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The Use of Ultrasonic Mesaurements Determining the Quality of the Dimension Stone Blocks

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Abstract

Natural stone, namely marbles is a specific type of mineral raw material extracted as large monolithic blocks in quarries. An important specificity of extraction of natural stone is the requirement of the compactness. Tectonics and excavation complicates are difficult to ensure and growing demand of large blocks of natural stone. Irregularities (micro-macro cracks, porosity and cavity) in blocks effect block quality can be determined visually by ultrasonic measurements. Ultrasonic devices are simple, practical, portable, making cheap research and in situ research in the field or fabric. Ultrasonic waves propagate inside the stone at different velocities, depending on direction. Ultrasonic techniques are particularly useful in studies of stone features such as elasticity, anisotropy, physical and mechanical properties of natural stone and other construction materials to characterize the materials.

The paper will be presented to the application of ultrasonic measurements (P wave) in situ measurements of the state of the block using the method in determining the quality of the blocks in order to facilitate the marketing and provision of guarantees on the dimension stone blocks quality. Additionally, statistical correlations between ultrasonic pulse velocity and mechanical and physical properties of natural stones (marble) are presented and discussed.

Keywords: Ultrasonic measurements, P wave, Block quality, Marble

INTRODUCTION

Natural stone, namely marbles is a specific type of mineral raw material extracted as large monolithic blocks in quarries (Figure 1).

Marble is a rock which can be cut and polished, recovered in block in adequate sizes and having commercial value.

Ultrasonic techniques have been used for many years in geotechnical practice and mining science. They are employed in the field for geophysical investigations and in the laboratory for the determination of the dynamic properties of rocks. Since these techniques are non-destructive and easy to apply, they have increasingly been used. Most researchers [2–4] studied the relations between rock properties and sound velocity. P-wave velocity is a good index for the quality of rocks and other materials (e.g., mortars, lime) [5, 6].

Some researchers [7, 8] used the P-wave velocity for the estimation of weathering depth of building stones. The main factors that influence P-wave velocity in rocks are lithology, texture, density, porosity, anisotropy, grain size and shape, water contact, stress, temperature, weathering, alteration zones, pores and microcracks, bedding planes, and joint properties (roughness, filling materials, water, dip and strike, etc.). An important specificity of extraction of natural stone is the requirement of the compactness. Tectonics and excavation complicates are difficult to ensure and growing demand of large blocks of natural stone. Irregularities (micro-macro cracks, porosity and cavity) in blocks effect block quality can be determined visually by ultrasonic measurements.

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In the study, the application of ultrasonic measurements (P wave) in situ measurements of the state of the block using the method in determining the quality of the blocks in order to facilitate the marketing and provision of quarantees on the dimension stone blocks quality were presented. Additionally, statistical correlations between ultrasonic pulse velocity and mechanical and physical properties of marbles are presented and discussed.

