Establishing relationship between effective elastic moduli and stress state using critically stressed fractures concept

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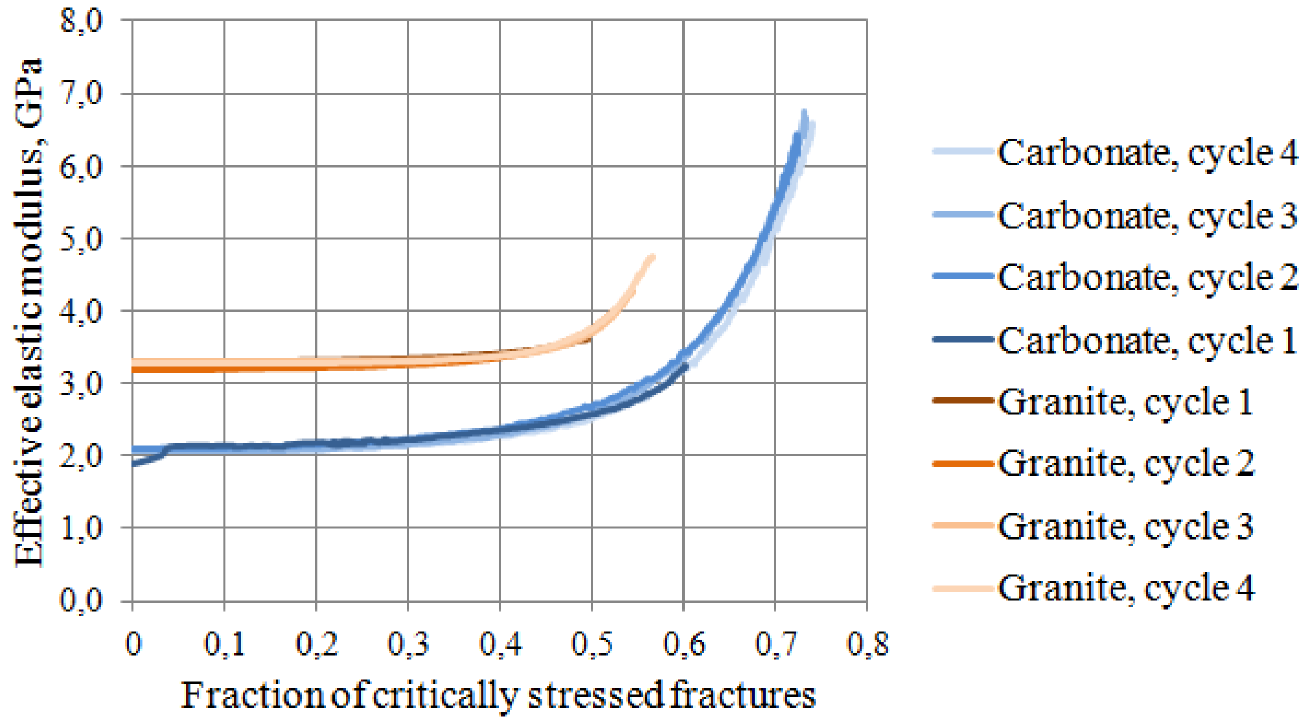
In the paper the results of experimental studies of rock geomechanical behavior are presented. These results were used as a basis for estimating the stress state from critically stressed fractures analysis.

A series of triaxial tests on the rock samples was performed in this study. Each sample was subjected to radial and axial stresses. The stress-strain curves were analyzed with volumetric strain –axial stress curve being of especial interest. It appeared that after a certain critical point (related to the start of microfractures propagation inside the sample) the volumetric strain curve is nonlinear. A mathematical model for this nonlinear behavior is also introduced.

At the same time the critically stressed fractures were analyzed. It was postulated that the fractures appear in the rock and their stable propagation takes place after the stress state exceeds a critical one determined by the fracture initiation Griffith criteria. Loading the sample above this critical state leads to appearance of critically stressed planes, which spatial orientation can be determined for each stress state. The fraction of critically stressed fractures was introduced as a nominal parameter defined as the ratio of areas of the Mohr’s circle being above the frictional failure envelope to the full area of Mohr’s circle.

It appeared that the dependence between volumetric strain of the sample and the fraction of critically stressed fractures remains the same for different loading cycles –fig. 1. Here we use effective elastic modulus which is partial derivative of axial stress with respect to volumetric strain. The result is the same for different rock samples and loading conditions –the curves from different loading cycles merge providing the fraction of critically stressed fractures to relate the current stress state and measurable variance in elastic modulus of the medium.
The obtained result may be interpreted in the following way: whenever one can see that the elastic modulus of a certain domain of the rock strongly differs from the mean elastic modulus, it may be related to the presence of critically stressed fractures in this domain. In case when no other reasons from such local extrema are observed and one has obtained a typical elastic modulus –fraction of critically stressed fractures curve (like the one at fig. 1) for this particular rock, it becomes possible to numerically evaluate the fraction of critically stressed fractures. This provides an extra relationship between principal stresses while solving the inverse problem of in-situ stress state estimation.

Keywords: Geomechanics, Critically stressed fractures, In-situ stress


Effective elastic modulus, GPa
8,0
7,0
6,0
5,0
4,0
3,0
2,0
1,0
0,0
0
0,1
0,2
0,3
0,4
0,5
0,6
0,7
0,8
Fraction of critically stressed fractures
Carbonate, cycle 4
Carbonate, cycle 3
Carbonate, cycle 2
Carbonate, cycle 1
Granite, cycle 1
Granite, cycle 2
Granite, cycle 3
Granite, cycle 4