ISSN 2229-5518

Study of thermal conductivity of light concrete based on rice husks

V. K. DOKO, A. C. HOUGAN, E. C. ADJOVI, D. Y.AYITE, K. BEDJA

Abstract— Rice production generates waste after decortications. These rice husks which, if they are not used for energy, they provide a space for the environment and therefore can be used in the manufacture of composite materials. This study deals with the determination of the thermal conductivity of composite cement-rice husk, rice husk-sand-cement and sand-cement method '' comparison" based on the principle of guarded hot plate. Composites studied exhibit the following physical characteristics: composite 1, rice husk cement, has a density of 901.17 ± 30.11kg/m^3, a porosity of 31.22 ±0.25% and a thermal conductivity of 0.638 ± 0.061 W / m K, while the composite 2, sand-cement has a density of 2220.00± 73.33kg/m^3, a porosity of 8.61 ± 0.22% and a conductivity Thermal 1.30± 0.27 W / m K. In view of the results, rice husk composites have better thermal performance because we have a reduction of the thermal conductivity of about 50% compared to the sand-cement composite.

Index Terms—rice husks, agricultural waste, porosity, density, thermal performance, hygroscopic.

1 Introduction

The main concern of the builders is the sustainability of their buildings. The latter was made possible by the use of high-performance materials in terms of strength and durability. Aspects of comfort were treated only afterwards. The construction principle based on the juxtaposition of different materials, each with a task assigned. However, the accumulation of different materials attracted less because they become expensive and eventually occupy a significant volume. The current trend in homebuilding is to promote composite products able to fulfil many purposes. The builder no longer seeks only the mechanical performance, but he also wants to improve other qualities such as thermal conductivity materials that fall within the area of thermal comfort. This change of perspective explains the recent development of lightweight concrete, capable of playing the role of insulation, while maintaining sufficient levels of performance. These materials are studied simultaneously on two themes: mechanical/thermal or mechanical /acoustic. The present work aims to study the subject of a lightweight thermal namely rice husk cement. A second factor explaining interest in lightweight concrete is environmental awareness. This awareness can be explained in two ways. Lightweight materials are good thermal insulators because of the volume of air they contain, so they can achieve substantial energy savings. In addition, the use of aggregates plant is part of a sustainable development approach. It has the advantage of using a renewable resource, unlike aggregates quarries which are finite in time.

Several research works have made the object of study of composites of rice husk cement. We can cite the work of S. Tamba [1] R. Jauberthie et al [2] D. Ayité [3]. However, these studies have not led to the study of heat transfer of the composite.

For example, the work of S. Tamba It appears that the formulation of concrete studies of rice husk conducted concerning concrete structures in reinforced concrete. As D. Ayité has formulated concrete 250kg/m3 assayed for the production of infill carriers or notfor building structures (blocks and interjoists).

Studies have shown the existence of a quasi-linear dependence between conductivity and density [4]. Boutin [5] shows that it is important to remember that the presence of water decreases the insulating materials in proportions. Compaction, reducing the volume of air contained in composite [6] has the disadvantage of increasing its thermal conductivity [7], [8]. The work presented here has no ecologist vocation. It is simply to show that the use of aggregate plants may offer new possibilities in the development of building materials.

2 Characteristics Of Composite Components

Characteristics of concretes depend mainly on their components. Therefore, it is necessary to be familiar with the materials to be used in making concrete rice husks. Then, various tests were performed on materials: rice husks, sand and cement.

2.1 Rice Husk

Rice husk consists of a shell-shaped zone, tapered at the extremities and convex in shape. This shell is situated in the longitudinal direction and has a roughened surface more or less porous. It is brown. The texture is relatively fragile. The average length of the rice husk is of the order of 8 to 10mm. Rice husks that will aggregate in this study come from the rice ofMalanville, a town located about 850 kilometers from Cotonou, capital of Benin. The different tests made on these rice husks are: density, water absorption and particle size.

