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Evaluation of mechanical and dynamical behaviors of two types of clastic sedimentary rocks at servo-controlled triaxial test according to their texture and structures

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Abstract

Determining the mechanical and dynamic parameters of the rocks under different environmental conditions of laboratory, device, and rock samples tested. Triaxial test is one of the most useful tests for the mechanical behavior of rocks, which be done by advanced servo-controlled devices, which can determine important parameters such as mechanical strength, modulus of deformability and variations in the velocity of the wave during loading continuously.

In this paper, at first, some of the physical and geological characteristics of two types of clastic rocks (sandstone and tuff) evaluated, and then their mechanical and dynamic parameters determined during the servo-controlled triaxial test in different conditions of lateral and axial stress studied. The values of parameters such as modulus of deformability, the Poisson's ratio, and longitudinal and transverse wave velocities, which are usually stated constant, change with increasing axial and lateral stresses during the test because the sample's behavior changes from elastic to plastic during the test. Therefore, providing a fixed value for a parameter can't be logical and must specify the conditions for its determination along with the declared number. The results of triaxial test of this study, carried out by the ISRM standard method, show that the resistance values, the modulus of deformability, the Poisson's ratio and the wave velocity of the longitudinal and transverse waves for the sandstone sample are higher than that of the pyroclastic sample, due to the difference in physical properties and the structure and texture of these two rocks. The range of variations of these parameters is different in two specimens.

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Keywords: *servo-controlled triaxial test, clastic sedimentary rocks, Mechanical strength, deformeability, wave velocity*

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Extended Abstract:

1. Introduction

Determining the mechanical and dynamic parameters of the rocks under different environmental conditions of laboratory, device, and rock samples tested. Triaxial test is one of the most useful tests for the mechanical behavior of rocks, which be done by advanced servo-controlled devices, which can determine important parameters such as mechanical strength, modulus of deformability and variations in the velocity of the wave during loading continuously.
In this paper, at first, some of the physical and geological characteristics of two types of clastic rocks (sandstone and tuff) evaluated, and then their mechanical and dynamic parameters determined during the servo-controlled triaxial test in different conditions of lateral and axial stress studied. The values of parameters such as modulus of deformability, the Poisson's ratio, and longitudinal For determination of mechanical and dynamic properties of rocks, various tests are available. The stress-strain behavior of rocks depending on rock type, physical and mechanical properties of rocks, homogeneities and isotropy of them, type of test for determining stress-strain relationships of rocks, test procedure and the machine used for the test. The triaxial test of rock as a convenient method may show the behavior of rock during loading in the complete range containing elastic, plastic, failure and even post-failure stages.
Many factors such as loading rate, moisture content, temperature, and lateral pressure can affect the behavior of rocks in the triaxial test. In addition, some properties of rocks such as Young's modulus, Poisson's ratio and velocity of compressional and shear waves (VP and VS respectively) are variable during the test. Also, the dynamic elastic modulus that is determined by wave velocities can be different compared to the static value.
In this study, the value of static and dynamic parameters of two various clastic rock types ere determined continuously by the triaxial test. The results show that the values and ranges of the various parameters are different in two rock specimens.

2. Materials and methods

In this research, the rock samples selected for triaxial tests are sandstone and pyroclastic rocks (tuff). To determine geological rock specifications, a handy description of samples, thin section study, and X-ray analysis were conducted. The texture and structure of these rocks were determined by polarized microscope and XRF (X-Ray Fluorescence) and XRD (X-Ray Diffraction) analysis. The cores with diameters of about 38 mm were taken from the rocks’ blocks to conduct a servo-controlled triaxial test with ultrasonic test synchronizes. The sample length is approximate twice the diameter. The tolerance of perpendicularity and flatness of the specimens met the specifications of the ASTM, D4543 recommended method. The ends of all the specimens were carefully polished to minimize the end effect during loading.
The multistage triaxial tests were conducted on these samples according to the ISRM standard method. At any stage of constant lateral stress, the axial stress increase til before the fracturing of the specimen is observed by the online monitoring of stress-strain in behavior. The axial and lateral strains of the sample were continuously monitored by one axial LVDT and 6 lateral LVDTs extensometers connected to the specimen. Simultaneously, the compressional and shear waves were sent and received at any stage. Totally, 34 ultrasonic tests including 17 ultrasonic P-wave and 17 S-wave were done for sandstone sample and 50 ultrasonic tests (P-and S-wave every 25 tests) were conducted for pyroclastic rock specimen.

