Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) 6(7): 157- 163
© Scholarlink Research Institute Journals, 2015 (ISSN: 2141-7016)
jeteas.scholarlinkresearch.com

Thermal Transmittance of Exterior Walls Using the Composite Illite Clay – Cork

Soumia Mounir[1], Abdelhamid Khabbazi[1], Asmae Khaldoun[2], Youssef Maaloufa[1]

[1]LEME, Université Mohamed V-Agdal, EST Salé, 227 Avenue Prince Héritier, Salé, Maroc;
[2]Al Akhawayn University Avenue Hassan II, BP 104, 53000 Ifrane, Maroc.
Corresponding Author: **Asmae Khaldoun**

Abstract
The development of insulating materials using materials suitable for sustainable buildings development and poverty alleviation by the decrease of their energy consumption and the increase of the comfort of its inhabitant with very low income is very crucial. For this purpose, a series of experimental studies were performed on a type of clay samples, the clay is taken from a mountainous zone in Morocco and was analyzed by the mean of X-ray diffraction. The results show that the clay sample is mainly made up of Illite/muscovite which is a non-swelling clay.Hot plate method and Flash methods were carried out on unfired clay/cork bricks prepared at different proportion of cork. The density of the cork used in this study is 160 Kg/m^3, the thermal conductivity is 0.049-0.05W.m^{-1}.K^{-1}. The results obtained indicate that for the Illite clay, the thermal conductivity decrease by adding cork from 0.51 W.m^{-1}.K^{-1} (for clay alone) to 0.32 W.m^{-1}.K^{-1} (60% of cork), to 0.259 (80% of cork), to 0.246 W.m^{-1}.K^{-1} (for 100% of cork). Finally a comparison of thermal transmittance of exterior walls in Morocco and Mediterranean area for instance Italy was done from the composite material clay-cork air dried using the thermal blocks (Illite clay-100% cork) instead of the existing standard thermal block to see their effect on the energy efficiency of building.

Keywords: composite illite clay, hot plate method, flash method, thermal conductivity, thermal block air dried

INTRODUCTION

Insulation in mountainous area such as Bensmim is the most effective way of improving a home's energy efficiency and can make your home more comfortable as it acts as a barrier to heat flow. In fact, by correctly installing insulation in ceilings and walls, you can effectively reduce heating costs by up to 50% and help to reduce green house gas emissions. Unfired clay blocks proved to be less cost and energy efficient. On the one hand, since clay will be extracted from the region itself and will be sun baked, unfired clay blocks will not require firing and transportation costs that usually largely affect the price of the brick. Furthermore, knowing that Bensmim is a poor rural area and the companies of brickyards in morocco such as Rabat brickyard consumes an exceed of energy (1305 KJ/kg instead of 1295 KJ/kg of international standard) according to the ministry of environment and the allemande company Hans Lingl Anlagenbau und Verfahrenstechnik GmbH & Co and in the supply of turnkey factories for the production of bricks ("Briqueteries," 2013).

According to those reason authors try in this work to improve insulation of a Mountainous area in Morocco for people with very low income by proposing a full brick composed from materials clay-cork and air dried which assure the best energy efficiency for houses. A review in state of the art gives authors the idea to use clay and cork so as to have an air dried brick with a good building insulation such as the work of Jelle which has treated the advantages and disadvantages of the thermal building insulation materials and consider that cork can be produced as both filler materials or as a boards (Jelle, 2011). Also the study of Asdrubali which treats the acoustical properties of sustainable materials both natural and from recycled materials and consider that cork show good thermal insulation properties , is light and can be very effective for impact sound insulation and not harmful for human health (F. Asdrubali, Schiavoni, & Horoshenkov, 2012). Another work of Khabbazi, and al. which describes the thermal and the mechanical properties of a new material based on granular cork and cement mortar by varying the percentages of cork by using the box method (Khabbazi, Garoum, & OMAR, 2005) .Another work, for Mounir and al. which studies the thermal characterization of a mixture of clay bounded by cork and evaluates the energy saving from this composites (Mounir, Maaloufa, Cherki, & Khabbazi, 2014). Moreover, a lot of researches have been done about clay such as the work of N.Laaroussi and al. concerning the thermal properties of a sample prepared using mixtures of clay bricks (Laaroussi, Cherki, Garoum, Khabbazi, & Feiz, 2013).

