Journal of Materials Science & Surface Engineering, 6(3): 797-801
ISSN (Online): 2348-8956; 10.jmsse/2348-8956/6-3.2

Effect of the Thickness on the Phase Shift and Damping of A Material Based on Rice Husks and Cement

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ABSTRACT
In this document, five samples of composite cement-rice-ball materials are made to thicknesses of 7.5; 10; 12; 15 and 20 cm. They are kept in the laboratory (LEMA) for two months. They are subsequently wrapped in glass wool, instrumented and exposed for five days to solar thermal stresses. The analysis of the data processing and the interpretation of the curves show that the increase in thicknesses improves the damping and the phase shift of this material. However, we note an asymptotic limit to this evolution, which shows that beyond a certain value of the thickness these parameters no longer evolve.

ARTICLE HISTORY
Received 21-02-2018
Revised 22-03-2018
Accepted 26-03-2018
Published 02-05-2018

KEYWORDS
Thermal
Phase shift
Amortization Composite
Rice ball - Cement

Introduction

The habitat as thought by our ancestors is directly derived from the objects of nature (stone, wood etc.). It is worth recalling that the palaces of the Pharaohs were built with clay and straw. The search for aesthetics and the struggle against precariousness have distanced the contemporary world from this vision. The current discourse is the return to ecological or green habitats since the problems created by the modern design of the building threaten the very survival of humanity. In coastal regions in sub-Saharan Africa, erosion and the advancement of the sea to the mainland due to the uncontrolled exploitation of quarries is a matter of great concern.
Meanwhile, industrial waste from rice bulk clutters our production units or ends up being dumped into the wild because we do not know what to do with it. It is quite natural that research in the LEMA laboratory is oriented towards the search for new building materials based on rice husks, with the aim of providing an alternative to the use of marine sand, which causes serious problems environmental. However, these new materials must meet the requirements of being available, less expensive, having good mechanical and thermal properties and not too thick. The composite cement-rice-ball material is derived only from water and cement rice bullet waste. Not a handful of marine sand is used.
This work follows the work of Doko (2013) [1], which showed that the composite materials of cement-ball of rice have interesting mechanical properties. In particular, they can be used for the production of lightweight concrete. PRODJINONTO (2016) [2] has classified these materials and those used in sub-Saharan Africa in terms of damping and phase shift. From this classification, the composite cement-ball of rice, presents the best damping and phase shift for a fixed thickness of 7.5 cm. It is therefore necessary to study the effect of the thickness on this composite.
The approach and details which led to the result announced in the summary are set out in the remainder of this document.

Experimental

Preparation of samples

Five samples of the composite cement-rice husk are made (see photograph 1). They are manufactured under the same conditions, same proportions of water, cement and rice husk see: PRODJINONT (2016) [2]; DOKO (2013) [1]. They have the same surface area of $14.5 \times 10\ cm^2$. As for the thicknesses, they are respectively 7.5; 10; 12; 15 and 20 cm.

Figure 1: Samples of rice ball material–cement

Instrumentation

Hardware

For the experiment, six (06) Peltier flowmeter calibrated elements, six (06) Type K surface temperature measurement thermocouples, a glass wool roll, an Agilent 34970A data acquisition unit and a computer are used.

Procedure

The operating method implemented here has already been tested successfully by PRODJINONTO (2011, 2016) [2-3]. A Peltier element and a thermocouple are attached to the base of each sample at its center. The samples are then all packed in 7 cm thick glass wool, except the top surface of $14.5 \times 10\ cm^2$ of surface. A Peltier element and a thermocouple were used to collect the external solar flux and temperature received by each sample on this upper side of the 7.5 cm thick sample. It should be noted that this

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Contents lists available at http://www.jmsse.in/ & http://www.jmsse.org/

face of this specimen is finely painted in matt black to standardize the solar flux over this entire surface. The wires of the Peltier elements and of the thermocouples are then connected to the acquisition unit, which in turn is connected to the computer for real-time recording of the data (see Fig. 2, 3 and 4). Starting the recording operations can start with the startup of the computer and the data acquisition unit, adjustments relating to the types of elements connected to the control unit and the measuring ranges. The selected measurement step is (10 s). Samples are exposed to solar thermal variations. The measurement campaign lasted five (5) days. It is important to note that before the protocol described above, the samples are packaged in a metrology laboratory or have the same conditions of temperature and pressure for two months. In a nutshell, the samples are kept under the same conditions.

