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COMPARISON OF THE MEASUREMENT OF CHANGES OF THE ULTRASONIC WAVE VELOCITY IN THE PROCESS OF DEFORMATION FOR DIFFERENT TYPES OF EQUIPMENT

Abstrakt

The comparison of measurement of ultrasonic P - wave and S - wave velocities changes in the process of deformation has been presented in this paper. The experiments were performed in Institute of Geonics AS CR in Ostrava and Strata Mechanics Research Institute PAS in Cracow and the results was compared. It was confirmed that configuration of measurement system, which was disposable in both laboratories, did not influence the measurement results and the results of measurement were very similar.

Key words: Ulrasonic wave velocity, physical rock properties

Introduction

Cracks, failures and other inhomogenities are the mediums strongly influence the ultrasonic wave propagation. The ultrasonic wave velocity measurement is usually used before laboratory geomechanical tests to avoid the testing of anomalous samples. However, the measurement of the ultrasonic wave velocity in the process of deformation is one of the method enables the monitoring of the degree of failure in the rock samples, too. Moreover, it is possible to observe the changes of dynamic Young's modulus and Poisson ratio in the process of deformation.

Method of measurement

The measurement was performed in two institutions with different equipment and with the same methodology to compare the influence of the system of measurement on results.

The rock testing system Instron 8500 (max. load 5000 kN) with a special cell for measurement of longitudinal and transversal wave velocity in the process of deformation (fig. 1) was used in Strata Mechanics Research Institute of the Polish Academy of Sciences in Cracow (hereafter IMG PAN). The measurement of axial and lateral deformations were performed by strain gages (Kanciruk, 1995).

The apparatus used for measuring ultrasonic wave delay contains of a digital oscilloscope, an ultrasonic testing device and two identical anvils. The oscilloscope of Tektronix 2230 type is a typical instrument used for observation of periodical and non-periodical electric signals. It makes it possible to measure time periods of non-repetitive signals with resolution of 50ns. In case of repetitive signals the resolution is up to 0,5 ns.

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The ultrasonic testing instrument DI-23P was produced by Inco (Warsaw – Poland) several years ago. It was destined for industrial testing of metal goods. For the above-mentioned measurements the device plays a role of generator of exciting pulses only. The anvils are of Unipress – Warsaw production. Each of them contains two piezoelectric ultrasonic transducers: one for transmitting (or receiving) P-wave, the other for S-wave. The transducer resonant frequency is 1 MHz. The tested cylindrical specimen is placed between the anvils. Their solid construction makes it possible to use them during uniaxial tests with load up to 400 kN. In spite of this, that the apparatus is rather of temporary character, it makes it possible to perform measurements of P- and S-waves delay during crossing rock specimens.

The instrument DI-23P can produce electric pulses repeating every 20 ms. Their amplitude can vary from 500 to 1500V, duration time is about 2 μs. The pulses are attached across a 2-pole switch to one of the anvils transducers, playing the role of waves transmitters. The receiving transducers are attached to two oscilloscope channels switched simultaneously. Thus, all of transducers operate in the alternating mode. The received signals are observed on the oscilloscope display. Additionally the output of the instrument DI-23P is connected to the oscilloscope synchronizing input “EXT”. The delay between the exciting pulse and the first positive peak of the received signal can be easily measured. For typical rock specimens the measuring resolution of 20 ns or even 10 ns is quite sufficient.

Not only the tested specimen produces ultrasonic waves delay. The anvils have their own delay, too. Therefore, before the experiment the anvils delay for P- and S-waves must be measured. For P-waves delay measurement the faces of the anvils are covered with a thin layer of couplant (for example glycerin), and tightly contacted together. For S-waves delay measurement the anvils must be loaded by force about 10 kN. The values are then subtracted from the results obtained during the specimen test.

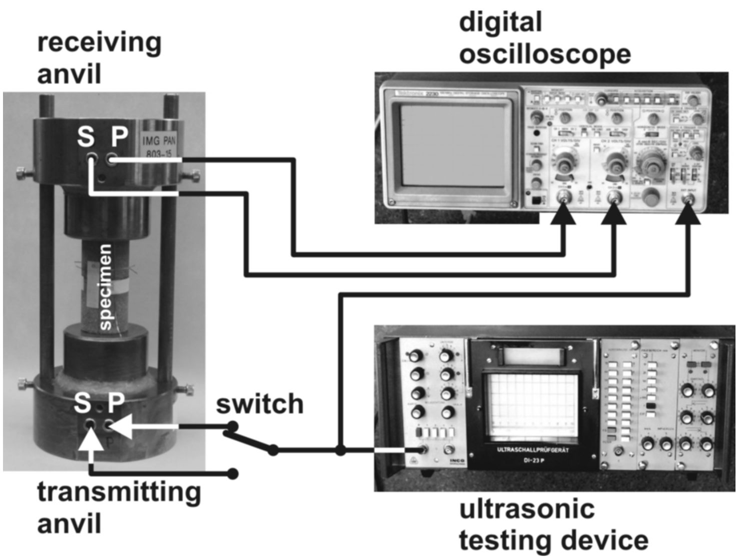

Fig. 1 The apparatus to test propagation of ultrasonic waves in rock specimens in IMG PAN Cracow

