Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2017, 4(9):498-505

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Heat Distribution in a Multilayer in Dynamic Frequency Modulation: Influence of the exciting pulse, and the thermal exchange coefficients

Cheikh Thiam[2], Alassane Diene[2], Youssou Traore[1,2], M. S. Ould Brahim[1], Aliou Diouf[1], Ould Mohamed Bah[1], Issa Diagne[1], Gregoire Sissoko[1]

[1]Laboratoire des Semi-conducteurs et d'Energie Solaire, Faculté des Sciences et Techniques, Université Cheikh Anta Diop, Dakar, Sénégal
[2]Ecole Polytechnique de Thiès, Sénégal

Abstract In this article, we present a study of heat distribution in a multilayer in dynamic frequency modulation under influence of extrinsic parameters such as, exciting pulse, the thermal exchange coefficient in front and back faces. The device in question consists of a kapok layer sandwiched between two coatings of raw earth.
This study presents the temperature variation and the quantity of thermal flow per square meter under the effect of the exciting pulse and the thermal exchange coefficient.

Keywords Multilayer/three layer/raw earth/kapok/dynamic frequency modulation/heat exchange coefficient

1. Introduction

The control of building materials, especially those based on the combination of local materials with agricultural residues [1] and plant products [2], is a scientific research domain in which the improvement of the thermal comfort of housing environments deals with [3,4]. The study of the thermal transfer on multilayers [5-8] which one of them is a local heat insulator [9] from vegetable origin is proposed by some authors. And others proposed techniques of materials intrinsic parameters [10-13] determinations that characterize the heat distribution.
In this way, A. Wereme *et al*., [14] characterized sawdust and kapok as local materials. By means of two test tub with an annular space between them, allowing the installation of the kapok wool. Temperature sensors are used to measure the temperature in different points of the device. The measure of global thermal exchange coefficient and the conductivity is obtained with various values of density.
On the other hand Y. Jannot and T. Djiako [3], presented a study of the thermal conductivity measure of an insulating material with a three layers device. The device is in a cylindrical geometry which consists of brass / sample / brass layers and is submitted to an impulsive signal. The obtained results highlight the evolution of the reduced sensibility of the insulating material [5].
In this work, we propose a study in dynamic frequency modulation, the temperature and thermal flow evolution in the device under the influence of the exciting pulse and thermal exchange coefficients in the front and back faces.

2. Presentation Du Modele

The model of study, consist of a kapok layer [15] confined between two layers of raw earth filler, is put on a climatic stress in dynamic frequency modulation.

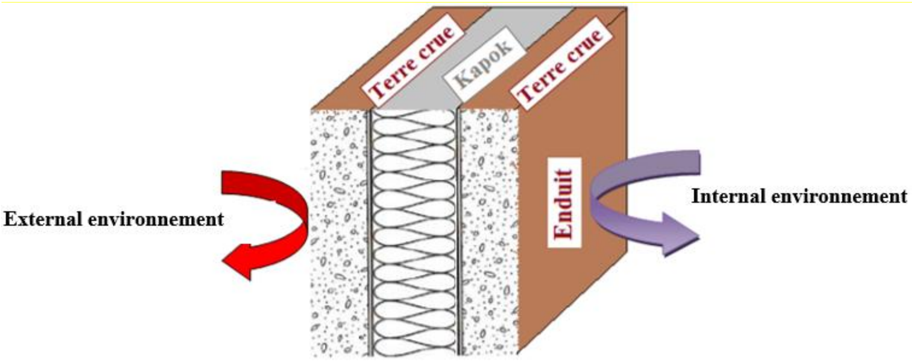

Figure 1: Modelling of the Device

2.1. Simplified Model

The figure 2 presents the simplified plan of the studied model with the characteristic of each layer

