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Evaluation of the block punch index test for predicting the strength of sandstones

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Abstract

Strength measurement of rock requires testing that must be carried out on test specimens with particular sizes in order to fulfill testing standards or suggested methods. Often, the coring process breaks up the weaker core pieces, and they are too small to be used in either index tests or conventional strength tests such as point load index (Is) and Brazilian tensile strength (BTS). One of the index tests to indirectly determine the rock strength is the block punch index (BPI) test, which requires flat disc specimens without special treatment. This study aimed to evaluate the applicability of the BPI test for predicting the uniaxial compressive strength (UCS), BTS and IS of the sandstones by empirical equations. Also, we have compared the performance of the BPI and IS for predicting the UCS and BTS. It was experimentally shown that BPI is a reliable method for predicting the UCS, BTS and Is of the sandstones under study. Moreover, the results indicate that BPI could be utilized with same importance as Is for predicting the UCS, while predicting the BTS by Is appears to be more reliable than BPI.

Keywords: Block punch index; Brazilian tensile strength; Point load index; Sandstone; Uniaxial compressive strength

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Extended Abstract:

1. Introduction

Strength measurement of rock is considered to be necessary in various rocks engineering design approaches as well as for the strength classification of rock materials. The UCS, BTS and I_S are among the important mechanical properties in strength measurements of rock that are determined in laboratory on core specimens according to test standards (ASTM) or suggested methods (ISRM). Measurement these properties require testing that must be undertaken on test specimens with particular sizes in order to fulfill testing standards or suggested methods. However, there are some of shortcomings associated with these conventional tests. For example, preparation of specimens with particular sizes in order to fulfill testing standards or suggested methods, the amount of time and labor necessary for specimen preparation, provisions for expensive testing equipment and testing durations may cause difficulties in strength measurement, particularly for weak or thinly stratified rocks. These difficulties motivated researchers to develop rock strength index tests that give reasonable results to determine directly and indirectly the rock strength using as small a specimen as possible (Ulusay and Gokceoglu, 1997).

The aim of this study is to provide more insight and to add more information to the correlation between BPI with UCS, BTS and Is of 15 different sandstones. Moreover, we have compared the performance of the BPI and I_S for predicting the UCS and BTS.

2. Materials and methods

To carry out the research, sandstone different outcrops in the city surroundings of Khoramabad were visited and a great number of block samples from 15 different sandstones were collected. These sandstones are similar in mineralogical composition but different in strength. The block samples varied from 20×35×35 to 30×40×40 cm^3 in size were collected to fulfill the purpose of this research. Each block sample was inspected to ensure that it would provide standard testing specimens. During the sampling, rock types free from alteration zones, bedding planes and fracture were selected to eliminate any anisotropy effects on the measurement.

To fulfill the aims of the research, the strength tests including the BPI, UCS, BTS and I_S were carried out in Damghan and Lorestan universities, Iran. Five specimens in the form of cylindrical were used to perform each test and then their mean values were obtained.

3. Results and Discussion

3.1. Predicting the UCS, BTS and $Is_{(50)}$ by BPI_C

Using the simple or multiple regression analyses for predicting the rock properties are commonly encountered in the literature.

In this study, we have used from the simple regression analyses to develop the sets of empirical equations among the BPI_C, UCS, BTS and $Is_{(50)}$. For this purpose, linear ($y = ax + b$), power ($y = ax^b$), exponential ($y = ae^x$) and logarithmic ($y = a + \ln x$) regressions were undertaken with 95% confidence limits. Authors attempted to develop best correlation between different variable for to attain the most reliable empirical equation. The results of the regression analyses are given in Table 1.

As seen in Table 3, a logarithmic, power and linear correlations between UCS and BPI_C, BTS and BPI_C and $Is_{(50)}$ and BPI_C, respectively, were considered as the best fits, based on the highest R^2. In general, better correlation has a higher R^2. Since the values of the determination coefficients between different types of correlations (exponential, linear, logarithmic, and power) are very small (Table 1), and on the other hand, for simplicity, we have considered linear correlations between different strength parameters.

