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Examining the relation between rock mass cuttability index and rock drilling properties

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ABSTRACT

Drilling rate is a substantial index value in drilling and excavation operations at mining. It is not only a help in determining physical and mechanical features of rocks, but also delivers strong estimations about instantaneous cutting rates. By this way, work durations to be finished on time, proper machine/equipment selection and efficient excavation works can be achieved. In this study, physical and mechanical properties of surrounding rocks and ore zones are determined by investigations carried out on specimens taken from an underground ore mine. Later, relationships among rock mass classifications, drillability rates, cuttability, and abrasivity have been investigated using multi regression analysis. As a result, equations having high regression rates have been found out among instantaneous cutting rates and geomechanical properties of rocks. Moreover, excavation machine selection for the study area has been made at the best possible interval.

1. Introduction

In order to yield a high efficiency of mechanical excavation/cutting machines (hydraulic breakers, roadheaders, TBMs, drilling rigs etc.) working in underground mines or open pits, they have to be selected considering the features of the rocks to be cut. Improper machine selection and faulty determination of cutting bit consumption would lead to a rise of excavation/cutting costs resulting in inefficient operation of machines having high initial investment costs.

Prior to excavation, type of excavation machine and cutting bit to be used, and performance of excavation machine have to be determined. In order to achieve this aim, index experiments have to be performed in laboratory to gather information on rock's drillability and cuttability. Many researchers highlighted that physical, mechanical and rock mass properties of a rock should firstly to be determined while finding out rock's drillability and cuttability. Some formulas pointing out drilling and cutting performances resulting from in situ and laboratory experiments such as schmidt hammer hardness test, point load strength index test, shore hardness test, drilling rate index (DRI), cone penetration test are widespread used by many researchers (Fowell and McFeat–Smith, 1976; Aleman, 1981; Howarth et al., 1986; Kovscek et al., 1988; Karpuz et al., 1990; Nilsen and Ozdemir, 1993; Akcin et al., 1994; Bilgin et al., 1996; Thuro, 1996; Huang and Wang, 1997; Kahraman, 1999; Kahraman et al., 2003; Tanaino, 2005; Akun and Karpuz, 2005; Peila and Pelizza, 2009; Adebayo et al., 2010; Yarali and Kahraman, 2011; Deliormanli, 2012; Dahl et al, 2012; Yarali and Soyer, 2013; Ceryan, 2014; Karaman et al., 2015; Fattah and Lashin, 2016, Ozfirat et al., 2016).

By using advanced testing methods it is nowadays possible to determine the drillability and abrasivity of a rock. The most preferred ones of these tests are the drilling rate index (DRI) known as drillability index and the Cerchar abrasivity index (CAI) known as abrasivity index tests. The Cerchar abrasivity index is the most used testing method in depicting abrasivity of rocks. Abrasivity is one of the most important parameters affecting drilling rate and especially abrasion of drill bit.

The abrasion of drilling/cutting bits is a dominant factor in engineering surveys and rock excavation costs at mining and tunneling works (Plinninger, 2008). The drillability of a rock depends on the rock itself, on the drilling equipment and working style. Detailed parameters on rock's drillability are given in Fig. 1.

In this study, the raw data set obtained from the experimental works is used to investigate the relationships among drilling rate index (DRI), rock mass cutting index (RMCI) and some strength properties of rocks such as uniaxial compressive strength (UCS),