According to all those studies authors try in this work to improve the thermal properties of the material clay by combining it with additives granular cork and characterizing its thermal properties using the recent asymmetrical Hot Plate (Bouchair, 2008; Jannot,

Felix, & Degiovanni, 2010; Lin et al., 2014; Yves Jannot, 2011) and Flash methods (Degiovanni, Batsale, & Maillet, 1996; Degiovanni, Laurent, & Prost, 1979; Parker, Jenkins, Butler, & Abbott, 1961). Furthermore, they studied the effect of volume fraction granular cork variation on the thermal properties of the composites obtained. Finally a comparison of thermal transmittance for exterior walls between the stratigraphy of Moroccan and Mediterranean area such as Italy was conducted to evaluate the best energy efficient system clay-cork.

Cork (Bussler, 1961) is natural, ecological, hydrophobic and renewable product with important thermal and acoustic properties due to its microstructure and porosity. It is coming from Mediterranean area (Moroccan, Portuguese, Algerian, Tunisian…Forests). Clay is a mineral coming from the decomposition of rock. It's a heterogeneous material on different scales. The mineral clay is formed specially from a mixing of hydrated phyllosilicate. The majority mineral gives the names of this phyllosilicate. It is combined with a different mineral like: Carbonate; silica; oxide and hydroxide of aluminum and Ferriferous mineral.

DESCRIPTION OF USED MATERIALS

CLAY

The clay sample extracted from Bensmim area close to Ifrane was characterized through X-ray diffraction. The results are represented in figure 1

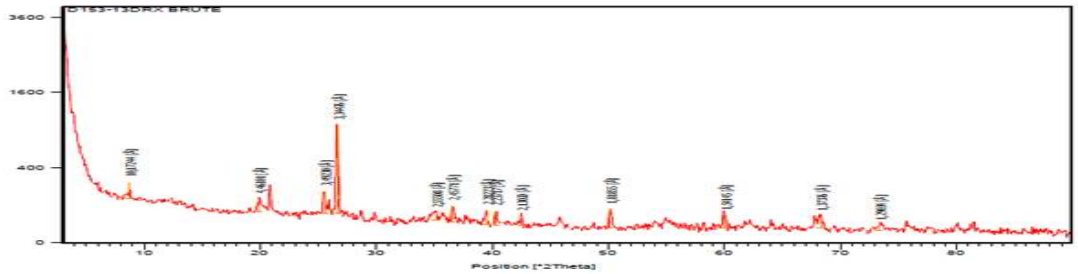


Figure 1: X-Ray diffractometer spectrum of the clay sample extracted from Ifrane Region

The results presented above show that the X-Ray diffraction of the powdered soil sample presents various peaks occurring at different positions. A predominance of quartz in the soil, SiO2 (d=3.34A°). The Clayed part is composed of Muscovite/Illite (d =10.00 A°). More XRD analysis were conducted through oriented planes to study more the clay part of the sample. The results are represented in the figure 2

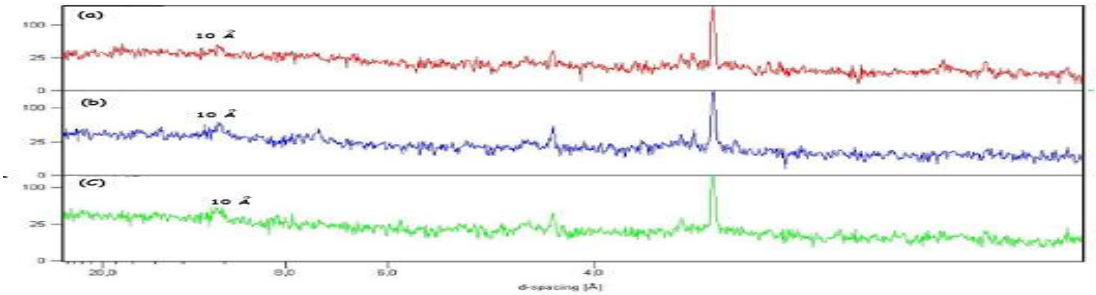


Figure 2: X-Ray diffraction of the (a) clay sample oriented,(b) clay calcinated at 500°C and oriented lame saturated with ethylene glycol

The figure 2 confirms the presence of the non swelling clay Illite/muscovite clay reflection d=10.00 present at the angle 2θ equal 8° at the interatomic spacing. No change in the present pics was observed after ethylene glycol saturation which confirms again the absence of swelling clay.

