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Investigation into engineering parameters of marls from Seydoon dam in Iran

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ABSTRACT

The quality of designed structures embedded in rocks is strongly related to rock strength parameters of intact rock. Measuring different parameters from tests could be very expensive in designing phase of projects. Estimating some parameters from other ones can reduce costs and time of project procedure. In this paper, the relationships between static and dynamic parameters of marls are studied by using the single and multiple linear regressions. For this purpose, several marl core samples from Seydoon region, Khoozestan Province in Iran are collected and tested. Some equations with sufficient correlation have been obtained to predict the engineering parameters of marls, especially the uniaxial compressive strength (UCS).

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1. Introduction

Rock properties and their way of description have become interesting subjects for many years. Mechanical properties of rocks are important because they are major inputs for many geotechnical analyses. On one hand, the intact rock parameters, such as uniaxial compressive strength (UCS) and elasticity modulus (E), have been always considered specifically due to their applications in geotechnical design, rock classification and rock failure criteria (Dehghan et al., 2010). On the other hand, geomechanical parameters of discontinuities basically control the rock mass behaviors. These discontinuities along with weathering can affect rock mechanical parameters dramatically. Thus it should be considered that mechanical properties of specific rock type differ from one region to another.

It is usually difficult for rock mechanics engineers to directly obtain the specific design parameters of interest. For example, the procedure for measuring UCS has been standardized by both American Society for Testing and Materials (ASTM) and International Society for Rock Mechanics (ISRM) (Bieniawski and Bernede, 1979). In addition to its cost and time-consuming nature of this test, it requires well-prepared rock cores, which is often difficult or even impossible for weak rocks. Therefore, many researchers show interest to correlate simpler tests, such as destructive tests like point load and Brazilian tests and non-destructive ones like ultrasonic wave velocity, Schmidt hammer and index tests, as indirect alternative tests for estimating UCS and other strength parameters of rocks (Horsrud, 2001; Kahraman, 2001; Yasar and Erdogan, 2004; Chang et al., 2006; Çobanoğlu and Çelik, 2008; Yagiz, 2008; Diamantis et al., 2009; Moradian et al., 2010; Minaeian and Ahangari, 2011; Bruno et al., 2012; Azimian et al., 2013; Jahed Armaghani et al., 2014; Karaman et al., 2014; Kaya and Karaman, 2015; Madhubabu et al., 2016). Researches have shown that there are relations between densities, index properties, slake durability index, point load strength and Brazilian strength with mechanical properties of rocks. The relations were analyzed by various statistical methods such as single regression analysis, multiple regression analysis, fuzzy inference system and artificial neural networks (Karakus and Tutmez, 2005; Yılmaz and Yuksek, 2007; Tiryaki, 2008; Dehghan et al., 2010; Manouchehrian et al., 2012; Rabbani et al., 2012; Singh et al., 2012; Mishra and Basu, 2013; Liu et al., 2014; Kainthola et al., 2015; Momeni et al., 2015; Jahed Armaghani et al., 2016).

The rocks even with the same mineralogical composition have different properties due to geological historical events and

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tectonics of the region. Since the equations and curves for specific region may fail to apply for other regions caused by geological differences, some researchers started focusing on specific rock type properties for a specific zone (Yasar and Erdogan, 2004; Yagiz, 2010; Bruno et al., 2012; Azimian et al., 2013; Giambastiani, 2014; Li et al., 2014; Cheshomi et al., 2015; Madhubabu et al., 2016).

Some equations between different rock properties for carbonate or weak rocks are shown in Table 1. Because there are few researches about marls and extremely weak and weak rocks (0.25–25 MPa in UCS values according to ISRM (Brown, 1981)), several marl samples from Seydoon region dam site located in Khoozestan Province of Iran are studied in this paper.

2. Case study: Marls from Seydoon region

The Seydoon region formation was selected as a case study for this research. All rock samples were collected from this region, which is located in Khoozestan Province near Aala river in Iran (Fig. 1). The region is in faulted place of Zagros Mountains through Asmari and Pabede formations which are located in the range of 9 km of the river path. These formations contain marl, shale and limestone from Miocene and Oligocene-Eocene and divided the second and third geological periods. Fig. 2 shows the region of collected marls located between 50°10′–50°15′ geographical longitude and 31°10′–31°15′ geographical latitude lines. By drilling operation for geotechnical investigations of dam site in some wellbores, it is found that there is an aquifer at a depth of 36 m. Also investigations claimed that Pabedeh structure in this region consists of extremely weathered marls with less than 25% of rock quality designation (RQD) which is classified as completely weathered rock.