The axial force is work on by mechanical press ZWICK 1494 (max. load 600 kN) in Institute of Geonics of Academy of Sciences of the Czech Republic in Ostrava (hereafter ÚGN AV ČR). The measurement of axial deformation is registered from the press Zwick crossbar, the lateral deformations are measured with special strain gage sensors for measurement of lateral deformation of tested specimen (Konečný & Dombková, 2006).

The ultrasonic wave velocity measurement is provided by ultrasonic PC ISA card UMT-12 produced by Ultramet (Radom – Poland). The card is connected to PC 386. This UMT-12 card functions both as a transmitter and receiver of ultrasonic signal. The anvils are of Unipress – Warsaw production, analogous to anvils used in Cracow (fig. 2). The parameters are similar for both types of anvils; however, this type is constructed for triaxial measurement, too.

Original Basic Software of the UMT-12 displays the registered signal on PC monitor. The reading of values is realised manually by operator.

Although the both systems are very similar, the comparison measurement was performed to obtain the data measured by the same methodology.

The marble from Lipová locality was selected as a reference material. This monomineral rock (calcite compose nearly 100%) is known from the previous research as a material with good reproducibility of the results. Tested specimens of cylindrical shape with diameter of 48 mm, approximately, were drilled from rock blocks perpendicularly to metamorphic foliation. The ends of samples were sawed by diamond saw and polished. The slenderness ratio of specimens was 2:1 (high: diameter), finally.

Before placing between the anvils specimen's faces have also been covered with a couplant. After many years' experiments (at the beginning such couplants like glycerin, gel used for medical USG tests or greases were used) it has been found out that the best couplant, particularly for porous specimens, is the edible bee honey. The anvils and the specimen are put to uniaxial testing instruments like the above-mentioned Zwick or Instron and loaded up to the specimen failure.

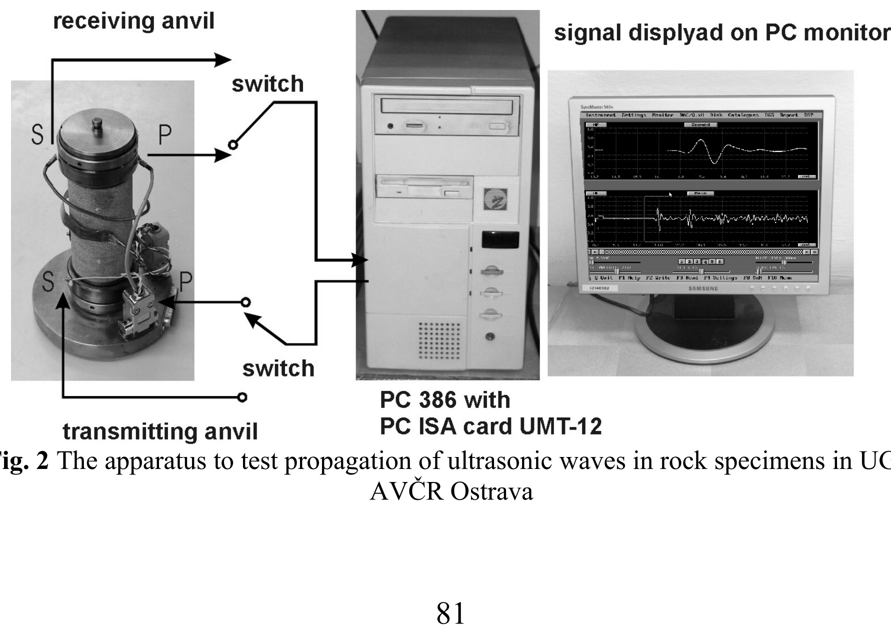

Fig. 2 The apparatus to test propagation of ultrasonic waves in rock specimens in UGN AVČR Ostrava

The research results

The following results were obtained with the use both the system Instron equipped with a precise load-cell of the measuring range equal to 325 kN and mechanical press Zwick. The advance velocity of the actuator piston had been set at 0,25 μm/s. The both systems can work in automatic mode. Therefore after their proper programming and starting their work they function without any further operation throughout the whole experiment. The measurement of ultrasonic waves delay time to pass through a specimen under examination is manually performed. It does not ensure a great frequency of measurements, yet with an adequately slow increase in load, alternating measurements taken every 30 seconds give up to 100 or even more results. A typical experiment takes about one hour.

Comparison of data from experiments on granite and marble confirms a good agreement of results from both system of measurement.

The example of results of measurement of marble (No. 10558) which has been tested by Instron 8500 in Cracow is visible in figure 3.

