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Experimental method of measuring coefficient of transmission capacity and energy storage building a wall

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ABSTRACT

Currently, a new revolution is taking place in the construction of habitus in Europe, respect for nature, ensuring comfort and less energy. In this context, different software currently on the market, offering, for given climatic conditions, the composition of the walls of the building to ensure a transmission inertia, but inertia absorption. But so far, there is no method for measuring coefficient of transmission and storage of in-situ construction, to confirm or refute the data from artificial stones. This work raises this obstacle by developing a simple easy to implement and inexpensive method.

Key words: Coefficient of transmission, storage capacity, inertia transmission, absorption inertia.

Introduction

Rationalization of energy is a critical issue for countries suffering the pangs of cold much of the year. The building, in fact, is one of the most energy-intensive sectors with e.g. more than 43% (ADEME; measurement program 2007-2008 # Construction segment, the Millennium II) of the total energy produced in France. It is also one of the most polluting with about 23% (HQE, press release, Paris September 16, 2009 # JP Chang (eds): << Inventory of air pollutant emissions in France) emissions of greenhouse gases emissions. To cope with the increasing demand, the serious environmental problems and in-fine soaring energy costs, various means to fight against the loss and waste are deployed in Europe struggle against thermal bridges (responsible for about 30% (RT 2005) consumption) prediction, which works for the energy just hour after hour and implemented in the package (shops, storage rooms products etc..) and recently the energy storage in the walls of the building for future use or to protect against changes in external temperature. Knowledge of parameters such as: the transmission coefficient and the storage capacity are very important links in the control of energy saving in the building. The growing interest in government, in power saving mode, and the concept of Eco-building for the return to passive buildings (Dincer, 2002; Grigull, 1988), have pushed in recent years, many researchers to deepen, by theoretical and experimental studies (Bilgen and Richard 2002.; Magyari and Keller 1998; Asan 2006), the understanding of this method of energy storage. Magyari and Keller for their part, exhibited a thickness maximizing the energy stored in a homogeneous wall subjected to a harmonic excitation at one side and held to the other adiabatic. These results were subsequently generalized (Cossali 2007) with periodic heating conditions in general linear limits.

However, most of these studies have focused on a homogeneous wall or simulations needs to use multilayer walls. For this purpose, different software on the market offering, given the weather data, the

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composition of the walls of the building. But there is not, to our knowledge, a method of in-situ measurement of basic parameters such as the transmission coefficient and the energy storage capacity of a building wall, in the direction of confirming or invalidate the results of wall subjected to solar excitement. The method was applied to the western wall of Napevomo building located on the Esplanade des Arts et Métiers in Talence (Bordeaux). The results are satisfactory and augur good prospects.

Materials and Methods

The wall used as a basis for experimentation is the west wall of Napevomo building located on the Esplanade des Arts et Metiers in Talence (Bordeaux). It is a building that has participated in the first Solar Decathlon Europe 2011 in Madrid, where he won numerous awards for its technological innovations along the lines of sustainable development, while ensuring predictions from theoretical calculations. This article provides a solution to this problem by providing a method for joint measurement of coefficient of transmission, energy storage capacity of a

comfort conditions copies. Said wall is structured as follows (Table 1).

Experimental Background

Analysis of thick materials by infrared thermography laboratory proves a difficult problem because of the excitation power needed for its implementation. It is even more complicated when dealing with heterogeneous materials such as those used in the building or the walls of the latter to analyze in situ. The difficulty also comes from the inability of the heating engineer to maintain the excitation flux constant over a specified period of time. To overcome these difficulties, the use of solar flux is adopted with the following device (Figure 4).

Table 1 Composition of the west wall Napevomo

No	Description Material	Thickness [mm]	ρ [Kg/m3]	k[W/(mK)]	Cp [J/(kg.K)]	μ
1	Maritime Pine Cladding	22	500	0.14	1500	35
2	Of highly ventilated air space	40	-	-	-	1
3	Wood fiber board	100	170	0,042	2100	5
4	Wood fiber insulation	120	55	0,038	2100	5
5	Pine frame maritime45/120 [between 600mm axis]	120	500	0.14	1500	35
6	Wood fiber board	8	800	0.1	2100	60
7	Air blade unventilated [Blank Technology]	40	-	0,155	-	1
8	Gypsum panel cellulose	12.5	1125	0.36	1100	13
9	Raw land panel	40	1950	0.87	850	8
10	Gypsum panel cellulose	12.5	1125	0.36	1100	13

