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Thermal and ultrasonic properties of Estremoz marbles, Portugal

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Synopsis

Thermal and ultrasonic properties are non-destructive methods used to determine dimension stones anisotropy. Both methods are very simply to operate and give results quickly, nevertheless in particular rocks of visible textural anisotropy such as the Estremoz Marbles, a special care must be taken when doing the cubic samples to test. In fact to get better results one of the cube face must be parallel to the foliation plane (*XY*), so the others are perpendicular and one them must be cut along the stretching direction (*XZ*), consequently the third face of the cube (*YZ*) will be perpendicular to the others (also to the local fold axis when it is present).

An ultrasonic standardization will enable the determination of possible structural defects, such as discontinuities, which may exist within marketable blocks, noticeable for instance, when speeds are lower than typical for marbles observed. The thermal properties are particularly important when processes related with heating and cooling of buildings must be considered.

It's know that dimensions stones processing efficiency, as well as aesthetical characteristics, could be improve if the stones anisotropy are considered. Combine these two parameters an expedite procedure could guide stone manufacturer to obtain better results from the quarry to the final products.

Keywords

Thermal properties, ultrasonic properties, dimension stone, Estremoz marble

Ultrasonic measurement

The ultrasonic test is based on measuring the time that a high frequency wave takes to cross a body. For this end, two diametrically opposed points are defined, where one is placed a transducer which will convert one electric pulse into one ultrasonic wave and another, a receiver transducer that reconverts the waveform back into an electrical signal. The monitoring in a central unit of the apparatus, allows to determine the speed propagation of the wave, allowing a physical characterization of the body to the sample.

This test intend to determine a standard speed for various types of marble, as well as for the different directions related to calcite preferred orientation.

Since marble is an essentially monomineralic rock, this standardization will enable the determination of possible structural defects, such as discontinuities, which may exist within marketable blocks, noticeable for instance, when speeds are lower than typical for marbles observed.

The ultrasonic test were performed on 6,5 cm edge cubes and for each sample of marble, ultrasonic velocity measurements were performed dried at room temperature, oven dried at 60 °C and water saturated, in the Geoscience Centre of the University Göttingen.

The records were obtained using a Fluke 192 and USG30 Generator, Scopemeter 60 MHz 500 MS / s, a Light House 2000 - SM program, UPG emitter transducer, 250 kHz and

UPE-T receiver transducer. The frequency used was of 250 kHz, obtaining the direct measurement of the P-waves velocity (Vp).

In spite of some marbles have the same hue, they were collected in different places in the Estremoz Anticline, and there may be differences from a structural and mineralogical point of view. However, for the sake of discretion, the different chromatic types of marbles were grouped into seven major families: White, White with Veins, Cream with Veins, Pink, Tiger Skin, Ruivina and Marinela. Tab. 1 shows the average values of the velocities (km/s) obtained by each chromatic type.

Table 1 Marble ultrasound average velocity (km/s). In each of the three measurement conditions, lowest and higher values are underlined.

	Dried at Room			Dried at 60º C			Water saturated		
	X	Y	Z	X	Y	Z	X	Y	Z
White	4,525	4,530	4,066	4,446	4,300	4,152	5,327	5,333	5,214
White with veins	4,744	4,969	4,433	4,711	4,935	4,110	5,437	5,567	5,047
Cream with veins	4,742	4,874	4,422	4,669	4,792	4,326	5,879	5,849	5,326
Pink	4,619	4,605	4,444	4,665	4,971	4,447	5,768	5,763	5,598
Tiger Skin	4,536	4,988	4,551	4,427	5,067	4,463	5,510	5,650	5,266
Ruivina	4,604	4,981	4,375	4,500	4,945	4,236	5,697	5,872	5,458
Marinela	5,427	6,165	5,274	5,721	6,280	5,365	5,826	6,400	5,365

Thermal properties

Thermal conductivity, thermal diffusivity, and specific heat were measured rock samples of this study in the University of Évora Geosciences Department Mechanical Tests Laboratory with an ISOMET 2104 Heat Transfer Analyser (Fig. 1) which allows measuring the three properties simultaneously. The thermal probe used to make the measurements has a range between 2.00 and 6.00 W/mK. The average values for the thermal conductivity, the thermal diffusivity, and the specific heat of samples were obtained by placing the probe in the six polished faces of the 8 cm edge cubes tested (not the same used in the ultrasonic tests, but these 8 cm edge cubes will be tested as soon as possible in the Geoscience Centre of the University Göttingen). Opposite faces were named A and A'; B and B'; C and C´. The calculated average values as well as the standard deviations are presented in Table 2.

