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RESEARCH ARTICLE

INFLUENCE OF THICKNESS ON PHASE SHIFT AND DAMPING OF A CEMENT – RONIER FIBER COMPOUND

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ABSTRACT

In this document, four samples of composite materials of cement - fiber of the ronier are manufactured to thicknesses of 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. Flow and temperature data are collected and processed. Curves of external and internal temperature variations as a function of time as well as those of variations in phase shift and damping as a function of the thicknesses are plotted. The analysis of the data processing and the interpretation of the curves shows that the damping is a decreasing function of the thickness whereas the phase shift increases with the thickness of this material. However, we note an asymptotic limit to these variations, which shows that beyond a certain value of the thickness these parameters do not change any more.

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INTRODUCTION

Originally, the habitat was designed only from objects directly derived from 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 bioclimatic or green ecological habitats since the problems generated by the modern design of the building threaten the very survival of humanity. In coastal regions in sub-Saharan Africa, erosion and sea-to-continent erosion due to wild exploitation of sand quarries is a matter of great concern. At the same time, industrial wastes of raspberry fibers clutter our production units or end up being discharged into the wild because we do not know what to do with them. It is natural that research in the LEMA laboratory is oriented towards the search for new building materials based on fiber of the ronier, with the aim of providing an alternative to the use of marine sand causing 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 material of the cement-fibers of the ronier is produced solely from waste root fibers, water and cement. Not a handful of marine sand is used. This work follows the work of Doko (2013), which has shown that the composite materials of cement-fibers of the ronier have interesting mechanical properties. In particular, they can be used for the production of lightweight concrete. PRODJINONTO (2016) has classified this material and those used in sub-Saharan Africa in terms of damping and phase shift. From this classification, the composite cement-fibers of the ronier is one of the best in terms of damping and phase shifting for a fixed thickness of 7.5 cm. It is therefore necessary to study the effect of thickness on these parameters. The approach and details that led to the results announced in the summary are set out in the remainder of this document.

MATERIALS AND METHODS

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

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Instrumentation: Hardware: For the experiment, five (05) Peltier flowmeter calibrated elements, five (05) 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) [3, 2]. 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 face of 14.5 × 10 cm^2 of surface. It is arranged on the upper surface of a sample, a Peltier element and a thermocouple which have been used to collect the external solar flux and temperature received by each of the samples.