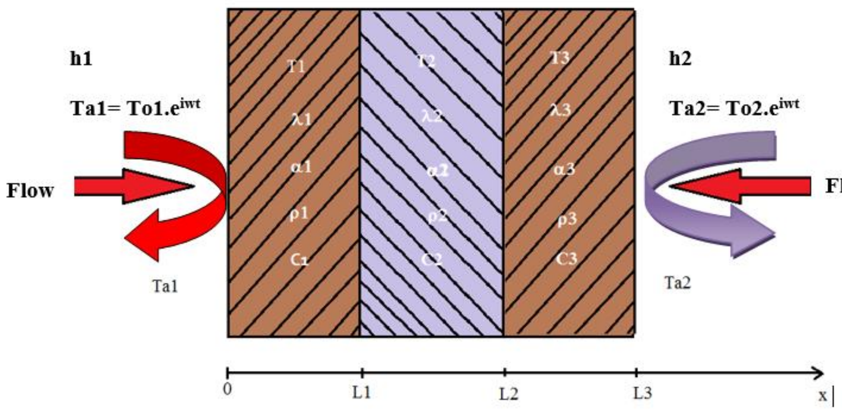

Figure 2: Transversale Section View

- Ta1 = front face temperature,
- Ta2 = back face temperature,
- T1= T (0, t) isothermal temperature for x=0,
- T2= T (L, t) isothermal temperature for x=L,
- h1= hc1+hr1 front thermal exchange coefficient,
- h2= hc2+hr2 back thermal exchange coefficient,
- hc convective thermal exchange coefficient
- hr coefficient of thermal exchange radiative

2.2. One dimension heat equation

When a system is submit to a gradient of temperature, we shall note a phenomenon of thermal transfer governed by the following equation:

$$\lambda \cdot \frac{\partial^2 Tj}{\partial x^2} + Pp = \rho \cdot C \cdot \frac{\partial T_j}{\partial t}$$

With :

- λ ($W.m^{-1}K^{-1}$) material's thermal conductivity
- C ($J.Kg^{-1}.K^{-1}$) material's specific heat
- P_p ($W.\ m^{-3}$) heat sink
- ρ ($Kg.\ m^{-3}$) material's density
- x (m) thikness of the device.
- T (K or °C) temperature in a considered point.

In the absence heat sink we have Pp=0

the heat equation becomes:

$$\frac{\partial^2 Tj}{\partial x^2} - \frac{1}{\alpha j} \cdot \frac{\partial T_j}{\partial t} = 0$$

Avec $\alpha_j = \frac{\lambda_j}{\rho_j \cdot C_j}$

The indications j = 1, 2, 3 represents the various layers of the device.

The solution of continuity the equation gives the temperature expression in every layer which is written under the shape:

$$\bar{T}1 = (A1 \cdot sinh(\beta1 \cdot x1) + B1 \cdot cosh(\beta1 \cdot x1) \cdot e^{j\omega t}$$
$$\bar{T}2 = (A2 \cdot sinh(\beta2 \cdot x2) + B2 \cdot cosh(\beta2 \cdot x2) \cdot e^{j\omega t}$$
$$\bar{T}3 = (A3 \cdot \sinh(\beta3 \cdot x3) + B1 \cdot \cosh(\beta3 \cdot x3) \cdot e^{j\omega t}$$

To determine the Aj , Bj coefficients, the following borders conditions on are defined:

$$\begin{cases} -\lambda1 \cdot \left.\frac{\partial T1}{\partial x}\right|_{x=0} = h1(Ta1 - T(x=0,t) \\ \lambda1 \cdot \left.\frac{\partial T1}{\partial x}\right|_{x=L1} = \lambda2 \cdot \left.\frac{\partial T2}{\partial x}\right|_{x=L1} \\ T1(L1,t) = T2(L1,t) \\ \lambda2 \cdot \left.\frac{\partial T2}{\partial x}\right|_{x=L2} = \lambda3 \cdot \left.\frac{\partial T2}{\partial x}\right|_{x=L2} \\ T2(L2,t) = T3(L2,t) \\ -\lambda3 \cdot \left.\frac{\partial T3}{\partial x}\right|_{x=L3} = h2(T3(L3,t) - Ta2 \end{cases}$$

