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The Changes of P-Wave Velocity of Rock Samples Over Time

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Abstract

The main aim of this study was to determine the variation of the P- wave velocity of carbonate rocks over time. Samples of carbonate rocks like dolomite and limestone were carried out from three quarries. The study was done in May and November 2015. To test equipment Pundit Lab+ was used, which measure the transmission time of ultrasonic wave. On the base on the transmission time P- wave seismic velocities were calculated. It allows to compare the results obtained for one time interval and to calculate, using the Student's t test, if differences of P- wave seismic velocity values are significant.

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Keywords: ultrasonic measurement; P- wave velocity; carbonate rocks

1. Introduction

Determination of the physical and mechanical properties of rocks is the most interesting problem which is still not definitely solved despite of a lot of scientists who try to do it. It seems to be very important to make an assessment of the elastic properties of rocks which can be studied in laboratory using cylinder samples [3–5, 7–9, 13] and also directly in quarries using geophysical methods [10, 14]. The rock under the influence of external forces undergoes compression and decompression. The deformation of the body is the result of moves of its particles relative to each other. Rocks within the rock mass there are under the pressure of the surrounding rocks. Depending on the pressure size, rocks there are in a specified state of compression and a specified state of deformation [1, 2, 6]. At the moment of output from the deposit and remove the existing pressure, annealing process begins and elastic strain decays. The decompression of rock causes the change of properties such as hardness, grindability, porosity and strength. In addition to decompression phenomena, another process takes place like moisture loss.

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In the process of deposit documentation the tests are done immediately after extraction of the rock from the rock mass but in many cases, these tests are carried out after a certain time when the analysed samples were stored by some time under certain conditions.

The study of the P- wave seismic velocity shows the importance of the time factor to determination of the physical parameters of a sample.

The measurements of the seismic wave velocity were performed in three Triassic carbonate quarries: one limestone deposit (deposit 1) and two dolomite deposits (deposit 2 and deposit 3). From each quarry blocks of rocks were collected to laboratory measurements.

2. Laboratory measurements

From blocks of rocks were cut cuboids with a length of 0.1 m and section 0.05 m x 0.05 m. The Ultrasonic Instrument Pundit Lab+ Swiss company Proceq was applied. The ultrasonic impulses are repeatedly transmitted to the sample and then recorded as the time (t) of the ultrasonic wave passing through the sample. The rock specimens were mounted between the transmitter and receiver transducer holders. The length of sample is a way (s). It is possible to calculate the velocity (v) using the formula v = s / t. In order to ensure close contact between the surface of sample and transducers it was used special paste. The frequency of elastic signals used for transmission measurement is 250 kHz. The pulse length is 2μs. The accuracy of time of arrival of P- wave is 1 μs. The research included approximately 3000 measurements in May [11] and approximately 2500 in November. The samples were stored in room temperature. The study was performed using three samples from each quarry. The anisotropy coefficient k was calculated for each sample from equation:

$$k = \frac{v_{p\max} - v_{p\min}}{v_{p\,mean}} \cdot 100\% \tag{1}$$

average of the velocities corresponding to all measured directions. The values of the maximum and minimum velocities and coefficients of anisotropy are summarised in Table 1.

3. Result and discussion

The obtain P- wave velocity values, measured at an interval of half a year, have not shown significant differences (Table 1, Fig. 1). In the case of deposit 1 the seismic wave velocity value was higher in May than in November. In the case of deposits 2 and 3, the situation is reversed, the seismic wave velocity is higher after six months.

The samples of beige limestone from the deposit 1 characterise by cracks filled with calcite. In the sample 1 cracks are not visible on the surface but there are numerous small cracks in length in the range of from 1–2 mm to 20 mm. The velocity values and anisotropy coefficient k = 11 % indicate on the anisotropy. In the sample 2 it is observed two cracks perpendicular respectively to axis 1 and 2. These cracks cause that velocities in this sample have similar values for all axes and the coefficient k = 3.6 % does not indicate the presence of the anisotropy. In the sample 3 we can also see cracks with a diameter of 2 mm and filled with calcite, air or clay material. Values of the velocity and the coefficient k show a distinct anisotropy. The highest value of velocity 6800 $m \cdot s^{-1}$ occurs in a plane parallel to the cracks.

The grey limestone sample coming from the deposit 2 contains the inclusions of calcite with spherical or hemispherical shape. The packing of inclusions parallel to axis 1 and 3 causes the occurrence of the anisotropy.

Obtained values of velocities for deposit 1 are larger than of the deposit 2 what may be due to the effect of unstressing or the difference between the physical properties of the rocks.

The structure of dolomite samples from the deposit 3 has a more homogeneous character hence the coefficient k has a smaller value. The samples are dark yellow to gray color. In the samples 1, 2 and 3 there are open cracks of 0.1 mm filled with clay material. These cracks are perpendicular to the axis 1.