THREE DİMENSİONAL MODELİNG OF ROCK QUALİTY DESİGNATİON (RQD) İN A LİMESTONE QUARRY (TRABZON, TURKEY)

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ABSTRACT

Rock slope stability analysis is performed to design safe and functional slopes in open pit mines. A proper design of slopes leads to improve slope stability and safety and correspondingly reduces costs, extends the life of mines and decreases the stripping ratio. Rock quality designation (RQD) index measures the percentage of rock within a borehole. RQD is used as a standard parameter in borehole logging. Its simplicity allows designers to decide a proper and stable design in open pit mines.

This study includes borehole analysis, discontinuity measurements and observations of Taşönü (Trabzon) limestone quarry (Northeast, Turkey). In the study area, 3 large-scale planar failures occurred between 2005 and 2007 years. After these failures, new tension joints formed behind the failure zone. Clay layer having up to 110 centimeter thickness has been held responsible for these failures. The purpose of this study is to analyze rock classification system by RQD. To achieve this purpose, five boreholes were drilled behind the failure zone. Total length of boreholes was 193 meters. Boreholes formation roughly includes limestone and volcanic breccia. RQD values are 20.40, 26.13, 18.57, 50.09 and 36.72 in percentage for limestone formation in the boreholes. Beside this, RQD values found as 50.58, 44.15, 42.73, 40.13 and 34.87 in percentage for total lengths in the boreholes.

This study evaluated the boreholes and modeling RQD values in the limestone quarry, analyzing all boreholes and recording the length of discontinued rock specimens. Borehole data including RQD values and formation and digital terrain model (DTM) was created in Gemcom Surpac 6.2 package program with three dimensional modelling. RQD values for modeling classified as very poor, poor, fair, good and excellent like described in the literature. The result includes boreholes and the RQD distribution models through the limestone quarry. This study shows the significance of boreholes evaluation and RQD modeling to analyses and evaluation of rock failure and potential future failures.

Keywords: Borehole evaluation, RQD, slope stability, 3D modeling

Introduction

Taşönü (Araklı-Trabzon) limestone quarry has been exposed to three large-scale planar failures between 2005 and 2007 years. It is figured out that the failures occurred on clay layers. The factors such as high slope angle and bench height in the quarry, uncontrolled blasting operations and intense rainfall have been reported to cause failures by studies carried out between 2004 and 2015 years (Erçıkdı et al., 2006). After these failures, raw limestone supply from the quarry came to a standstill. Therefore, 5 different exploratory drillings were bored north side of the landslide area. For the purpose of evaluation of boreholes, detailed RQD calculation has been put into effect.

The rock quality designation, RQD, is a rock mass classification system. RQD was firstly proposed by Deere (1964) as an index of evaluating rock quality quantitatively. After this, RQD has become a topic of various assessments (Deere et al. 1967; Cording and Deere 1972; Merritt 1972; Deere 1989). RQD is a core recovery percentage calculated by measuring rock core pieces over 100 mm in length (optimal in NX cores).

This study evaluated the boreholes and modeling RQD values in the limestone quarry, analyzing all boreholes and recording the length of discontinued rock specimens. Borehole data including RQD values and formation and digital terrain model (DTM) was created in Gemcom Surpac 6.2 package program with three dimensional modelling. RQD values for modeling classified as very poor, poor, fair, good and excellent like described in the literature. The result includes boreholes and the RQD distribution models through the limestone quarry.

Site Description

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The Araklı-Taşönü limestone quarry is placed approximately 40 km from Trabzon city in northeast of Turkey (Figure 1) (Aliyazıcıoğlu et al, 2015). The quarry is managed by Aşkale Cement Factory and utilizes the limestone-rich Kirechane formation. Kirechane formation includes different limestone formations such as biomicritic limestone, macro fossil void limestone and sandy-clayey limestone (Karaman vd., 2013).

The quarry has experienced three separate planar failures, which occurred between 2005 and 2006 (Figure 2). It has been indicated that landslides occured on a clay layer which is up to 100 cm thick and 20-30 degree inclined (Ceryan, 2009).

