Original Research Article

THERMOPHYSICAL CHARACTERIZATION OF GRANITE, BASALT AND MARBLE ORNAMENTAL STONES IN BENIN

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ABSTRACT

This work aims to evaluate the thermophysical characteristics of local ornamental stones in order to facilitate their choice as efficient flooring materials.

Methodology: Three varieties of the most known and requested ornamental stones on the market which include granite, marble and basalt extracted from the Beninese ground and subjected to asymmetric hot plane method to determine their thermal effusivity, thermal conductivity, thermal diffusivity and volumetric heat capacity. The parallelepiped-shaped samples of 10 cm × 10 cm × 3 cm were performed for measurements.

The followings are the results of the different rocks studied: granite (3.22 ± 0.01 W.m^{-1}.K^{-1}, 2470.51 ± 0.006 J.m^{-1}.K^{-1}.s$^{-1/2}$, 1.70 ± 0.01µm².s^{-1}, 1892.88 ± 6.86 KJ.K^{-1}.m^{-3}); marble (4.94 ± 0.02 W.m^{-1}.K^{-1}, 3416.34 ± 0.009 J.m^{-1}.K^{-1}.s$^{-1/2}$, 2.09 ± 0.01 µm².s^{-1}, 2362.73 ± 7.90 KJ.K^{-1}.m^{-3}) and basalt (3.85 ± 0.008 W.m^{-1}.K^{-1}, 2744.22 ± 0.004 J.m^{-1}.K^{-1}.s$^{-1/2}$, 1.967 ± 0.008 µm².s^{-1}, 1956.49 ± 4.07 KJ.K^{-1}.m^{-3}).

Therefore granite is more insulating and marble has better ability to store heat.

Keywords: ornamental stones, Thermophysical properties, less energy-intensive, energy storage material.

BOM

λ : Thermal conductivity (W.m^{-1}.K^{-1})

λ_L : Value of the thermal conductivity derived from the literature(W.m^{-1}.K^{-1}).

a : Thermal diffusivity (**µ**m².s^{-1})

a_L : Value of the thermal diffusivity derived from the literature (µm².s^{-1}).

E: Thermal effusivity (J.m^{-1}.K^{-1}.s$^{-1/2}$)

ρC: Volumetric heat capacity (KJ.K^{-1}.m^{-3})

T_{mod}: Temperature given by the model

T_{exp}: Temperature given by experience

u_x: Standard uncertainty of x

u_C(y): Composite standard uncertainty of y

OBRGM: Office search Benin geological and mining.

1. INTRODUCTION

Benin has huge deposits of ornamental stones with a wide variety of products. These stones, after having been worked, ensure the aesthetic finishing to be used for tiling floors and walls. The low level of exploitation is indicative of many problems. The followings were identified as some of the challenges:

- The Thermophysical performance of these ornamental stones are not known to encourage investors.
- The relationship between the aesthetic aspect of these stones and their potential for use as materials for insulation in the modern architecture.
- Artisanal mining methods do not have much care for these stones to preserve their coatings hence it limits their fields of application (Fig. 1).

Not many studies are on the characterization of ornamental stones. Moroccan building stones were subjected to petrographic and characterization studies [1**, 2**]. The influence of the petro-structural feature on the mechanical properties of the quartzites of atacora in Benin revealed that the Micro-Deval coefficients in the sites of Berecingou are 6.4% and 8.3% respectively [3]. Furthermore, the characterization of bilayer mineral showed that 20% of coarse sand, is resistant to bending three points at 9.875MPa, compression at 22.083MPa with a normal water absorption rate [4]. **[5-8] focused their work on the rocks properties while [9, 10] preferred to stress on the effective pressure law for permeability and parameterization of micro-hardness distribution in granite.**

No thermophysical characterization of local ornamental stones of granite, marble, and basalt was undertaken. This study carefully addressed these stones with regards to their energy efficiency, coating materials, for durability, aesthetic appearance and finishing for building.

Fig. 1. Photograph of a building of a prestigious School of the Trades of the Future

2. MATERIAL AND METHODS

Rock samples were extracted from Benin in West Africa. Granite and basaltic rocks were from the Marian Grotto of Dassa-Zoumé and of the basin volcano sedimentary rocks of Idaho-mahou in Savalou, respectively. Marble were taken from a pileat Bagbononhoue in Abomey (Fig. 2).