Table 1. Summarized the simple regression analyses results

Parameters	**Regression equations**	**Equation type**	**Determination coefficient (R^2)**
$UCS–BPI_C$	$UCS= 20.528e^{0.0958BPI}$	Exponential	0.90
	$UCS= 4.7469\ BPI_C + 6.905$	Linear	0.92
	$UCS = 43.201 \ln (BPI_C) – 44.235$	Logarithmic	0.93
	$UCS= 7.1747BPI_C^{0.8805}$	Power	0.92
$BTS–BPI_C$	$BTS= 2.5067e^{0.0758BPI}$	Exponential	0.83
	$BTS= 0.381BPI_C – 62.782$	Linear	0.84
	$BTS= 3.482 \ln (BPI_C) – 1048$	Logarithmic	0.85
	$BTS = 1.0904\ BPI_C^{0.6971}$	Power	0.85
$Is_{(50)}– BPI_C$	$Is_{(50)}= 2.3188e^{0.0685BPI}$	Exponential	0.83
	$Is_{(50)} = 0.3002\ BPI_C + 1.6419$	Linear	0.85
	$Is_{(50)} = 2.7126 \ln (BPI_C) – 1.5495$	Logarithmic	0.84
	$Is_{(50)} = 1.1124BPI_C^{0.6217}$	Power	0.83

3.2. Comparative study between performance of the BPI_C and $Is_{(50)}$ for predicting the UCS and BTS

UCS and BTS were correlated with the $Is_{(50)}$. It be seen that the trend of data shows an increase in UCS and BTS with increase in the $Is_{(50)}$. Also, it can be seen that best-fitted correlations between UCS and BTS with $Is_{(50)}$ were found to be represented by linear regressions. The equations for the correlation between UCS and BTS with $Is_{(50)}$ are, respectively:

$UCS = 14.357\ Is_{(50)} – 12.612$, ($R^2$=0.91) (for $32.6<UCS<65.7$ and $3.35<Is_{(50)}<5.41$) (1)

$BTS = 1.2303Is_{(50)} – 0.3104$, ($R^2$=0.93) (for $3.79<BTS<6.49$ and $3.35<Is_{(50)}<5.41$) (2)

Comparison of correlation between UCS with BPI_C and $Is_{(50)}$ shows approximately the same determination coefficients (i.e. 0.93 and 0.91, respectively). The correlation data between BTS and BPI_C is the more scattered than it that is between BTS and $Is_{(50)}$. As a result, determination coefficient between BTS and BPI_C (R^2= 0.85) is significantly lower than that between BTS and $Is_{(50)}$ (R^2= 0.93). This shows that $Is_{(50)}$ than BPI_C is the more accurate for predicting the BTS of samples.

4. Conclusions

The BPI_C, UCS, BTS and $I_{S(50)}$ for 15 different sandstones were determined in the laboratory. By analyzing the results of laboratory tests, the following regression equations have been developed as follows;

*$UCS = 4.7469\ BPI_C + 6.905$, ($R^2$=0.92) (for $32.6<UCS<65.7$ and $6.00< BPI_C <12.69$)

*$BTS = 0.381BPI_C – 62.782$, ($R^2$=0.84) (for $3.79<BTS<6.49$ and $6.00< BPI_C <12.69$)

*$Is_{(50)} = 0.3002\ BPI_C + 1.6419$, ($R^2$=0.85) (for $3.35<Is_{(50)}<5.41$and $6.00< BPI_C <12.69$)

*UCS = 14.357 $Is_{(50)}$ – 12.612, (R^2=0.91) (for 32.6<UCS<65.7 and 3.35<$Is_{(50)}$<5.41)
*BTS = 1.2303 $Is_{(50)}$ – 0.3104, (R^2=0.93) (for 3.79<BTS<6.49 and 3.35<$Is_{(50)}$<5.41)
Proposed regression equations were compared with those available in the literature as well as were validated by the t-test and the 1:1 diagonal line. The results showed that UCS, BTS and $Is_{(50)}$ can be predicted using BPI_C with good accuracy. Moreover, the results indicated that BPI_C could be used with similar importance as $Is_{(50)}$ for predicting the UCS; while $Is_{(50)}$ is the more reliable than BPI_C for predicting the BTS.

Due to specimen preparation without special treatment and performing the test with a simple apparatus, the BPI test can be offer a quick, easy and cheap means for predicting the mechanical properties of different rock types, particularly the heavily jointed rock and/or thinly stratified rock masses. However, further researches are necessary to investigating the performance and accuracy of the BPI_C for predicting the strength of rocks as well as to check the validity of the proposed equations for the other rock types.

References:

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