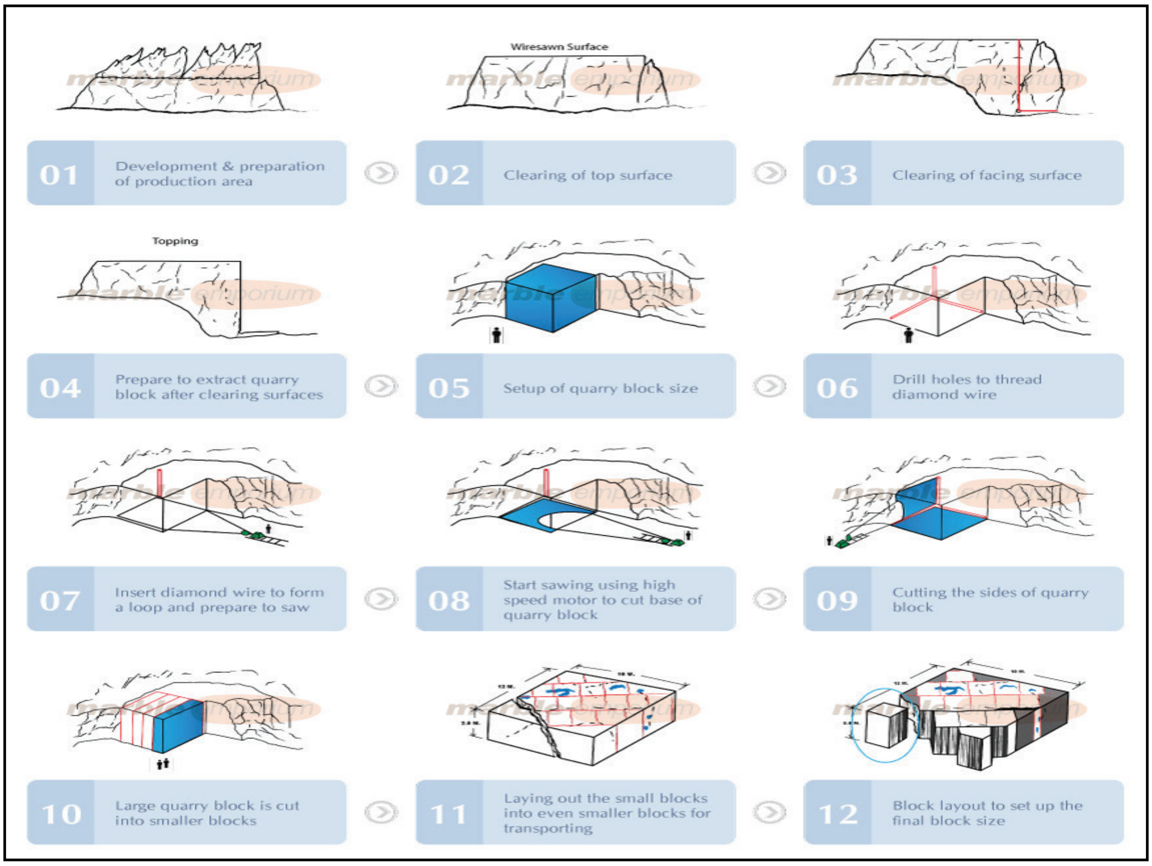

Figure 1. Marble production process [1]

MATERIALS and METHODS

Material

In this study, light colour, limestone marble (Silifke and Kozan region, Turkey) were used. A number of block samples in size of 40×40×40 mm³ cube specimens were prepared and P wave velocities were measured on each cube specimens prior to sawing. Later, the samples were sawn off the blocks in thicknesses of 2 cm in order to form sets of test (Figure 2 and 3).

Figure 2. P wave velocity measurement of Silifke and Kozan region marbles

Figure 3. Silifke and Kozan region marbles

Methods

In this study, some of the physical and mechanical properties of the Silifke and Kozan region marbles were determined.

- Physical properties were determined using saturation and buoyancy techniques, as recommended by TS EN 1097-2 [9].
- The compressive strength test was conducted on an ELE Auto machine with 40×40×40 mm³ cube specimens.
- The hardness of the marbles was determined by Shore Scleroscop.
- The ultrasonic wave tests were performed by an ultrasonic instrument manufactured by Proceq Inc. Portable untrasonic non-destructive indicator tester, which has two transducers (a transmitter and a receiver) having a frequency of 54 kHz. The device generates and receives ultrasonic waves and has a digital display of the results. The test was repeated three times in three perpendicular directions and the mean values were recorded as the P-wave velocity.

RESULTS and DISCUSSION

The means of the physical and mechanical analyses results of the marbles are presented in Table 1.

The physical and mechanical properties depend not only on the properties of the individual minerals, but also upon the way in which the minerals are assembled. Carbonate rocks in particular occur with a wide range of porosities and hence of mechanical character. Compressive strength decreases with increase in porosity and micro and macro cracks [10, 11].

The P-wave velocity in the limestones ranges between 3.500 and 6.500 km/s [12]; while, for a calcite crystal, the P-wave velocity is 6.490 km/s [13]. In the tests, the P-wave velocities in Silifke and Kozan region marbles were measured and the results are given in Table 1. The P-wave velocity, as a natural characteristic of rocks and different materials, depends on their micro- and macro-structure, the existence of minor cracks and porosity and the characteristics of their mineralogical components, such as elastic parameters, density and micro-porosity [13]. Increased velocity with an increase in the dry apparent weight and vice versa is reported by Babuska [14] and Kopf et al. [15].

The correlations of P-wave velocity with the water absorption, specific weight, hardness (shore) and uniaxial compressive strength are presented in Figure 4 and 7, respectively.