CORK

Cork coming from oak Maamora tree is a flexible material, light, compressible, resistant to gases and liquids, fire resistant and it acts as an outstanding acoustic and thermal insulator. Moreover, it's highly resistant to abrasion. Indeed all these characteristics are immensely influenced as a result of its chemical properties comprising of mainly suberin (45%) which can be echoed (Bussler, 1961). The density of used cork is 160 Kg/m^3; the thermal conductivity is 0.049-0.05$W.m^{-1}.K^{-1}$

Figure 3: Images of Illite Clay in different volume fraction of granular cork

DESCRIPTION OF THE EXPERIMENTAL APPROACH

Samples Preparation and Their Corresponding Densities Measurement

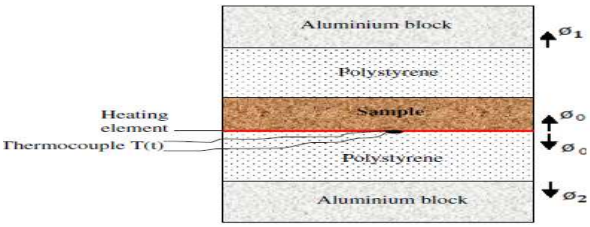
Authors prepared many four samples corresponding to four different percentage volume fraction of

granular cork which size is (d-D= 6.3-8mm) by using a normalized sieving process to take into account the effect of volume fraction of granular cork on the thermal properties of the medium. We proceeded to the preparation of many samples. our experience has been done in a mold which dimensions are 100x100x20mm3, in this mold we filled a volume fraction of granular cork until we get a full mold, then we considered that this volume of cork corresponds to 100% in the samples and according to this, we calculated the proportion corresponding to 80% as well as 60% of volume fraction granular cork. Then we added clay in order to fill in the void existing between grains of cork. Furthermore, authors prepared samples of clays without granular cork, having the same dimensions as the other three, in order to compare the thermal properties variation of the mixture. The four samples are then drawn in a stove, to remove moisture present into the pores of each one. Next, dry masses are measured and packed in plastic bags so they can maintain uniform moisture content near zero. The experimental measurements will be performed on these dry samples material. From the knowledge of the dimensions and masses of the fours samples, Authors could easily determine the apparent density of each one. However, the density of the granular cork is determined by the water volume variation method: weighing a quantity of granular cork that filled in a vessel containing a known water volume; the change in volume of water corresponds to the volume of impregnated cork, so we deduce the density of granular cork (The quantity of water penetrating into the granular cork is negligible considering the short experiment's duration which's 5s, due to hydrophobic character of cork). Knowing separately the densities of clay, granular cork and that of the mixture and depending on the mixture's law, we can deduce the granular cork volume fraction in each sample of the composite material according to the formula shown below

$$\gamma = \frac{\rho_{c+co} - \rho_c}{\rho_{co} - \rho_c} \quad (1)$$

: ρ_{co} , ρ_c and ρ_{c+co} are respectively the densities of granular cork, clay and that of the composite