Several petrography tests have been done on the thin section samples to identify the mineral types of these marls (Fig. 3). A severe reaction with cold and diluted acid was observed. The main part of each thin section contains carbonate and clay minerals. All samples contain a large amount of clay (at least 25% of the total sample) and the majority of samples are made of marl, clay and limestone. In X-ray studies on thin sections, a significant amount of montmorillonite was observed in clay minerals of samples. This assemblage causes the rock to be weakened in the presence of water. Montmorillonite has a high swelling capacity due to hydration of its interlayer sodium. The hydration of cations presented in montmorillonite imparts a hydrophilic nature of the clay surface (Lagaly, 1994). The sodium cation can take up water which creates an interlayer spacing and causes cracks to be developed in rock structure.

3. Experimental studies

Thirty six marl samples obtained from different depths were collected during drilling of geotechnical investigation boreholes by core barrel to study different relations among various test parameters. Average porosity of samples was reported as approximately 20%. Several tests such as triaxial compression test, uniaxial compression test, index properties test, point load test, Brazilian tension test and ultrasonic test have been performed, and their results are listed in Table A1 in the Appendix.

Referring to Table A1, there is a significant decrease in the cohesion of rocks at the depth between 30 m and 40 m. During sampling, an aquifer was found at the depth between 30 m and 40 m. Decrease in the cohesion of rocks at this depth would result from washing effect by the aquifer.

3.1. Triaxial compression test

This kind of test is usually used to determine the strength parameters of intact rock like cohesion and angle of internal friction (Fig. 4). The samples from drilled cores are prepared by cutting them to a specified length so that the ratio of height/diameter of the samples is between 2 and 3. These tests have been done under different confining pressures.

3.2. Uniaxial compression test

The uniaxial compression test is used for estimating the compressive strength of rock samples under uniaxial loading. It can be done under either load- or strain-controlled condition. Depending on monitoring parameters during testing, several engineering properties of rocks can be obtained from this test.

All uniaxial compression tests on samples in this research were performed by MTS machine (Fig. 5). These samples have been collected from the depths of 10–60 m. Cylindrical samples were extracted from Seydoon region with 54 mm in diameter and 110–113 mm in length. Sample ends were polished and flattened to meet ISRM ±0.2 mm accuracy (Bieniawski and Bernede, 1979). Because marls were strongly weathered and weak against water and cutting blade, their cutting process were very critical and needed special care to success. Thus high-speed thin cutting blade was used for sample preparation in this study.

Basu et al. (2013) and Singh et al. (2016) studied different failure characteristics of granite, schist and sandstone samples under uniaxial compressive loading. They grouped them into six categories, i.e. axial splitting, shearing along a single plane, double

Table 1
Equations for different rock properties obtained in the literature.

No.	Equation	R^2	Sample type	Reference
1	$UCS = 7.3I_{s(50)}^{1.71}$	0.82	188 samples (limestone, sandstone and marls)	Tsiambaos and Sabatakakis (2004)
2	$V_P = 0.032UCS + 2.02$	0.8	13 samples of various carbonate rock types	Yasar and Erdogan (2004)
3	$UCS = 9.95V_P^{1.21}$	0.83	27 different rock samples containing marls and other carbonates	Kahraman (2001)
4	$UCS = 165.05\exp(-4.45/V_P)$	0.7	44 samples of limestone, 12 samples of sandstone and 8 samples of marl	Moradian and Behnia (2009)
5	$UCS = 0.026V_P - 20.207$	0.9	40 marl samples	Azimian et al. (2013)
6	$UCS = 56.939\ln I_{s(50)} - 1.6551$	0.92		
7	$UCS = 13.244I_{s(50)} + 0.13V_P - 16.987$	0.94		
8	$UCS = -11.813 - 2.572n + 23.665I_{s(50)} + 41.654\nu + 12.197\rho - 0.001V_P$	0.91	Almost weak and extremely weak carbonate rocks	Madhubabu et al. (2016)

Note: $I_{s(50)}$ is the point load index corrected to a sample diameter of 50 mm, V_P is the P-wave velocity, n is the porosity, ν is the Poisson's ratio, ρ is the density, and R^2 is the coefficient of determination.

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