2.1.1 Granular Composition

This property gives information on the quotas of grain types that are contained in rice husks. The proportions in which the dimensions are larger than 0.063 mm is determined by sieving. As for the proportions of less than 0.063 mm, the separation is by sedimentation.

This bend reflects the weight distribution of the aggregate component elementary aggregates of the granular composition obtained, the fineness modulus rice husksis determined using the formula:

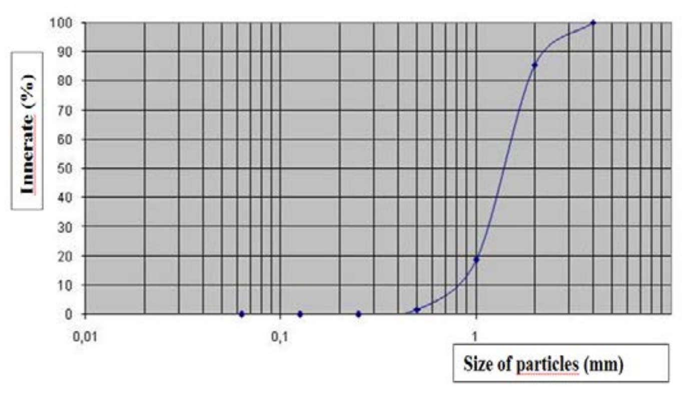

Fig. 1.Granulometric bend of rice husks.

Where Mf is the fineness modulus of rice husks and Σm the sum of percentages of refusals accumulated on modulus sieve 23-26-29-32-35 and 38 (or diameter 0.16 - 0.315 to 0.63 – 1.25 – 2.5 - 5 - 10 - 20 - 40 and 80 mm). As a result of fineness modulus rice husks, one can obtain 3.79.

2.1.1.1 Densities

The bulk density d of rice husks is determined using the expression

$$d = \rho_g / \rho_e (2)$$

Where ρ_g is the density of rice husks without gaps between the grains and ϱe is the density of water. The bulk density of rice husk in its natural state and wet, respectively 0.101 and 0.142.

2.1.1.2 Water Absorption

For determining the rate of absorption of water, a mass of 100g of rice husks is introduced into a test tube of 2000 cm3. This test tube is then filled with water while being stirred to remove air bubbles trapped in the concavities of rice husks. The amount of additional water to keep theconstant level is measured in function of time. This has allowedsetting up the line of kinetic bend of water absorption (figure 2).

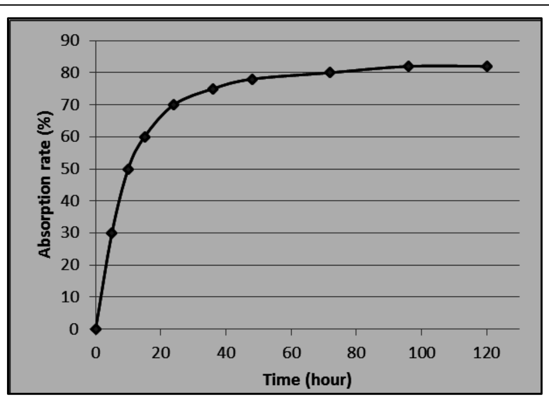

Fig. 2.Kinetic bend of water absorption of rice husks.

2.2 Cement

The cement used in this study is the CPJ 35 produced by the factory CIMBENIN. After compression test, the resistance to the compression at 7 and 28 days were respectively 27.9 MPa and 35.5 MPa.

3 Formulation Of Experimental Composite

3.1 Composite N°1

The composite cement-rice husk is dosed at 500 kg/m³ or C / R = 1.28 where C is the cement mass and R the mass of rice husks. For C/R, we use the relationE/C = 0.40 with E the mass of water.

3.2 Composite N°2

The sand cement mortar formulation is as follow: cement/sand = 1/6 (S/C= 1/6) dosed at 250 kg/m³ water/cement=1/(E/C=1/1). These relations are purely voluminal masses.