Figure 2: Packaging preparation of the sample

Figure 3: Samples coated in glass wool with thermocouple and Peltier element below

Description of the experiment

The measurements are made over a period of five days. The acquisition step is 10 s. In total, about 50,000 temperature and flow data are recorded. These are the temperatures and fluxes of the bases of the samples covered by the glass wool and those of the upper side of the sample of thickness 7.5 cm painted in black matt which gives the thermal state of the environment.

Data Processing Method

The concern in this work is to study the effect of thickness on the damping and the phase shift of this kind of material.
To achieve this, a Matlab program was developed, which initially enabled the cutting of batches of 8640 data representing each measurement day. They are then organized by average of 6 to obtain data in minutes. Finally, by an average of 60, the hourly information relating to each measurement day is obtained. The temperature curves as a function of time are plotted for each measurement day. What is hoped for is an increasing evolution of the damping and the phase shift as a function of the thickness of the sample until it reaches an asymptotic value. This can make it possible to make a reasoned choice of the thickness of the material given the weather conditions of the environment in which a building with walls made of this material can be erected. In order for everything to be as expected, the curve of the evolution of the outside temperature (environment) must be higher, at least at a time of day, than that of the temperature at the base of the samples. It is worth recalling here that the samples are coated in glass wool about 7 cm thick, except in their sun-exposed (environment).

Presentation of the curves of the temperature variations of the different thicknesses of the second day (D2) and the third day (D3)

In the Fig. 4 the variations of the indoor and outdoor temperatures are presented for the five samples tested for the second and third day.
In the preceding figures, the time is plotted on the abscissa and the values of the temperatures obtained by successive means are plotted on the ordinate. The amortizations obtained each day are shown on the various curves. On the left, these are the curves corresponding to the second day of recording and to the right, those relating to the third day. The blue curves refer to the temperatures measured below the samples protected by the glass wool and those in green color those relating to the obtained values of the thermocouple placed above the sample of 7.5 cm. The phase shift values are of the order of a few hours and are therefore difficult to represent. It can be noted that the peak of outside temperature is around 14 hours (14 h). The temperature difference between the outside and the inside does not exceed 5 ° C between 0 am and 7 am. It is also observed that the curves intersect at around 17 o'clock where they initiate their fall.

Curve of variation of the damping as a function of the thicknesses

Amortization for each of the five samples and for each day is aggregated. An average of its values is calculated for each sample therefore for the different thicknesses. The curve which follows shows the variations of the damping means as a function of the thicknesses. In the Fig. 5a, an increasing evolution of the damping with the thickness is observed. For example, for a thickness of 12 cm of this rice-cement composite, a damping of about 12 ° C is read. This is a very interesting result if one considers this relatively small thickness of the material. Indeed, with a thickness of 12 cm of the material, a wall is capable of maintaining a temperature of -12 ° C. relative to the outside temperature in the enclosure of a building. This curve presents a horizontal asymptote of equation 13 ° C., which proves that beyond a certain value of thickness (20 cm for example) no more damping gain is obtained. In the Fig. 5b, the data of Fig. 5a, are used to model the evolution of damping as a function of thickness. A curve was sought under Matlab, which gives a better approximation of the data. The equation curve:

$$Y = -0.00276 \times X^4 + 0.155 \times X^3 - 3.3 \times X^2 + 30.7 \times X - 94.1 \qquad (1)$$

can thus make it possible to calculate a damping Y in degree (° C.) which can be expected for a given thickness X in centimeter (cm). Equation (1) can also be resolved to determine a suitable thickness for desired damping.