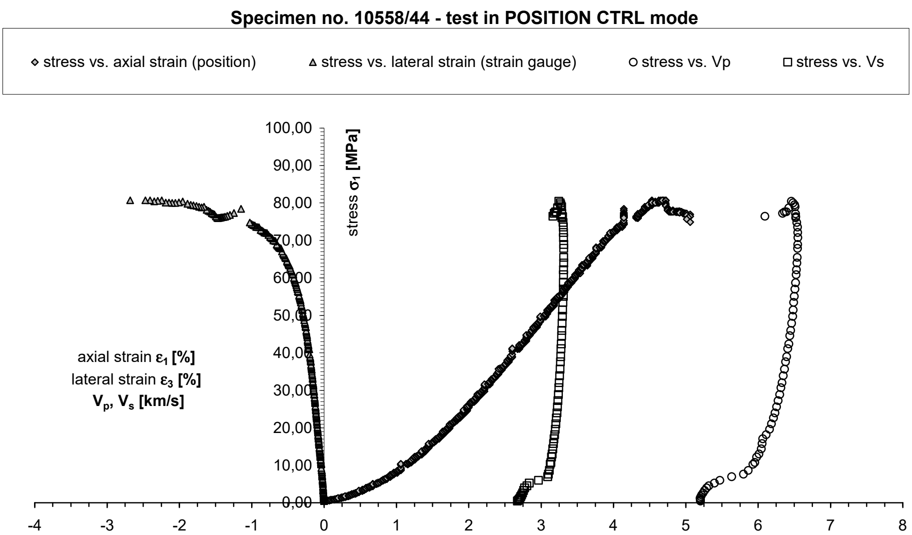

Fig. 3 Graphs of uniaxial measurement of the marble No. 10558/44

The example of results of measurement of the same type of marble (No. 10558) measured by Zwick 1494 in Ostrava is visible in figure 4.

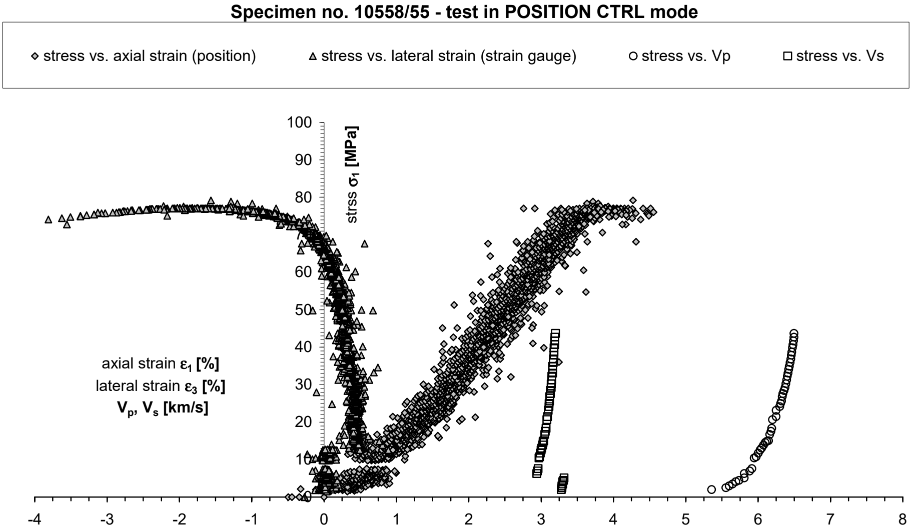

Fig. 4 Graphs of uniaxial measurement of the marble No. 10558/ 55

It is visible from the graphs, that the results of measurement are very similar regardless of system of measurement. Although, some defect occurs during measurement of specimen No. 10558/55 in Ostrava. This defect takes effect during the loading in value 8 MPa. However, there is no affecting in next process of loading.

The measurement with oscilloscope and ultrasonic testing device from Cracow with anvils from Ostrava and measurement with ultrasonic PC ISA card UMT-12 from Ostrava with anvils from Cracow was performed too, to insure about the compatibility of the measurement system.

Conclusions

The comparison of the ultrasonic wave velocity changes in the process of deformation was performed in two laboratories – namely in Strata Mechanics Research Institute of the Polish Academy of Sciences in Cracow and Institute of Geonics of Academy of Sciences of the Czech Republic in Ostrava. It was confirmed that configuration of measurement system, which is disposable in both laboratories, do not influence the measurement results.

This method of measuring of ultrasonic P- and S-waves velocities in rocks specimens during uniaxial tests, in spite of using mostly non-specialist instruments, still produces good results for rocks. It is one of the ways to monitor the degree of specimen destruction. However, the measuring results are used to determine dynamic material constants, as it has already been described (Nowakowski 2005, Konečný 2008).

The above mentioned methodology will be applied for judgement of physical properties of granitic rock massif in Jeroným historical mine and for Liberec granite.

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