Considering the initial temperature Ti, and posing $\bar{T}$ as the added temperature:

$$T = \bar{T} + Ti$$

The expression of the equation of the heat becomes:

$$\frac{\partial^2 T(\bar{T} + Ti)}{\partial x^2} - \frac{1}{\alpha i} \cdot \frac{\partial T(\bar{T} + Ti)}{\partial t} = 0$$

The new boundary conditions will be written in the shape:

$$\begin{cases} -\lambda1 \cdot \left.\frac{\partial \bar{T}1}{\partial x}\right|_{x=0} = h1(Ta1 - (\bar{T} + Ti) \\ \lambda1 \cdot \left.\frac{\partial \bar{T}1}{\partial x}\right|_{x=L1} = \lambda2 \cdot \left.\frac{\partial \bar{T}2}{\partial x}\right|_{x=L1} \\ \bar{T}1(L1,t) + Ti = \bar{T}2(L1,t) + Ti \\ \lambda2 \cdot \left.\frac{\partial \bar{T}2}{\partial x}\right|_{x=L2} = \lambda3 \cdot \left.\frac{\partial \bar{T}2}{\partial x}\right|_{x=L2} \\ \bar{T}2(L2,t) = \bar{T}3(L2,t) \\ -\lambda3 \cdot \left.\frac{\partial \bar{T}3}{\partial x}\right|_{x=L3} = h2(\bar{T}3(L3,t) + Ti - Ta2 \end{cases}$$

3. Results and Discussions

3.1. Evolution of the temperature and the density of flow

3.1.1. Influences of the exciting pulsation

The following curves highlight the temperature and the thermal flow evolution through the material under the influence of extrinsic parameters such as: the exciting pulse and exchange coefficients in front and back faces

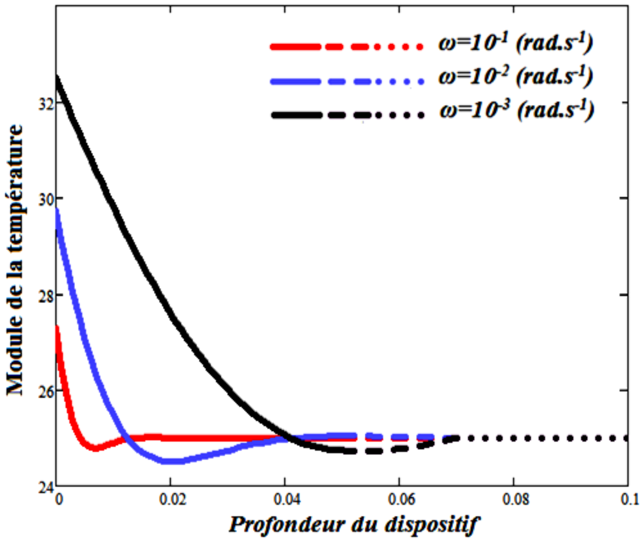

Figure 1: Temperature evolution according to the depth under the influence of the exciting pulse in the material's layers h1 =100 W.m^{-2}.K^{-1}; h2=0.05 W.m^{-2}.K^{-1};

The curves at figure 3 present the temperature evolution according to the depth with fixed values of the exchange coefficient on front and back faces.

In the device, the temperature transmitted in the front face is weak all the more as the value of pulsation is big. With various values of the exciting pulse we notice that curves have an almost identical look. The temperature evolution follows a diminution until depth's value of 0.07 m corresponding to the kapok layer superior limits depth.

For big pulse values (10^{-2}, 10^{-1}rad.s^{-1}), the kapok layer temperature module follows an almost stable look in the value of 25 °C corresponding to the back face temperature value.

