Original Research Article

CHARACTERIZATION OF BENIN ORNAMENTAL STONES THERMOPHYSICS: CASE OF GRANITE, BASALT AND MARBLE

.

ABSTRACT

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

Location and duration of the study: the study was conducted at the LEMA from May to December 2015.

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Methodology: Three varieties of the most known and requested ornamental stones on the market, have been selected for this work. This is granite, marble and basalt extracted from the Beninese ground. This study allowed us to use the asymmetric hot plane method to determine the thermal effusivity, thermal conductivity, thermal diffusivity and volumetric heat capacity of these materials. The parallelepiped-shaped samples of 10 cm × 10 cm × 3 cm have been performed for measurements.

Results: Investigations have shown that granite has the lowest thermal conductivity value (3.22 W.m^{-1}.K^{-1}); effusivity (2470.51 J.m^{-1}.K^{-1}.s$^{-1/2}$) and diffusivity (1.70. 10^{-6} m².s^{-1}) and the highest value of the volumetric heat capacity (2362.73 KJ.K^{-1}.m^{-3}) is obtained with marble.

Conclusion: The granite seems to have a character more insulating and the marble has a strong ability to store heat, than the other two materials.

Keywords: ornamental stones, Thermophycials properties, less energy-intensive and 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 (m².s^{-1})

a_L : Value of the thermal diffusivity derived from the literature (m².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

The Benin has huge deposits of ornamental stones with a wide variety of products to consider an expansion of domestic production. These stones, after having been worked, ensure the aesthetic aspect of finishing and can in this case used for covering floors and walls. But it is clear that this wealth is unfortunately very little exploited particularly in the area of the building to residential tenancies. This low level of exploitation is indicative of a multitude of problems that prevents the ornamental stone sectorto take off. We can mention among other things:

- The Thermophycials performance of these ornamental stones not yet known, which does not encourage investors to engage in buildings for which there do not have a technical guarantee of energy saving.
- A lack of alliance between 'aesthetic aspect of these stones and their abilities as a material insulation in the modern architecture.
- Artisanal mining method with irregular shapes and a bad provision of these stones in the coating. So the appearance of finishing that present these stones shapes no national built heritage, which limits their fields of application (Figure 1).

On the bibliography on the topic, it is important to note that few studies devoted to the characterization of ornamental stones in the literature. Thus, 11 Moroccan varieties of building stones have been subject of a Petrographic study [1]. The study of the influence of the petro-structural feature on the mechanical properties of the quartzites of atacora in Benin revealed that the Micro-Deval coefficients obtained at the level of the sites Berecingou and are respectively 6.4% and 8.3% [2]. Furthermore, the characterization of bilayer mineral material helped show that 20% of rate of coarse sand, the Bilayers offer good resistance in bending three points (9.875MPa), compression (22.083MPa) with a water absorption rate normal [3]. Other works are devoted to the origin and evolution of the term "small granite" [4].However, no study is addressed thermophysical characterization of local ornamental stones such as granite, marble, and basalt. Which explains the interest on these stones which can be used in the coating of buildings when their thermophysical characteristics are known. This study is therefore part of a logic of valorization of these stones in the building as more energy efficient coating materials, offering both durability and aesthetic appearance of the finishes.

Fig. 1. Picture of the building of the prestigious school of the trades of the future

2. MATERIAL AND METHODS

2.1 Origin of raw materials

The raw materials used in the present work are extracted from the ground of Benin in West Africa. Selected granite and basalt rocks are from the Marian Grotto of Dassa-Zoumé and of the basin volcano - sedimentary of Idaho-mahou in Savalou, respectively. As for marble, it was extracted reserve of marble Bagbononhoue in Abomey (see location in Figure 2).

Fig. 2. Geographical location of rock sampling sites

2.2. Method of estimating thermophysicals properties

In this work, we used an asymmetric hot plane device [5] for sample characterization.

As shown in Figure 3, a section probe (10 cm ×10 cm) is placed below the sample. A type K thermocouple consisting of wires of 5.10^{-3}mm in diameter is placed below the probe. This set is placed between two blocks of extruded polystyrene foam of 5 cm and on the other hand two aluminum blocks of thickness 4 cm to impose the temperature on the contact surfaces. A flow step is sent into the heating element and the temperature is recorded in the center.

This system is modeled with a unidirectional heat transfer hypothesis (1D) at the center of the sample during measurement.