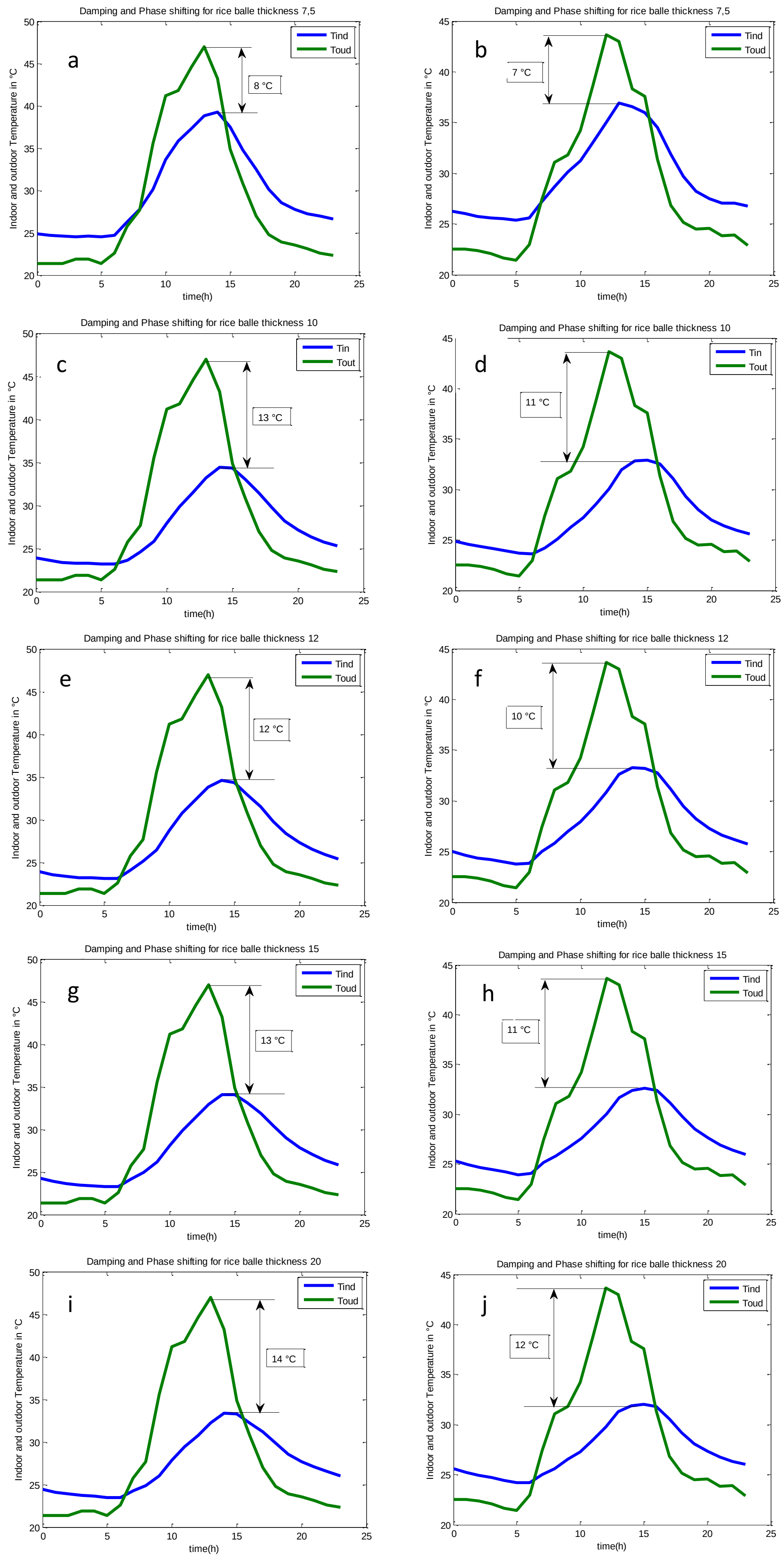

Figure 4: Variations of temperatures (a) D2 (7.5 cm), (b) D3 (7.5 cm), (c) D2 (10 cm), (d) D3 (10 cm), (e) D2 (12 cm), (f) D3 (12 cm), (g) D2 (15 cm), (h) D3 (15 cm), (i) D2 (20 cm), (j) D3 (20 cm)

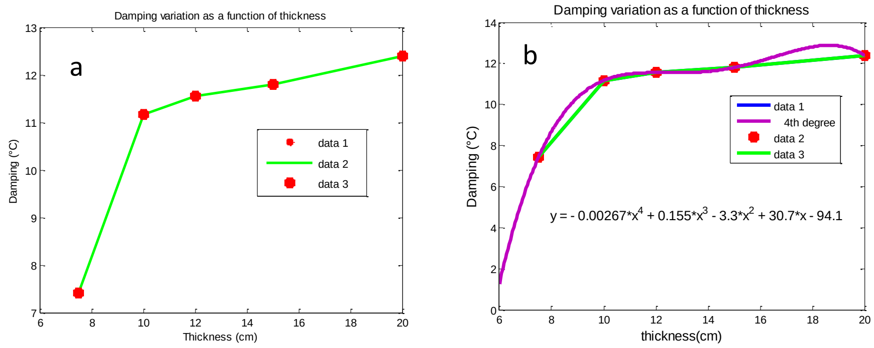

Figure 5: (a) Damping variation as a function of thickness, (b) Damping modeling as a thickness function