Figure 1: Location of the Araklı-Taşönü limestone quarry (Aliyazıcıoğlu vd., 2015)

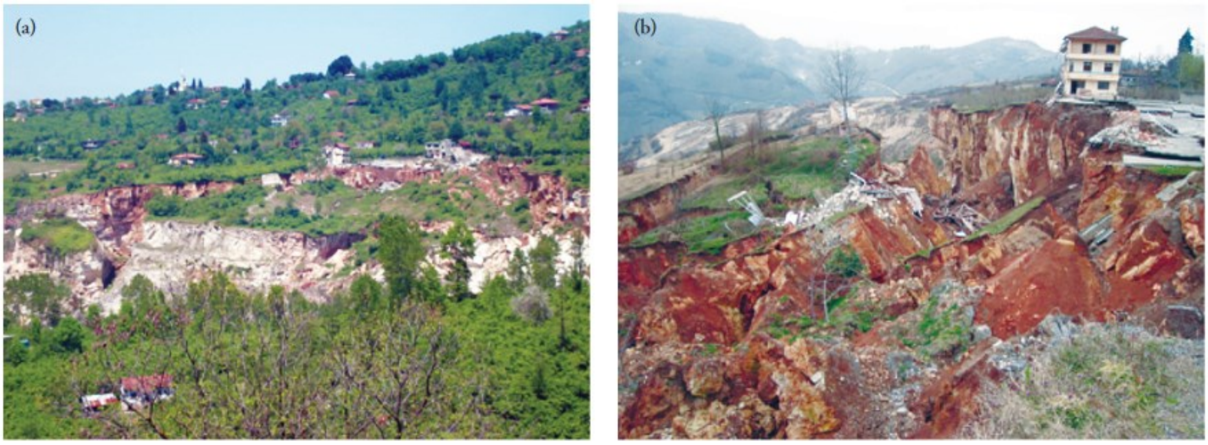
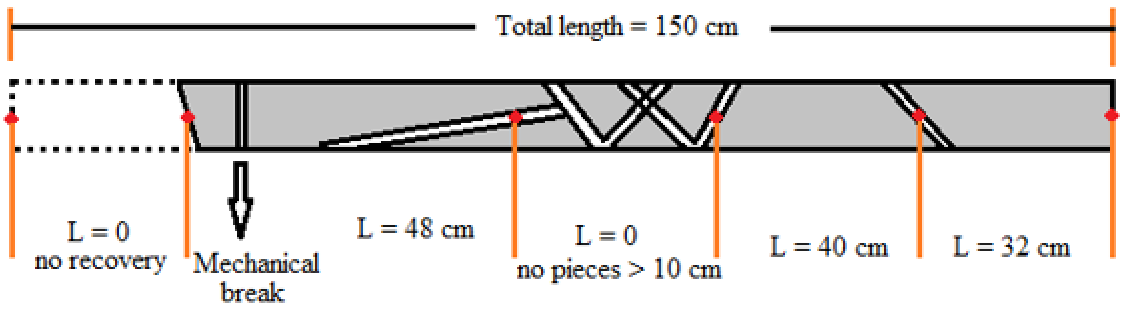


Figure 2: A general view (a) and a closer view (b) of failure region (Karaman vd., 2013)

Rqd Calculation

Rock quality designation (RQD) is the calculation of the degree of discontinuities or fractures in a rock mass. It is calculated by measuring sound rock pieces in a borehole and dividing the total sound rock pieces to total core length (Figure 3). High quality rock is described having more than 75 % in RQD, low quality as less than 50 % (Table 1).