Figure 1 Photograph of the component temperature sensor and flow

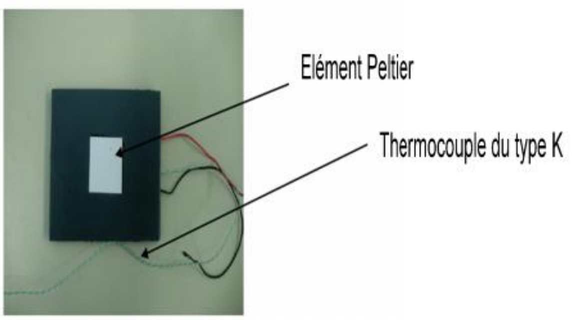
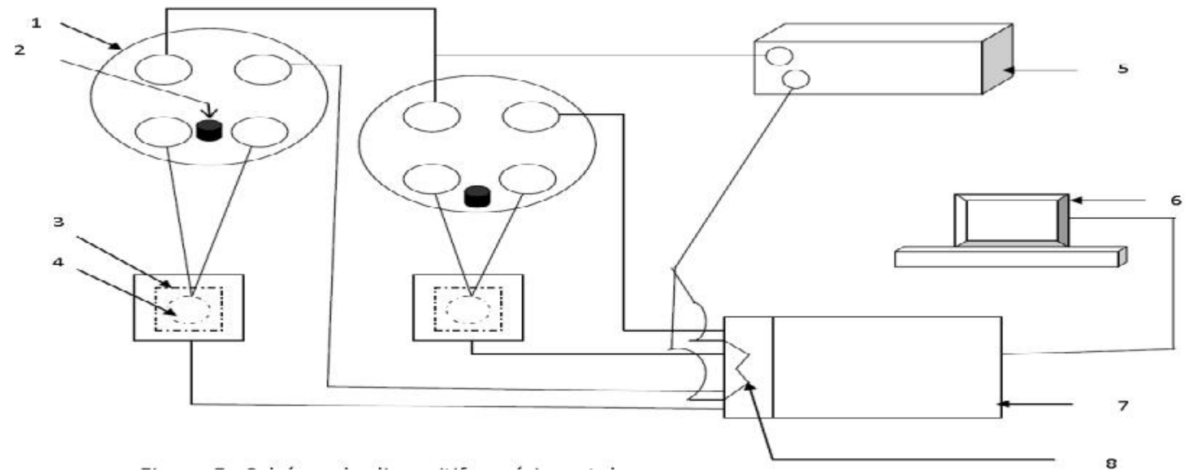


Figure 2 Photograph of the complete measuring device

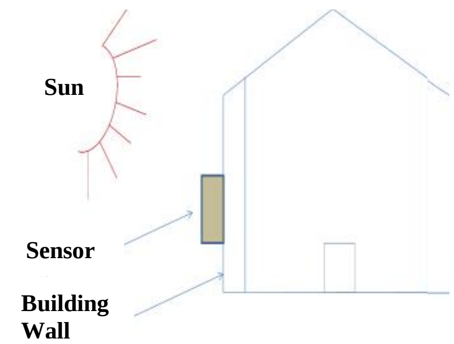
Figure 3 Schematic of the acquisition system



1-Transmitter converter; 2-Zero setting device; 3-Peltier; 4-K type thermocouple; 5-Stabilized power supply; 6-PC; 7-Central acquisition: NATIONAL INSTRUMENTS NI USB 6009 8 INPUTS 14-bit Multifunction I / 0; 8-Resistance.

The expected Thermal performance (from simulation calculations according to the RT 2005) on the west wall with mud are:
U = 0.18 W/ (m^2.K) : Transmission coefficient,
Cp = 29 Wh / (m^2. K) : basic dynamic storage
Φ = 14.8 h thermal phase of the wall and μ the vapor diffusion factor. The measuring device comprises a Peltier element calibrated flowmeter and a temperature measuring thermocouple surface type K See Figures 1, 2, 3.

Figure 4 Measurement of temperature and flow on the west wall of the building Napevomo



The characteristics of the experimental context:
- experimental environment is the external and internal environment
- the field flux the sun
- the measuring instrument is subjected to variations of meteorological parameters (wind, sunlight, humidity, pressure, rain, etc..) outside.

