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# CORRELATION BETWEEN UNCONFINED COMPRESSION STRENGTH AND POINT LOAD INDEX FOR AL-MAFRAQ BASALT ROCK

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**Keywords:** uniaxial compressive strength; point load test; rock; point load index.

**Abstract.** *Determination of rock strength is vital in the applications of geotechnical engineering. Unconfined Compressive Strength (UCS), also known as Uniaxial Compressive Strength (UCS), is one of the most important strength properties of rocks. Because of the time it consumes and the higher cost; the USC is usually compared to strength obtained by Point Load Test (PLT) which is practically used to determine the rock strength index (Is(50)). This paper aims at investigating the possible relationship between Uniaxial Compressive Strength (UCS) and the point load index (Is(50)) for Basalt rock taken from Al-Mafraq, Jordan. Laboratory experiments including UCS and PLT have been carried out on thirty-nine (39) Basalt rock samples collected exclusively from different locating within Al-Mafraq district. Based on the results of this work, the (UCS) was founded to be correlated with (Is(50)) through a linear relationship having a correlation constant of 21.4.*

## 1 INTRODUCTION

A basalt rock in Jordan is an extension to the North Arabian Basaltic Level. Basalt is a dark-colored, fine-grained heavy extrusive volcanic igneous rock that was derived from magma and extent over different areas in Jordan (Figure 1). It covers a territory of about 11,000 km$^2$ extending from the upper east of Jordan, Al-Mafraq district, and expands northwest into Syria and southeast into Saudi Arabia. In the meantime, a gathering of little mainland volcanic rocks are available in central Jordan.

Basalt can be utilized in quite a lot of geotechnical applications, for instance; Basalt rock stones were used centuries ago in building the old city of Um Al-Jimal, Al-Mafraq district (Figure 2). Moreover, Basalt rock can be used in producing rock wool, pipes, and can also be used as a construction material [1,2].

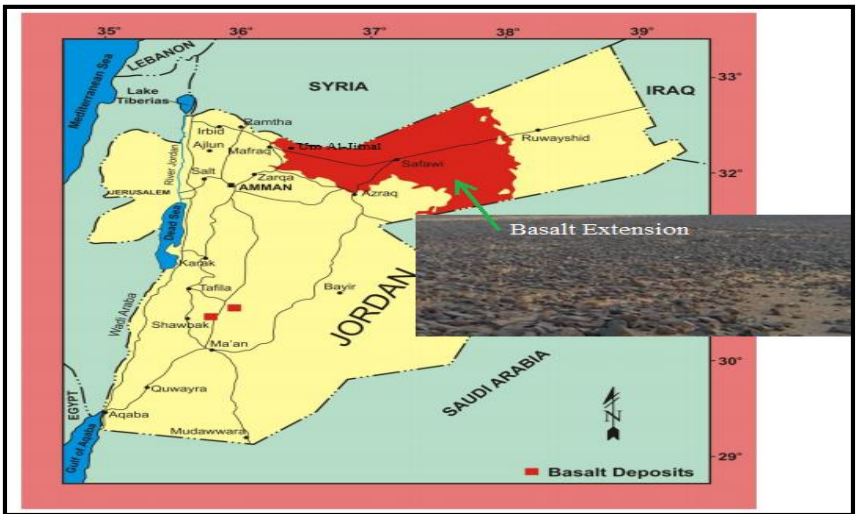


Figure 1. Occurrence and extension of Basalt in Jordan.

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Figure 2. Basalt rock as a building stone, the old city of Um Al-Jimal, Al-Mafraq district.

The uniaxial compressive strength (UCS) value of a certain rock is an essential property to be known. Generally, the UCS is engaged in the slope stability investigation, the design of foundations resting on near rock strata, and in the analyses of tunnels and in rock and mines as well. Despite that the Uniaxial Compressive Test (UCT) is time-consuming and costly, it is not always possible to conduct the UCT on rock samples, specifically, for highly weathered rocks. Correlations that associate the uniaxial compressive strength UCS with the strength obtained from the simpler and faster test known as point load test (PLT) and expressed as Point load Index ($Is_{(50)}$), exist in the literature. Some of these correlations are presented in Table 1 below. Most of the existing correlations have been developed for a huge variety of rock regardless its type. The majority of the existing correlations ended up with quite closer conclusions that indicate the UCS values are approximately within the rage of 24 times the point load index [3].