RQD is the borehole core recovery percentage including only pieces of solid cores which are equal or longer than 10 cm in length. It is measured along the centerline of the core. In this respect, rock pieces not hard or soft and soil parts is not included. RQD was originally implemented to use with core diameters of 54.7 mm (NX core size)



Total length of core run = 150 cm

$$RQD = \frac{\sum length\ (L) of\ core\ pieces > 10\ cm}{Total\ length\ of\ core\ run}$$

$$RQD = \frac{32 + 40 + 48}{150} x\ 100\ \% = 80\ \%$$

RQD = 0 – 25% very poor
RQD = 25 – 50% poor
RQD = 50 – 75% fair
RQD = 75 – 90% good
RQD = 90 – 100% excellent

Figure 3: Procedure for measurement and calculation of RQD (after Deere, 1989)

Table 1: Rock quality designation (RQD) classification index

RQD	Rock Mass Quality
< 25 %	Very poor
25 – 50 %	Poor
50 – 75 %	Fair
75 – 90 %	Good
90 – 100 %	Excellent

In the limestone quarry, 5 different boreholes drilled and total length of boreholes was 193 meters (Figure 4) (Aliyazıcıoğlu vd., 2015). Boreholes formation roughly includes limestone and volcanic breccia (Figure 5). All boreholes' core boxes are measured one by one (max. 1.2 m) and calculated their RQD values, values of borehole number 1 is given in Table 2 as an example. RQD values are 20.40, 26.13, 18.57, 50.09 and 36.72 in percentage for limestone formation in the boreholes. Beside this, RQD values found as 50.58, 44.15, 42.73, 40.13 and 34.87 in percentage for total lengths in the boreholes.

Figure 4: Core boxes belonging to borehole number 4 (Aliyazıcıoğlu vd., 2015)

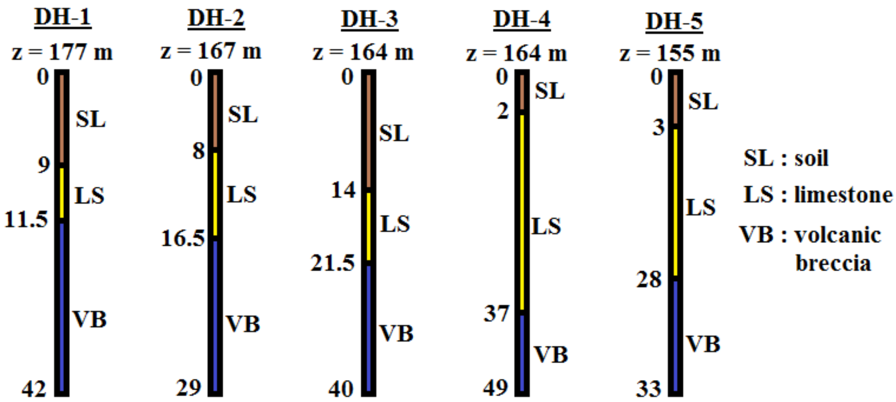


Figure 5: All boreholes with formation and depth values

Borehole No. 1			
From (m)	To (m)	RQD (%)	Rock Mass Quality
0.00	8.00	-	-
8.00	9.20	10	Very poor
9.20	10.50	31	Poor
10.50	11.70	10	Very poor
11.70	13.00	20	Very poor
13.00	14.30	20	Very poor
14.30	15.50	35	Poor
15.50	16.70	60	Fair
16.70	18.00	60	Fair
18.00	19.30	54	Fair
19.30	20.50	95	Excellent
20.50	21.80	28	Poor

21.80	23.00	62	Fair
23.00	24.00	100	Excellent
24.00	25.20	87	Good
25.20	26.40	58	Fair
26.40	27.60	65	Fair
27.60	28.70	96	Excellent
28.70	30.00	42	Poor
30.00	31.20	51	Fair
31.20	32.50	24	Very poor
32.50	33.70	48	Poor
33.70	34.80	85	Good
34.80	35.90	60	Fair
35.90	37.00	66	Fair
37.00	38.00	82	Good
38.00	39.00	75	Good
39.00	40.00	97	Excellent
40.00	41.00	62	Fair
41.00	42.00	86	Good

Table 2: Detailed core boxes RQD values for borehole number 1

Three Dimensional (3d) Modeling

Limestone quarry modeling has been made by using Geovia Surpac 6.2 package program (URL-1). The program is used as 3 dimensional (3D) modeling of topographic maps, modeling and visualization of core drilling and combining with surface model, applying geostatistical analysis by creating database, ore deposit modeling from drillings, block modeling and underground and open pit mine modeling (Aliyazıcıoğlu, 2011).