The strategy of our approach is to measure the input and output of the system flow $\varphi(0,t)$ and temperature $T(0,t)$ over time.

Manipulations

We disposed outside and inside the wall, a sensor composed of: a thermocouple, and a Peltier element. The thermocouples are connected to the stabilized power supply (24.2 V LASCAR; Tunable) that converts the voltage signals with the aid of two amplifiers. The Peltier elements are themselves connected to the stabilized power supply. While this set is connected to the datalogger which in turn is connected to the PC for recording data in real time.

Data Processing

A measurement campaign was carried out over five days. Data recording is done in steps of 10 s. In total, approximately fifty thousand (50,000) data is stored in a table with four columns including: changes in external and internal flows and changes in external and internal temperatures. After removal of some outliers Matlab program that has to average amplitude of successive intervals 360 to obtain time data. Then cutting a section of length 24 was used to extract the daily values. Information on the thermal behavior of the wall on five days are grouped into matrices 24x4 size designated by Ji ($i \leq 5$).

Some trends from the data set forms

We present here the curves for J1 and J3 and a compilation of five days. On the third day (J3), the curves are atypical because it had rained until early afternoon. This demonstrates the accuracy of our equipment even sensitive to changes of the environment. For other days the curves are similar to J1. External data are red.

Figure 5a The curves of flow variations (left) temperature (right)

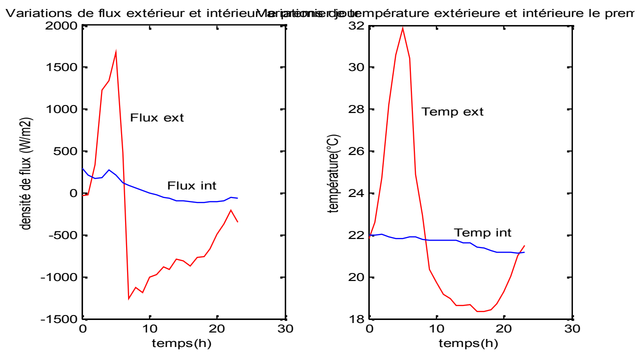


Figure 5b The curves of flow variations (left) temperature (right)

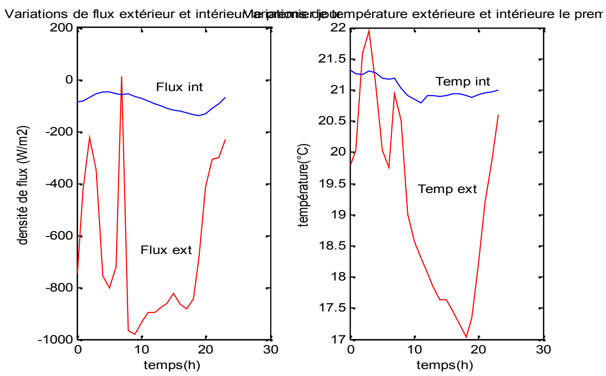


Figure 6a Compilation of changes in internal and external flows

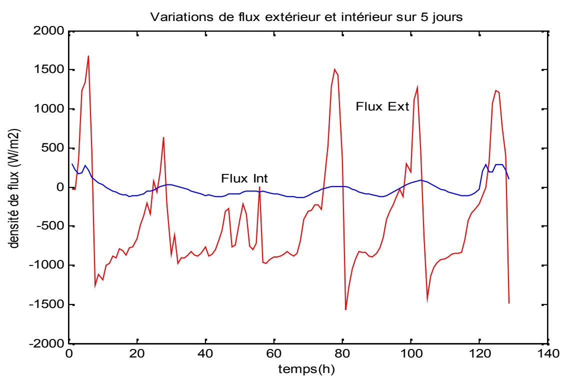
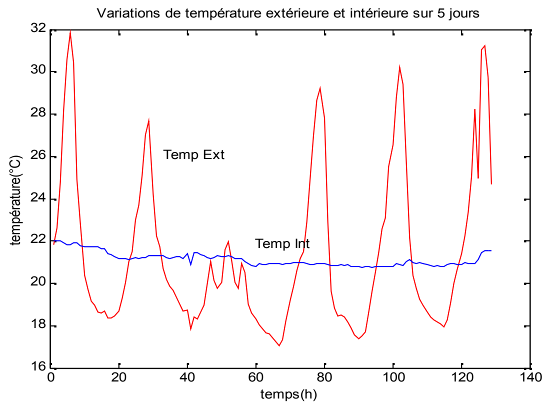