| Author (s) | Suggested correlation equation | Rock type |
|---|---|---|
| Andrea et al. [4] | UCS=15.3 Is(50)+16.3 | |
| Deere and Miller [5] | UCS=20.7 Is(50)+29.6 | |
| Broch and Franklin [6] | UCS=23.7 Is(50) | Various rock types |
| Bieniawski [7] | UCS=23.9 Is(50) (Sandstones) | Sandstones |
| Read et al. [8] | UCS=20 Is(50) | Sedimentary rocks |
| Vallejo et al. [9] | UCS=17.4 Is(50) | Sandstone |
| Singh and Singh [10] | UCS=23.4 Is(50) | Quartzite |
| Kahraman et al. [11] | UCS=10.91 Is(50)+27.41 | Various rock types |
| Karaman and Kesimal [12] | UCS=20.42 Is(50) -5.146 | Various rock types |
| Sharo and Tawaha [13] | UCS=23.5 Is(50) | Basalt |
| Sharo and Al-Shorman [14] | UCS=7.6 Is(50) + 24.3 | Basalt (Al-Tafila area) |

Table 1: Correlations equations between Uniaxial Compressive Strength (UCS) and Point Load Index (PLI)

From Table 1 we can illustrate that even for the same rock type correlation may change if the site tested changed. This may also explained by the slight difference in the formation and occurrence of a certain rock type. For Al-Mafraq district Basalt rock, there is little well-documented research findings in the literature that correlates the Uniaxial compressive strength UCS and the Point Load Index PLI ($Is_{(50)}$). Therefore, this study has been carried out to estimate the indirect procedures of assessing the uniaxial compressive strength (UCS) of specific rock types by correlating the UCS with the PLI. In this work, Basalt rock samples collected from the Al-Mafraq area were considered in order to evaluate the possible correlation between the UCS and PLI. Comparisons with other correlations were also investigated to evaluate the prediction of the suggested correlation. The results were also statically analyzed to determine the degree of goodness $R^2$ of the proposed correlation.

## 2 RESEARCH METHODOLOGY

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This research paper was conducted based on thirty-nine samples prepared from blocks that were taken from the Al-Mafraq Basalt region, Jordan. The rock cores were then cut with 50 mm diameter and 150 mm height. The Uniaxial Compression Test UCS was performed on samples of height to diameter ratio of ( $h/d \approx 2$ *to* $3$). On the other hand, the PLT was performed on a sample of height to diameter ratio of ( $h/d \approx 0.5$ ).

The standards for performing laboratory tests for the Uniaxial Compression test (UCS) and for the PLT are summarized in Table1.

| No. | Test | Illustration | Standard No. | Title of Standard |
|---|---|---|---|---|
| **1.** | Point Load Test (PLT) |  | D5731-08 [15] | Standard Method for Determination of the Point Load Strength Index of Rock. |
| **2.** | Unconfined Compression Test (UCT) |  | D7012-10 [16] | Standard Test Method for Compressive Strength and Elastic Modulus of Intact Rock Core specimens under Varying States of Stress and Temperatures. |

Table 2: Standards for performing laboratory UCS and PLT tests.

In the USC the tested samples were polished from their ends to reduce the end friction effect. The compression resistance by this test is then given by:

$$Q_c = F_c / A \quad (1)$$

Where: $Q_c$: is the (UCS)
$F_c$: is the axial compression load
A: is the area of applied load

Point Load Test (PLT) was carried out by loading the two faces of the rock with (De) express the distance between them (the height of the sample). The geometric requirement of the specimens for the test is shown in Figure 3.

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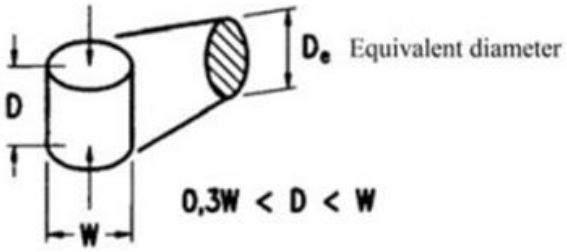


Figure 3. Geometric requirements of the specimens for the Point Load Test (UNE 22950-5:1996).

