Use of the Block Punch and Point Load Tests to Predict the Compressive Strength of Gneissic Rocks; with Particular Reference to the Size Effect

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Abstract: Various correlations have been established with regard to rock strength indices for different types of rocks around the world. In Sri Lanka, having several types of sedimentary and metamorphic rocks, least attempt has been made in relation to the particular subject area. In order to fulfil the need to a certain extent, this research was carried out to study correlations between rock strength indices specifically in Sri Lankan gneissic rocks. The study reveals information with regard to an emerging, yet powerful rock strength index known as Block Punch Index, which could be used with same significance as that of Point Load Index, while predicting Uniaxial Compressive Strength. The study further compares the strength indices and their variations in relation to size effect. It finally presents conclusions drawn relating to strength indices of Sri Lankan gneissic rocks with several recommendations.

Keywords: Uniaxial Compressive Strength, Point Load Index, Block Punch Index, Gneissic rocks, rock strength index, size effect

1. Introduction

Gneissic rocks have been used in a variety of civil engineering applications ranging from road layering to construction of foundations of high-rise buildings. Their strength plays a major role in determining the suitable rock type for the above applications. Therefore, it is important to identify the factors that affect the strength of these rocks.

There are several important factors which affect the strength of rocks such as mineral composition, micro-discontinuities,macrodiscontinuities, joints, bedding planes parting and minor faults etc. When considering the intact rock, sample size is one of the most critical factors influencing its strength (Uniaxial Compressive Strength).

In rock engineering, Uniaxial Compressive Strength (UCS) is one of the most important and widely used strength parameter of rocks. But for the simplicity, many rock engineers rely on index tests to predict the UCS of rocks.

In estimating UCS globally, the Point Load Index ($I_{s(50)}$) has proved to be efficient. But an emerging rock strength index such as Block Punch Index (BPI) might also be used in this regard.

Therefore, the main focus of this research is to explore the applicability of the Block Punch Index in estimating Uniaxial Compressive Strength of gneissic rocks in Sri Lanka in relation to the specimen size.

2. Material and Methods

The samples were obtained for the purpose of representing the general gneissic rocks in Sri Lanka. Rock samples that have undergone any weathering or carrying any form of weaker planes in its body were avoided to minimize their effect on rock strength.

The site selected for the sample collection was a quarry site of CML-MTD Constructions (Pvt) Ltd. located at Thudugala, Kalutara, Sri Lanka.

The rock type available at the site was a common gneissic rock in Sri Lanka having a reasonable composition of Quartz and Feldspar. It also contained smaller amounts of Mica and Garnet.

2.1 Specimen Preparation and Testing

Specimens were prepared in sets of three for UCS, PLI and BPI. All three specimens in a given set were taken from the same core in order to effectively compare the different strength indices. Following table presents the procedural guidelines for all three tests conducted.

Table 1.Test Procedure Guidelines

Test	Procedure Guideline
UCS	ASTM D7012 - 10 Standard Test Method for Uniaxial Compressive Strength (UCS) and Elastic Moduli of Intact Rock Core Specimens
PLI	ASTM D5731 - 08 Standard Test Method for Determination of the Point Load Index (PLI) of Rock
BPI	The Modified Block Punch Index Test - Ulusay, Resat, and Candan Gokceoglu

Average sizes of the specimens were as follows:

UCS - Cylindrical specimens with average diameter and length of 54.2 mm and 110.9mm.

PLI - Block specimens with average width, breadth and length of 21.2mm, 23.3mm and 43.7mm.

BPI - Disc specimens with average diameter and thickness of 54.2mm and 10.1mm

After preparation the samples for testing, all the specimens were numbered, air-dried for 24 hours and, oven-dried for 6 hours at 105 °C. A total of 26 samples were tested in the course of research.

UCS test was performed using Amsler testing machine at the Structural Engineering Laboratory at the Department of Civil Engineering, University of Moratuwa.

PLI test was done using the Heico test machine at the laboratory of ELS (Pvt) Ltd.

BPI test was performed by fixing the BPI test apparatus to the Point Load test apparatus in place of the platens.

