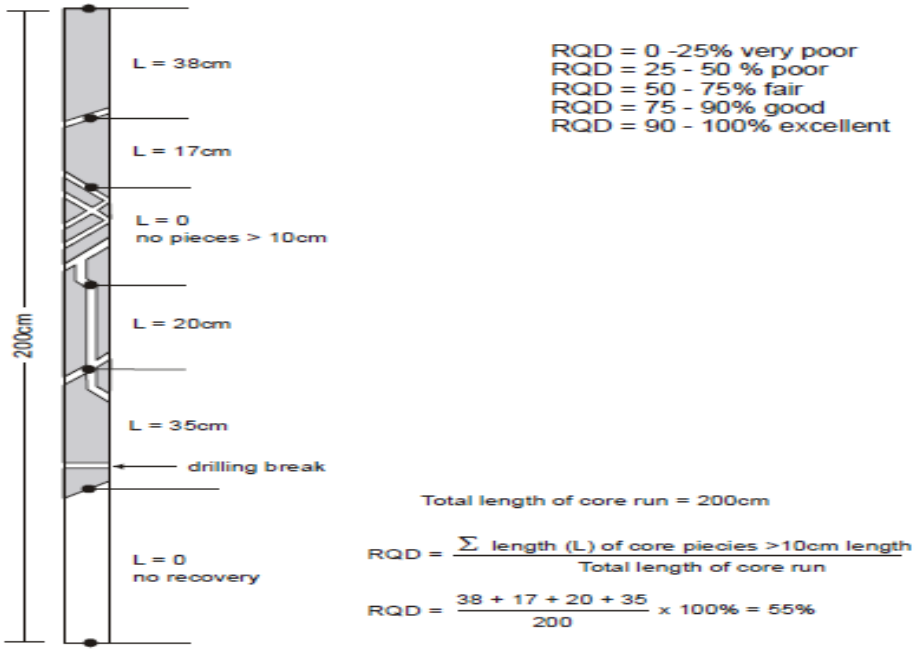

Figure 1: Procedure for measurement and calculation of *RQD* (Deere, 1989).

Table 1: RQD classification index

RQD	Rock mass quality
<25%	very poor
25-50%	Poor
50-75%	Fair
75-90%	Good
90-100%	Excellent

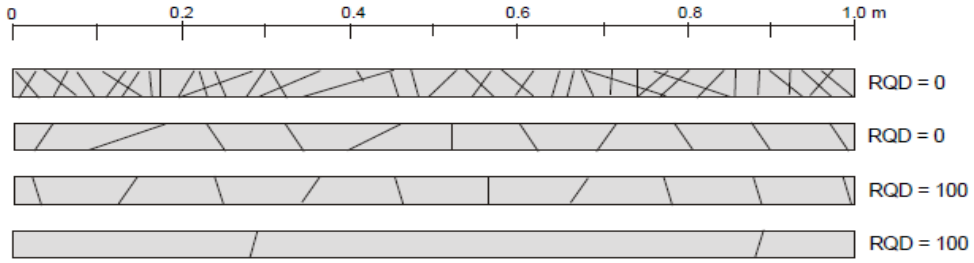

Figure 2: RQD values for various joint densities along drill cores (Deere, 1989).

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.

~~To overcome these limitations the application of RQDc may be employed. The RQDc…~~

STUDY AREA

The study area was NYAKUNGURU area which is 2-3 kilometers west of GOKONA pit in the Hamlet of Nyamichele. The project was located within Musoma Mara Nyanzian Greenstone Belt, which contains Nyabigena, Gokona and Nyabrama Gold mines located in North Mara mineral distinct (approx. 8 Moz Au) in Tanzania. Nyakunguru area includes plagioclase-Quartz porphyritic, spherulitic, breccia textured and flow banded rhyolitic rocks interlayered with minor amounts of proximal volcanogenic and epiclastic sediments. Areas are dominated by massive, flow-banded and breccia textured rhyolite are mapped as Magena member (Ana), while areas dominated by spherulitic rhyolite are mapped as Nyarwana Member (Anr).