In this study, except from standard borehole modeling or geostatistical values, RQD values is modeled by using Surpac 6.2. Beside this, topographical digital terrain model (Figure 6) and potential failure zone is added to this model to analyze RQD values in 3 dimensional and understand the different RQD values by location and individually. Potential failure zone is released by Aliyazıcıoğlu et al. (2015) that three boreholes (3,4 and 5) includes sheared zone in core samples such that it could be a sign for a new failure in near future. Sheared zones has seen in 17, 34.5 and 24.5 meters in 3,4, and 5th boreholes respectively (Figure 7).

In the first approach, RQD classification index is used for the separation value of RQD modeling. Topsoil is not taken into effect as it has no hard rock pieces or not giving any RQD values. Additionally, volcanic breccia is not added to modeling as it proportionally gives higher RQD values (Figure 7).

Even though, RQD values can be modeled as a block model like modeling any type of orebody. In this study, only RQD classification of "very poor" is modeled to illustrate the possibility of three dimensional modeling of RQD values (Figure 8).

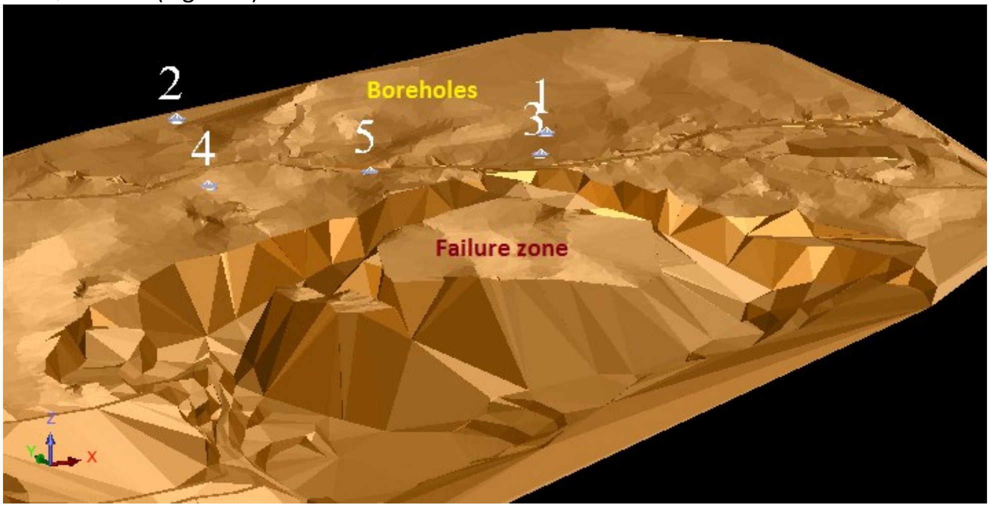


Figure 6: Limestone quarry digital terrain model (DTM) and location of boreholes

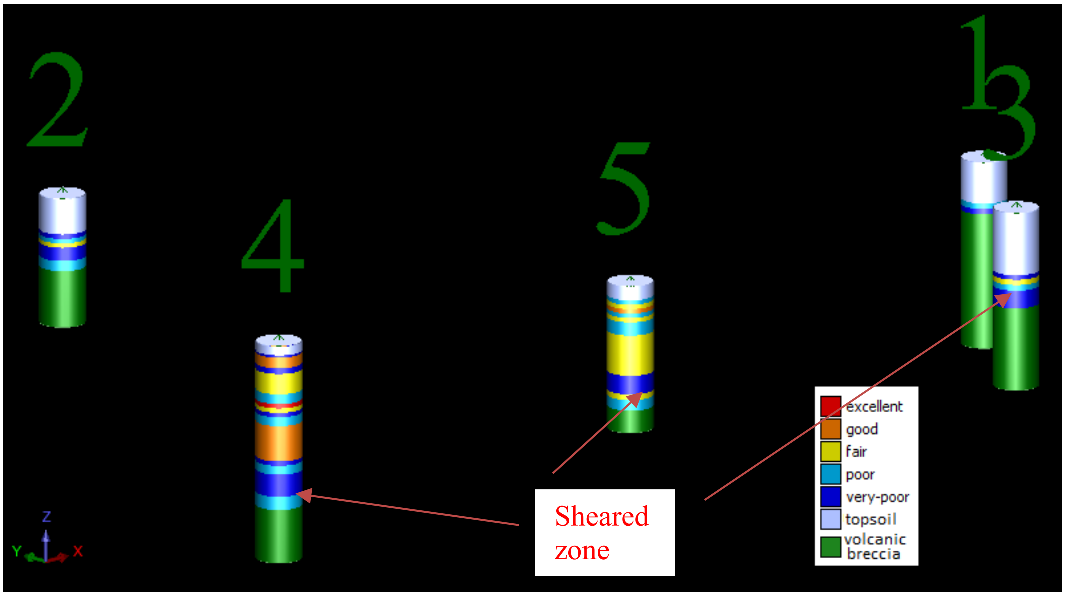


Figure 7: Boreholes with RQD values (differentiated by classification index)

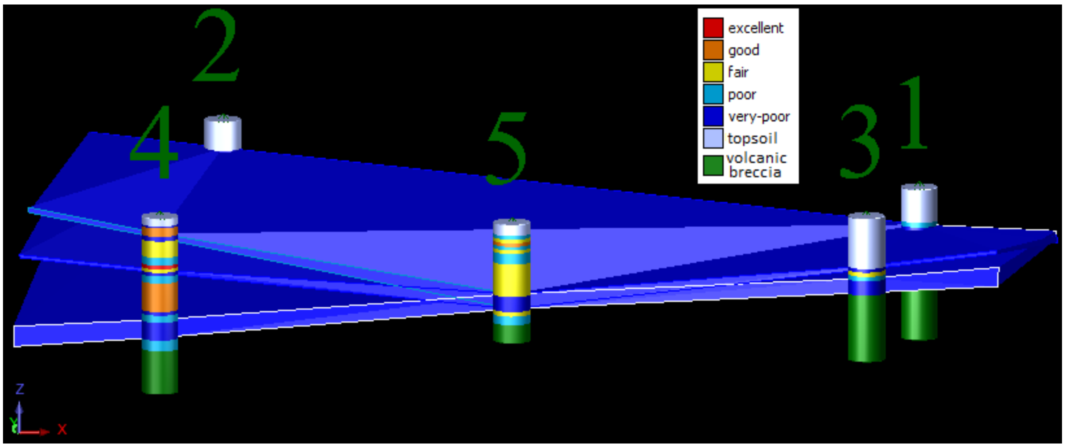


Figure 8: Block modeling of RQD classification of "very poor"

Result And Discussion