Table 1. Analysis results of the marble samples

		Uniaxial Compressive Strength (MPa)	P Wave Velocity (km/sn)	Water Absorption (%)	Shore Hardness	Specific Weight (g/cm³)
1	**Kozan Region Marble**	70.12	4.29	0.364	26.0	2.656
2		75.28	4.54	0.330	30.0	2.658
3		75.60	4.80	0.313	30.0	2.659
4		76.70	4.80	0.296	31.1	2.663
5		76.90	4.81	0.271	32.0	2.665
6		77.14	4.81	0.259	32.1	2.666
7		77.44	4.82	0.238	32.3	2.674
8		77.80	4.82	0.230	32.5	2.674
9		77.88	4.83	0.226	32.5	2.675
10		78.22	5.48	0.224	32.6	2.676
11		78.46	5.51	0.221	32.6	2.677
12		84.62	5.52	0.220	32.9	2.679
13		87.72	5.52	0.219	33.2	2.680
14		89.90	5.58	0.216	33.3	2.682
15		91.16	5.60	0.204	33.3	2.683
16	**Silifke Region Marble**	97.20	5.63	0.129	33.3	2.684
17		99.58	5.70	0.115	33.5	2.688
18		99.78	5.70	0.100	33.7	2.698
19		99.86	5,72	0.097	34.0	2.700
20		100.04	5.72	0.092	34.0	2.700
21		100.34	5.72	0.091	34.1	2.701
22		100.42	5.73	0.089	34.1	2.704
23		101.02	5.74	0.089	34.3	2.707
24		101.89	5.75	0.087	34.3	2.708
25		102.86	5.80	0.087	34.3	2.710
26		103.36	5.83	0.083	34.6	2.713
27		104.12	5.87	0.077	34.8	2.716
28		104.48	5.90	0.074	35.0	2.720
29		104.58	5.96	0.061	35.2	2.729
30		105.70	6.00	0.059	36.0	2.730
31		108.50	6.01	0.057	36.2	2.766
32		115.36	6.02	0.056	38.0	2.785

A power correlation between water absorption and P-wave velocity was obtained, as shown in Figure 4. The correlation coefficient of the relationship is 0.85. A power correlation between uniaxial compressive strength and P-wave velocity was obtained, as shown in Figure 7. The correlation coefficient of the relationship is 0.84.

The relationships between specific weight, hardness (shore) and P-wave velocity resulted in quite weak correlation coefficients, as seen in Figure 5 and 6. The correlation coefficient of the relationship is 0.63 and 0.78, respectively.

Using P-wave velocity, it will be just possible to have information about the quality of the marble without the more direct analysis processes which are more laborious and expensive.