3. Tests results

The grey color sandstone sample was composed of Quartz, Albite, Muscovite and Chlorite minerals, respectively. According to Pettijohn et al., 1972, the classification of sedimentary rocks, feldspathic greywacke sandstone has the best adaptation on it. The average grain size is 0.1 mm and has good sorting and angular shape under microscopic study. The rock sample seems to be isotropic and homogeneous.

The pyroclastic light brown color specimen showed slight bedding. The rock specimen coring was obtained perpendicular to bedding. The grains have moderate roundness with an average size of 0.15 mm. The clayey matrix filled the pore spaces between the grains in the rocks that have poor sorting. Quartz, Calcite, Albite, Kaolinite, Muscovite, Montmorillonite and Goethite are dominant minerals. The rock according to the classification of pyroclastic rocks (Gillespie and Styles, 1999) is called tuff.

The cylindrical specimens of these two rock types that are prepared according to ASTM D 4543, were tested by the multi-stage method of ISRM. For sandstone specimens, a triaxial test is done by 3 stages with lateral stress of 5, 10 and 15 MPa and increasing axial stress up to 175, 230 and more than 250 MPa, respectively. Fig. 1 shows the stress-strain in curves of sandstone at various lateral and axial stresses.

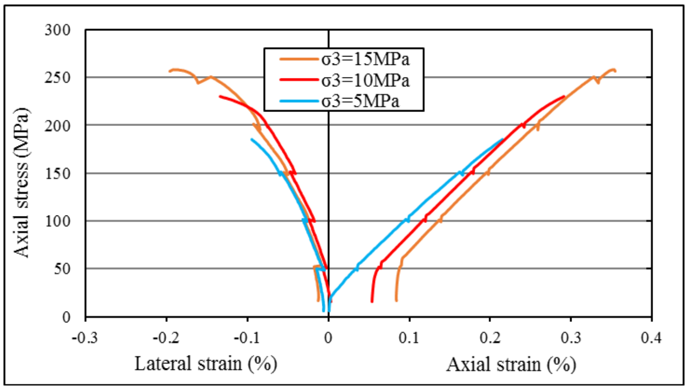


Fig. 1. Stress - strain curves of sandstone at various lateral and axial stresses.

Also, Fig. 2 shows the stress-strain in curves of tuff at various lateral and axial stresses. This specimen was tested at 5, 10, 15 and 20 MPa lateral stresses. In addition, according to the relation between axial and lateral strain, Poisson's ratio values change during the test.