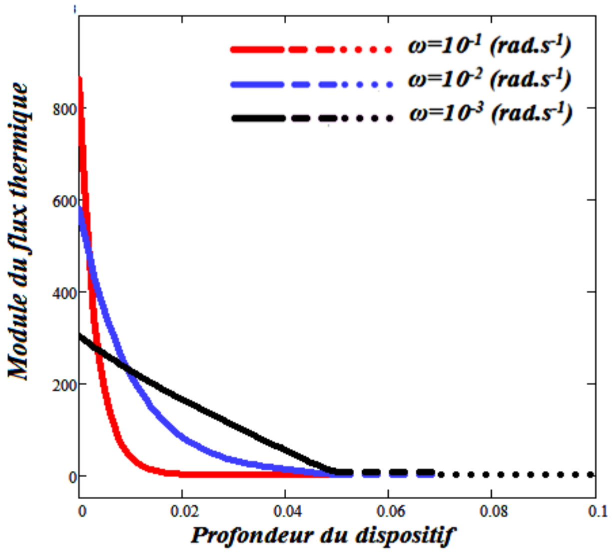

Figure 2: thermal flow evolution according to the depth for various values of the exciting pulse; h1 =100 W.m^{-2}.K^{-1}; h2=0.05 W.m^{-2}.K^{-1};

The figure 4 presents the profile of the thermal flow evolution in the depth of the material. In a low value of the exciting pulse, corresponding to a long period of excitement, the thermal flow evolution follows to an almost static look. The evolution in frequency modulation is observed with rather low values of pulse.

The exchanged flow decreases exponentially and stabilizes from a deep point of 0.05 m, corresponding to the first raw soil layer.

Tables 1-2: Evolution of the transfer phenomena under the influence of the exciting pulse

	Exciting pulse *rad.s*$^{-1}$		
Temperature at x=	10^{-1}	10^{-2}	10^{-3}
0	27.277	29.714	32.504
0,02	25.005	24.509	27.61
0,04	25.062	25.062	25.062
0,05	25	25.039	24.743
0,06	25	25.027	24.768
0,07	25	25	25
0,08	25	25	25
0,09	25	25	25
0,1	25	25	25

	Exciting pulse *rad.s*$^{-1}$		
Flow density at x=	10^{-1}	10^{-2}	10^{-3}
0	862.23	579.87	303.6
0,02	1.8526	82.901	163.92
0,04	0.0054	12.59	53.653
0,05	0.18093	5.8378	5.8378
0,06	5.8127	5.8127	5.8127
0,07	0.18543	0.18543	0.18543
0,08	0.15804	0.15364	0.15364
0,09	0.27207	0.27207	0.27207
0,1	0.50923	0.50923	0.50923

3.2. Influence of the heat exchange coefficients

Curves below show the module of the temperature evolution in the depth of the device under the influence of the front exchange coefficient.

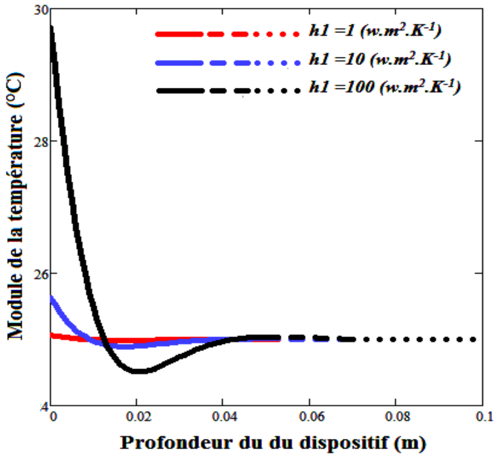

Figure 3 : Temperature Evolution according to the depth under the influence of the front exchange coefficient in layers of the material; $\omega=10^{-3}$ *(rad.s*$^{-1}$*); h2=0.05 (W.m*$^{-2}$*.K*$^{-1}$*);*

In the depth of the layers, with various values of the front exchange coefficient, the temperature module evolution takes place according to an exponential decay. It follows itself a stabilization in the temperature of the isolated environment from the deep point of 0.05 m.

