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A new testing method for indirect determination of the unconfined compressive strength of rocks

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ABSTRACT

A new testing method for the indirect determination of unconfined compressive strength (UCS) of rock core samples is presented. As known, there exist several methods for indirect estimation of UCS, such as point load index (I_s), Schmidt hammer, sonic velocity, block punch strength test, etc. Although the point load index testing method is widely used to estimate UCS, there are many problems and limitations related to this method as reported in the recent literature. The “core strangle test” (CST) proposed in this paper overcomes some of these deficiencies and limitations. The principle of this test depends on the “strangle” type of loading a core along a circle perpendicular to the core axis. In the first stage of this study, blocks of different types of rocks having the strength in a range from weak to strong were collected and cored for UCS, point load index and CST tests. These tests were then conducted and relationships between UCS with $I_{s(50)}$ and CST were empirically explained and discussed.

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1. Introduction

Strength characteristics of rocks are very important parameters for rock mass classification and design of structures either upon or inside rock. In addition, they are essential for judgment about their suitability for various construction purposes. Numerical and analytical methods in design approaches also require failure properties. In order to determine the unconfined compressive strength (UCS) of a rock sample, circular cylinders having a height to diameter ratio of 2.5–3.0 and a diameter preferably not less than NX core size is needed. The ends of the specimen must be flat to 0.02 mm.

In some cases, core samples having a sufficient height cannot be obtained because of the rock mass properties. For this reason, many testing methods, such as point load index, Schmidt hammer, sonic velocity, punch index, shore test, etc., have been proposed for indirect determination of UCS.

Schmidt hammer has been used worldwide as an index test for a quick rock strength and deformability characterization due to its rapidity and easiness in execution, simplicity, portability, low cost and non-destructiveness. Schmidt hammer was originally developed for measuring the strength of hardened concrete [1] but it can also be correlated with rock compressive strength according

to Miller [2] and Barton and Choubey [3]. The principle of the test is based on the absorption of part of the spring-released energy through plastic deformation of the rock surface, while the remaining elastic energy causes the actual rebound of the hammer. This method was used for estimation of UCS and various empirical equations were proposed by many researchers [4–24]. The main shortcomings, limitations and problems related to this testing method are (a) anisotropy and heterogeneity of the rocks, very small test conduction area, (b) roughness on the surfaces where the test is applied, (c) vibration in the rock during test may set the specimen in motion, (d) test direction, and (e) there have been a number of different empirical equations proposed for different types of rocks.

Sonic velocity (V_p) is a useful index for estimation of the mechanical properties of hard and soft rocks. This test is a non-destructive test and conducted by measuring the pulse velocity between transducers of receiver and emitter. However, many papers and reports can be found for estimation of UCS by sonic velocity and presentation of the relations between sonic velocity and rock sample/rock mass [4,21,25–39]. The relationships obtained from this test were found by Shalabi et al. [24] to be weaker than the results of Schmidt hammer and shore tests.

The shore hardness test is a convenient and inexpensive method for measuring and comparing the hardness of rocks. The device measures the relative values of hardness by a diamond tipped hammer which drops vertically and freely from at rest at a height on to a horizontal test surface [40]. Some papers presenting the relationship between shore and UCS are [5,24,41–45]. These papers revealed that the relations mostly depend on rock

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mineralogy, anisotropy, and the correlations obtained from this test are weaker than those obtained from the Schmidt hammer. The main shortcoming associated with this test can be explained that the rock hardness values determined by shore test are obtained from a random mineral, and anisotropy and/or heterogeneity of the rocks cause the problem.

The block punch index (BPI) test is intended as an index test for the strength classification of rock materials and can be correlated with the UCS. However, there are some shortcomings associated with this conventional test, it allows to obtain UCS of rock cores divided into small disks, due to the presence of thin bedding or schistosity planes [46]. This test can be conducted on very thin specimens only. Irregular failure (invalid test result) occurrence causes a requirement of too many rock specimens.

Point load index test is a well-known method and especially used when the core samples having a sufficient height cannot be obtained. This test was first suggested by Broch and Franklin [47], and accepted by the ISRM [48] and Anon [49]. In this test, rock specimens are broken by application of concentrated loads in points through a pair of spherically truncated, conical platens as explained in ISRM [50]. Although shortcomings related to this method have been reported in many papers, it is being still used to predict UCS [5,11,26,47,51–68]. Shortcomings, limitations and problems related to point load index test are as follows: (a) tested rocks are generally anisotropic and heterogenic, but tests are applied in very small area; (b) irregular failures (invalid test result) frequently occur and cause a requirement of too many rock specimens; (c) the specimen may move during loading; and (d) micro-fissures may cross the conical platens.

