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Investigation of the ability of ultrasonic parameters to evaluate the physical and mechanical characteristics and durability of carbonate rocks

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Abstract

In this research by analyzing the signals of ultrasonic waves and obtaining the ultrasonic parameters in nine carbonate rocks from different parts of Iran, the ability of these parameters to assess the physical and mechanical properties and durability of rocks was investigated. For this purpose, firstly the petrographic, physical and mechanical properties of studied rocks were determined and then, in order to determine the durability of samples, long-term weathering tests of slake durability and wetting-drying up to 15 and 50 cycles were carried out, respectively. Moreover, a precise ultrasonic device capable to record wave signal was used and ultrasonic parameters of compressional wave velocity (V_P), maximum amplitude (A_{max}), spatial attenuation (α_s), and temporal attenuation (α_t) were determined from recorded signals, before and after wetting-drying cycles. Results indicated that each of the ultrasonic parameters has different capabilities in rock characterization, such as V_P can assess both physical and mechanical properties more accurate in comparison with other ultrasonic parameters. Results also indicated that A_{max} and α_s detect the development of the microcracks resulted from wetting-drying cycles and the development of weathering within rocks more better than V_P. On the other hand, α_t is not sensitive to the weathering development in rock, while if this parameter is corrected and converted to α_{tc}, it can detect the development of weathering within rocks.

Keywords: *Carbonate rocks, wave velocity, wave amplitude, wave attenuation, durability*

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Extended Abstract:

1. Introduction

Nondestructive test of ultrasonic measurements has been increasingly used worldwide, both for the site and laboratory conditions, due to its simplicity and rapidity in execution, portability, low cost, and non-destructiveness. Compressional wave velocity (V_P) is the most used ultrasonic parameter in previous studies. However, there are many ultrasonic parameters that can be used for rock characterization as well as for evaluation of the durability of rocks (Benavente et al., 2006; Martínez-Martínez et al., 2011 and 2013; Wang et al., 2017). In this research by analyzing the signals of ultrasonic waves and obtaining the ultrasonic parameters of compressional wave velocity (V_P), maximum amplitude (A_{max}), spatial attenuation (α_s), and temporal attenuation (α_t) in nine carbonate rocks from different parts of Iran, the ability of these parameters to assess the physical and mechanical properties and durability of rocks was investigated.

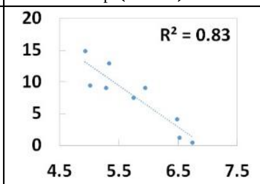
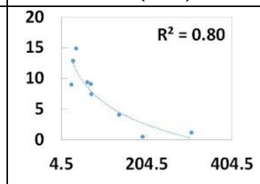
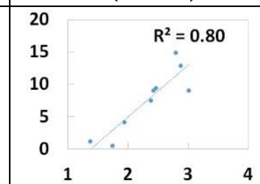
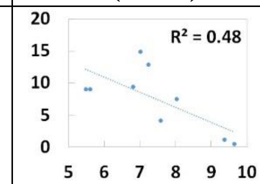
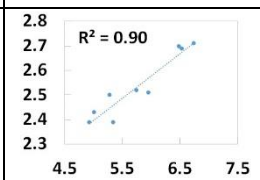
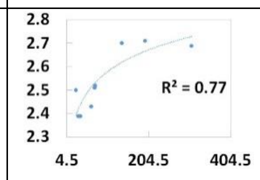
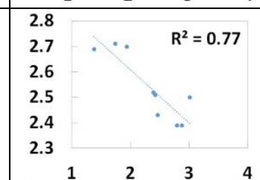
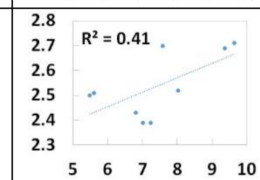
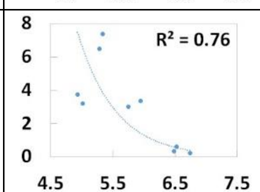
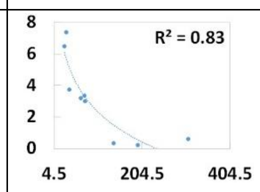
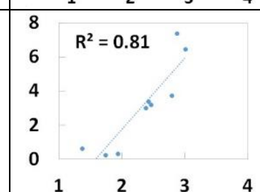
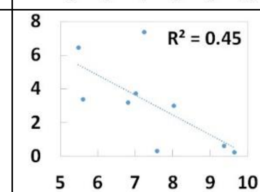
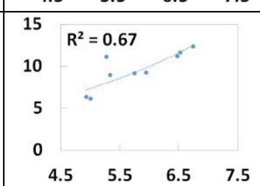
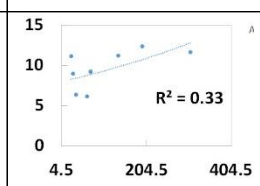
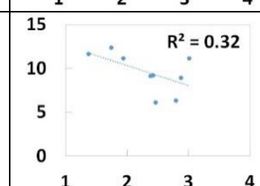
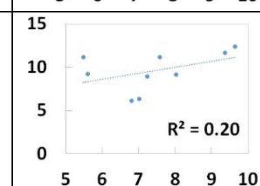
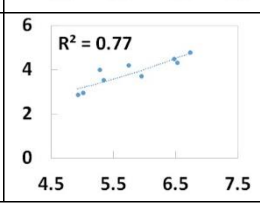
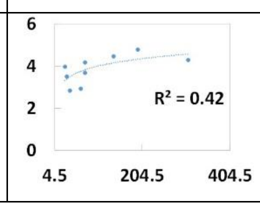
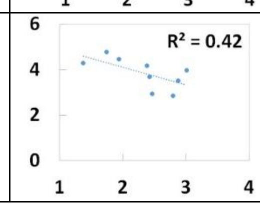
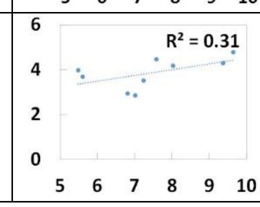
2. Materials and methods

