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Relation between microstructure and physical and engineering properties of sandstones, with emphasis on quartz content

A. Lakirouhani[1*] , M. Bakhshi[2], A. Zohdi[3]

[1] Department of Civil Engineering, University of Zanjan, Zanjan, Iran
[2] Department of Civil Engineering, University of Zanjan, Zanjan, Iran
[3] Department of Geology, University of Zanjan, Zanjan, Iran

ABSTRACT: The composition, texture and microstructure of rocks affect their physical and mechanical properties such as dry unit weight, porosity, p-wave velocity and Brazilian tensile strength. The aim of this study was to investigate the effect of mineralogy sandstone characteristics on physical and mechanical properties of sandstone in three groups with low mean quartz (less than 65%), moderate (65 to 80%) and high (more than 80%) and 26 samples were collected from southern province of Zanjan city Then, a comprehensive program of rock mechanic tests are planned and mineralogical properties and engineering parameters such as dry unit weight, porosity, P-wave velocity and Brazilian tensile strength were determined and their relationship was investigated using linear regression analysis. The results show that the mineral composition is effective on the strength properties and increasing the quartz mineral content in the samples, two physical parameters of dry unit weight and P-wave velocity and a mechanical parameter Brazilian tensile strength increase. Also, due to the correlation between physical parameters, P-wave velocity can be predicted with appropriate approximation using porosity parameter for sandstone in studied regions and the results can be used in geomechanical studies.

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INTRODUCTION

Rock strength is one of the most important parameters in the field of rock mechanics [1]. In order to classify the rocks and design structures inside or outside the rock masses, the study of strength properties and the deformability of rocks is vital importance [2]. The study of technical literature shows that the strength properties of rocks are directly related to their textural parameters [3, 4]. In recent decades, many scholars have focused on the relationship between the texture and strength properties of rocks and the impact of textural parameters on strength properties. Most studies have investigated the effects of microstructure properties, including mineral composition, porosity, grain size and shape on rock strength. There are contradictory results on the effect of mineralogy on rock resistance [5]. Some researchers [6, 7] reported a positive effect of quartz mineral content on two engineering parameters of p-wave velocity and Brazilian tensile strength. Bell in 1978, studying on the Fell sandstone in the northeast of England, stated that quartz mineral has no effect on the Brazilian tensile strength [8]. In 1994, Ulusay et al., With petrography and rock mechanics studies conducted on Kozlu sandstone in the north of Turkey, concluded that quartz mineral content does not have an effect on the p-wave velocity [9]. Shakur and Bonley, in 1991, stated that an increase in the mineral content of quartz would reduce the Brazilian tensile strength [10].

*Corresponding author's email: rou001@aut.ac.ir

In this research, for the first time, due to the geological characteristics of the Lalun and Zaigun Formations and the Top-quartzite sandstone unit in southern Zanjan province, With a view to more complete and accurate understanding of the effect of quartz mineral content on the sandstone engineering features, a comprehensive program of rock mechanics tests including three physical parameters (dry unit weight, porosity, p-wave velocity) and a mechanical parameter (Brazilian tensile strength) were designed. Detailed mineralogy studies were conducted on three types of sandstone with a mean low, medium and high quartz percentage. Also, using linear regression analysis, the correlation between the mentioned engineering features with mineralogy parameters was investigated.

SITE LOCATION, MATERIAL AND SAMPLING

26 sandstone samples were taken from 2 Zaigun and Lalun formation and Top-quartzite sandstone unit. To prepare the required samples, geological maps of 1: 100000 Khodabandeh-Soltanieh [11] and 1: 100000 Zanjan province were examined and suitable outcrops were selected. In the course of several field visits, 50 manual samples of stone blocks with approximate dimensions of 40 × 40 × 30 cm were taken to examine their petrography and mineralogical composition and samples were examined for weathering

Table1. Linear correlation coefficient between engineering properties of studied sandstones.

