Correlation between uniaxial strength and point load index of rocks

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ABSTRACT

Determination of rock engineering properties is important in civil, mining and geotechnical engineering. Uniaxial Compressive Strength (UCS) is one of the most important properties of rocks. Point Load Test (PLT) is practically used in geotechnical engineering to determine rock strength index. Despite that the PLT is fast, economical and simple in either field or laboratory, Uniaxial Compressive Test (UCT) is time-consuming and expensive. UCS can be estimated using Point Load Index (PLI). So, implementation of correlation between results of PLT and UCT is of interest.

In this research correlation between the results of point load test and uniaxial compressive test are presented for rock samples from three sites in Iran. Two rock types including Shale and Marlstone have been utilized in this research. Correlations between UCS and PLI in this study are verified with proposed equation by previous researchers.

Keywords: Point Load Test (PLT), Uniaxial Compressive Test (UCT), Point Load Index (PLI), Compressive Uniaxial Strength (UCS), Experimental study

1 INTRODUCTION

The rock strength is an important property for classification of rocks. Uniaxial Compression Strength (UCS) is one of the most important properties of rock that widely used in geotechnical, civil and mining projects. Despite there are standard methods (ASTM, 1984; ISRM, 1985) for determination of UCS and laboratory test is a reliable and direct method to estimate UCS, using direct method in determining UCS is time consuming and expensive in laboratory. Because of these limitations researchers have attempted to use Point Load Index (PLI) as an indirect method of estimation of rock uniaxial compression strengths (D’andrea et al., 1965; Broch and Franklin, 1972; Bieniawski, 1975; Hassani et al., 1980; Forster, 1983; IRSM, 1979 and 1985; Ghosh and Srivastava, 1991; Singh and Singh, 1993; Ulusay et al., 1994; Kahraman, 2001; Quane and Russel, 2003; Tsiambaos and Sabatakakis, 2004). Most of the presented equations by the researchers give similar results, but in few cases there is wide variation. Previous researches show that the correlation between UCS and PLI needs to be studied.

In this research the results of UCT and PLT on rock cores are presented and correlation between UCS and PLI are compared with the equations presented by previous researchers.

2 SAMPLE PREPARATION

The PLT was conducted on 34 sample cores and the UCT was carried out on 34 rock cores including shale and marlstone obtained from three different sites in Iran. For these samples, PLT and UCT are conducted at same depth of sampling. Depths of coring of rock samples are varied from 0.0 to about 30.0m from the ground level. Nine test specimens are from shale and the others are from marlstone rock samples.

Preparation of samples was carried out according to ASTM D4543-08. Rock core were cut and polished to achieve desired dimensions and acceptable tolerances. Sample ends were polished to reduce the end friction effects in UCT.

3 POINT LOAD TEST

The PLT is used as an efficient and applicable method to rock classification (Broch and Franklin, 1972; Guidicini et al., 1973; Bieniawski, 1975; Brook, 1977; Greminger, 1980; Forster, 1983). Based on this method failure of rock is occurred due to tensile stress. PLT is a cost effective alternative method to indirectly obtain USC and can be conducted on rock sample without using any special sample preparation. The point load tester can be used as a portable devise at site. In PLT, rock samples are compressed between two conical steel platens until failure occurs.
American Society for Testing and Materials has established the basic procedure for conducting and calculation of point load strength index (ASTM D5731-08).

There are three main types of PLT; axial, diametral and lump or block. Axial and diametral types are performed on rock core samples. The point load strength index determined by PLT must be corrected to the standard equivalent diameter ($D_e$) of 50mm (Peng and Zhang, 2007). If the cores being tested have approximately 50mm diameter, such correction is not needed. The suggested equation for PLI value $I_s$, by ASTM is as followed:

$$I_{s(50)} = (D_e / 50)^{0.45} P_r / D_e^2$$  \(1\)

where $P_r$ and $D_e$ are the failure load and the equivalent diameter which is the core diameter for immaterial test.

4 UNIAXIAL COMPRESSION TEST

Uniaxial compression test is a most commonly used laboratory test to investigate mechanical properties of intact rocks. The results of UST are used in most of engineering projects.

The methodology for UCS is standardized by International Society of Rock Mechanics (ISRM, 1981) and American Society for Testing and Materials (ASTM, 1984). In UCT, the length-to-diameter ratio of samples should be on the order of two, UCS value can be calculated using the following simple Equation:

$$UCS = \frac{F}{A}$$  \(2\)

where $F$ and $A$ are maximum applied load and specimen cross sectional area, respectively. If the length-to-diameter ratio is not on the order of two, UCS should be corrected as following equation, according to ASTM:

$$UCS^* = \frac{UCS}{0.88 + (0.24d/h)}$$  \(3\)

where $UCS^*$ is the corrected UCS for $h/d=2$, $h$, $d$, and $A$ are the height, diameter and cross sectional area of the specimen, respectively.

