Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 191 (2017) 134 – 141

Procedia Engineering

www.elsevier.com/locate/procedia

Symposium of the International Society for Rock Mechanics

The Methodology for the Young Modulus Derivation for Rocks and Its Value

Piotr Małkowski*, Łukasz Ostrowski

** AGH University of Science and Technology, Department of Geomechanics, Civil Engineering and Geotechnics, al. Mickiewicza 30, 30-059 Kraków, Poland*

Abstract

Young modulus is one of a basic geo-mechanical parameters used for the defining of the phenomena in rock mass. It is determined based on a uni-axial compressive test. According to the International Society of Rock Mechanics one may calculate it in three different ways as the tangent, secant and average modulus. This discretion causes, as the result that one can obtain results, which differ from each other significantly, even threefold or more.

The laboratory tests for Carboniferous rocks: claystones, mudstones, sandstones and coals are presented in the paper. The modulus value distributions for the recommended methodology were compared using statistical analysis. The typical range of the elastic linear deformability for the chosen rock types was determined. Thus the evaluation of the best Young modulus determination method was performed. Tangent Young modulus was recommended as the guiding one, studied with the range of 25-75% of ultimate stress. 503 rock samples have been investigated for this analysis.

Peer-review under responsibility of the organizing committee of EUROCK 2017

Keywords: "rock mechanics, Young's modulus; laboratory rock tests; range of elasticity"

The elastic behaviour of rocks and the range of their elasticity are of crucial importance in rock engineering. In solving problems in mining engineering or tunnelling, the change of stress fields forced by an excavation drivage first depends on the elastic and then the post-failure properties of rock. Hence, determining the rock mass properties appropriately is of crucial importance for a roadway stability evaluation and support design. Among elastic rock properties one may mention: Young’s modulus, shear modulus, bulk modulus and Poisson’s ratio. As the shear modulus and bulk modulus are functions of Young’s modulus and Poisson ratio the last two parameters are the most

* Corresponding author. Tel.: +48 604 055 842; fax: +48 12 617 20 59.
E-mail address: malkgeom@agh.edu.pl

1877-7058
Peer-review under responsibility of the organizing committee of EUROCK 2017
doi:10.1016/j.proeng.2017.05.164

important in solving geo-mechanical problems. Some authors even emphasise, that elastic modulus becomes a critical parameter to describe the rocks' behaviour under load because of their brittleness [1, 10]. All numerical models for stress and deformation analyses such as FLAC, PHASE or UDEC use Young's modulus for solving rock engineering problems [11]. Young's modulus is also a base to derive a deformation modulus of blocky and jointed rock masses, which are non-elastic.

Studying the suggested methods for determining deformation rock properties in uniaxial compression there are three different equal methods [12]. Based on different test results' interpretation one can obtain three different values of the same quantity. It can confuse some designers and lead to erroneous conclusions and inappropriate decisions in mining and rock engineering.

There are results of Young's modulus investigations in uniaxial compression tests. The tests were carried out on four Carboniferous rocks: coals, claystones, mudstones and sandstones. The elasticity range of rocks was determined and then the best laboratory method for Young's modulus determination has been recommended.

1. Elastic behaviour of rocks and suggested methods for determining their deformability

When dealing with the mechanical behaviour of solids, the assumption is that they are: homogeneous, continuous and isotropic but rocks are much more complex and their mechanical properties vary according to scale, minerals' composition or matrix type [1, 5, 11]. However in practice engineers expect definite values of rock properties for the rock types. The only way of provide them are by extensive laboratory and field investigations.

The basic strength laboratory test for rocks is a uni-axial compression. Every rock behaves elastically up to the point when propagated cracks change the manner of deformation into quasi-plastic and, reaching peak strength, a rock starts to break down, changing its strength properties. Generally one may identify four phases of rock deformation before it fails (pre-failure) and one phase beyond the peak strength (post-failure – Fig. 1). There are:

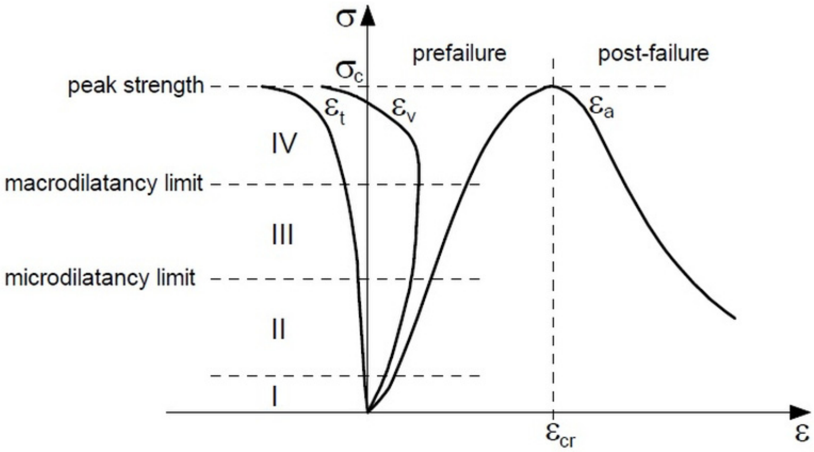

Fig.1. Typical stress-strain chart for rocks, ε_a – axial deformation, ε_t – transverse deformation, ε_v – volumetric deformation.

- *Compaction phase (I)* – the primary cracks and joints and inter-grain pores close under rising load. The stress-strain curve can be linear or non-linear because of the primary micro cracks' density and their geometry;
- *Linear elastic deformation phase (II)* – elastic deformations predominate in this phase, but some non-linear behaviour is possible. The stress-strain curve is linear;
- *Stable fracturing phase (III)* – the start of this phase is the micro-dilation limit when the separation of cracks and their propagation in the directions parallel to the main compressive stress direction begins. The stress-strain curves for volumetric and transversal deformations cease to be linear. Acoustic emission increases;
- *Unstable fracturing phase (IV)* – exceeding the macro dilatancy limit the crack opening mode begins, followed by crack sliding mode initiation and their unstable propagation. Increasing and joining of the cracks is the reason