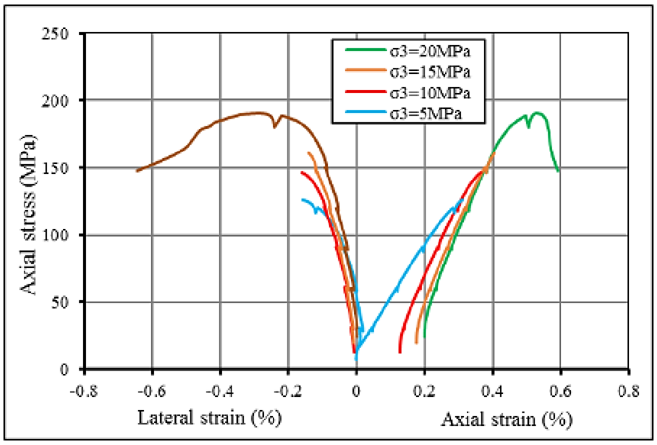
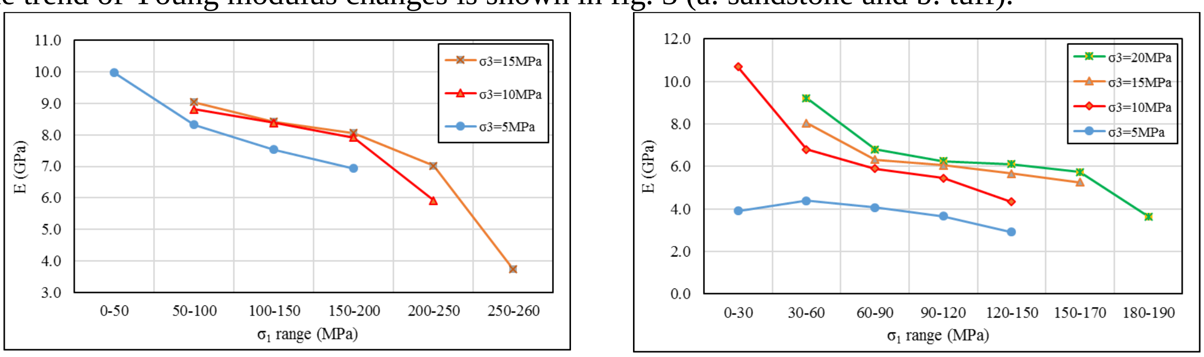


Fig. 2. Stress - strain curves of tuff at various lateral and axial stresses.

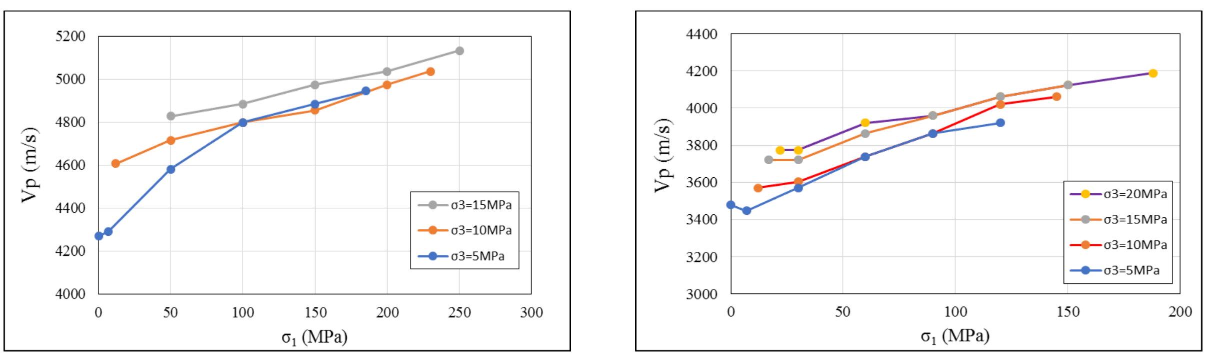
The trend of Young modulus changes is shown in fig. 3 (a: sandstone and b: tuff).



a b

Fig. 3. Relation between Young modulus and axial and lateral stresses; a: sandstone and b: tuff.

In order to compare the P-wave velocity in two specimens, the behavior of both the rock types during various axial and lateral stresses is shown in fig. 4. S-wave velocities in both samples have almost similar behavior in comparing with P-waves but the values of S-waves velocities were less.



a b

Fig. 4. Relation between P-wave velocity and axial and lateral stresses; a: sandstone and b: tuff.

4. Conclusion

A comparison of stress-strain in curves for sandstone and tuff at various axial and lateral stresses implies that sandstone has more strength than tuff and less axial and lateral strains until failure. According to their mineralogy, this difference was predictable.

The Young modulus of specimen decrease as axial stress increases as specimen behavior changes from elastic to plastic. Also, the Young modulus of the specimen becomes higher with increasing lateral stress that means the increase of lateral stress has made specimen hardened.

The velocity of the P wave has a direct relationship with axial and lateral stresses on both specimens. The values of VP in sandstones are greater than tuffs.

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