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LABORATORY MEASUREMENT OF THE ULTRASONIC WAVE VELOCITY IN TRIAXIAL CONDITIONS

LABORATORNÍ MĚŘENÍ RYCHLOSTI PRŮCHODU ULTRAZVUKOVÝCH VLN ZA TROJOSÉHO STAVU NAPJATOSTI

Abstract

Measurement of the ultrasonic wave velocity on rock samples is one of the standard methods of laboratory study of geomaterials. However, the utrasonic wave velocity change due to impact of state of stress. Therefore, the measuremet is performed both in uniaxial and triaxial state of stress to study the ultrasonic wave velocity changes in the process of loading. The method of measurement in triaxial state of stress and first results are presented in this paper.

Abstrakt

Měření rychlosti průchodu ultrazvukových vln na horninových zkušebních tělesech patří ke standardním metodám laboratorního studia vlastností geomateriálů. Rychlost ultrazvuku se však mění s napěťovým stavem, ve kterém se zkušební těleso nachází. Aby bylo možno studovat tyto změny je rychlost ultrazvukových vln měřena nejen při jednoosém zatěžování v průběhu měření pevnosti v tlaku, ale nově také za trojosého stavu napjatosti při triaxiálních zkouškách. V příspěvku je podán popis této metodiky, nově vyvinuté na Ústavu geoniky AV ČR, v.v.i. a první výsledky měření.

1 INTRODUCTION

The measurement of ultrasonic wave velocity is one of the standard, non-destructive methods applied in geomechanical laboratory measurement. It is important for the analysis and evaluation of seismic, sonic and microseismic field data. In addition the dynamic Young's modulus and Poisson's ratio could be calculated from these data. Both of this modulus are the basic constants permitting the determination of the dependence between stresses and strains for a linearly elastic material. The usual method of measurement is in uniaxial state of stress (Nowakowski, 2005) or with no action of the force. The new conception of measurement, developed in Institute of Geonics AS CR, enables the measurement in triaxial state of stress.

2 METHOD OF MEASUREMENT

The base of the measuring equipment is triaxial cell KTK 100 with maximum confining pressure of 100 MPa (Fig. 1). The axial force is work on by mechanical press ZWICK 1494 with maximum force of 600kN. The triaxial cell is equipped with special ultrasonic jaws enables the measurement of longitudinal ultrasonic wave passing through the specimen (P wave) and the velocity of a lateral ultrasonic wave passing through the specimen (S wave). The triaxil cell is additionally furnished with special strain gage sensors for measurement of lateral deformation of tested specimen. The axial deformation is registered from the press Zwick crossbar (Konečný & Dombková, 2006).

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Fig. 1 Triaxial cell KTK 100 in mechanical press ZWICK 1494

The specimens of cylindrical shape are used for this type of experiment. The diameter of tested specimens is 48 mm and the high is 96 mm so that the high-to-diameter ratio (slenderness ratio) is 2. The specimen is fixed in utrasonic jaws and covered with gum rubber to protect it from oil generating the confining pressure. The contact faces of jaws and specimen are painted with honey to ensure good ultrasonic wave propagation. The ready-made specimen is putted in the triaxial chamber. The confining pressure is controlled by hydraulic oil.

Ultrasonic wave emission and registration supply the ultrasonic PC ISA card UMT-12. The signal is conduct by bushing into triaxial cell. The signal from strain gage sensors is conduced accordingly.

This setting enables the measurement immediately on the tested specimen in comparison with setting utilizing the transmitting of the signal through loading piston (Donald et. al. 2004).