3. Results and Discussion

Test results were corrected by applying relevant size and area corrections whereas Table 2 summarizes the corrected results of three tests conducted.

Table 2.Test Results

Sample no	UCS (Mpa)	PLI (MPa)	BPI (MPa)
1	46.03	7.72	9.89
2	29.80	6.63	6.45
3	53.68	10.56	15.59
4	41.82	8.05	6.93
5	36.66	7.37	7.85
6	40.51	7.68	9.49
7	53.30	8.33	14.04
8	51.92	7.78	8.81
9	34.18	6.31	6.72
10	44.28	7.67	9.03
11	40.51	8.27	10.00
12	32.84	6.38	6.54
13	36.66	7.29	8.59
14	35.42	6.95	7.84
15	40.50	7.42	8.98
16	47.75	10.14	10.55
17	29.38	6.00	5.87
18	45.67	8.01	10.10
19	114.11	11.81	22.92
20	34.10	6.23	7.43
21	28.57	5.38	5.80
22	38.74	7.74	7.57
23	52.87	7.69	12.41
24	56.66	9.89	14.08
25	44.67	9.21	10.92
26	105.56	10.03	19.80

Based on the above results graphs were plotted between PLI vs UCS (figure 1) and BPI vs UCS (figure 2).

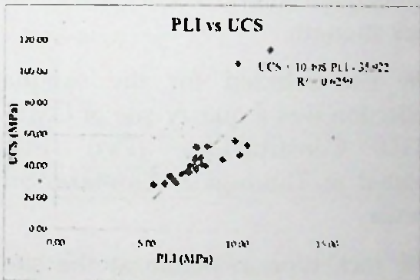

Figure 1.Best fit curve for PLI vs UCS

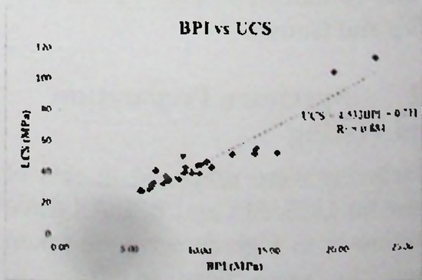

Figure 2.Best fit curve for BPI vs UCS

Following linear relationships were derived between BPI and UCS and PLI and UCS.

$$UCS = 4.533\,BPI + 0.711 \qquad R^2 = 0.884$$

$$UCS = 10.408\,PLI - 35.922 \qquad R^2 = 0.6259$$

The relationship between BPI and UCS could be considered as stronger than the relationship between PLI and UCS due to its higher coefficient of determination.

Considering the intercepts of both relationships, PLI has a more deviated value of -35.922 from zero compared to 0.711 of BPI. But apparently UCS should reach zero when its estimate reaches zero. There itself BPI marks its important position as a better estimate for UCS.

When gradients are considered the gradient of UCS and PLI curve is more than twice that of UCS and BPI curve. For a better estimation the gradient should be close to one theoretically. Besides, when the gradient is higher, the estimate is multiplied by a higher factor which introduces significant errors in the final values. Therefore when gradient values are considered, BPI becomes a better estimate for UCS than PLI.

There were early established relationships between UCS, PLI and BPI by D.A. Mishra and A.Basu such as UCS = 4.02BPI + 36.16 and UCS = 10.90PLI + 49.03 for Granite rocks. But the equations derived above are slightly deviated from these. It is mainly due to the reason that estimation of UCS from any other rock strength index is highly dependent upon the type of rock under consideration.

4. Conclusions

Block Punch Index test can be used with more importance than the Point Load Index test while estimating Uniaxial Compressive Strength of gneissic rocks in Sri Lanka. The errors introduced in the estimation using BPI are less significant than those introduced in the estimation using PLI. Block Punch Index test is preferred to Point Load Index test when irregular or block specimens are considered.

The relationship derived for the estimation of UCS from BPI is slightly deviated from those suggested by Ulusay et al(UCS=5.1BPI) and D.A. Mishra, A.Basu (UCS = 4.02BPI + 36.16). Therefore, it can be concluded that prediction of UCS from BPI is highly dependent upon the type of rock being tested.

More accurate relationships could be obtained by increasing the number of test specimens.

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