This study evaluated the boreholes and modeling RQD values in the limestone quarry, analyzing all boreholes and recording the length of discontinued rock specimens. Borehole data including RQD values and formation and digital terrain model (DTM) was created in Gemcom Surpac 6.2 package program with three dimensional modelling. RQD values for modeling classified as very poor, poor, fair, good and excellent like described in the literature.

RQD values are 20.40, 26.13, 18.57, 50.09 and 36.72 in percentage for limestone formation in the boreholes. Beside this, RQD values found as 50.58, 44.15, 42.73, 40.13 and 34.87 in percentage for total lengths in the boreholes.

After analyzing RQD models of boreholes, it is obvious that calculation of RQD along the borehole in total will give different classification index according to formation RQD values. Also, being more specific, it is important to see the true location of boreholes in 3D as limestone RQD changes from one core box to another one. According to RQD values, especially for 3rd ,4th , and 5th boreholes, the. values are "18.57% - very poor", "50.09% - fair" and "36.72 - poor" for limestone respectively. On the other hand, it is all "very poor" in the boreholes near to the sheared zone emphasized in modeling.

The result includes boreholes and the RQD distribution models through the limestone quarry. This study shows the significance of boreholes evaluation and RQD modeling to analyses and evaluation of rock failure and potential future failures. Thus, three dimensional modeling is seen to provide a significant contribution to slope stability assessment in order to see a larger failure surface areas and to identify risky areas healthier.

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