IV. MATERIALS AND METHODS

The field equipment used include Hand lens, Compass, Global positioning system (GPS) device, Geological hammer, Magnetic pencil, Scale ruler (1:5000), Back packs, Field note book, Core trays, Sample bags, Marker pens, Protractor and Colored. The ROCKS used in this project are from DIAMOND DRILL (DD) hole with ID GKRCD-0345. The method used in this project is Diamond drill method (DD) in which the length of drilled core is recovered and arranged well in core tray for further investigation/ analysis.

RESULTS AND OBSERVATION

The measuring of RQD was done at core shed (laboratory) of exploration department of NORTH MARA AFRICA BARRICK GOLD (ABG) and the results were as analysed in the table below.

Table 2: RQD Results from Nyarukunguru Gold Mines

HOLE ID GKRSD-0345	DEPTH FROM (METRES)	DEPTH TO (METRES)	L total core run (D)	L sum of >100 mm (E)	RQD=E/D*100	ROCK MASS QUALITY
NYAKUNGURU	40	40.5	0.5	0.5	100.0	EXCELLENCE
	40.5	43.5	3	2.25	75.0	GOOD
	43.5	46.5	3	2.8	93.3	EXCELLENCE
	46.5	48	1.5	1.19	79.3	GOOD
	48	49.5	1.5	1.2	80.0	GOOD
	49.5	50.8	1.3	0.7	53.8	FAIR
	50.8	51.3	0.3	0.31	103.3	EXCELLENCE
	51.3	53.3	2	1.9	95.0	EXCELLENCE
	53.3	56.3	3	3	100.0	EXCELLENCE
	56.3	59.3	3	3	100.0	EXCELLENCE
	59.3	62.3	3	2.92	97.3	EXCELLENCE
	62.3	65.3	3	3	100.0	EXCELLENCE
	65.3	68.3	3	3	100.0	EXCELLENCE
	68.3	71.3	3	3	100.0	EXCELLENCE
	71.3	74.3	3	3	100.0	EXCELLENCE
	74.3	77.3	3	3	100.0	EXCELLENCE
	77.3	80.3	3	3	100.0	EXCELLENCE
	80.3	83.3	3	2.97	99.0	EXCELLENCE
	83.3	85.3	2.7	0.53	19.6	VERY POOR
	85.6	86.3	0.8	0.36	45.0	POOR
	86.3	89.3	3	1.38	46.0	POOR
	89.3	92.3	3	2.93	97.7	EXCELLENCE
	92.3	95.3	3	2.9	96.7	EXCELLENCE
	95.3	98.5	3	3	100.0	EXCELLENCE
	98.3	101.3	3	1.31	43.7	POOR
	101.3	103.7	2.4	1.41	58.8	FAIR
	103.7	106.8	3.1	1.92	61.9	FAIR
	106.8	109.9	3.1	1.98	63.9	FAIR
	109.9	113	3.1	1.64	52.9	FAIR
	113	116.3	3.1	1.82	58.7	FAIR
	116.1	119.3	3	2.36	78.7	GOOD