## 3 RESULTS AND DISCUSSION

### 3.1 Test Results

Uniaxial compressive strength (UCS) and the point load test was carried out on 30 samples of Basalt. Tests results for UCS and PLT (expressed in terms of point load index, $Is_{(50)}$) acquired from the 30 Basalt samples are plotted in Fig.1

The thirty- four samples were tested test to examine the possibility of proposing a correlation equation between UCS and PLI expressed as ($Is_{(50)}$) for Al-Mafraq Basalt rock. Tests results are illustrated in Figure 4.

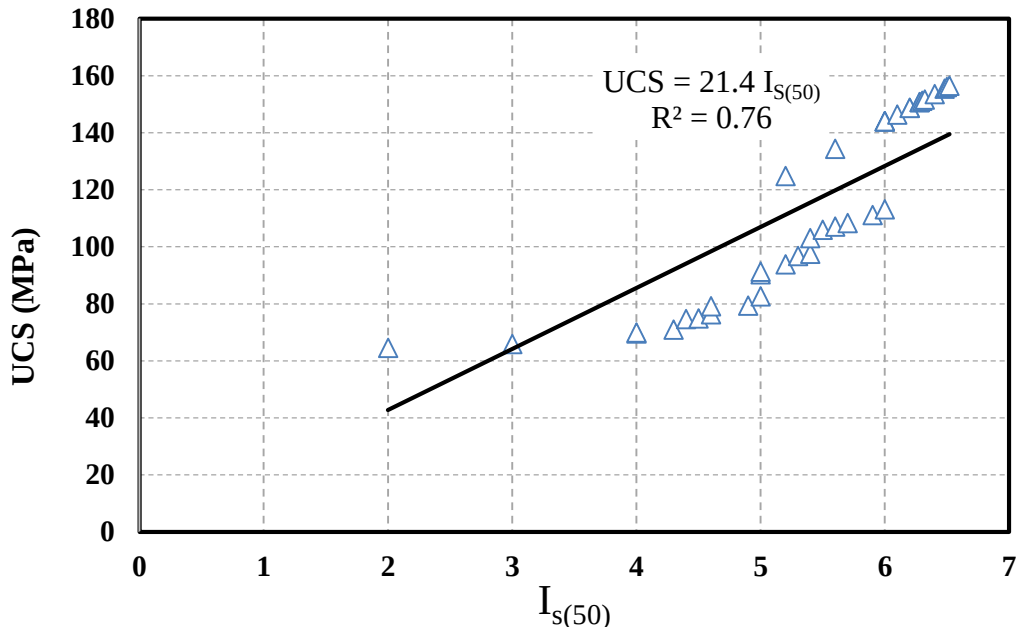


Figure 4. Correlation between UCS and PLI for Al-Mafraq Basalt rock.

Figure 1, also, proves that the possible correlation between the uniaxial compressive strength (UCS) and the point load index (PLI) for Al-Mafraq Basalt may slightly differ from those suggested for other rock types (see Table 1). According to Fig. 1, the distribution of data approves that a good correlation between UCS and PLI does exist. By regression analysis, this correlation may be stated as in the following equation (Eq. 2):

$$UCS = 21.4\ (Is_{(50)}) \quad (2)$$

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### 3.2 Comparison with Other Correlations

In order to validate the proposed correlations between the USC and the PLI for Al-Mafraq Basalt rock, compassion with other correlations have been conducted. The outcomes of Eq. 1 were compared to the correlations proposed by Broch and Franklin [6], Karaman and Kesimal [12], and sharo and Tawaha [13] and summarized in Table 1. In comparing with these correlations, the author avoided correlations developed for known rock types other than Basalt rock and selected not to choose more than one correlation for the same author. Figure 5 below illustrates the comparison results conducted herein.