ASYMMETRICAL HOT PLATE METHODS DESCRIPTION



Combining those five equations, the system leads to

$$\theta(p) = \frac{\Phi_c(p)}{\frac{E_1}{E_2}\frac{D_1}{B_1}} \quad (7)$$

Transient Hot Plate method

The thermal effusivity (E) and thermal capacity (ρ_c) were measured using the transient hot plate method(Yves Jannot, 2011) (Jannot et al., 2010). Contrary to the classical and symmetrical Hot plate transient method, which required two similar samples; we used here the recent asymmetrical experimental device (represented in Figure 5 (a) and 6) that allows characterizing materials by using only one sample. The system is modeled with the hypothesis that the heat transfer remains unidirectional (1D) at the center of the sample(Jannot et al., 2010)

$$\begin{bmatrix} \theta \\ \Phi_{02} \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ R_c & 1 \end{bmatrix} \begin{bmatrix} 1 & R_c \\ 0 & 1 \end{bmatrix} \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \begin{bmatrix} 0 \\ \Phi_1 \end{bmatrix}$$
$$= \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \begin{bmatrix} 0 \\ \Phi_2 \end{bmatrix} \quad (2)$$

$$\begin{bmatrix} \theta \\ \Phi_{02} \end{bmatrix} = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \begin{bmatrix} 0 \\ \Phi_2 \end{bmatrix} \quad (3)$$

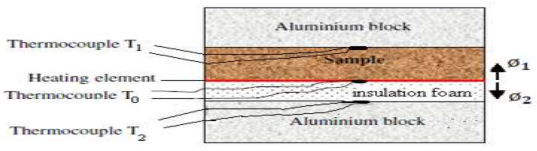
$$\Phi_0 = \frac{\theta}{p} = \Phi_{01} + \Phi_{02} \quad (4)$$

C_h the thermal capacity of the heating element per area unit: $C_h = \rho_h\ c_h\ e_h$; Rc the thermal contact resistance between the heating element and the sample. *P* is the Laplace parameter

$$A = D = \cosh\left(\frac{pe}{E}e\sqrt{p}\right);\ B = \frac{\sinh\left(\frac{pe}{E}e\sqrt{p}\right)}{E\sqrt{p}};\ C = E\sqrt{p}\sinh\left(\frac{pe}{E}e\sqrt{p}\right) \quad (5)$$

$$A_i = D_i = \cosh\left(\sqrt{\frac{p}{a_i}}e_i\right);\ B = \frac{\sinh\left(\sqrt{\frac{p}{a_i}}e_i\right)}{\lambda_i\sqrt{\frac{p}{a_i}}};\ C = \lambda_i\sqrt{\frac{p}{a_i}}\sinh\left(\sqrt{\frac{p}{a_i}}e_i\right) \quad (6)$$

E is the sample thermal effusivity $E = \sqrt{\lambda \rho c}$, ρc the sample thermal capacity, e the sample thickness, λi the Polystyrene thermal conductivity; a_i is the Polystyrene thermal diffusivity, e_i the Polystyrene thickness



The method's principle is to estimate the value of the parameters (E), (ρc), (Rc) and (Ch) that minimize the sum of the quadratic error $\Psi = \sum_{j=0}^{N}\left[T_{exp}(t_j) - T_{mod}(t_j)\right]^2$ between the experimental curve and the theoretical curve

calculated with relation using the Levenberg-Maquardt algorithm(Marquardt, 1963). The inverse Laplace transformation is realized by using the De Hoog algorithm(de Hoog, Knight, & Stokes, 1982)

Hot Plate in Steady State Regime

The Hot Plate method in steady state regime (Jannot et al., 2010; Yves Jannot, 2011; Yves Jannot, Benjamin Remy, & Alain Degiovanni, n.d.) enables to characterize thermal conductivity (λ) of samples. Figure 2 (b) illustrates the experimental device of this method, once the system reaches the steady state regime, we can write:

$$\phi=\phi_1+\phi_2;\ \phi_1=\frac{\lambda_1}{e_1}(T_0-T_1);\ \phi_1=\frac{\lambda_2}{e_2}(T_0-T_2) \quad (8)$$

$$\lambda_1=\frac{e_1}{T_0-T_1}\left[\phi-\frac{\lambda_2}{e_2}(T_0-T_2)\right] \quad (9)$$

ϕ is the total flow emitted by the heating element. λ_1 The thermal conductivity of the sample that we look for, e_1 the thickness of the sample; $\lambda_2 = 0.04\ W.m^{-1}K^{-1}$ and $e_2 = 10\ mm$: are successively thermal conductivity and thickness of the insulating foam