4 Preparation And Conditioning Specimens

Various tests have been made to characterize our composites. It is the mass density, moisture content and porosity. After properly bonded with silicone grease Plexiglas with one side of the composite, the thermocouples are inserted in some holes of 1mm diameter. The same holes are in the Plexiglasand in the composite (figure 5). Specimens which are notimmediately subject to the conductivity test are wrapped in aluminum foil in order toavoid externalinfluence on physical characteristics as defined. The physical characteristics of our specimens studied are summarized in Tables 1 and 3.

TABLE 1
PHYSICAL CHARACTERISTICS OF THE COMPOSITE TEST TUBES N°1

Test tubes	Voluminal mass kg/m^3)	Rate of humidity (%)	Porosity (%)
Test tube 11	932	11.43	31.21
Test tube 12	903	10.42	31.56
Test tube 13	832	10.32	31.65
Test tube 14	943	11.47	30.83
Test tube 15	880	10.35	30.96
Test tube 16	917	11.38	31.15
Average	901.17	10.90	31.2
Grap-type	30.11	0.53	0.25

TABLE 2
NOMENCLATURE

Symbol	Quantity	Unit
ρ_g	voluminal mass of rice husks	Kg/m^3
ρ_e	voluminal mass of water density	Kg/m^3
Mf	Module lightness	
λ	thermalconductivity	W/mK

TABLE 3
PHYSICAL CHARACTERISTICS OF THE COMPOSITE SPECIMENS N°2

Test tubes	Voluminal mass kg/m^3)	Rate of humidity (%)	Porosity (%)
Test tube 21	2110	4.38	8.84
Test tube 22	2150	4.24	7.96
Test tube 23	2190	4.35	8.86
Test tube 24	2370	4.62	8.72
Test tube 25	2290	4.53	8.64
Test tube 26	2210	4.37	8.64
Average	2220.00	4.42	8.61
Grap-type	73.33	0.11	0.22

5 MEASUREMENT OF THERMAL CONDUCTIVITY OF COMPOSITES

For a better understanding of the thermophysical properties of composites, we measured in the permanent statethe thermal conductivity subjecting the samples to a gradient temperature. For a given material, the range of variation of the conductivity is quite large and depends on several factors, including temperature and water content. Knowledge of this property is especially useful for calculating the thermal resistance of building elements.The measurement of thermal conductivity is quite delicate and it requires a long period of experimentation and precise control of different parameters. Generally, methods for measurement of thermal conductivity, we must first determine the flow or thermal field from measurements of temperature variation at different points of the studied composites and depending on predefined temperature ranges.

The experimental device used is the one that has been set up at the Polytechnic School of Abomey-Calavi (Figure 3), Benin Republic, and is based on the exploitation of thermal field in stationary state[9- 10- 11]. The method called method of"comparison" or"Plexiglas Etalon" based on the principle of the classical method of guarded hot plate.

The temperature of the outer surface of the Plexiglas- plate is maintained at the set temperature T_1 by means of a plate cooler (35 x 35 x 1.5 cm^3) associated to a regulator. The outer face of the plate-specimen studiedis in contact with the wall of the exchanger in which wateris circulating. It is assumed that the temperature of the plate-specimen is constant and is maintained at T_2. Both test tubes are thermally in series and subjected to a difference of temperature between the two outer faces. One of the plates being defined as the reference specimen of known conductivity $\lambda_0$the knowledge of the thermal field in permanent state in the specimen can be traced back to the conductivity of the plate tested λ_x.

The assumptions for the experimentations are: isotropic and homogeneous thermal conductivity

λ = Constant, heat transfer is assumed unidirectional the temperatures T_1 and T_2 of the faces of the sample are imposed the side faces of the sample are isolated (see Figure 5).

Thermal conductivity is calculated using the formula: $\lambda_x = \lambda_0.(gradT)_0 / (gradT)_x$ (3)

Values ofgradients $(gradT)_0$ and $(gradT)_x$ were approximated for each specimen by the value of the slope of the best linear regression line:

If we have

$P_0 = (gradT)_0$ and $P_x = (gradT)_x$,

so $\lambda_x = \lambda_0 \cdot (P_0 / P_x)$ (4)

Each test has led to two thermograms, one on the Plexiglas (reference material) and the other the composite sample studied (Figure 6 and Figure 7).