Fig. 2. Geographical map of Benin showing rock sampling sites

2.1. Determination of thermophysical properties

The following methods were used for thermophysical characterization of the materials [11-19]. The asymmetric hot plane device [11] was used for the sample characterization. In the process, a section probe (10 cm ×10 cm) is placed below the sample (Fig. 3). The device has a type K thermocouple consisting of wires of 5.10^{-3} mm in diameter, placed below the probe. The set is placed between two blocks of polystyrene foam of 5 cm and two aluminum blocks of thickness 4 cm to generate temperature at the contact. A flow step is sent into the heating element and the temperature is recorded at the center. The system is modeled with a unidirectional heat transfer hypothesis (1D) at the center of the sample during measurement.

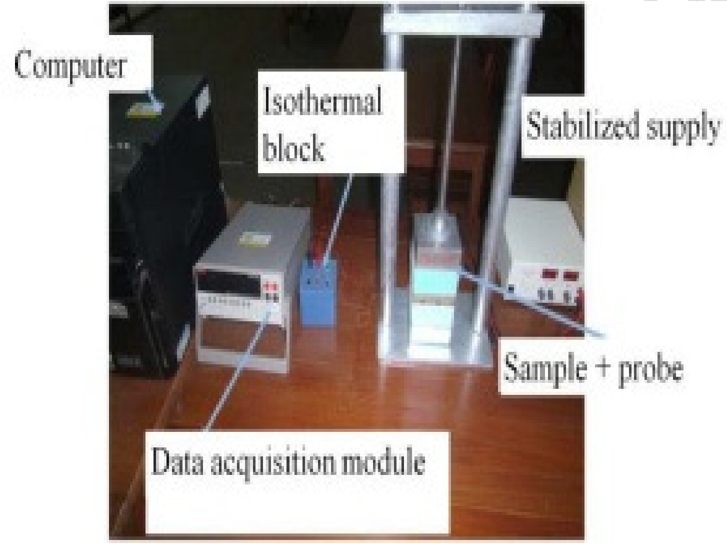

Fig. 3. Experimental mechanism of thermical characterization of experience test

To begin the measurement, there are two parameters:

- The data acquisition time
- The intensity of the heating current.

At a given time and intensity sensitivity for ρc, there is a rise in temperature of about 10 °C for a model of one-way transfer (1 D) with the assumption that the difference between the temperatures Tmod model and the one given by the Texp experience. Fig. 4 shows temperatures of the front and back curves and of residues obtained for granite.

Where there is a rise in temperature of the front, 10 °C 180 nearby for an intensity of 0.625A.

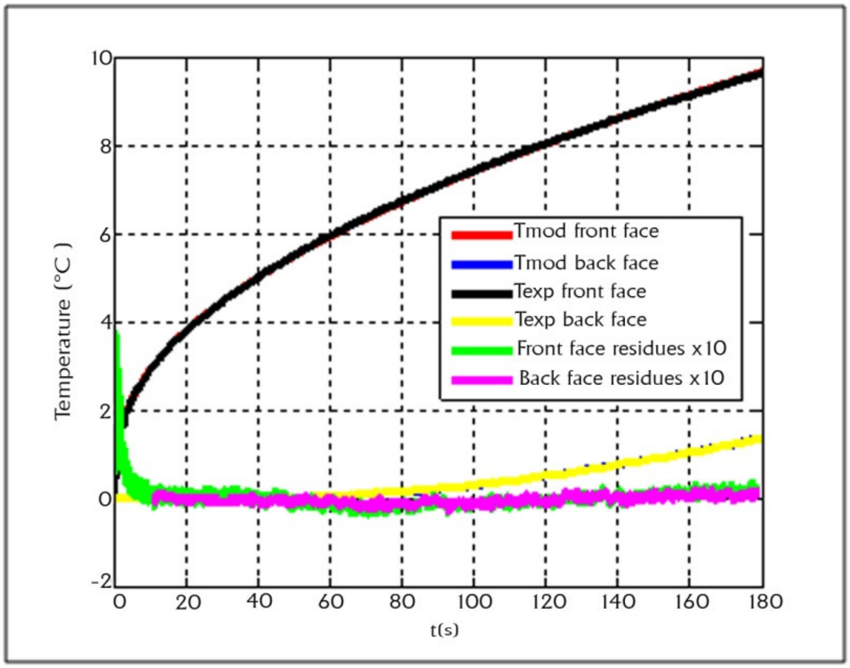

Fig. 4. Model curves for experimental and test on the granite waste

2.2- Assessment of uncertainties

The asymmetric hot plan method to determine experimentally λ thermal conductivity and the thermal effusivity E with their respective uncertainties. Has the thermal diffusivity and volumetric heat capacity ρC were determined from the following formulae:

$$a = \frac{\lambda}{\rho C} = \frac{\lambda^2}{E^2} \qquad (1)$$

$$\rho C = \frac{E^2}{\lambda} \qquad (2)$$

The uncertainty in the calculation of ‘’a’’and ‘’ρC’’ are evaluated by the propagation method of uncertainties.