FLASH METHOD

Experimental approach of the flash method

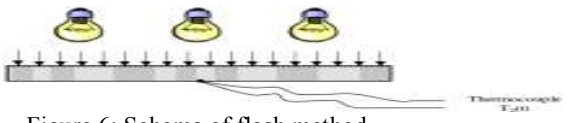


Figure 6: Schema of flash method

This method permits to determine the diffusivity of solid (Degiovanni et al., 1996, 1979), .Its principle is described in the figure 4.we send a strong luminary flow on the sample's parallel faces in a short period. A thermocouple in touch with the bottom face permits to register the rise of temperature in the moment when the face receives the flash. A modeling of heat transfer in the sample has been done to estimate the thermal diffusivity with the experimental thermogram. According to laplace. The method of quadruples permits to write

$$\begin{bmatrix}\theta 1(p)\\ s1\ (p)\end{bmatrix}=\begin{bmatrix}\cosh qe & \frac{1}{\lambda qs}\sinh qe\\ \frac{1}{\lambda qs}\sinh qe & \frac{1}{\lambda qs}\sinh qe\end{bmatrix}\begin{bmatrix}\theta 2(p)\\ s2\ (p)\end{bmatrix}=\begin{bmatrix}A & B\\ C & D\end{bmatrix}\cdot\begin{bmatrix}\theta 2(p)\\ s2\ (p)\end{bmatrix}$$

According to the Laplace transformation:

$$\emptyset 0(p)=L[\beta 0(p)]=\beta 0/p[1-\exp(-pt0)] \quad (11)$$

We combine this relation we have

$$\theta 2(p)=\frac{\phi 0}{p}\cdot\frac{1-\exp(-2t0)}{C+2Ah+Bh2} \quad (12)$$

RESULTS

Density

The density measurements of all samples were made by weighing each one and knowing their dimensions. Concerning the granular cork, it was made using the water volume variation method. Different samples were made with the variation of the volume fraction percentage of granular cork in the medium. The results that are presented in Figure 7 show a correlation between densities and volume fraction granular cork.The results of Illite clay cork characterization indicate that the density is decreasing from 2029 (kg/m^3) (clay alone) to 1109(kg/m^3) (composite100%-cork)

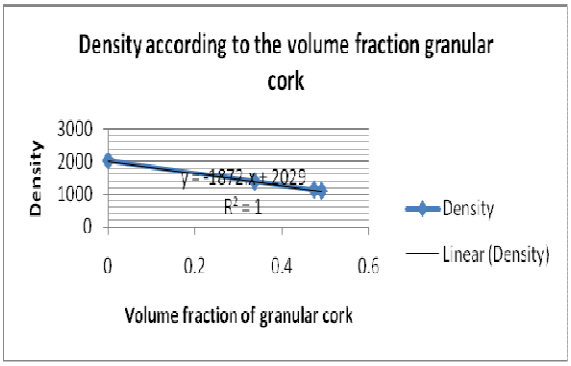


Figure 7: Figure of density according to the volume of granular cork

Thermal Effusivity by the Asymmetrical Transient Hot Plate Method

Authors apply the method for each sample with (w/g=0.25).Figure 8 shows the correlation between thermal effusivity and volume fraction granular cork. This thermal property for Illite clay decreases from 862 *to* 492 (*J.m^{-2}.K^{-1}.s$^{-1/2}$) (for composite 100% cork)* with the increase of granular cork volume fraction from 0 to 0.49

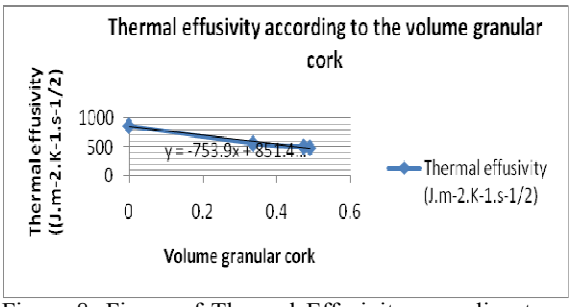


Figure 8: Figure of Thermal Effusivity according to the volume of granular cork

Thermal Conductivity by the Method Hot Plate In Steady State Regime

Authors use the hot plate method in the steady state regime to characterize this thermal property. Results show that thermal conductivity for Illite clay decreases from 0.51(clay alone) to 0.246 (W.m^{-1}.K^{-1}) (for composite clay-100% cork).Figure 9 shows the correlation between thermal conductivity and volume fraction granular cork