Calculation of the thermal conductivity of the composite is obtained by using equation (4), and the results are assigned in Table 4 and Table 5.

Data processing including plotting the bends that show the thermal field, the regression line and the calculation of the conductivity is done on the computer using the operating software "EXCEL 2007".

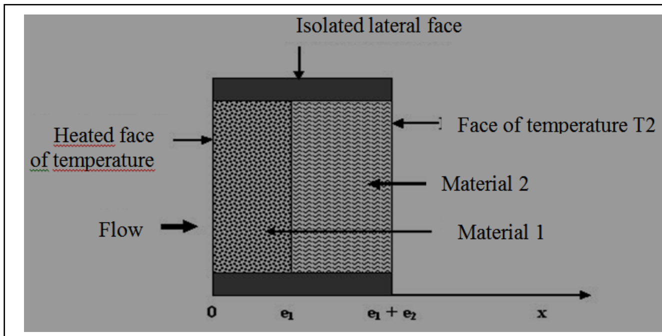

Fig.4.Diagram of mathematical model [12].

Fig.5.Sample measurement.

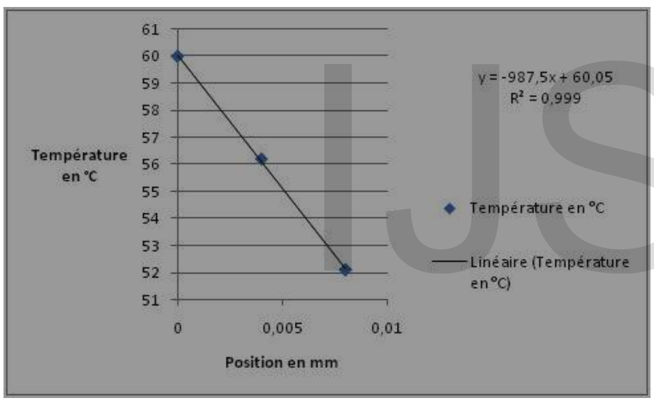

Fig.6.Field in thermal control material (Plexiglas).

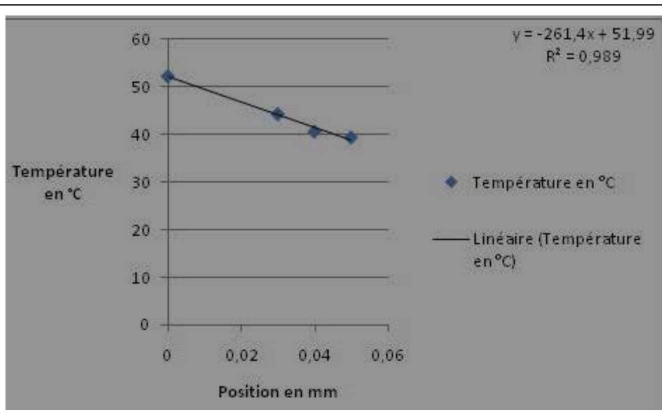

Fig.7.Field in thermal Composite1.

TABLE 4
THERMAL CONDUCTIVITY OF THE COMPOSITE SPECIMENS NO. 1

Test tubes	Thermal conductivity (W/mK)
Test tube 11	0.695
Test tube 12	0.673

TABLE 5
THERMAL CONDUCTIVITY OF THE COMPOSITE SPECIMENS N° 2

Test tubes	Thermal conductivity (W/mK)
Test tube 21	1.06
Test tube 22	1.14
Test tube 23	1.7
Average	1.3
Gap-type	0.27

The literature review gives some values of the thermal conductivity of some building materials. Thus the brick of mortar of ordinarysand has a thermal conductivity of 1.15 W/mK [4]; the hydraulic concrete, a thermal conductivity of 1.8 W/mK [4], the concrete mortar stabilized sand, a thermal conductivity of 0, 8 W/mK [11] and expanded clay concrete, a conductivity of 0.46 W/mK. [4] Composites studied such as rice husk-cement and sand-cement respectively have a thermal conductivity of 0.638 W/mK and 1.30 W/mK. The value of 0, 638 are much lower than those of the materials mentioned above. Based on the results and in terms of physical properties, we find that the thermal conductivity increases with increasing moisture content and density, and decreases with the increase of porosity of the composite .These results are confirmin the works of V. Cerezo[7] who worked on vegetable (hemp) concrete.