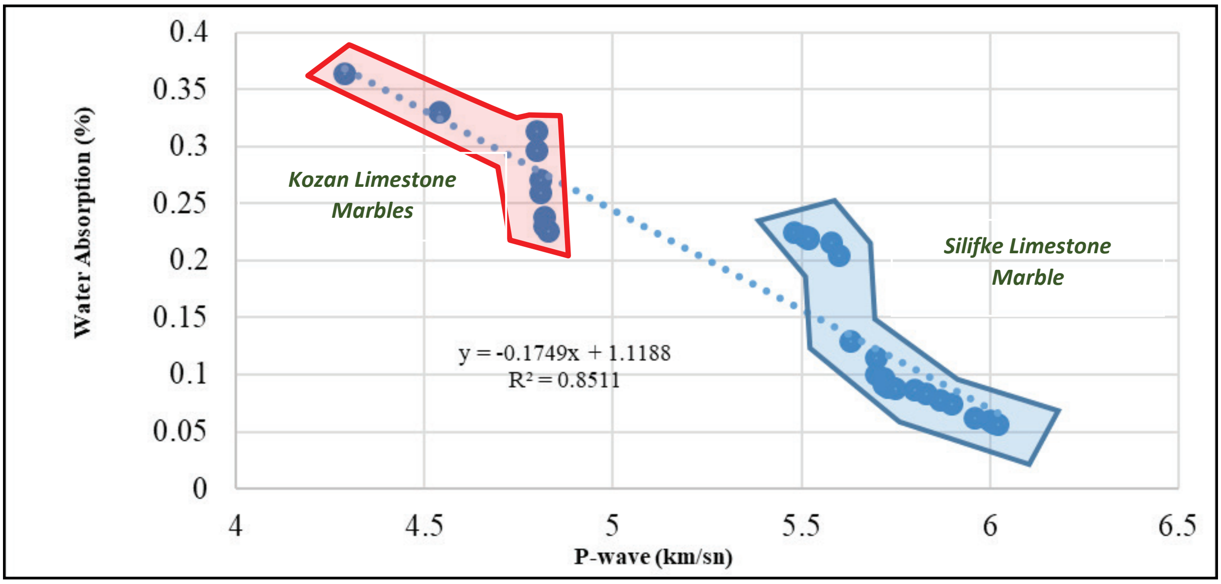

Figure 4. Correlation of P-wave velocity vs. water absorption for marbles

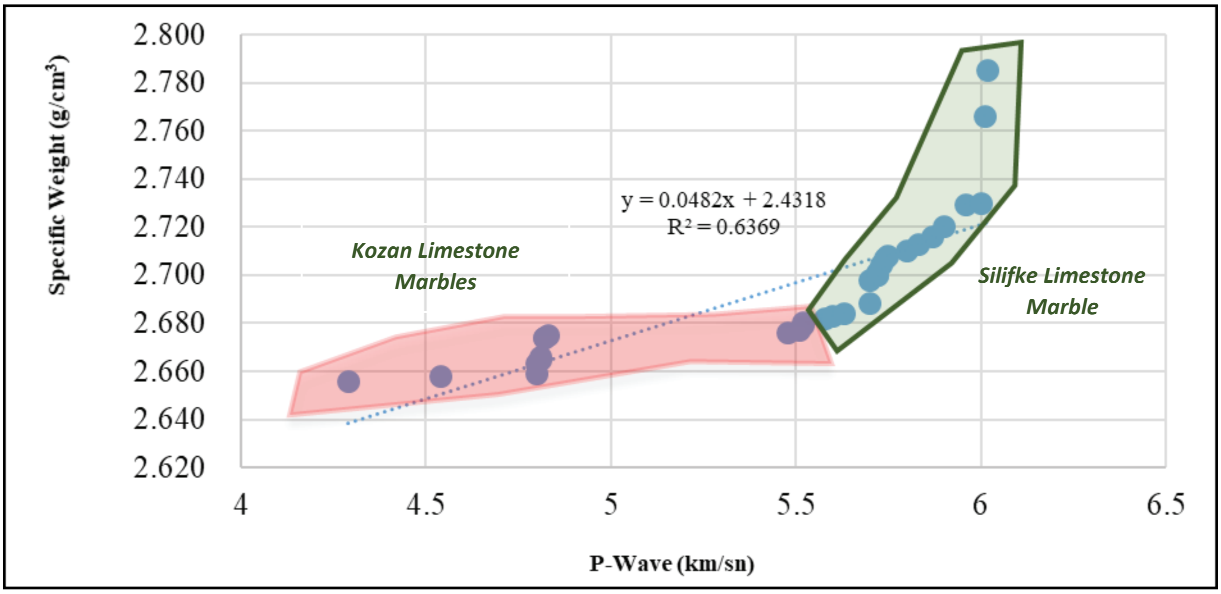

Figure 5. Correlation of P-wave velocity vs. specific weight for marbles

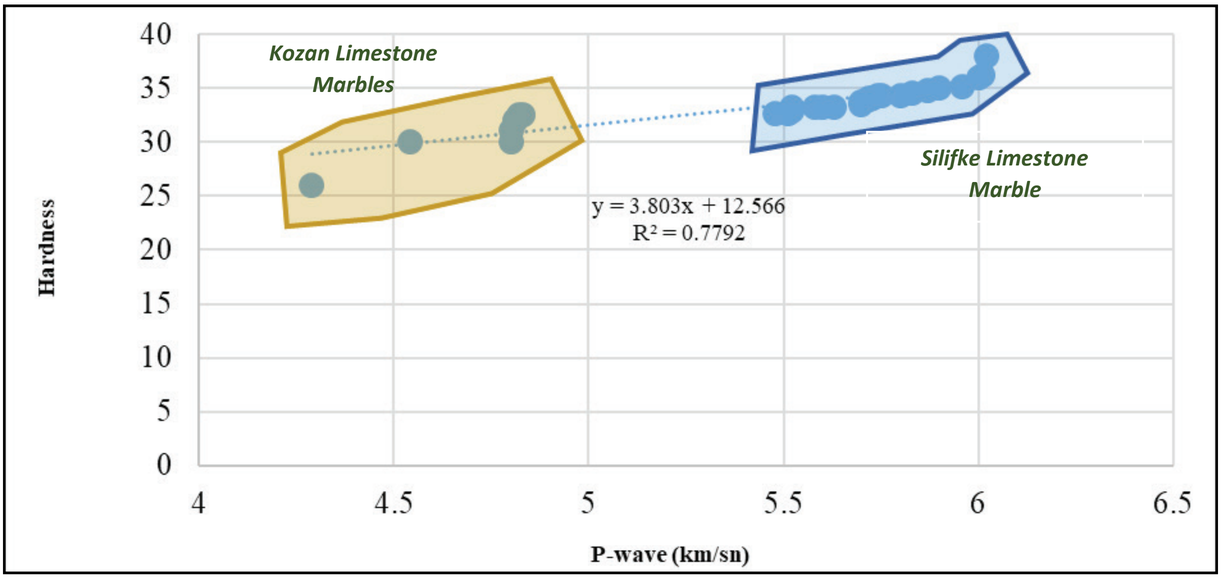

Figure 6. Correlation of P-wave velocity vs. hardness (shore) for marbles

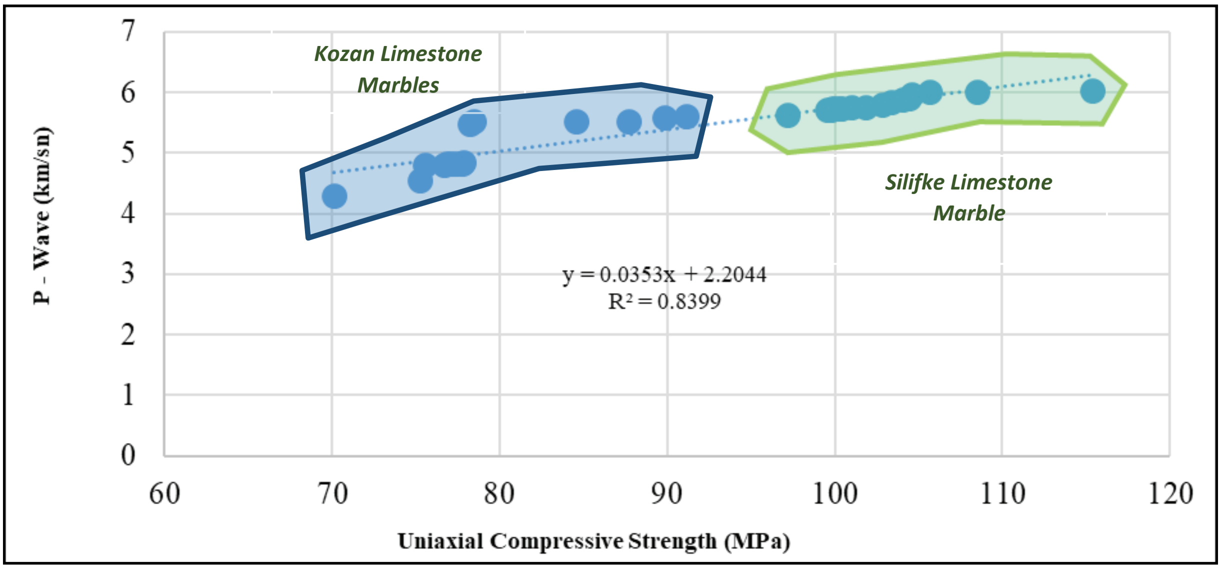

Figure 7. Correlation of P-wave velocity vs uniaxial compressive strength for marbles

CONCLUDING COMMENTS

The results of simple regression analyses may suggest that the relationships between P-wave velocity and water absorption and uniaxial compressive strength values are meaningful. Under certain conditions, it may be difficult and complicated to measure the uniaxial compressive strength of rocks. The use of empirical relationships to estimate the uniaxial compressive strength of rock can be more practical and economical. The equations found in the literature are derived using the rocks from different geological origins to estimate the UCS from P-wave velocity.

In this way, more reliable predictions will be possible for project engineers and researchers.

The application of ultrasonic measurements (P wave) in situ measurements of the state of the block using the method in determining the quality of the blocks in order to facilitate the marketing and provision of guarantees on the dimension stone blocks quality significant difference with the other irrigation levels.

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