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 ($A_{\text{max}}$), spatial attenuation ($\alpha_s$), and temporal attenuation ($\alpha_t$) 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 ($\rho_b$), real density ($\rho_s$), effective porosity ($n_e$), total porosity ($n_t$), and water absorption ($w_{\text{abs}}$) 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, $A_{\text{max}}$ and $\alpha_s$ predict the slake durability of rocks more accurate than $V_P$. Results also indicated that $A_{\text{max}}$ and $\alpha_s$ 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 $\alpha_t$ 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

<table>
<thead>
<tr>
<th></th>
<th>$V_p$ (km/s)</th>
<th>$A_{max}$ (mV)</th>
<th>$\alpha_s$ (dB/cm)</th>
<th>$\alpha_t$ (dB/ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total porosity (%)</td>
<td>20 15 10 5 0</td>
<td>20 15 10 5 0</td>
<td>20 15 10 5 0</td>
<td>20 15 10 5 0</td>
</tr>
<tr>
<td>Bulk density (gr/cm$^3$)</td>
<td>2.8 2.7 2.6 2.3</td>
<td>2.8 2.7 2.6 2.3</td>
<td>2.8 2.7 2.6 2.3</td>
<td>2.8 2.7 2.6 2.3</td>
</tr>
<tr>
<td>Effective porosity (%)</td>
<td>8 6 4 2 0</td>
<td>8 6 4 2 0</td>
<td>8 6 4 2 0</td>
<td>8 6 4 2 0</td>
</tr>
<tr>
<td>Brazilian Tensile Strength (MPa)</td>
<td>15 10 5 0</td>
<td>15 10 5 0</td>
<td>15 10 5 0</td>
<td>15 10 5 0</td>
</tr>
<tr>
<td>Point Load Index (MPa)</td>
<td>6 4 2 0</td>
<td>6 4 2 0</td>
<td>6 4 2 0</td>
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</tbody>
</table>

4. Conclusion

According to the results obtained in this study, it can be concluded that $V_p$ 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 $\alpha_s$ 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 $V_p$ when physical and mechanical properties of carbonate rocks should be evaluated, and it would be better to apply $A_{max}$ and $\alpha_s$ parameters for the evaluation of the durability of carbonate rocks.

References