6 CONCLUSION

This work whose experimentations have been conductedin the laboratory LEMA of the Polytechnic school of Abomey-Calavi has permitted to:

- make composite products from aggregates plant: rice husks;
- measure and assess the effect of density, moisture content and porosity on the thermal conductivity.So, the more the composites contain water the more they conduct heat ; the more composite products contain fine particles the more they conduct heat.

From the foregoing, we hold that the manufacture of composite materials based on rice husk, in addition to its environmental benefits and recovery of waste, open the way for their use in habitat for a better thermal comfort.

REFERENCES

[1] S. Tamba," lightweight concretes based waste cellulosic,"Thesis for doctoral degree, INSA de Rennes, Rennes - France, 2001.

[2] R. Jauberthie, F. Rendell, S. Tambaet I. K. Cissé," Rice husk lightweight mortars," 2000.

[3] D. Ayité," Characterization of concretes based rice husk Togo," Thesis for doctoral degree from the University of Lome, Togo, 2011.

[4] "Autoclaved Aerated Concrete," CEB manual of design and technology. Lancaster England, the Construction Press Ltd., 1978.

[5] C. Boutin, "Thermal conductivity of autoclaved aerated concrete: modeling méthodeautocohérente,"Materials and Structures, 29, 1996.

[6] T. Nguyen, V. Picandet, Amziane S., Baley C," Influence of compactness and hemp hurd characteristics on the mechanical properties of lime and hemp concrete," Orgagec'08-Third European Symposium,Organic materials for construction: Technical and environmental performance," Paris, Marne-la-Vallée (France), 27-28 - 29 August 2008a.

[7]V. Cérézo, Propriétés mécaniques, thermiques et acoustiques d'un matériau à base de particules végétales : approche expérimental et modélisation théorique. Thèse Génie Civil. Lyon : Institut National des Sciences Appliquées de Lyon, 2005.

[8] S. Elfordy, F. Lucas, F.Tancret., Y. Scudeller, L Goudet " Mechanical and thermal properties of lime and hemp concrete (« hemprete ») manufactured by a projection process ". Construction and Building Materials, Vol 22, 10, pp. 2116-2123, 200.

[9] C. Cordier, Caractérisation thermique et mécanique des bétons de chanvre: rapport de stage de fin d'études Ecole doctorale MEGA. Vaulx-en- Velin: ENTPE, 1999.

[10] M. Conte, A. Giradey, P. Bilodeau et R. Beaulieu, Métrologie thermique, Les Editions le Griffon d'Argile, 1986.

[11] J. L. Fannou, Contribution à la mesure de la conductivité thermique des matériaux locaux de construction, Mémoire de DEA SPI, Université d'Abomey-Calavi, 2002.

[12] A. Houngan, Caractérisation hygrothermique des matériaux locaux de construction au Bénin: diffusivité massique et isotherme de sorption, conductivité et diffusivité thermique, Thèse de doctorat de l'université de Nancy, 2008.

Author details :

V. K. DOKO: Ecole Polytechnique d'Abomey-Calavi EPAC, University of Abomey-Calavi, Benin

Email: dokovalery@yahoo.fr

Tel: (229) 97 60 03 10

A. C. HOUGAN: Ecole Polytechnique d'Abomey-Calavi EPAC, University of Abomey-Calavi, Benin

E. C. ADJOVI: Ecole Polytechnique d'Abomey-Calavi EPAC, University of Abomey-Calavi, Benin

D. Y. AYITE: University of Lome, Togo

K. BEDJA: University of Lome, Togo