$$[u_C(\mathrm{a})]^2 = \left(\frac{\partial a}{\partial \lambda}\right)^2 (u_\lambda)^2 + \left(\frac{\partial a}{\partial E}\right)^2 (u_E)^2 \qquad (3)$$

$$u_C(\mathrm{a}) = \sqrt{\left(\frac{\partial a}{\partial \lambda}\right)^2 (u_\lambda)^2 + \left(\frac{\partial a}{\partial E}\right)^2 (u_E)^2} \qquad (4)$$

By integrating the partial derivatives:

$$u_C(\mathrm{a}) = \sqrt{\left(\frac{2\lambda}{E^2}\right)^2 (u_\lambda)^2 + \left(-\frac{2\lambda^2}{E^3}\right)^2 (u_E)^2} \qquad (5)$$

In addition:

$$[u_C(\rho C)]^2 = \left(\frac{\partial(\rho C)}{\partial \lambda}\right)^2 (u_\lambda)^2 + \left(\frac{\partial(\rho C)}{\partial E}\right)^2 (u_E)^2 \qquad (6)$$

$$u_C(\rho C) = \sqrt{\left(\frac{\partial(\rho C)}{\partial \lambda}\right)^2 (u_\lambda)^2 + \left(\frac{\partial(\rho C)}{\partial E}\right)^2 (u_E)^2} \qquad (7)$$

By integrating the partial derivatives:

$$u_C(\rho C) = \sqrt{\left(-\frac{E^2}{\lambda^2}\right)^2 (u_\lambda)^2 + \left(\frac{2E}{\lambda}\right)^2 (u_E)^2} \qquad (8)$$

3. RESULTS AND DISCUSSION

Table 1 shows the results of the thermal characteristics of the three samples. It can be seen that the values of volumetric heat capacity and thermal conductivity of three granite samples are in agreement with those reported [19,20]. On the other hand, values of the thermal conductivity of the marble and basalt appear to contradict values of workers [19]. There are two possible hypotheses: the first is that the tests were not carried out at the same temperature and the second is that the current samples and those used by previous workers have the same chemical and physical properties as well as mineralogical composition. The second seems more likely.

Moreover, the thermal diffusivity and conductivity obtained with granite seem to contradict other values [21]. This observation seems to confirm the second hypothesis.

Table 1: Results of the Thermophycial measures.

		Average values	
Parameters	Marble	Basalt	Granite
E($J.m^{-1}.K^{-1}.s^{-1/2}$)	3416.34±0.009	2744.22±0.004	2470.51±0.006
λ($W.m^{-1}.K^{-1}$)	4.94±0.02	3.85±0.008	3.22±0.01
λ_L($W.m^{-1}.K^{-1}$)	2.3-3.2[19]	1.2-2.3[19] and 1.7-2.5 [20]	2.6-3.1[19];2-4[20] and 2.8[21].
a ($\mu m^2.s^{-1}$)	2.09±0.01	1.967±0.008	1.70±0.01
a_L($\mu m^2.s^{-1}$)			1.07[21].
ρC ($KJ.K^{-1}.m^{-3}$)	2362.73±7.90	1956.49±4.07	1892.88±6.86

4. CONCLUSION

The thermophysical properties of granite, marble and basalt were determined by asymmetric hot plane method.

The results obtained showed that granite has the lowest value of thermal conductivity, effusivity and diffusivity respectively equal to 3.22 $W.m^{-1}.K^{-1}$; 2470.51$J.m^{-1}.K^{-1}.s^{-1/2}$ and 1.70. $\mu m^2.s^{-1}$ while the highest value of the thermal capacity is marble 2362.73KJ.K^{-1}.m^{-3}. Therefore, granite is a more insulating while marble has a strong capacity to store heat than the other two materials.

Also, from a practical point of view, the results presented in this study show that the choice of granite would have a significant impact on energy consumption as the other two study materials. So, it should be used as inner coating of the housing material.

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