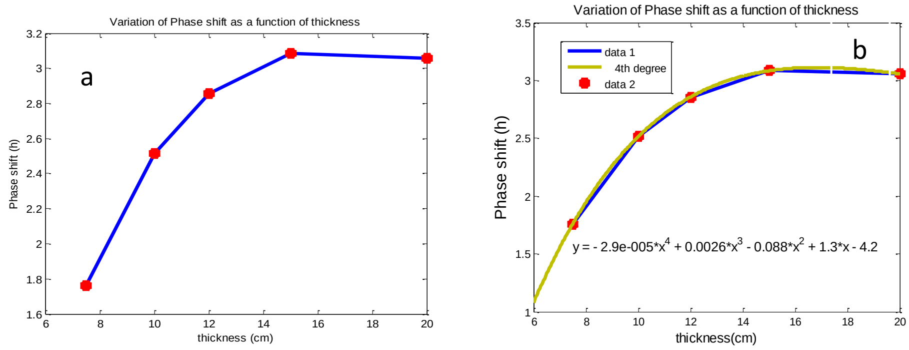

Figure 6: (a) Variation of the phase shift as a function of thickness, (b) Modeling the phase shift as a thickness function

Curve of variation of the phase shifts as a function of the thicknesses

Another important parameter sought for the building walls supposed to provide better conditions of comfort is the phase shift. The phase shift is defined as the time interval between the indoor temperature peak and the outdoor temperature peak. The larger it is, the more little the walls are influenced by external thermal variations. As before, a Matlab program was used to calculate the daily phase shift for the five samples. An average of the five measurements per sample is retained for each of the thicknesses. The curve which follows shows the variations of this parameter with respect to the thickness.

On the Fig. 6a, It is observed that phase shift is an increasing function of the thickness of this composite rice-cement composite. The thickness of 7.5 cm gives a phase shift of about 1 h 48. But the curve seems to admit a horizontal asymptote of the order of about 3 h 15. In other words, beyond a certain thickness value, the phase shift no longer varies. It is possible, from the Fig. 6a, that by simple projection, that one can link a thickness to a phase shift and reciprocally. In figure 6b, the data in Fig. 6a are used to give a representative model of the sample. The model is obtained in the following equation (2):

$$Y = -2.9 * 10^{-5} * X^4 + 0.0036 * X^3 - 0.088 * X^2 + 1.3 * X - 4.2 \qquad (2)$$

In this equation, Y represents the phase shift in hours (h) and X the thickness in centimeters (cm). It is thus possible to make a reasoned choice of the parameters phase shift - thickness.

Results and Discussion

The composite rice ball - cement studied offers very interesting advantages. With thicknesses of not more than 20 cm, however, damping values between 8 and 13 ° C. can be obtained. These values are reached for the bar soil at thicknesses of the order of 50 cm and a little more for the sand and cement bricks. This material is thus gained in living space. Moreover, for a thickness of 15 cm, a phase shift of 3 h 15 can be obtained. It is stated in the literature that for a wooden frame wall, isolated by glass wool, the phase shift is only 2 h 13 for a thickness of 22 cm. Therefore, this material gives a better result than this composite with a gain of about 1 hour for a thickness of 7 cm less. Generally, outdoor temperature peaks are between 13h: 30 and 14h: 00. With a 3h: 15 phase shift, the peak of the interior temperature would be between 16h: 43 and 17h: 15. But at this moment, the sun is already starting to slumber. It is a very suitable material for regions of temperate climate.

It is important to recall the experimental conditions which are rather severe. The samples are coated in 7 cm thick glass wool. They are subject to direct incident radiation. These conditions undoubtedly influenced the results obtained which would be better in a real situation. Indeed, a building wall is not subjected to the incident radiation and therefore receives only a fraction of this radiation. In addition, the internal and external convections soften the atmosphere and allow a good breathing of the walls that accumulate less heat than in our experimental condition. Thus, the results presented are guaranteed for very unfavorable conditions of heat wave.

Conclusions

In tackling this issue, we were trying to solve both ecological and environmental problems. Ecological problem because, the waste of rice balls are produced by thousands of tons each year, and we frankly do not know how to get rid of them. Environmental problem because, the exploitation of sand quarries has reached disturbing proportions. The ravages of the waves in furies on the entire West African coast call for international aid.

These two problems are indeed resolved. The material uses only waste rice husks and cement. Moreover, with a low thickness of 15 cm, we obtain a phase shift of approximately 3 h 15 and a damping of at least 12 ° C. There is also a gain in living space since these results are obtained for composite walls of thickness beyond 22 cm. It is a material which gives better guarantees of mechanical properties.

There remains, however, a study of the aging of this material. One could also see if it cannot go in combination with other materials to improve its phase shift. Perhaps coatings of certain qualities could bring this solution.

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