Indirect Tensile Tests of Rocks

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Determination of mechanical properties of rocks is an important and at the same time difficult task. Compared to granular soils, rocks have a way higher stiffness and strength, which not only requires the use of specialized, more powerful loading devices, but also causes difficulties in the preparation of the samples of a required shape. In addition, rocks have significant tensile strength. This makes a construction of testing instruments complex and costly. Therefore, installations that allow to solve several problems by tooling package changing are valued in survey laboratories. Universal methods are valued as well. These methods include indirect tensile tests.

Uniaxial tensile tests are regulated in Russia by GOST 21153.3 “Rocks. Methods for determination uniaxial tensile strength”. This document provides for three versions of testing, the first of which is direct tension test. Its implementation is associated with the following difficulties. First, it is necessary to transmit a tensile force, that is quite high sometimes, to the specimen. Consequently, grips that securely hold the specimen during the experiment are necessary. Fixation of the lateral surface only may not be enough, therefore many designs use specimens in the shape of a dog-bone, by the “flanges” of which the grip holds the specimen. The production of such specimens of regular geometric shape decreases the productivity of laboratory and requires the special equipment (and often also a room for it). Furthermore, half of a specimen mass turns to dust.

Secondly, not every loading device and measuring system can operate in the same range of axial compressive and tensile forces. This restricts the uniform applicability of the method and does not allow to implement it in existing loading devices.

That is why indirect tensile methods are more versatile. Method of destruction of cylindrical samples by compression along the generatrixes (known abroad as the Brazilian test) allows testing on cylindrical samples with diameters between 30 and 60 mm, which significantly reduces the cost of the experiment. Cylinder is placed horizontally between upper and lower loading platens or wedges, after which a compressive load is applied, causing the specimen to fail along its vertical axis. Uniaxial tensile strength is determined by the formula:

$$\sigma_t^c = K \cdot \frac{P}{S} \cdot 10,$$

where P is the axial force when the specimen fails, S is the cross-sectional area of the specimen along the splitting plane, K is the proportionality factor.

The proportionality factor takes into account the concentration/deconcentration of stresses at the contact with the specimen, depending on the method of transferring the compressive force (platen or wedge). In world practice, thin steel rods are sometimes used instead of wedges to transfer the load along the line. In addition, there are test options with relatively soft layings (to prevent local sample crushing) and curved jaws (for better alignment). Russian regulatory document requires to use a segmental hinge to ensure alignment.

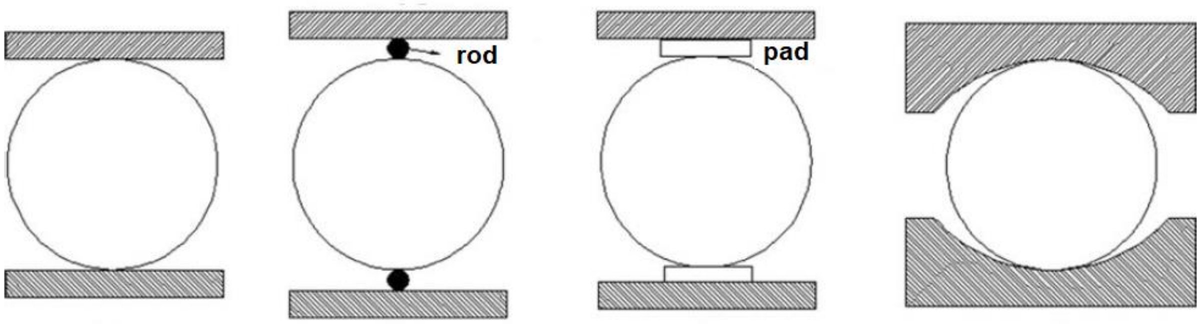

Figure 1. Variants of loading configurations when testing cylindrical specimens by compression along generatrixes

Another indirect tensile test method is loading irregularly shaped samples with spherical indenters. This type of testing is very popular and widely used by survey providers, since it does not require complex tooling and any preparation of the samples. It is assumed that an irregularly shaped specimen should be placed between two oppositely directed spherical indenters. Load application causes the splitting of the specimen, after which the cleave area should be determined and the uniaxial tensile strength should be calculated. Obviously, the test is considered to be successful if the sample is divided into no more than two parts by destruction.

It should be noted that this type of test is described in two valid documents. Section 3 of GOST 21153.3-85 assumes this test is carried out only to determine the tensile strength:

$$\sigma_t = K \cdot \frac{P}{S} \cdot 7{,}5,$$

where P is the axial force at failure, S is the cross-sectional area of the specimen along the splitting plane, K is the scale factor taken depending on S.