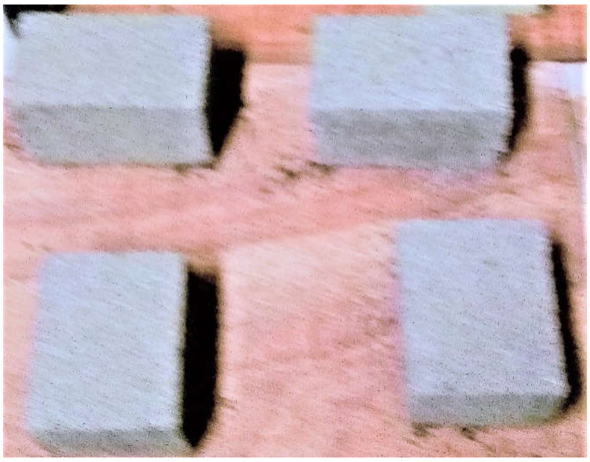

Figure 1. Samples of rice ball material – cement

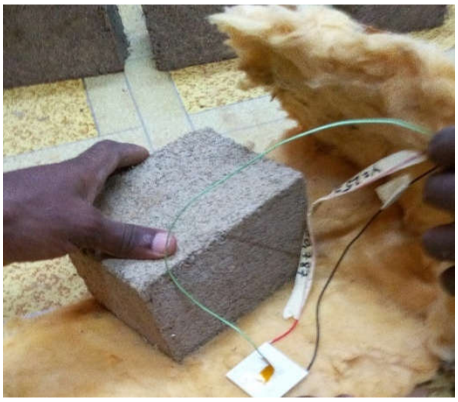

Figure 2. Packaging preparation of the sample

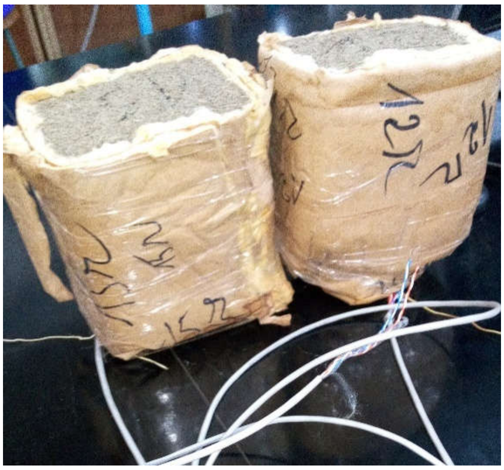

Figure 3. Samples coated in glass wool with thermocouple and Peltier element below

The wires of the Peltier elements and the thermocouples are then connected to the data acquisition unit, which in turn is connected to the computer for real-time recording of the data (see Figures 2, 3). 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 temperature and pressure conditions for one week. In a nutshell, the samples are kept under the same conditions.

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 painted in black matt which gives the thermal state of the environment.

Data Processing Method

New substitute materials, to be effective, must be bioclimatic, ecological, green and less energy intensive. They must, therefore, respond to cross-cutting imperatives. Over the past ten decades, many research efforts have been directed towards achieving these imperatives through practical work and simulations. Some authors such as COSSALI G.E (2007) [4, 5], COULIBALY et al, (2011) [6] and LAGESSE et al. (2013) [7] have made significant advances on this issue. In this process of characterization of building materials, the use of quadrupoles, see PRODJINONTO (2016) [2], revealed the thermal retention capacity, the transfer coefficient and the phase shift which is about 1 h For a 7.5 cm thick sample of this material. The material is fairly well known from a mechanical point of view (DOKO) and by the knowledge of some thermophysical properties. 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 a correlation between damping, phase shift and sample thickness. 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.

Presentation of the curves of the temperature variations of the different thicknesses of the second day (D2) and the third day (D3): In the following (Figures 4 - 7), the variations of the indoor and outdoor temperatures are presented for the four samples tested for the second and third day.