The dynamic Young's modulus (E) or Poisson’s ratio (ν) are determined based on the measurements of the velocity values of sound waves passing through the specimen. This is described by the following formula (Lama & Vutukuri 1978):

$$E = \frac{\rho V_S^2 \left(3V_P^2 - 4V_S^2\right)}{V_P^2 - V_S^2} \qquad (1),$$

$$\nu = \frac{V_P^2 - 2V_S^2}{2\left(V_P^2 - V_S^2\right)} \qquad (2),$$

where:

ρ – specimen density $\left[\frac{kg}{m^3}\right]$,

V_P – the velocity of a longitudinal ultrasonic wave passing through the specimen (P wave) $\left[\frac{m}{s}\right]$,

V_S – the velocity of a lateral ultrasonic wave passing through the specimen (S wave) $\left[\frac{m}{s}\right]$,

Both dynamic Young's modulus and Poisson’s ratio was calculated for different values of state of stress.

3 THE RESEARCH RESULTS

The influence of the increasing of hydrostatic pressure on dynamic modulus changes was measured. It was observed, that increasing of hydrostatic pressure cause the obvious increase of both P wave and S wave velocities. Consequently the increasing of Young's modulus and Poisson’s ratio due to increasing of hydrostatic pressure is visible in figure 2.

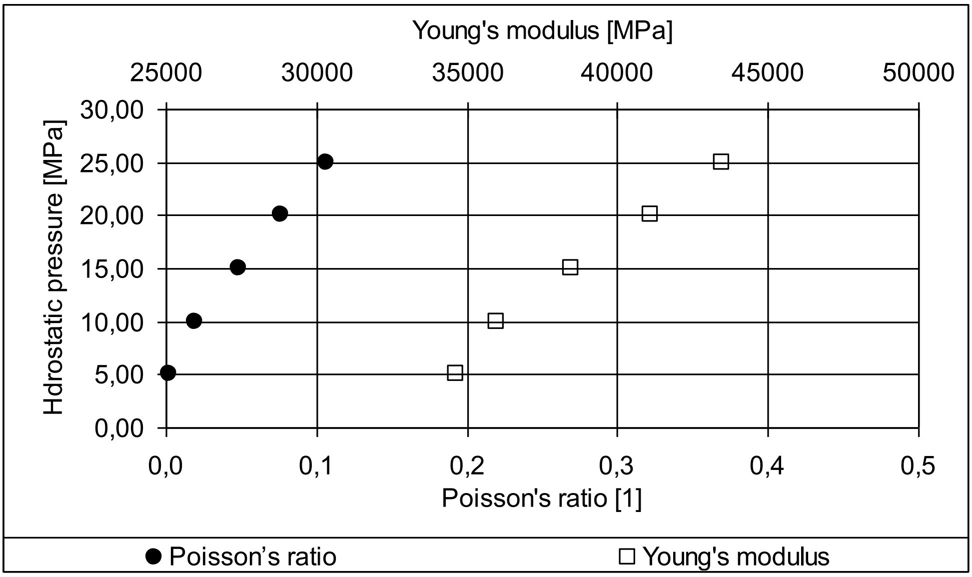

Fig. 2 Example of the dependence of dynamic Young’s modulus and Poisson's ratio on hydrostatic pressure (carboniferous sandstone)

Nevertheless, this adjustment of experiment enables the measurement of ultrasonic wave velocity changes in dependence on axial stress increasing in triaxial state of stress. In this case the static Young’s modulus and Poisson's ratio are determined by the analysis of the curves of dependence between the stress and longitudinal and lateral strains, obtained during this triaxial compression test. The problematic part of this experiment is the increasing of the confining pressure in triaxial cell due to deformation of specimen and inputting of loading piston into triaxial cell.

4 CONCLUSIONS

The new method of measurement of the laboratory measurement of the longitudinal and lateral ultrasonic wave velocity in triaxial conditions was successfully tested. It was confirmed, that increasing of hydrostatic pressure considerably influences the dynamic Young’s modulus and Poisson's ratio. The general advantage of tested configuration is the possibility of the contemporaneous observation of the changes of static and dynamic modulus changes in dependence on stress. The question of the control of constant confining pressure will be solved in the near future.

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