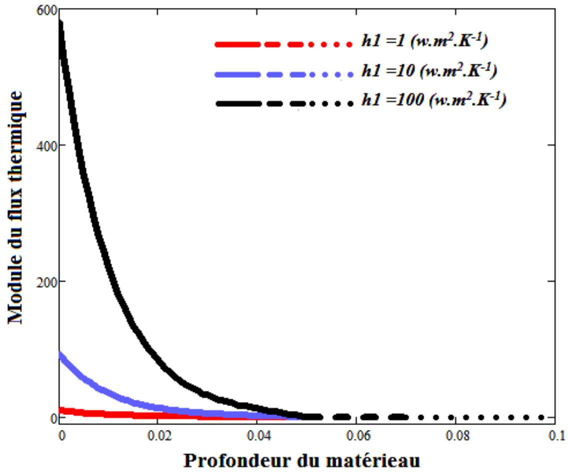

Figure 4: Thermal flow module evolution according to the depth under influence of the front exchange coefficient in the layer: $\omega=10^{-3}$ *(rad.s*$^{-1}$*); h2=0.05 (W.m*$^{-2}$*.K*$^{-1}$*);*

Under the influence of the exchange coefficient, an almost identical evolution of the module of the thermal flow is observed.

For various values of the exchange coefficient, the thermal flow follows an exponential decay until a stabilization in the first raw soil layer. From the deep point of 0.05 m, the exchanged thermal flow stabilizes and nullifies in the kapok layer. From tables 2-3, values giving the evolution of the thermal transfers are presented.

Tables 3-4: Temperature and thermal flow evolution under the influence of the exchange coefficient in the front face

	Front exchange coefficient h1 ($W.m^{-2}.K^{-1}$)		
Temperature at x=	**1**	**10**	**100**
0	25.06	25.633	29,8
0,02	24.989	24.898	24,5
0,04	25	25	25
0,05	25.039	25.039	25
0,06	25.027	25.027	25
0,07	25	25	25
0,08	25	25.001	25
0,09	25	25	25
0,1	25	24.998	25

	Front exchange coefficient h1 ($W.m^{-2}.K^{-1}$)		
Flow density at x=	**1**	**10**	**100**
0	9.94	94.11	579.87
0,02	1,567	13.454	82.901
0,04	0,2159	2.2678	12.59
0,05	0.1726	0.18093	0.17259
0,06	0,1338	0.13388	0.13388
0,07	0.0299	0.12975	0.12975
0,08	0.0650	0.07166	0.07166
0,09	0.1558	0.18928	0.18928
0,1	0.4536	0.45367	0.49994

3.3. Influence of the exchange coefficient in the back face

The following figures highlight the thermal flow evolution in the depth of the device under the influence of the back face exchange coefficients.

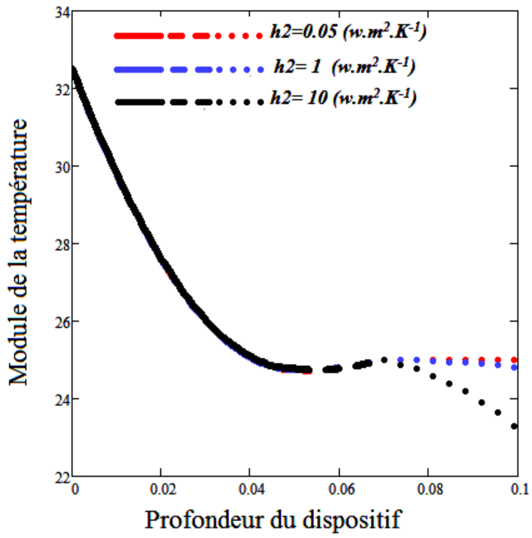

Figure 5: Evolution of the temperature module according to the depth under the influence of the back face exchange coefficient in the layers.ω=10^-3^ (rad.s^-1^); h2=0.05 (W.m^-2^.K^-1^);

For various values of the back face exchange coefficient, the temperature module follows an exponential and identical decay in the first two layers of the device. Within the last layer of soil thelow values of the thermal exchange coefficient in the back face have no incidence on the evolution of the temperature which remains constant in the value of the isolated environment temperature.