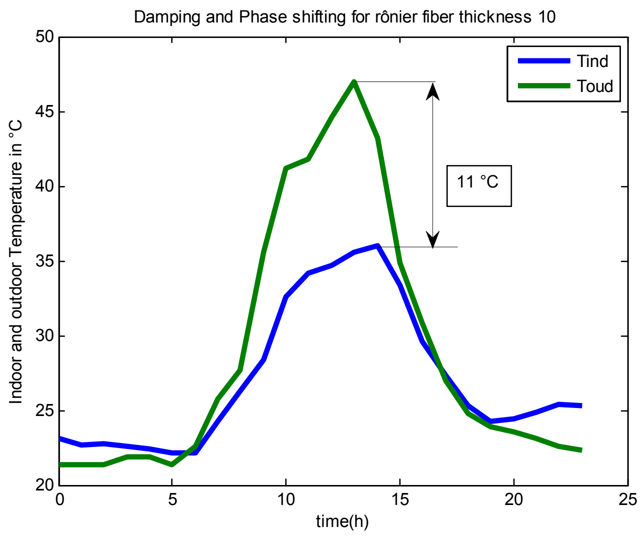

Figure 4.a. Variations of temperatures D2 t=10 cm

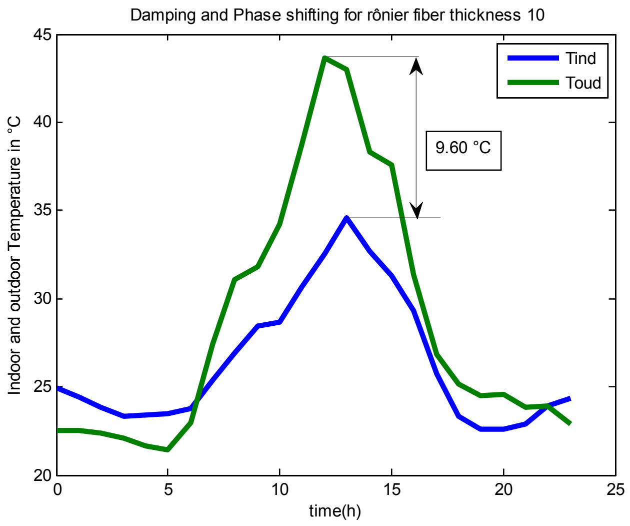

Figure 4.b. Variations of temperature D3 t = 10 cm

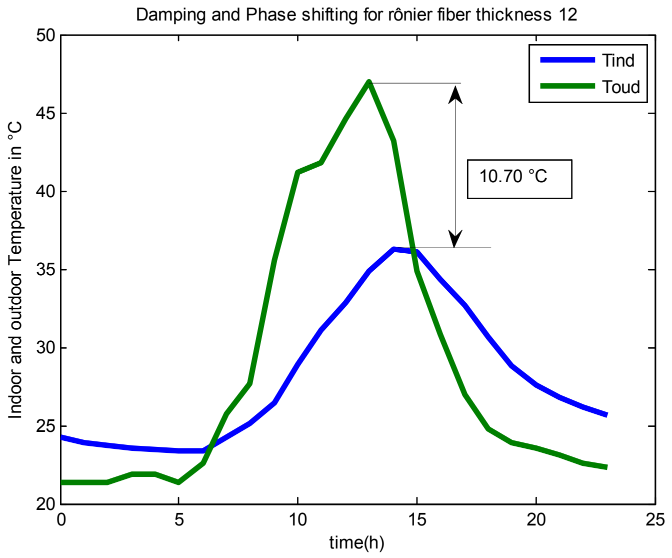

Figure 5.a. Variations of temperatures D2 t=12 cm

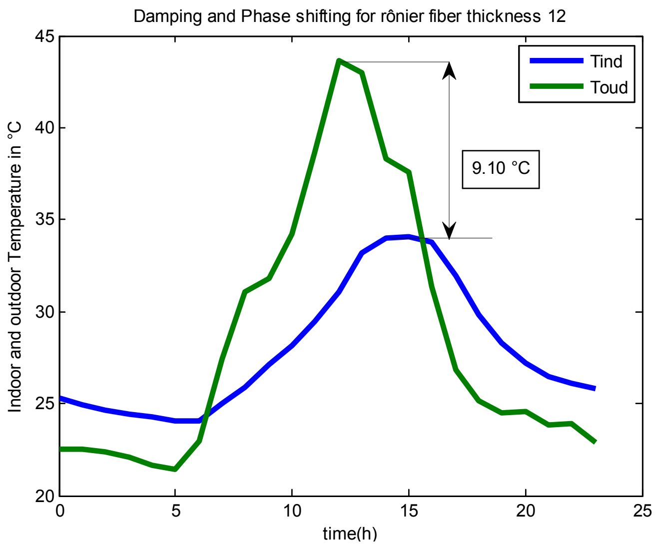

Figure 5.b. Variations of temperature D3 t = 12 cm

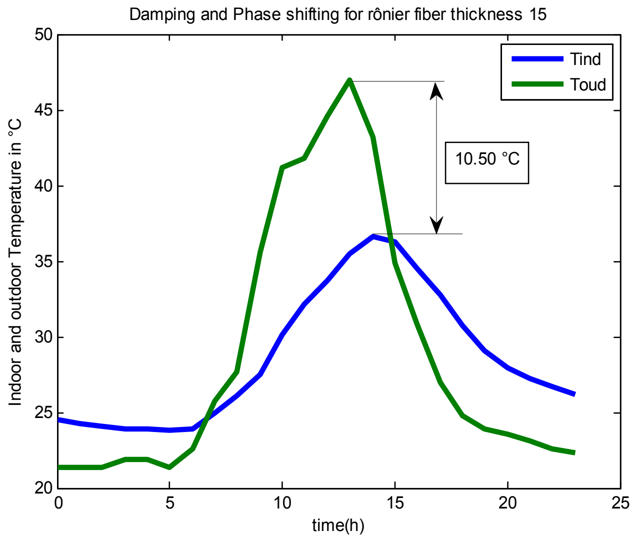

Figure 6.a. Variations of temperatures D2 t=15 cm

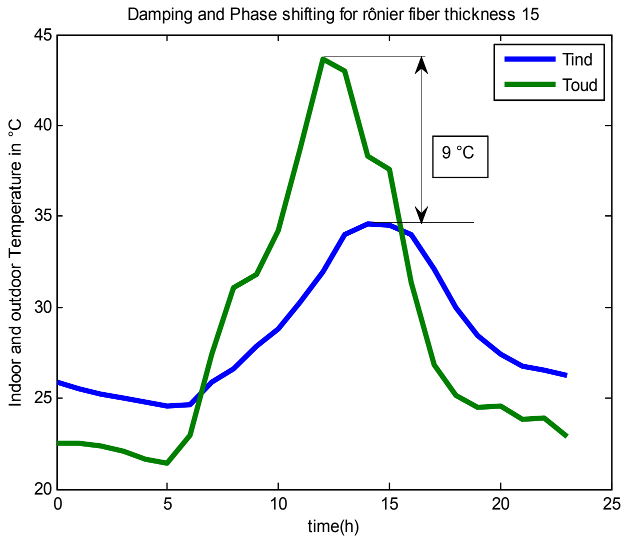

Figure 6.b. Variations of temperature D3 t = 15 cm

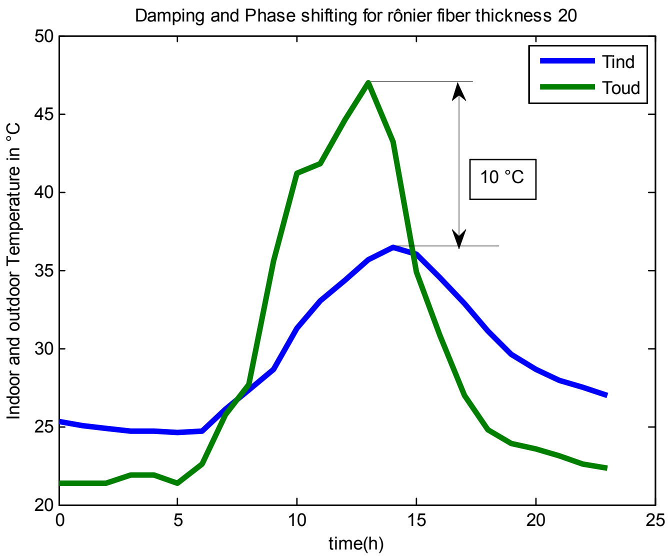

Figure 7.a. Variations of temperatures D2 t=20 cm

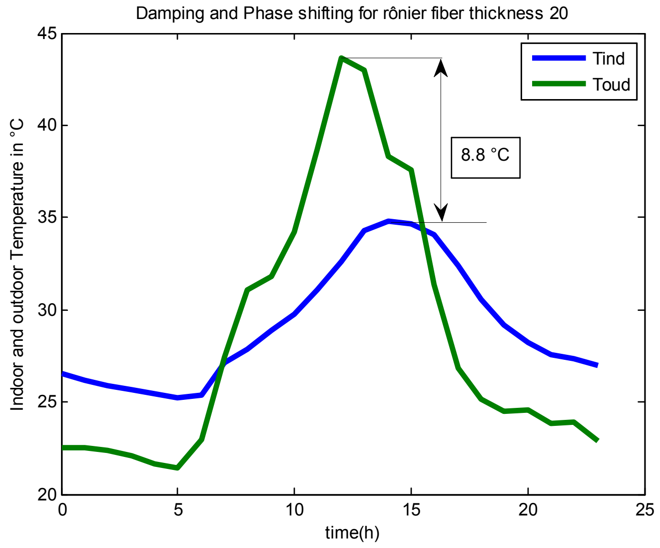

Figure. 7.b. Variations of temperature D3 t = 20 cm

In the preceding figures the time in hours is plotted on the abscissa and on the ordinate the values of the temperatures obtained by successive means. The damping obtained each day are shown on the various curves. indicated by D2 with the corresponding thicknesses by t while those of the third by D3.. 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 values obtained from the thermocouple placed above a sample. 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 4 ° C between 0 am and 7 am. It is also observed that the curves intersect at about 16 hours when they start their fall.

Curve of variation of the damping as a function of the thicknesses: The calculated thermal damping values for each of the four samples and for each day are grouped together. 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.