	γ_d	n	BTS	Vp
Vp	0.72	-.080	0.69	1
BTS	0.46	-0.72	1	
n	-0.59	1		
γ_d	1			
Legend: γ_d = dry unit weight, n= porosity, BTS= brazilian tensile strength, Vp= p-wave velocity				

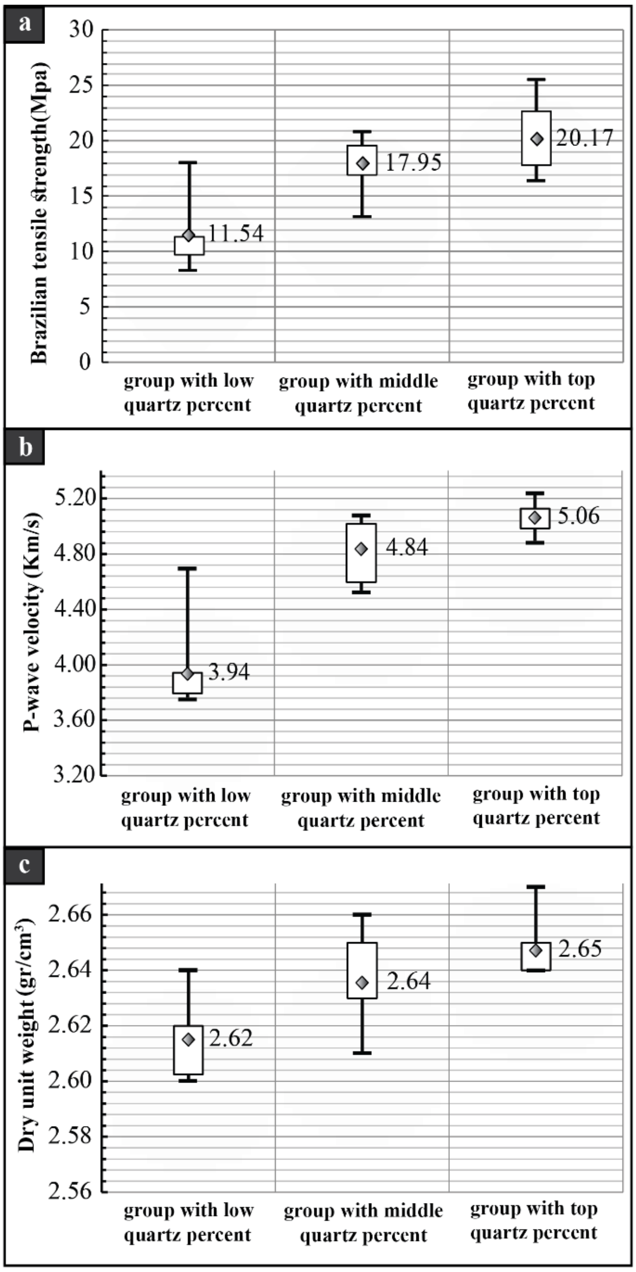

Fig. 1. Graphs related to changes in the studied engineering properties of the sandstone in relation to the quartz mineral content (a) Brazilian tensile strength (B) p-wave velocity (c) dry unit weight

and lack of large cracks. Thin sections were prepared from manual samples and then completely studied by polarized microscopy. From 50 thin sections studied, 26 specimens that were suitable from the perspective mineralogy and weathering were selected and the block samples for rock mechanics tests were transferred to Zanjan University. Cylindrical cores were prepared from blocks based on ISRM 2007 standards that were used to perform engineering tests [12]. In order to study the mineralogical properties of sandstone, the thin section provided from cores that obtain from blocks and studied using polarized microscopy. In addition to petrographic studies, the mineralogical composition of the sandstone was studied by X-ray diffraction device (XRD). Three samples randomly selected and analyzed to obtain a precise combination of mineralogy. XRD or X-ray diffraction method is a widely used method for investigating the properties of crystals and the formation of rock-forming minerals. In this method, X-ray diffraction on the sample is used to examine the properties of the sample. For this analysis, the materials should be well-powdered and homogeneous. Information obtained from the X-ray diffraction on crystals and rock-forming minerals represents the type of rock forming minerals. By comparing the graphs obtained in this analysis with standard mineral graphs, it is easy to find different minerals, especially fine minerals that under normal microscopes it is not possible to be identified [13]. Some engineering properties of sandstone, such as (dry unit weight, porosity, brazilian tensile strength, and p-wave velocity) were calculated according to the International Rock Mechanics Association (ISRM). The percentage of the components of the granular composition of approximately 300 grain by the Gazzi-Dickinson method introduced in 1984 by Ingersoll et al, computed And the quartz, feldspar, rock fragment, mica, calcite and cement percentages of each specimen were determined [14] and divided Based on the Folk charts. [15] Using SPSS 21 software, the linear relationship between mineralogy variables and engineering features has been investigated.