For exchange coefficient values more and more raised, we note a temperature fall in values lower than the temperature of the isolated environment.

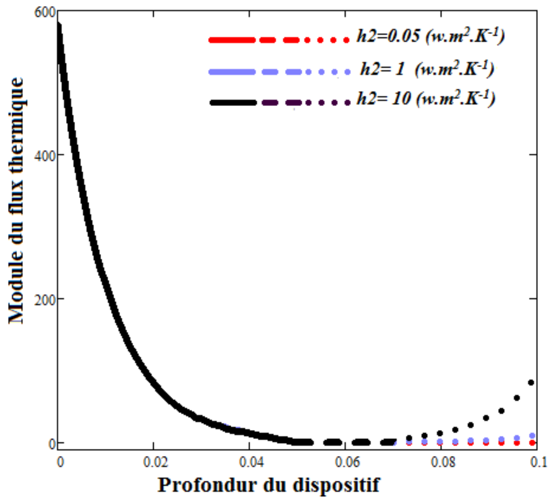

Figure 6: Thermal flow module evolution according to the depth under the influence of the back face exchange coefficient in the layers of the device; $\omega=10^{-3}$ (rad.s^{-1}); h2=0.05 (W.m^{2}.K^{-1});

The thermal flow evolution of takes an exponential and identical decay for various values of the back face exchange coefficient, until the deep point of 0.05 m. From this point the thermal flow adopts different thermal behavior. Indeed, for a relatively low values of back face exchange coefficient, the thermal flow remains constant and equal to zero. The thermal flow increases according to the evolution of the values of the exchange coefficient.

The following tables give the synthesis of the values illustrating the phenomena under influence of the back face exchange coefficient.

Tables 5-6: Temperature and the thermal flow evolution under the influence of the back face exchange coefficient

	back face exchange coefficienth2 (*W.m^{-2}.K^{-1}*)		
Temperature at x=	**0.05**	**1**	**10**
0	32.51	32.51	32.51
0,02	27.61	27.61	27.61
0,04	25.15	25.15	25.15
0,05	24.77	24.77	24.77
0,06	24.77	24.77	24.77
0,07	24.99	24.99	24.99
0,08	24.99	24.97	24.64
0,09	24.99	24.99	24.05
0,1	24.99	24.82	23.21

	back face exchange coefficient h2 (*W.m^{-2}.K^{-1}*)		
Flow density at x=	**0.05**	**1**	**10**
0	579.87	579.87	579.87
0,02	82.90	82.90	82.90
0,04	12.59	12.59	12.59
0,05	0.24	0.24	0.24
0,06	0.15	0.15	0.15
0,07	0.53	0.53	0.53
0,08	0.07	1.42	13.48
0,09	0.18	3.76	35.62
0,1	0.49	9.94	85.37

4. Conclusion

Our study had for main objective, to make a study of the thermal distribution in a multilayer in frequency dynamic regime under the influence of extrinsic parameters for the device such as the exciting pulse and the of exchange coefficients in front and in back faces. We so noticed that the front face temperature remains low at high values of the exciting pulse.

The front and back face exchanges coefficients influence the thermal transfers only at the level of the outer layers of the device.

In some, with physical variable studied, the results show the mitigation of the evolution of the temperature and the thermal flow in the depth of the device (plan), following an exponential decay and a stabilization in temperature value of 25°C. This is due to the big quantity of thermal flow absorbed by the first filler of raw earth layer.

So the use of a multilayer device will permit to solve a big part problems related on the local materials valuation with the aim of an energy efficiency of buildings.