The main problem is sourced from the more or less heterogeneity or anisotropy, thus the point load index test should be preferably conducted at least ten tests per sample. If the rock is heterogeneous or anisotropic, the test number should be more than ten. Modes of failures are also important for a valid test. If the rock is broken as invalid shape, the test should be rejected.

In the point load index test, failure occurs by loading of a *point*, which essentially means that it has no length and width. Whereas a line has an ideal zero-width, infinite length and contains an *infinite number of points*. If the rock is loaded through as line instead of a point, the effect of the heterogeneity or anisotropy is lessened. In order to overcome the shortcomings associated with point load index testing method, the *core strangle test* (CST) method and apparatus has been developed in this study. Results of the study indicate that the CST allows the UCS to be determined easily and sensitively. The CST has been developed for determina-

tion of UCS in situations where cores having standard dimensions cannot be obtained.

2. Principles of testing method CST and apparatus

2.1. Principles of CST

The basis of the proposed testing method partly depends on the indirect determination of the UCS by point load index testing method. The main problem related to point load index testing method is sourced from the loading of very small area (*point*) in spite of the heterogeneity and anisotropy of the rocks. In order to overcome this problem, a new testing method in which loads are applied through a circle (*line*), had been developed. Thus, loaded numbers of *points* were extremely increased. The core strangle test is intended as an index test for the strength classification of rock materials, and for determination of unconfined compressive strength. The test measures the core strangle index (CSI) of rock specimens in the form of core having a length of 25 mm or more, and rock specimens are broken by the load applied through a circle perpendicular to the core axis as a “strangle”. The test can be performed with portable equipment in the laboratory. If the facility for coring the rocks is available, it can also be conducted in the field.

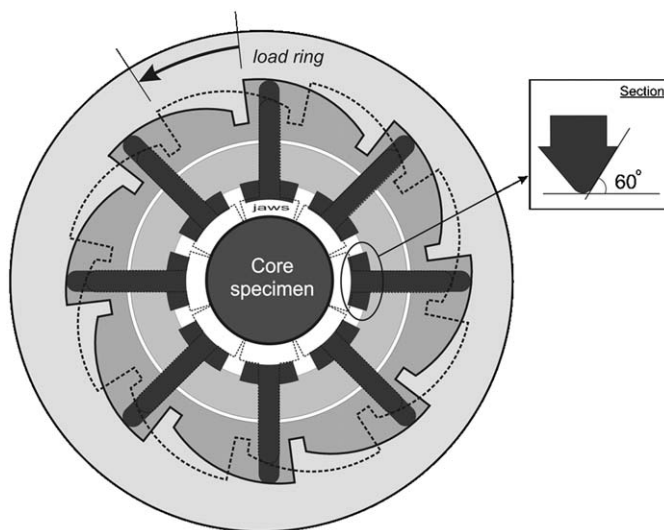


Fig. 2. Loading unit and section of a jaw.

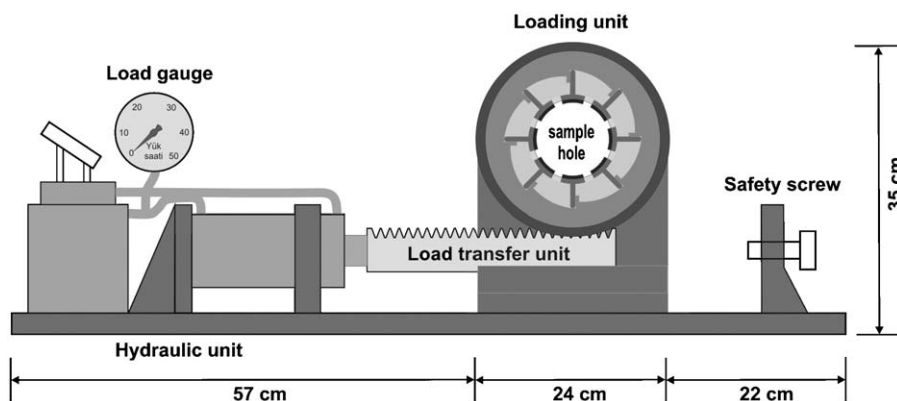


Fig. 1. Designed test machine and main units.

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