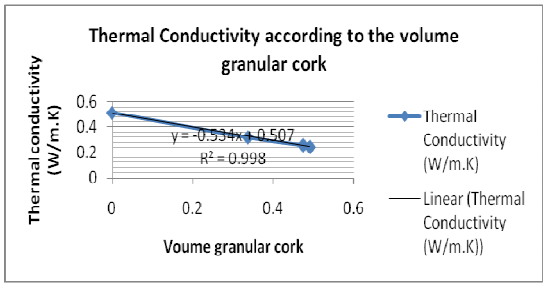


Figure 9: Figure of Thermal conductivity according to the volume of granular cork

Thermal Diffusivity by the Flash Method

Results show that thermal diffusivity of the composites decreases from $5.07.10^{-7}$ (clay alone) to $3.09 .10^{-7}(m^2.s^{-1})$ (clay-100% cork) when the volume fraction cork increase from 0 to 0.489. Figure 10 shows the correlation between thermal diffusivity and volume fraction granular cork

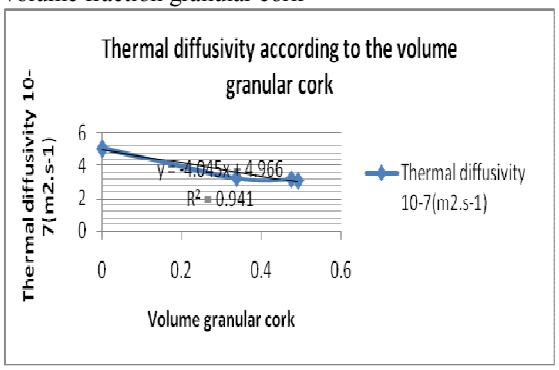


Figure 10: Figure of Thermal diffusivity according to the volume of granular cork

Thermal Transmittance Of An Exterior Walls In Morocco And In Italy As A Mediterranean Area

According to the research of Asdrubali (Francesco Asdrubali, D'Alessandro, Baldinelli, & Bianchi, 2014) evaluating in situ thermal transmittance of green building masonries-A case study where the thermal transmittance of different thickness and layer for an exterior walls is calculated. The thermal transmittance is calculated according to the ISO 6949 using the formulae.

$$\frac{1}{U} = \frac{1}{h_i} + \frac{1}{h_e} + \sum_i \frac{e_i}{\lambda_i} \qquad 13$$

In the thesis of Idchabani (Idchabani, 2014),the composition of Moroccan wall is composed from :standard brick of 7cm-air gap 7cm-standard brick of 7cm.Authors will analyze the value of thermal transmittance using instead of standard wall's block of Morocco and Mediterranean area (Italy) (using Asdrubali's research(Francesco Asdrubali et al., 2014)), our proposed thermal block of λ=0.246W/m. K

We conclude that the thermal block proposed in our research reduced thermal transmittance in standard Moroccan wall's from 1.44 $W/m^2.K$ to $0.93W/m^2.K$. and for the Mediterranean composition for the first case it gives above the same thermal transmittance .In the second case it reduces thermal transmittance from 0.29 to 0.23 $W/m^2.K$ which proves the interest of our thermal block clay_cork , in the third case the thermal blocks gives the same thermal transmittance as Asdrubali's thermal block in the fourth case it gives a value of thermal transmittance higher than the blocks of Asdrubali's (Francesco Asdrubali et al., 2014) as shown in table1. See Appendix

REFERENCES

Asdrubali, F., D'Alessandro, F., Baldinelli, G., & Bianchi, F. (2014). Evaluating in situ thermal transmittance of green buildings masonries—A case study. *Case Studies in Construction Materials*, *1*, 53–59. doi:10.1016/j.cscm.2014.04.004