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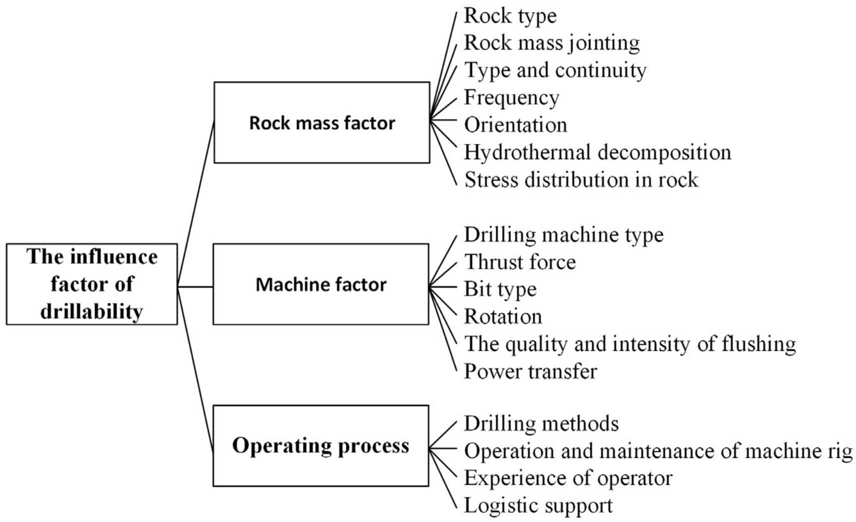

Fig. 1. The influence factor of drillability.

Brazilian tensile strength (BTS), Schmidt hardness (SH) and instantaneous cutting rate (ICR), unit volume over weight (UW), rock mass rating (RMR) and Cerchar abrasiveness index (CAI). At the end of the study, equations are suggested considering correlation coefficients among DRI, RMCI values and rock features mentioned above. Moreover, the most suitable excavation interval of the excavation machine has been found out as between 15 m^3/h and 46 m^3/h.

2. Materials and methods

2.1. Test procedure

In the study, properties of the specimens given below are determined. These properties are unit weight, cerchar abrasivity index, drilling rate index, uniaxial compressive strength, brazilian tensile strength and schmidt hardness. Also, RQD (Rock Quality Designation) and RMR values are obtained from drilling and field studies. Instantaneous cutting ratio (m^3/h) (ICR) and rock mass cutting index (RMCI) are calculated according to test data obtained. During calculation of ICR and RMCI, equations given below are used.

$$\mathrm{RMCI} = \mathrm{UCS} \times (\mathrm{RQD}/100)^{2/3} \quad (1)$$
(Bilgin et al., 2004)

$$\mathrm{ICR} = 719/(\mathrm{UCS})^{0.78} \quad (2)$$
(Gehring, 1989)

$$\mathrm{ICR} = 1739/(\mathrm{UCS})^{1.13} \quad (3)$$
(Gehring, 1989)

$$\mathrm{ICR} = 75.7 - 14.3\, ln\, (\mathrm{UCS}) \quad (4)$$
(Thuro and Plinninger, 1998)

$$\mathrm{ICR} = 0.28 \times \mathrm{P} \times (0.974)^{\mathrm{RMCI}} \quad (5)$$
(Bilgin et al., 2004)

where UCS is uniaxial compressive strength of rock (MPa), ICR is instantaneous cutting ratio (m^3/h), RMCI is rock mass cutting index and RQD is rock quality designation.

2.2. Uniaxial compressive strength (UCS)

Uniaxial compression tests are performed on trimmed cylindrical core samples, which are prepared according to ISRM, 2015 standarts and have a length-to-diameter ratio of 2.0–2.5. The samples are loaded with a loading rate of 150 kg/s. The tests are repeated for each rock sample several times and the average is recorded as the UCS value.

2.3. Brazilian tensile strength (BTS)

Brazilian tensile strength tests are conducted on core samples having a thickness to diameter ratio of 0.5. Again, a loading rate of 150 kg/s is applied here also. The tests are repeated for each rock type and the average is recorded as the tensile strength value.

2.4. Cerchar Abrasivity Index (CAI)

The Cerchar Abrasivity Test is a method to determine an index called Cerchar Abrasivity Index for the rock's abrasivity. A rock specimen, disc-shaped or irregular, is firmly held in the test apparatus. The stylus is lowered carefully onto the rock surface. While under a normal force of 70 N, the stylus is moved a total distance of 10.0 mm across the rock. The wear surface of the stylus tip is measured under a microscope to an accuracy of 0.01 mm. The CAI is

Fig. 2. Cerchar apparatus and sample.