Nine carbonate rocks include five different travertines and four different limestones have been collected for this research. Two thin sections obtained from each stone type were examined under an optical microscope to determine their petrographic characteristics including the mineralogical composition and texture. Some physical properties of the samples include the bulk density (ρ_b), real density (ρ_s), effective porosity (n_e), total porosity (n_t), and water absorption (w_{abs}) were determined. The core specimens from samples were taken in diameter of 54 mm Brazilian tensile strength test, point load strength test and ultrasonic measurements were performed on them. All physical and mechanical tests were carried out according to the procedures suggested by ISRM (1981). Then, samples were subjected to WD and SL tests in fresh water. The tests up to 100 and 15 cycles were carried out, respectively. In order to determine the durability of samples, long-term weathering tests of slake durability and wetting-drying up to 15 and 50 cycles were carried out, respectively. Moreover, a precise ultrasonic device capable to record wave signal was used and ultrasonic parameters were determined from recorded signals, before and after wetting-drying cycles according to the procedures outlined by Benavente et al. (2006) and Martínez-Martínez et al. (2011).

3. Results

Results indicated that most of the ultrasonic parameters have a good correlation with the physical and mechanical characteristics of studied rocks. Results indicated also that, in general, ultrasonic parameters have stronger correlations with physical properties than mechanical ones (Table 1). The values of determination coefficient of correlations (R^2) indicated that V_P can predict physical and mechanical properties more accurate in comparison with other ultrasonic parameters. On the other hand, A_{max} and α_s predict the slake durability of rocks more accurate than V_P. Results also indicated that A_{max} and α_s detect the development of the microcracks resulted from wetting-drying cycles and the development of weathering within rocks more better than V_P. The correlation between α_t and rock properties is very weak and this parameter cannot predict physical and mechanical properties with sufficient accuracy.

Table 1. Correlations between physical and mechanical properties and ultrasonic parameters

	V_p (km/s)	A_{max} (mV)	α_s (dB/cm)	α_t (dB/ms)
Total porosity (%)				
Bulk density (gr/cm^3)				
Effective porosity (%)				
Brazilian Tensile Strength (MPa)				
Point Load Index (MPa)				

4. Conclusion

According to the results obtained in this study, it can be concluded that VP is the most efficient ultrasonic parameter for the evaluation of different physical and mechanical properties of carbonate rocks. however, it predicts physical properties more accurate than mechanical ones. On the other hand, A_{max} and α_s evaluate the durability of rocks more accurate than V_P and they are the most efficient ultrasonic parameters for the evaluation of durability. In general, it would be better to apply VP when physical and mechanical properties of carbonate rocks should be evaluated, and it would be better to apply A_{max} and α_s parameters for the evaluation of the durability of carbonate rocks.

References

Benavente, D., Martínez-Martínez, J., Jáuregui, P., Rodríguez, M.A., García-del-Cura, M.A., 2006. Assessment of the strength of building rocks using signal processing procedures, Construction and Building Materials, 20: 562-568.

Martínez-Martínez, J., Benavente, D., García-del-Cura, M.A., 2011. Spatial attenuation: The most sensitive ultrasonic parameter for detecting petrographic features and decay processes in carbonate rocks, Engineering Geology, 119: 84-95.

Martínez-Martínez, J., Benavente, D., Gomez-Heras, M., Marco-Castaño, L., García-del-Cura, M.A., 2013. Non-linear decay of building stones during freeze–thaw weathering processes, Construction and Building Materials, 38: 443-454.

Wang, P., Xu, J., Fang, X., Wang, P., Zheng, G., Wen, M., 2017. Ultrasonic time-frequency method to evaluate the deterioration properties of rock suffered from freeze-thaw weathering, Cold Regions Science and Technology, 143: 13-22.