Thermal conductivity (in W/mK) is a thermal property that quantifies the ability of a rock to allow heat to go through it; it has to do with stationary heat flow and the higher its value the better heat flows through a rock. Thermal diffusivity (in m^2/s) reflects the ability of a rock to absorb and release heat; it has to do with non-stationary heat flow and the higher its value the better heat is absorbed or released from it. Specific heat (J/m^3K) represents the amount of heat a rock can accumulate and the higher its value the bigger the amount of heat it can accumulate. In general terms, thermal conductivity depends on open porosity, bulk density, mineralogy, anisotropy and size of the crystals, pressure, and temperature. Thermal diffusivity (α) depends on the thermal conductivity (K), the bulk density (ρ), and the specific heat capacity (C) of the rock (Amaral et al., 2013).

Fig. 1 Heat Transfer Analyser ISOMET 2104. The measuring probe is the black device on top of the rock sample.

Table 2 Values of the thermophysical properties measured on opposites faces (A, A'; B, B´and C, C') of cubic marble samples with the ISOMET 2104 using a surface probe (range between 2.00 and 6.00 W/mK). TC - Thermal conductivity; TD -Thermal diffusivity; VHC - Volumetric heat capacity. N - Number of measurements per sample.

		TC [W/mK]		TD [$\times10^{-6}$ m^2/s]		VHC [J/m^3K]	
		Mean	± s,d	Mean	± s,d	Mean	± s,d
White marble, N=5	A	**2,786**	0,021	2,280	0,056	**1,224**	0,026
	A'	2,694	0,046	2,262	0,079	1,194	0,034
	B	2,704	0,033	2,262	0,036	1,198	0,012
	B'	2,744	0,027	2,268	0,046	1,212	0,035
	C	2,746	0,044	2,278	0,079	1,206	0,038
	C'	2,738	0,056	**2,284**	0,049	1,196	0,029
Pink marble, N=6	A	2,662	0,026	2,238	0,035	1,198	0,031
	A'	2,644	0,050	2,234	0,069	1,187	0,027
	B	**2,676**	0,037	**2,278**	0,031	1,182	0,018
	B'	2,598	0,113	2,186	0,069	1,198	0,032
	C	2,632	0,055	2,206	0,051	**1,200**	0,027
	C'	2,638	0,062	2,200	0,055	1,198	0,030
Cream marble, N=6	A	**2,982**	0,150	**2,342**	0,078	1,263	0,041
	A'	2,918	0,099	2,240	0,114	1,268	0,062
	B	2,972	0,057	2,286	0,022	1,292	0,029
	B'	2,962	0,070	2,228	0,144	**1,332**	0,063
	C	2,938	0,120	2,284	0,085	1,282	0,027
	C'	2,936	0,059	2,284	0,068	1,278	0,041

Discussion and conclusions

Köhler (1991), created an interesting classification where it relates degrees of structural alteration of the marble caused by weathering and velocities of the compression waves.By establishing a comparison between the values of the ultrasonic velocities obtained in the tests carried out on the different chromatic marble types of the Estremoz Anticlinal and the classification suggested by Köhler, it is observed that even the velocities found in the plane against foliation (Z-axis) reveal a marble that fits in the second highest grade of the classification (rock in good condition), showing the high quality of these Portuguese Marbles.

In terms of the thermal measurements, it is possible to say that rocks can be classified (in a qualitative way) as good or bad by measuring the thermal conductivity. These data must be completed, at least with bulk density and the open porosity data. Even though the thermal properties values vary little amongst the rock samples, there is a tendence for the pink marble, shows lower values, what doesn't happens reggarding the ultrasonic properties.

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References

AMARAL, P.; CORREIA, A.; LOPES, L.; REBOLA, P.; PINHO, A. & LOPES, J. C. 2013. On the Use of Thermal Properties for Characterizing Dimension Stones, p8, In Rosa, L.; Silva, Z. & Lopes, L. eds. Proceedings of the Global Stone Congress, Key Engineering Materials Vol. 548 (2013) pp 231-238; © (2013) Trans Tech Publications, Switzerland;

KOHLER, W. 1991. UntersuchungenzuVerwitterungsvorgingenan Carrara-Marmor inPotsdam-Sanssouci. In: MOLLER, H.-H. (ed.)Steinschiiden - Steinkonservierung. Kolloq. ImRahmen des Kulturabkommenszw. derBRDund der DDR, Dresden, 2-60kt. 1989. BerichtezuForschung und Praxis in der Denkmalpflege inDeutschland, 2, Hannover, 50-54.

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