Asdrubali, F., Schiavoni, S., & Horoshenkov, K. (2012). A Review of Sustainable Materials for Acoustic Applications. *Building Acoustics*, *19*(4), 283–312. doi:10.1260/1351-010X.19.4.283

Bouchair, A. (2008). Steady state theoretical model of fired clay hollow bricks for enhanced external wall thermal insulation. *Building and Environment*, *43*(10), 1603–1618. doi:10.1016/j.buildenv. 2007.10.005

Briqueteries : comment réduire la consommation d'énergie. (2013, November 14). Retrieved July 7, 2014, from http://www.lavieeco.com/news /economie/briqueteries-comment-reduire-la-consommation-d-energie-27308.html

Bussler, W. (1961). Cooke, G. B.: Cork and the Cork Tree (Kork und Korkeiche). Pergamon Press, Oxford-London-New York-Paris, 1961, 121 S. Abb. (Band 4 der Reihe: International Series of Monographs on pure and applied Biology, Division: Botany) Gzl.: 50 s. 30,—

DM. Z Für Pflanzenernähr Düng Bodenkd, vol. 95; 1961. p. 63–63. *Zeitschrift für Pflanzenernährung, Düngung, Bodenkunde*, *95*(1), 63–63. doi:10.1002/jpln.19610950108

De Hoog, F. R., Knight, J. H., & Stokes, A. N. (1982). An Improved Method for Numerical Inversion of Laplace Transforms. *SIAM Journal on Scientific and Statistical Computing*, *3*(3), 357–366. doi:10.1137/0903022

Degiovanni, A., Batsale, J. C., & Maillet, D. (1996). Mesure de la diffusivité longitudinale de matériaux anisotropes. *Revue Générale de Thermique*, *35*(410), 141–147. doi:10.1016/S0035-3159(96)80010-9

Degiovanni, A., Laurent, M., & Prost, R. (1979). Mesure automatique de la diffusivité thermique. *Revue de Physique Appliquée*, *14*(11), 927–932. doi:10.1051/rphysap:019790014011092700

Idchabani, R. (2014). *Contribution a l'efficacité énergétique du bâtiment résidentiel au Maroc, modélisation et optimisation de l'isolation thermique*. Université Mohamed V Agdal, Faculté des sciences 44,Ibn Battouta BP1014-Rabat Maroc.

Jannot, Y., Felix, V., & Degiovanni, A. (2010). A centered hot plate method for measurement of thermal properties of thin insulating materials. *Measurement Science and Technology*, *21*(3), 035106. doi:10.1088/0957-0233/21/3/035106

Jelle, B. P. (2011). Traditional, state-of-the-art and future thermal building insulation materials and solutions – Properties, requirements and possibilities. *Energy and Buildings*, *43*(10), 2549–2563. doi:10.1016/j.enbuild.2011.05.015

Khabbazi, A., Garoum, M., & OMAR, T. (2005). Experimental study of thermal and mechanical properties of a new insulating material based on cork and cement mortar. *AMSE J Adv Model Simul.*, p. 73.

Laaroussi, N., Cherki, A., Garoum, M., Khabbazi, A., & Feiz, A. (2013). Thermal Properties of a Sample Prepared Using Mixtures of Clay Bricks. *Energy Procedia*, *42*, 337–346. doi:10.1016/j.egypro.2013.11.034

Lin, W., Fulton, P. M., Harris, R. N., Tadai, O., Matsubayashi, O., Tanikawa, W., & Kinoshita, M. (2014). Thermal conductivities, thermal diffusivities, and volumetric heat capacities of core samples obtained from the Japan Trench Fast Drilling Project (JFAST). *Earth, Planets and Space*, *66*(1), 48. doi:10.1186/1880-5981-66-48

Marquardt, D. W. (1963). An Algorithm for Least-Squares Estimation of Nonlinear Parameters. *Journal of the Society for Industrial and Applied Mathematics*, *11*(2), 431–441. doi:10.1137/0111030

Mounir, S., Maaloufa, Y., Cherki, A. bakr, & Khabbazi, A. (2014). Thermal properties of the composite material clay/granular cork. *Construction and Building Materials*, *70*, 183–190. doi:10.1016/j.conbuildmat.2014.07.108

Parker, W. J., Jenkins, R. J., Butler, C. P., & Abbott, G. L. (1961). Flash Method of Determining Thermal Diffusivity, Heat Capacity, and Thermal Conductivity. *Journal of Applied Physics*, *32*(9), 1679–1684. doi:10.1063/1.1728417

Yves Jannot. (2011). Théorie et pratique de la Métrologie thermique. Laboratoire d'Energétique et de Mécanique Théorique et Appliquée (LEMTA).