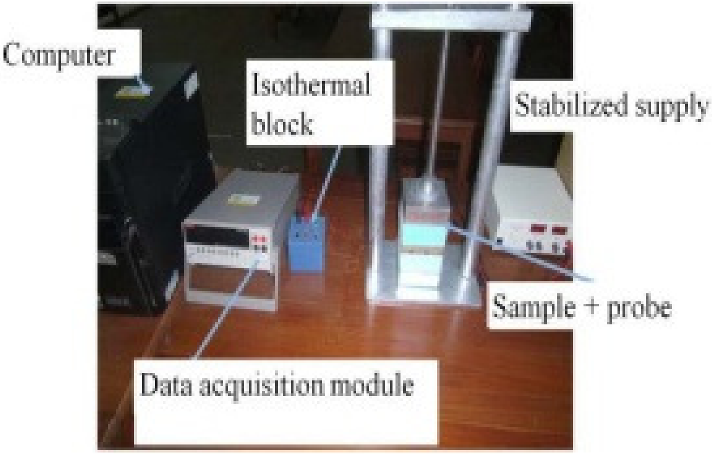

Fig. 3. Experimental mechanism of thermical characterization of experience test

2.3 Measurement procedure

To begin the measurement, there are two parameters:

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

Thus, we choose the values of time and intensity sensitivity allowing ρc and a rise in temperature of about 10 ° C required for a model of one-way transfer (1 d), assumption that will be checked afterwards by an analysis of residue: difference between the temperature given by the Tmod model and the one given by the Texp experience.

The operation is made for each sample. As illustration, we present figure 4 temperatures of the front and back curves and of residues obtained for granite.

We are seeing a rise in temperature of the front, 10 ° C 180 nearby for an intensity of 0.625A. By referring to the model and experimental curves, we see that the two curves overlap perfectly. The residues are also flat.

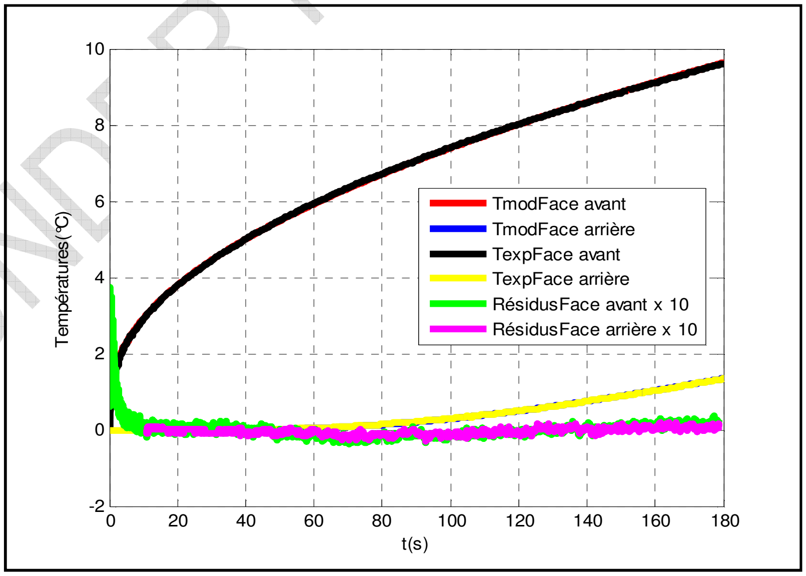

Fig. 4. Curve model and experimental and test on the granite waste

2.4- 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 are determined from the following formulas:

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

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

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

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

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

By integrating the partial derivatives,we find:

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

In addition:

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

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

By integrating the partial derivatives,we find:

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

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 granite samples three are in agreement with those reported in the literature [6-7]. On the other hand, values of the thermal conductivity of the marble and basalt appear to contradict the values of literature [6]. There are two possible hypotheses and probable: the first is that the tests are not carried out at the same temperature and the second is that our samples used for this work and those used for the bibliography results have the same properties of chemical, physical and mineralogical composition. The second seems more likely.

Moreover, the thermal diffusivity and conductivity values obtained with granite seem to contradict other values of literature [8]. This observation seems to confirm the second hypothesis.

Table 1: Results of the Thermophycials 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[6]	1.2-2.3[6] and 1.7-2.5 [7]	2.6-3.1[6];2-4[7] and 2.8[8].
a (10^{-6} m².s^{-1})	2.09±0.01	1.967±0.008	1.70±0.01
a$_L$(10^{-6} m².s^{-1})			1.07[8].
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 have been determined in the present work by the asymmetric hot plane method.

The results obtained showed that the 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 $1.70.10^{-6}$ $m^2.s^{-}1$ while the highest value of the thermal capacity is obtained with marble, 2362.73 $KJ.K^{-1}.m^{-3}$. It is therefore deduced that granite seems to have a more insulating character and marble has a strong capacity to store heat than the other two materials.

Further research, based on a larger number of rock varieties, particularly of magmatic origin, is conceivable to support the results of this study.

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