RESULTS AND DISCUSSION

To investigate the effect of quartz mineral content, the results of Brazilian tensile strength tests, p-wave velocity and dry unit weight related to the three groups of sandstone studied with a mean low, medium and high quartz percentage, are presented at Box plot in "Fig. 6" In "Table 4", linear correlation analysis is presented separately between the engineering characteristics and the minerals forming the studied sandstone to distinguish the parameters that have the greatest impact on the engineering properties of the samples. According to table 4 and plotted charts, the mechanical parameter of the Brazilian tensile strength increases with increasing the average percentage of quartz mineral and decreasing the percentage of feldspar mineral in the samples studied. The existence of cleavage and microstructures in the feldspar minerals found in the test samples can reduce the Brazilian tensile strength. Also, the presence of quartz mineral due to has little or no cleavage and fills the spaces between the other constituents will improve strength properties. The physical parameter of the p-wave velocity has also increased with an increase in the average percentage of mineral quartz. Mineralogical composition, average grain size and porosity are among the most important parameters affecting the p-wave velocity in rock samples, but in the studied samples, the porosity percentage varies from 0.77 to 2.6, and the average grain size is also observed in The sandstone range is classified with medium grain size, so these two parameters have no significant effect on the changes in the pressure velocity in the samples studied.

Considering that the major minerals in the studied samples are quartz and feldspar (orthoclase), the p-wave velocity of quartz mineral is higher than the feldspar mineral (orthoclase) [16].

Therefore, with increasing quartz mineral content in samples, the p-wave velocity also increased. The physical characteristic of dry unit weight has increased with increasing quartz mineral content in the samples “Fig. 6”. The quartz amount affects the engineering parameters of dry unit weight and porosity, so that quartz minerals fill the spaces between the grains [17] and with increasing average quartz percentage in the groups, dry unit weight is increased and porosity decreases. The results show that increasing the percentage of quartz mineral in the samples has improved three parameters of engineering of p-wave velocity, Brazilian tensile strength and dry unit weight.

CONCLUSIONS

26 sandstone samples from Lalun, Zaigun and Top-quartzite sandstone units of Zanjan province were investigated with the aim of investigating the impact of petrographic properties especially quartz mineral content on four engineering characteristics. Based on the tests and studies, the following results were obtained:

1- According to the percentage of the minerals forming the studied sandstone and the proposed Folk diagram for the classification of sandstone, the samples selected are from type of Arkose, Subarkose and Quartz arenite.

2- Ten mineralogy parameters were studied for different sandstones and their impact on engineering properties of sandstone was investigated. According to the results of this study, mineral quartz has an impact on the physical and mechanical properties of the sandstone examined and shows a meaningful relationship with them.

3- Investigation of correlation of engineering characteristics with petrographic parameters shows that mineralogical characteristics affect the strength properties of sandstone studied.

4- The mechanical parameters of the Brazilian tensile strength increase with an increase in the average percentage of quartz mineral in the samples studied, which suggests an improvement in the tensile strength of sandstone with an increase in the percentage of quartz mineral content in the investigated specimens.

5- P-wave velocity is one of the physical parameters that is studied in the sandstone samples and increases with increasing the percentage of mineral quartz and decreasing the percentage of feldspar mineral. The feldspar mineral is divided into two types of orthoclase and plagioclase. Considering that the feldspar contained in the sandstone is of orthoclase type and the p-wave velocity in orthoclase is less than quartz mineral, p-wave velocity is increased by increasing the average percentage of quartz minerals in samples.

6- According to the filler properties of quartz mineral in the studied samples, the average dry unit weight of the three groups of sub-arkose, arkose and quartz arenite sandstone increases with increasing quartz mineral content.

7- Two physical parameters of p-wave velocity and porosity have a significant correlation with the correlation coefficient (R = -0.85) that the obtained equation can be used to predict the p-wave velocity parameter using porosity. It should be noted that this equation is applied only to the sandstone of the study area and can not be extended to all sandstones.

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