Yves Jannot, Benjamin Remy, & Alain Degiovanni. (n.d.). Measurement of thermal conductivity and thermal resistance with a tiny hot plate (Vol. 39, pp. 11–31). LEMTA, Nancy-Université, CNRS, 2, avenue de la Forêt de Haye, BP 160 - 54504 Vandoeuvre Cedex France.

APPENDIX

Table 1. Results of thermal transmittance using the thermal block Illite Clay-Cork in Morocco and in the Mediterranean area

Mediterranean Wall Composition		**Moroccan Wall Composition**	
Type of Material	**Thickness (cm)**	**Type of Material**	**Thickness (cm)**
Case 1		**Case 1**	
Plaster	e=1.5 cm	Mortar	e=1.5 cm
Thermal Block λeq=0.24 W/m.K	e=15 cm	Brick of 7cm thickness R=0.16 W/m.K	e=7 cm
Thermal insulation λ=0.033 W/m.K	e=6 cm	Air gap	e=7 cm
Mortar	e=1 cm	Brick of 7cm thickness R=0.16 W/m.K	e=7 cm
Thermal Block λeq=0.24 W/m.K	e=12 cm	Mortar e=1.5 cm	e=1.5 cm
Total thickness	e=37 cm	Total thickness	e=24 cm
Calculated Transmittance 0.34 W/m^2.K		Calculated Transmittance 1.44 W/m^2.K	
Case 2		**Case 2**	
Plaster	e=1.5 cm	Mortar	e=1.5 cm
Thermal Block λeq=0.24 W/m.K	e=12 cm	Thermal Block λeq=0.24 W/m.K	e=21 cm
Air gap	e=2 cm	Mortar	e=1.5 cm
Thermal insulation λ=0.033 W/m.K	e=6 cm	-	-
Mortar	e=1 cm	-	-
Thermal Block λeq=0.24 W/m.K	e=18 cm	-	-
Total thickness	e=42 cm	Total thickness	e=24 cm
Calculated Transmittance 0.29 W/m^2.K		Calculated Transmittance 0.93 W/m^2.K	
Case 3		**Case 3**	
Plaster	e=1.5 cm	Mortar	e=1.5 cm
Thermal Block λeq=0.246 W/m.K	e=25 cm	Thermal Block λeq=0.24 W/m.K	e=7cm
Air gap	e=3 cm	Air gap	e=7 cm
Thermal insulation λ=0.033 W/m.K	e=6 cm	Thermal Block λeq=0.24 W/m.K	e=7 cm
Mortar	e=1 cm	Mortar	-
Thermal Block λeq=0.246 W/m.K	e=12 cm	-	-
Total thickness	e=49 cm	Total thickness	e=24 cm
Calculated Transmittance 0.27 W/m^2.K		Calculated Transmittance 0.27 W/m^2.K	
Case 4		**Case 4**	
Plaster	e=2 cm	Mortar	e=1.5 cm
Thermal Block λeq=0.246 W/m.K	e=25 cm	Thermal Block λeq=0.24 W/m.K	e=12 cm
Air gap	e=4 cm	Air gap	e=7 cm
Thermal insulation λ=0.033 W/m.K	e=6 cm	Brick of 7cm thickness R=0.16 W/m.K	e=7 cm
Mortar	e=1 cm	Mortar	e=1.5 cm
Thermal Block λeq=0.246 W/m.K	e=12 cm	-	
Total thickness	e=50 cm	Total thickness	e=29 cm
Calculated Transmittance 0.268 W/m^2.K		Calculated Transmittance 0.268 W/m^2.K	