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STRENGTH OF BRITTLE MATERIALS IN NONUNIFORM TRIAXIAL COMPRESSION

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Based on the analysis of a great body of the experimental data on the strength of concrete, rock and other brittle materials subjected to non-uniform triaxial compression, a general relation between the gain of the material strength and the pressure of the ambient fluid is derived.

A great number of publications deal with investigations on the strength of concrete and rock specimens tested in an impervious jacket under the stresses

$$\sigma_1 > \sigma_2 \geq \sigma_3 < 0 \quad (1)$$

where σ_1, σ_2 and σ_3 are the principal stresses. All the investigators indicate that the compressive strength of the specimens R_c increases with a build-up of pressure in the surrounding fluid ($\sigma_2 = \sigma_3 = P$). Several investigators have used a relation of the form

$$R_c = R_o \quad (2)$$

where R_c is the triaxial compressive strength of the material, R_o is the uniaxial compressive strength of the material at $P = 0$, and A is an empirical nondimensional coefficient. The values of A in equation (2) are generally given as applied to specific testing conditions. The authors know of no generalized data on determining the strength gain of brittle materials in nonuniform triaxial compression. Current strength hypotheses fail to give an answer to the problem.

The test results of about 250 experimental runs on specimens of the compressive strength in the range R_o = (15-350) MPa have been examined and generalized by the authors. Among these are the well-known experiments of Th. Karman [1], I. Handin and R. Hager [2], S. Ito [3], S. A. F. Murrell [4], B. V. Baidyuk [5], I. G. Goncharov [6], and others. The authors' test data which are partly reported in references [7] and [8] have also been included. Specimens made of concrete, cement mortar, marble, sandstone, limestone, schist, etc., have been tested. The cylindrical specimens have been tested in an impervious jacket, with condition (1) met. The size of the specimens, the jacket material and the loading rate varied from test to test. The statistical processing of a considerable body of the test data allowed the relation between the strength gain in triaxial compression and the values of P and R_o to be established with a fair degree of reliability. The experimental results plotted as the coordinates log R_o and log ξ where,

$$\xi = \frac{R_c - R_o}{R_o \cdot P}$$

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is the relative strength gain of the material under triaxial compression, are illustrated by Figure 1. As seen from the Figure, the strength gain decreases with increasing R_o. The statistical data reduction by the least squares method indicated that the correlation between log ξ and log R_o is close to the linear one, (the correlation coefficient $\eta = -0.9$). From the linear regression equation an empirical relation for determining R_c is obtained as

$$R_c = R_o + \frac{36P}{\sqrt{R_o}} \cdot b\ , \qquad (3)$$

where R_c, R_o and P are expressed in MPa, and b is the dimension factor of $MPa^{1/2}$.

The values of A in equation (2) may be estimated from

$$A = \frac{36}{\sqrt{R_o}} \cdot b\ . \qquad (4)$$

The values of A versus R_o are given in the Table.

Hence, it may be anticipated that the strength of 20 MPa concrete under triaxial compression will increase by 8P MPa, and that of 200 MPa solid rock only by 2.5P MPa.

To our knowledge, equation (3) has been first deduced in the U. S. S. R. It allows calculation of the expected strength gain of brittle material, with condition (1) observed and R_o - values varying over the range 20 to 300 MPa.

The above values of R_c refer to the case when there is no pressurized fluid in the voids and cracks of material. However, the voids and cracks in the concrete of dams or in rocks are usually saturated in full or in part with water under pressure. Designating the coefficient of the degree of void saturation under pressure as α, a formula is obtained for assessing the triaxial compressive strength of brittle materials $R_{c\alpha}$ at any degree of saturation under pressure

$$R_{c\alpha} = R_o + \frac{36Pb}{\sqrt{R_o}}$$

where in a general case $0 \leq \alpha \leq 1$.

Numerous triaxial compression tests on specimens manufactured from the concrete of the Sayano-Shushenskaya dam have been carried out, with water percolating under pressure through the concrete [2]. The tests revealed that a reduction in the strength gain with the values of $\alpha \approx 0.25$ is relatively small. These findings have been utilized in the design of the Sayano-Shushenskaya arch-gravity dam. In the dam portions under triaxial compressive stresses (approximately 50% of the volume of concrete in the dam) cement economy is achieved and the construction cost lowered thanks to the increase in the strength in triaxial compression.

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Table 1

R_o (MPa)	20	40	100	200	300
A	8	5.7	3.6	2.5	2.1

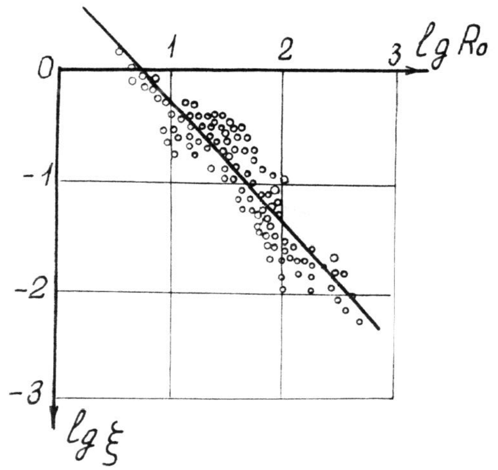

Figure 1