5 RESULTS AND DISCUSSION

The Proposed correlation equations for UCS and PLI which presented by the previous researchers are listed in Table 1.

The values of UCS and PLI obtained from 8 tests on shale specimens and 26 tests on marlstone specimens are plotted in Figs 1 and 2, respectively. Listed equations in Table 1 are used to compare the results of this study with the previous relationships. The Correlations between UCS and PLI for shale and marlstone specimens in this study are compared with those proposed equations in Table 1.

It should be mentioned that because of weathered and fractured nature of tested samples, the strength of rock samples were weak.

| Author(s) | Suggested correlation equation |
|-----------|-------------------------------|
| D’andrea et al (1965) | UCS=15.3 PLI+16.3 |
| Deer and Miller (1966) | UCS=20.7 PLI+29.6 |
| Broch and Franklin (1972) | UCS=23.7 PLI (Various rock types) |
| Bieniawski (1975) | UCS=23.9 PLI (Sandstones) |
| Hassani et al (1980) | UCS=29 PLI (Sedimentary rocks) |
| Read et al (1980) | UCS=20 PLI (Sedimentary rocks) |
| Singh (1981) | UCS=18.7 PLI=13.2 |
| Forster (1983) | UCS=14 PLI |
| Gunsallus and Kulhawy (1984) | UCS=16.5 PLI+51.0 |
| ISRM (1985) | UCS=(20, ..., 25) PLI |
| Das (1985) | UCS=14.7 PLI (Siltstone) |
| O’Rourke (1988) | UCS=30 PLI (Sedimentary) |
| Vallejo et al (1989) | UCS=17.4 PLI (Sandstone) |
| Cargill and Shakoor (1990) | UCS=23 PLI+13 |
| Tsidzi (1991) | UCS=(14, ..., 82) PLI |
| Grasso et al (1992) | UCS=25.6(PLI)^0.77 (Power relation) |
| Singh and Singh (1993) | UCS=23.4 PLI (Quartzite) |
| Ulusay et al (1994) | UCS=19 PLI+12.7 (Sandstone) |
| Chau and Wong (1996) | UCS=12.5 PLI |
| Smith (1997) | UCS =24 PLI (Sandstone/limestone) |
| Rusnak and Mark (1999) | UCS=21.8 PLI (Shale) |
| Kahraman (2001) | UCS = 8.41 PLI+9.51 (Other rock types) |
| Quane and Russel (2003) | UCS=24.4 PLI (Strong rocks) |
| Tsiambaos and Sabatakakis (2004) | UCS =7.3 PLI^{0.75} (Power relation) |
| Fener et al. (2005) | UCS=9.08 PLI+39.32 (Various rock types) |
| Kahraman et al. (2005) | UCS=10.91 PLI+27.41 (Various rock types) |
| Heidari et al. (2012) | UCS=5.575 PLI+21.92 (Gypsum) |
| Karman and Kesimal (2012) | UCS=20.42 PLI-5.146 (Various rock types) |

The results of tests on shale almost show a good
agreement with the previous relationships. It could be generally deduced that tests results of this study on shale have better agreement with the presented equations by Das (1985), Vallejo et al. (1989) and Smith (1997).

Also, the results of tests on marlstone are compared with the proposed equations for sedimentary rocks in Table 1; including, namely, sedimentary rocks, sandstone, siltstone and limestone. Despite scattering in data of this study, the results of test have a reasonable agreement with the previous relationships. Generally, the data points of this research have better agreement with Das (1985) equation for siltstone. It should be mentioned that the tested marlstone contains silt and clay, so the agreement of the results with the proposed curve for siltstone can be meaningful.

6 CONCLUDING REMARKS

34 UCT and 34 PLT are conducted on weathered and weak samples of marlstone and shale. Despite that the resulted data were scattered, totally there are almost agreements between the results of this study with pervious researches. Although, grateful studies were carried out by many researchers, the correlation equations for rocks need to be categorized with more detail.

Generally, the correlation between UCS and PLI for shale specimens is agreed well with the previous correlation equations. In the case of marlstones, the results are almost agreed with the presented equation for sedimentary rocks, in particular for siltstone (Das, 1985).

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