References

[1]. Salif Gaye F. Niang, I. K. Cissé, M. Adj, G. Menguy, G. Sissoko. (2001). Caractéristation des propriétés thermiques et mécaniques du béton de polymère recycle Journal des sciences Vol. 1, N°1 53-66

[2]. P. Meukam, Y. Janno, A. Noumow, T.C. Kofan, (2004). Thermo physical characteristics of economical building materials Ouvrage, Construction and Building Materials, volume 18, P.437–443

[3]. Y. Jannot and T. Djiako (1994). Energy saving and thermal confort for habitations in a tropical climate Int. J. Refrig. volume 17 Number 3

[4]. H. M'Sellem, D. Alkama (2009). Le confort thermique entre perception et évaluation par les techniques d'analyse bioclimatique –cas des lieux de travail dans les milieux arides à climat chaud et sec Revue des Energies Renouvelables Vol. 12 N°3 471-488

[5]. Y. Jannot, A. Degiovanni, G. Payet, (2009). Thermal conductivity measurement of insulating materials with a three layers device, International Journal of Heat and Mass Transfer 52, 1105–1111

[6]. A. Haji-Sheikh, J. V. Beck, (2002). Temperature solution in multi-dimensional multi-layer bodies, Int. J. Heat Mass Transfer 45, pp1865-1877

[7]. Youssou Traore, Issa Diagne, Cheikh Sarr, Mohamed Sidya Ould Brahim, Abdoulaye Korka Diallo, Hawa Ly Diallo and Gregoire Sissoko (2016). Influence Of Thermal Exchange Coefficient On The Heat Retention Rate Of A Concrete Wall Contiguous To A Thermal Insulation Tow-Plaster ARPN Journal of Engineering and Applied Sciences, Vol. 11, No. 5, pp 2835- 2840.

[8]. Youssou TRAORE, Alassane DIENE, Séni TAMBA, Khatry OULD CHEIKH, Moussa DIENG, El Hadji Bala Moussa Nyakhaté, Issa DIAGNE, and Grégoire SISSOKO (2017). Evaluation de l'Inertie Thermique à partir de l'Etude de la Capacité Equivalente de la Dalle en Béton Accolé à du Filasse-Plâtre en Régime Dynamique Fréquentiel International Journal of Innovation and Applied Studies, ISSN 2028-9324 Vol. 20 No. 2, pp. 609-615

[9]. I. Diagne, M. Dieng, M. L Sow, A. Wereme, F. Niang – G. Sissoko, (2010). Estimation de la couche d'isolation thermique efficace d'un matériau Kapok-plâtre en régime dynamique fréquentiel. CIFEM2010, Edition Université de Rennes 1, pp 394-399

[10]. Clark Iii L.M. Et Taylor R.E, (1975). Radiation loss in the flash method for measurement of thermal diffusivity Journal of Applied Physics, Vol. 46, n°2, pp.714-718.

[11]. Parker W.J., Jenkins R.J., Buttler G.P. And Abbott G.L., (1961). Flash method of determining thermal diffusivity heat capacity and thermal conductivity Journal of Applied Physics, Vol. 32, Issue 9 pp 1679-1684

[12]. Perrin B. Et Javelas R. (1987). Transferts couplés de chaleur et de masse dans des matériaux poreux consolidés utilisés en génie civil International Journal of heat and Mass Transfer, vol. 30, n°2, p. 297-309.

[13]. Blackwell J.H. (1954). Radial, axial flows in regions bounded by circulars cylinders Canadian Journal of Physics, vol. 31, p. 472-479.

[14]. Wareme, S. Tamba, M. Sarr, A. Diene, I. Diagne, F. Niang, G. Sissoko (2012). Caractérisation des isolants thermiques locaux de type sciure de bois et kapok : mesure de coefficient global d'échange thermique et de la conductivité thermique Journal des Sciences vol 10, N°1, PP 39 – 46

[15]. M.L. Voumbo, A. Wereme and G. Sissoko (2010). Characterization of Local Insulators: Sawdust and Wool of Kapok Research Journal of Applied Sciences, Engineering and Technology 2(2): 138-142