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Statistical Estimate of Uniaxial Compressive Strength of Rock Based on Shore Hardness

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Abstract

The paper presents the use of advanced stochastic simulation techniques for estimating the strength behavior of rock materials. The Shore Rebound hardness was measured on fifty rock specimens coming from eleven different geological localities in Czech Republic. The dry unit weight of every tested rock material was determined also. Uniaxial compressive strength of rock was evaluated then by conducting the compression test on every specimen. Empirical distribution of Shore hardness and dry unit weight variables obtained from laboratory tests was approximated by the best fitted theoretical probability distribution. The stochastic simulation using Latin Hypercube Sampling was conducted based on those distributions. Two different equations used for estimating the compressive strength of rock on the basis of Shore hardness in practice was used as model functions. Comparison and statistical evaluation of uniaxial compressive strength of rock determined by compression test and those obtained as a result of stochastic simulation is discussed. The description of probability distribution of uniaxial strength is obtained as a result of introduced analysis, which can be used as input for fully probabilistic design models of rock materials.

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*Keywords:*Rock mechanics; Shore Scleroscope; Rebound hardness; Uniaxial compressive strength of rock; Stochastic simulation techniques; Latin Hypercube Sampling; Test of goodness of fit; Probability distribution

1. Introduction

Several studies using Shore hardness have been done to estimate strength parameters of intact rock. For example: [1], [2] or [3]. Extension of referenced knowledge and practical experience in using of Shore hardness parameter from region of Czech Republic is presented in this paper. The authors collected relatively wide range of rock types,

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hence the results of examination of currently used correlations are general valid. Shore hardness of rock specimens was measured firstly. Uniaxial compressive strength was tested on the same specimens so obtained results can be correlated and reliably compared. Two basic formulas for estimation of UCS from Shore hardness were chosen for detailed analysis. Results of measurements were then used as inputs for stochastic simulation method and sensitivity analysis to evaluate the possibility of estimation of rock material strength in this way.

2. Description of tested rocks and laboratory tests

2.1. Locations of rock sampling

Samples of the rocks come from 11 different locations around Czech Republic, see Table 1. Places are concentrated in Northern Bohemia, in surroundings of Prague and in Moravia. Thus, selected rocks are covering considerable part of the country and they consist of wide variety of different rock types. The data contained in this paper give interesting opportunity to analyse possible correlations of characteristics among various rock types.

Table 1. Description of locations and rock types.

No.	Name of locality	Rock type	Origin
1	Dolní Kounice	Granodiorite	igneous
2	Ústi nad Labem	Trachyte	igneous
3	Velké Opatovice	Sandy marlite	sedimentary
4	Hrob	Paragneiss	metamorphic
5	Čertovy schody	Limestone	sedimentary
6	Dolní Žleb	Sandstone	sedimentary
7	Vlastějovice	Orthogneiss	metamorphic
8	Hanušovice	Amphibolite	metamorphic
9	Vilémov	Phyllite / Quartzite	metamorphic
10	Vrané nad Vltavou	Tuffite	sedimentary
11	Štěchovice	Shale	sedimentary

2.2. Laboratory tests

There were 5 samples of rock tested coming from each locality. Exceptions are locality no. 4 – Hrob where only two samples were possible to prepare and locality no. 7 – Vlastějovice with four extracted samples. The test specimens were prepared from drill cores therefore they had cylindrical shape with diameter 44 mm and height approx. 75 mm. The density was identified according precise measurement of dimensions and weight for each sample.

Further there was tested scleroscopic hardness with apparatus Shore–type D (manufacturer: The Shore Instrument & Mfg. Co. N. Y.). There were always 10 rebounds recorded on down and up base. It is 20 rebounds for each specimen totally. Obtained values were statistically processed afterwards and the uniaxial compressive strength was calculated according correlations (11) and (12). Finally, the uniaxial compressive strength was tested directly in hydraulic press Advantest 9 (manufacturer: Controls) in technological centre AdMaS. The speed of loading was set to approx. 0.3 MPa/s until failure. Moisture of samples during the test was equal to laboratory environment.