119.1	122.3	3.1	1.78	57.4	FAIR
122.2	123.3	1.7	1.27	74.7	FAIR
123.9	125.3	1.4	1.12	80.0	GOOD
125.3	127.3	1.9	1.25	65.8	FAIR
127.2	128.3	0.9	0.58	64.4	FAIR
128.3	129.9	1.6	1.5	93.8	EXCELLENCE
129.9	132.9	3	1.87	62.3	FAIR
132.9	134.3	1.4	1.1	78.6	GOOD
134.3	136.9	2.6	1.46	56.2	FAIR
136.9	139.7	3	2.04	68.0	FAIR
139.7	140.4	0.7	0.13	18.6	VERY POOR
140.4	143.3	2.9	2.45	84.5	GOOD
143.3	145	1.7	0.83	48.8	POOR
145	147.9	2.9	2.05	70.7	FAIR
147.9	149.5	1.6	1.4	87.5	GOOD
149.5	152.5	3	2.47	82.3	GOOD
152.5	155.5	3	2.32	77.3	GOOD
155.5	158.5	3	2.77	92.3	EXCELLENCE
158.5	161.5	3	2.89	96.3	EXCELLENCE
161.5	164.5	3	2.1	70.0	FAIR
164.5	167.5	3	0.77	25.7	POOR
167.5	170.5	3	0.73	24.3	VERY POOR
170.5	173.5	3	1.5	50.0	FAIR
173.5	176.5	3	0.64	21.3	VERY POOR
176.5	179.5	3	2.07	69.0	FAIR
179.5	182.5	3	2.78	92.7	EXCELLENCE
182.5	185.5	3	2.41	80.3	GOOD
185.5	188.5	3	1.82	60.7	FAIR
188.5	191.3	3	2.43	81.0	GOOD
191.5	194.5	3	1.95	65.0	FAIR
194.5	197.5	3	2.47	82.3	GOOD
197.5	200.5	3	3	100.0	EXCELLENCE
200.5	203.1	2.6	1.17	45.0	POOR
203.1	203.3	0.2	0.2	100.0	EXCELLENCE
203.3	206.3	3	2.66	88.7	GOOD
206.3	209.4	3.1	2.3	74.2	FAIR
209.4	212.6	2.9	1.9	65.5	FAIR
212.6	213.6	0.3	0.1	33.3	POOR
213.6	214.9	1	0.12	12.0	VERY POOR
214.9	215.8	0.9	0.1	11.1	VERY POOR
215.8	218.5	2.7	0.65	24.1	VERY POOR
218.5	220	1.5	1.9	126.7	EXCELLENCE
220	222.6	2.6	1.22	46.9	POOR
222.6	224.6	2	2.2	110.0	EXCELLENCE
224.6	227.6	3	1.12	37.3	POOR
227.6	230.3	2.9	2.6	89.7	GOOD
230.3	233.2	2.7	1.47	54.4	FAIR
233.2	236.2	3.1	0.65	21.0	VERY POOR
236.2	239.2	3.1	2.08	67.1	FAIR
239.2	242.4	3.1	1.93	62.3	FAIR
242.4	245.5	3.1	1.94	62.6	FAIR
245.5	248.5	3	2.5	83.3	GOOD
248.5	251.5	3	2.88	96.0	EXCELLENCE
251.5	254.5	3	2.67	89.0	GOOD
254.5	257.5	3	3	100.0	EXCELLENCE
257.5	260.5	3	3	100.0	EXCELLENCE
260.5	263.5	3	2.97	99.0	EXCELLENCE
263.5	266.5	3	2.75	91.7	EXCELLENCE
266.5	269.5	3	2.92	97.3	EXCELLENCE

269.5	272.5	3	2.85	95.0	EXCELLENCE
272.5	275.5	3	2.7	90.0	EXCELLENCE
275.5	278.5	3	2.57	85.7	GOOD
278.5	281.5	3	2.52	84.0	GOOD
281.5	284.5	3	2.9	96.7	EXCELLENCE
284.5	287.5	3	2.7	90.0	EXCELLENCE
287.5	290.5	3	2.55	85.0	GOOD
290.5	293.5	3	2.7	90.0	EXCELLENCE
293.5	296.5	3	2.55	85.0	GOOD
296.5	299.5	2.9	2.84	97.9	EXCELLENCE
299.5	302.5	3.1	2.99	96.5	EXCELLENCE
302.5	305.5	3	2.83	94.3	EXCELLENCE
305.5	308.5	3	2.84	94.7	EXCELLENCE
308.5	311.5	3	2.92	97.3	EXCELLENCE
311.5	314.5	3	2.45	81.7	GOOD

V. DISCUSSION

From the results above, the RQD of the rock in GKRCD-0345 hole is explained as follows.

a) From 40.00m to 83.30m, the RQD of the rock is very excellent (which is the phonolite cover).

b) From 83.30m to 85.30m, the RQD of the rock is very poor because this is the weathered part of the basement which is the contact between phonolite and basementrock.

c) From 85.30m to 89.30m, the RQD of the rock is poor which comprise the upper part of the basement that was exposed to weathering before the formation of phonolite.

d) From 89.30m to 242.40m, the RQD of the rock is between good and fair.

e) From 242.40m to 314.5m, the RQD of the rock is very excellent. This due to the fact that the area was under high shear and it is between the Utimbaru and Nyarwana fault hence high temperature and pressure was experienced in this area.

VI. 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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