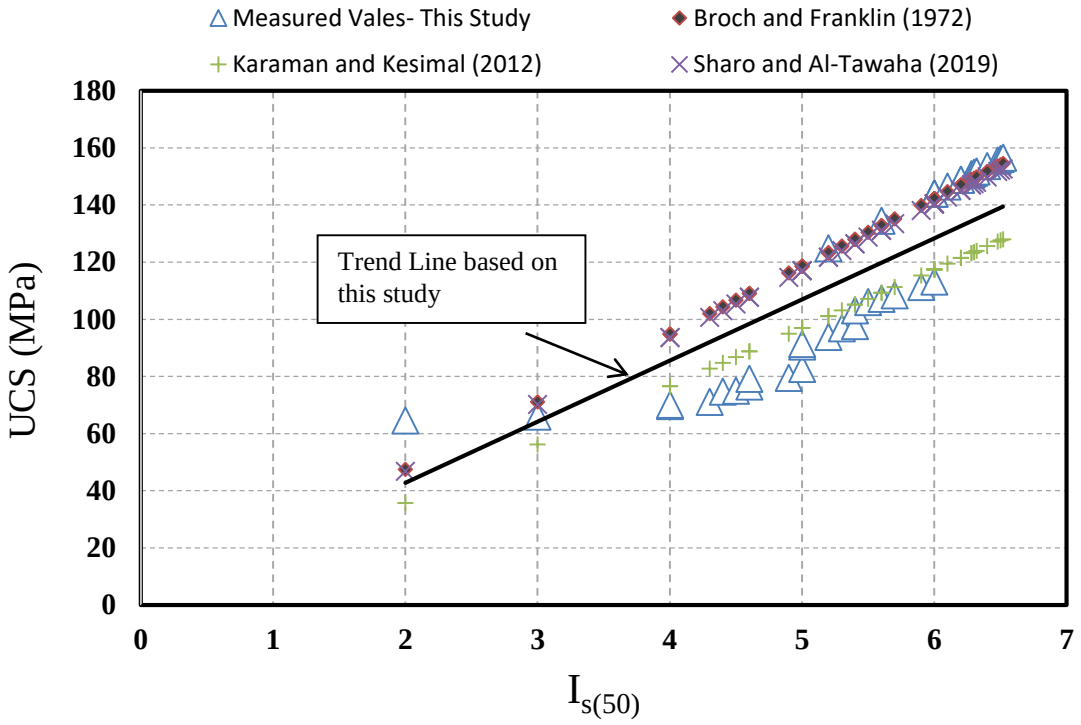


Figure 5. Correlation between UCS and PLI for Al-Mafraq Basalt rock.

As we can see, most of these correlations are generally either over-estimate the USC. To better understand this validation and comparison, a statistical analysis was performed and summarized in Table 3.

| Author (s) | UCS (MPa) | | | |
|---|---|---|---|---|
| | Range | Average Value | Standard Deviation | $R^2$ |
| This study (correlation) | 42.6 – 138.9 | 114.5 | 21.3 | 0.79 |
| Broch and Franklin [6] | 47.4 – 154.5 | 127.4 | 23.7 | 0.75 |
| Karaman and Kesimal [12] | 35.7 – 128.0 | 104.6 | 20.5 | 0.76 |
| Sharo and Tawaha [13] | 46.8 – 152.6 | 125.8 | 23.5 | 0.75 |

Table 3: Statistical analysis for this study compared with other studies on the correlation of UCS with PLI.

From the results above, one can judge that for Al-Mafraq Basalt rock the correlation between UCS and $Is_{(50)}$ is in good agreements with the other correlations available in the literature where the majority of these correlations restrict the correlation constant between UCS and $Is_{(50)}$ within the range of 20 and 24.

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## 4 CONCLUSION

The uniaxial compressive strength tests UCS and the point load tests PLT were carried out on thirty-nine Basalt rock deduced from Al-Mafraq district. The test results were analyzed statically using least regression analysis and a predictive equation for compressive strength based on Is(50) was developed.

Based on the work presented in this study the following conclusions can be drawn.

a) The (UCS) of Al-Mafraq Basalt rock was found to be correlated with (Is (50)) through a linear relationship.
b) The correlation constant for Al-Mafraq Basalt rock was best predicted to be in the order of 21.4.
c) The developed correlation between UCS and PLI is in line with the correlations in the literature.

From this study, it can be established that the UCS estimation equation with the PLI developed as a result of this study is an efficient tool to be used instead of using UCS tests which are expensive and not easy to conduct compared to the PLT.

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