Obviously, the unknown shape of the section does not allow to obtain an exact analytical solution for this method. This explains the need to use the empirical coefficient K. Another reason for inaccuracy is the difficulty in determining the cross-sectional area. The traditional method is to use graph paper, but modern devices can optimize and improve accuracy – for example, by scanning a print and determining its area using software.

There is also GOST 24494-81, which describes an installation with spherical indenters for determining the strain parameters. During the experiment, determination of uniaxial tensile strength (in full compliance with GOST 21153.3-85, the text contains a reference), uniaxial compressive strength (according to correlation equations, depending on the type of rock) and strain parameters is carried out.

The determination of strain parameters requires the additional installation of the measuring system of vertical displacements. In this case, several loading steps are performed, which makes it possible to determine not only the elastic modulus under uniaxial compression E_c, but also the contact modulus E_{cont} and the category of rock plasticity. Unfortunately, the method has limited applicability, since for particularly hard rocks the accuracy of measuring displacements may be insufficient, and the use of uniaxial compression in accordance with GOST 21153.2-84 will be required.

The value of the uniaxial tension strength obtained by any method can be used directly (for example, when calculating the stability of an underground working or a rocky slope) and in further interpretation of results. In particular, basing on σ_c and σ_t determined by direct tests, Mohr's circles can be plotted for the cases of uniaxial compression and tension, respectively. This makes it possible to determine the parameters of the Mohr–Coulomb failure criterion for rocks.

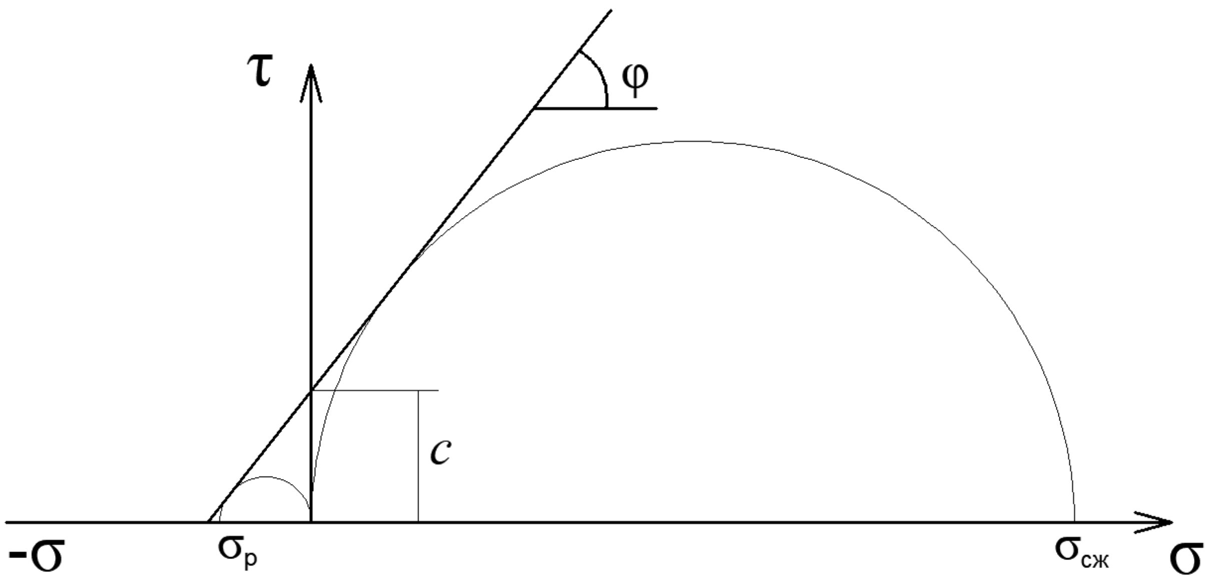

Figure 2. Scheme for determining the parameters of the Mohr–Coulomb failure criterion for rocks

It would be more correct to construct not a straight line, but an envelope according to the empirical dependence given in GOST 21153.8-88. This will allow to determine the parameters of shear strength in any required stress range. However, such tasks rarely arise in civil engineering, and relate more to mining.

OOO “Geotek” offers a wide range of loading devices and tooling packages for indirect tensile tests of rocks. Testing system includes the necessary equipment for creating static vertical action and all necessary measuring equipment. Tests are carried out in an automated mode with control of all test parameters in real time. The use of replacable tooling packages allows rational placement of the equipment in the laboratory.