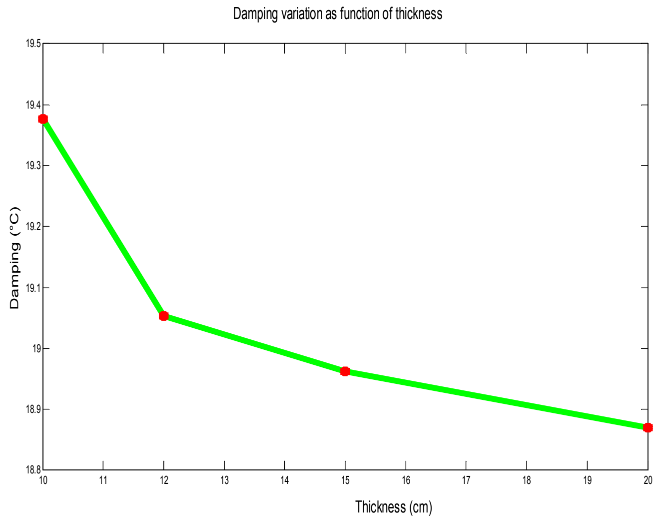

Figure 12a. Damping variation as a function of thickness

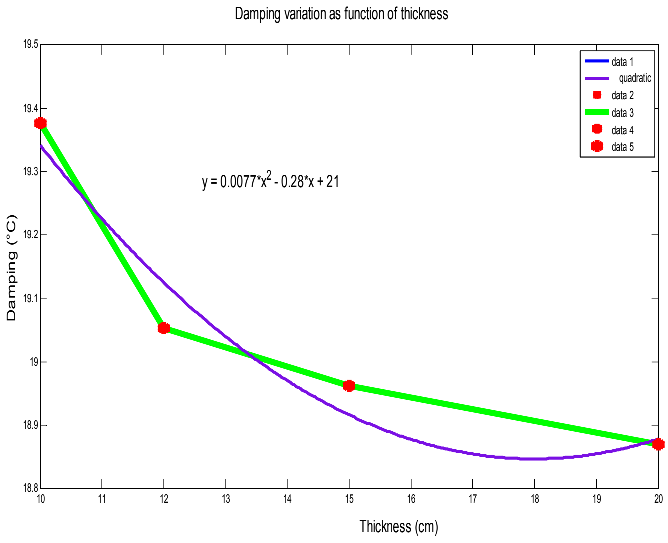

Figure. 12b. Modeling damping as a function of thickness

On Figure. 12, a decreasing evolution of the damping with the thickness is observed. For example, for a thickness of 12 cm of this composite of ronier - cement fibers, a damping of about 9.75 ° C is read, whereas for 10 cm, it is 11 ° C. This curve presents a horizontal asymptote of equation 9.5 ° C, which proves that beyond a certain thickness value (20 cm for example), the damping will not fall below 9.5 ° C. What is interesting here is that we have the assurance of a difference of 9.5 ° C between the peak of temperature on the outside and the peak of temperature on the inside from the moment when one has a thickness at least equal to 20 cm. The material can therefore be used for a particular purpose. In Figure 12b, we have described a model of the evolution of the damping according to the thickness which can help to make decisions. The equation that governs this model is written:

$$Y = 77 * 10^{-4} * X^2 - 0.28 * X + 21 \qquad 1$$

In this equation, Y represents the damping in degrees (° C) and X the thickness in centimeters (cm).

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 made it possible to calculate the daily phase shift for the four 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.

