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The Influence of Deformation of the Frame of Testing Device on the Accuracy of Brazilian Test and Indirect Assessment of Young Modulus

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Abstract: This article deals with determination of mechanical properties based on indirect measurements of brittle building materials like stones using portable device. Due to the fact, that the material samples may change their properties during transportation, it is preferred to test samples on site. For these reasons, portable testing device was developed. The testing machine operates on the split test principle. The device also shall to serve for estimation of other mechanical characteristics of the tested material, such as Young's modulus, compressive strength or flexural strength, etc. This paper concentrates on the effect of deformation of frame on the accuracy of indirect determination of mechanical properties.

Introduction

Direct assessment of elastic modulus E, tensile strength σUT or fracture toughness KIC of brittle materials represent a difficult problem for experimental instrumentation. Therefore alternative solutions have been proposed [1,2]. One of these alternative solutions, called the Brazilian test, has been popular for determining tensile strength for brittle building materials mainly due its simplicity. The Brazilian test is performed by compression with diametrically opposite concentrated loads on a disc specimen. When the specimen dimensions and maximum force at the moment of the fracture of sample is known, it is possible to calculate the tensile strength of material. If we know the relationship between load and displacement/deformation, it is possible to estimate other parameters of the material.

Experimental device

The testing device is primarily intended for split tests of core samples. Weight of the device is approximately 25 kg. The loading is performed by moving the lower grips upward. The lower grip is lifted by wedge mechanism. Linear movement of the wedge is implemented by screw rotation. Maximal loading force is limited by 100 kN. Loading force is registered by logger from measuring bolt. Force data are imaged by data-logger display and can be recorded by a computer in digital form. Loading displacement data are obtained directly by measuring instruments based on optoelectronics sensors and by non-directly by counting of the loading screw revolutions, both types of data can be recorded by a computer in digital form. Interchangeable jaws with different ratios $R_{jaw}/R_{specimen}$ are installed in the testing machine. The custom written software is used to control the test equipment. This software allows calculation of tensile strength R_T, compressive strength R_C and flexural strength R_F using data obtained from the test device, without further operator intervention.

Theory

Brazilian test and calculation of tensile strength. Theoretical basis for the split test is analytical solution developed by Hondros for determination of elastic modulus and Poisson’s ratio [1]. That failure is expected to initiate at the center of disc. The tensile strength R_T is expressed as

$$R_T = \frac{2F_{\max}}{\pi LD}, \tag{1}$$

where P is line load [N/m], L is thickness of the disc, and D is diameter of the specimen. When using jaws with the radius, a more accurate solution proposed by Koukoulis can be used.

Estimation of Young modulus. In the case of the known relationship between displacement and load, other mechanical properties such as Young modulus can be determined. Estimation of Young modulus can be based on following relationships

$$A(\Delta x) = \Delta x \cdot F(\Delta x), \tag{2}$$

$$\sum_{i=1}^{i_{macx}} \left(F_{measured}(x_i) - F_{simulated}(x_i)\right)^2 = \psi\left(E_{simulation}, \sigma_{simulation}\right), \tag{3}$$

where A is deformation work, Δx, resp x_i are the displacement, F is loading force, and E is Young modulus. Subscription indicates values measured directly by sensors. Subscription simulation indicates simulated values.

Experiments and effect of frame deformation

Specimens were prepared from sandstone by core drilling. The specimens were obtained in dry condition. Diameter of the specimens was 47-50 mm and length was about 70 mm. Specimens were loaded to final rupture by the developed portable loading device. Result of split test shows that the tensile strength σ_{UT} differs only a little from that obtained by other methods. In the case of other variables such as E, however, there are significant differences (order of 10 or more), which do not allow practical use of measurements of E. This behavior can be explained by the growing influence of deformation of the devices frame on indirect measurements. If the model based on the relationships Eqs. 2 and 3 is corrected by deformation of the frame, the results are better. For further practical use it is necessary to implement a set of additional measurements to create a table of corrections. These corrections must be implemented to the control software. The problem, however, is gaining generally valid correction because results differ for tests carried out for only one type of material (error between 20-150% depending on the sample). Deformation of the frame, jaws and the samples can be simulated by Finite Element Method. In order to refine results further, it is necessary to implement additional measurements.

Results

Corrections based on the relationships Eqs. 2 and 3 improve results of measurement. Implementation of the corrections to the control software improves accuracy of the measurement.

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