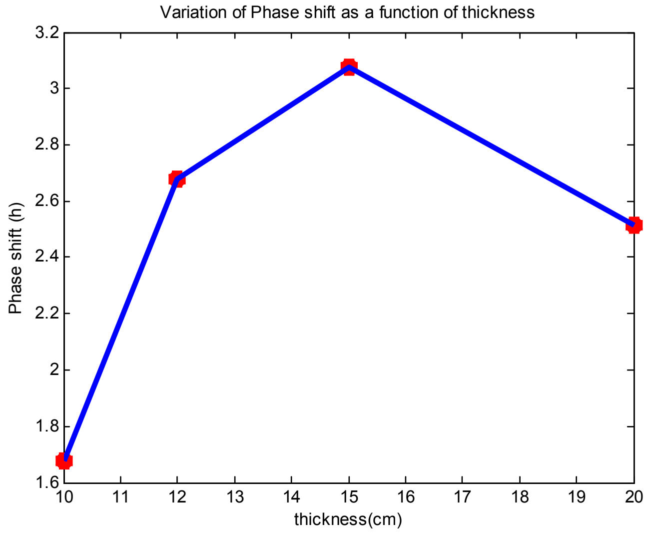

Figure 13.a. Variation of the phase shift as a function of thickness

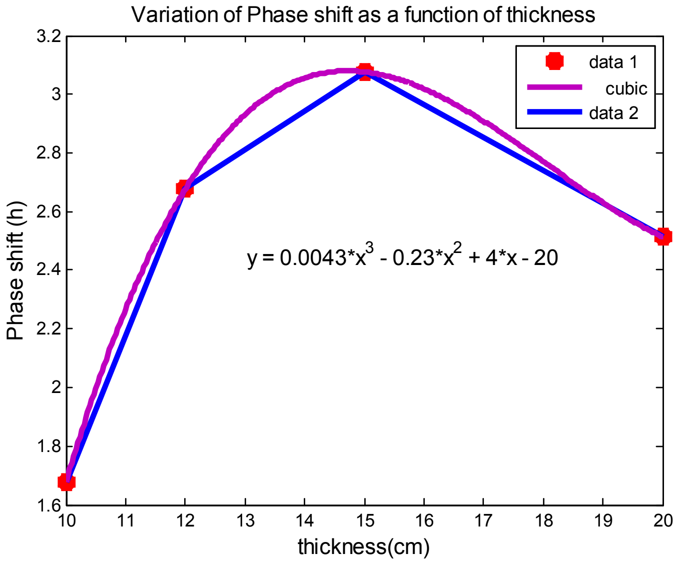

Figure 13.b Modeling the phase shift as a thickness

Figure 13.b: Modeling the phase shift as a thickness function. We observe in the figure 13.a, that the phase shift increases with the thickness for values between 10 and 15 cm. Beyond that, it begins to fall. For the thickness of 15 cm, there is the largest phase shift which is approximately 3 h 06.

The model is obtained in the following equation (2):

$$Y = 0.0043 * X^3 - 0.23 * X^2 - 20 \qquad 2$$

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.

Reviews: The composite fiber of the ronier - cement studied offers very interesting advantages. It is found that the material acts as a heat accumulator. The greater the thickness, the more difficult it is for the material to evacuate the stored heat, which explains its low phase shift and damping. For low thicknesses, however, there is a marked improvement in its parameters. The thickness of 12 cm appears to be an optimal thickness intermediate between the two extremes which have just been described. For this thickness of 12 cm, a damping of 9.75 ° C. and a phase shift of 2 h 42 are obtained. The material is very explicit: if relatively high damping and phase shift is desired, it will be necessary to choose a thickness weak, less than 12 cm. But if, on the contrary, the heat is to be concentrated, the choice of a low damping and a phase shift is made, it will be necessary to go beyond 12 cm. This material may be suitable for cold areas where heating is required. It can contain the heat produced by the radiators as long as the thickness is well chosen.

DISCUSSIONS

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 somewhat different in real situations. 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 and perspectives

In tackling this issue, we were trying to solve both ecological and environmental problems. Ecological problem because, the waste of fiber of ronier are produced in large quantities every year in Benin, and it is not clear 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 root fibers, water and cement. The material offers a variety of choices around whether to retain heat in an enclosure whose walls are made of this material. The material reveals a compromise thickness of 12 cm. With such a thickness, the damping will be 9.75 ° C and the phase shift of 2 h 42. If we observe that in the literature, a wooden frame wall insulated by glass wool has only a phase shift 2 h 13 for a thickness of 22cm, it can be said that the cement-fiber composite of the ronier is much better, Because it allows a phase shift gain of approximately 30 minutes, and this for a thickness of less than 10 cm. It is beautiful of vital space that is thus gained. There remains, however, a study of the aging of this material. One could also see if it can not go in combination with other materials to improve its phase shift. Perhaps coatings of certain qualities could bring this solution.

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