Figure 6b Compilation of changes in internal and external temperatures



Changes in external data perfectly red trace the frequency of the alternation of day and night 24 hours. As the curves for internal observations (blue), they have not undergone major changes. The inner wall temperature remained around 21°C while the flow oscillates around zero. It should be remembered that the measurements were made, doors, windows and other issues of solar closed, and any source of internal energy. In view of the wide variations in the outside, light and temperature fluctuations observed indoor environment cannot be attributed to heat conduction through the wall. It is therefore logical to say no disturbance occurred outside has had any effect on the inside. Furthermore, it is pertinent to say that the wall is well insulated since amplitude of 32°C outside not disturbed inside. Therefore, it can be considered a semi-infinite medium. Thermal analysis of the wall is very complex. It must take account of its thermal history when this analysis is undertaken. But it also depends on its ebb and flow of control during a day. A gust of wind, a passing cloud or a sudden intensification of solar activity can reverse for a time the flow direction. Given these difficulties, it seems more appropriate for estimating the transmission coefficient to calculate the point no point from an arbitrary initial temperatureT_0. The argument is that the ebb and flow are assumed zero mean, which is balancing any incident flux reaching the wall, penetrates to a depth that depends only on its intensity and the resistance opposed by the latter, regardless of thermal history.

Estimation method of transmission coefficient of the west wall of the building Napevomo

Incident flux entering and penetrating to a certain depth in the wall can be expressed by the following relationship.

$$\varphi_{ext}(t) -1/R\,[T_{ext}(t) - T_o + 273] + Cst \qquad (1)$$

or

$\varphi_{ext}(t) = U\Delta T + Cst$ (2)

wherein the local resistance is R (m2. K/W), U (W/m2. K) coefficient of local transmission wall, φ_{ext} and T_{ext} respectively flow and external temperature.

From the relation (2), and N observations of the pair (φ_{ext} (t), T_{ext}), a transmission coefficient may be estimated local point by point the intensity corresponding to a specific incident flux, independently of the thermal history of the wall. With Matlab notation, this translates into:

$U_{local} = \varphi_{extlocal}(t)./\Delta T_{local}$ (3)

It is important at this level, to recall the Matlab program to calculate ΔT_{local} every step

```
T0 = 10, J1 = T (:, 3);
 ΔT = zeros (24,1);
 T (1,1) = T (1)-T0;
 for j = 2:24
 ΔT(j,1)=T(j)-T(j-1)+273;
 end
```

After completing the program, the results are recorded in Table II.

Table 2 Estimated transmission coefficient

Values of the coefficient of local transmission				
J1	J2	J3	J4	J5
0.1194	0.3135	0.0499	0.5587	0.1222

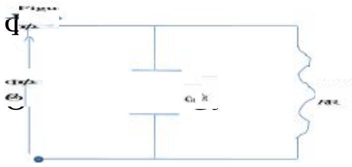
It important that the wall can behave alternately as transmitter or receiver flow. It all depends on the mood of the moment. In either case, the local flow resistance is the same. Thus, the minimum of the absolute value of each day which is grouped in Table 2. Minimum in order to get closer to the highest resistance against the flow in a day. It is entirely appropriate, retain for the moment, as the transmission coefficient of the wall, the average of these values. Average, because it helps to reduce the effects due to the thermal history of the wall.

$U = 0.2327\ W / m^2/K$ (4)

Given the role that the wall is designed to play, it is already considered as a body both capacitive and resistive. To account for the energy history of the wall, it is appropriate to adopt the model of linear least squares to estimate the storage capacity because it provides access to average values in the context of multidimensional diffusion.

Complete model by least squares linear

Figure 7 Schematic of a quadrupole complete medium semi-infinite



The pole diagram (Figure 7) can result in the following relationship:

$\Phi\ \varphi(0.\ \omega) = j\ \omega\ (pcd)\ \theta(0,\omega) + 1/R\ \theta(0,w)$ (5)

where $\varphi(0.\ \omega)$ and $\theta(0,\omega)$ are respectively the Laplace transforms of the flow and temperature.

The inverse Laplace transform of (5) is written

$\varphi_{ext}(t) = (pcd)\ dT_{ext}/dt(t) + 1/R\ T_{ext}(t) + Cst$ (6)

For N observations of $\varphi_{ext}(t)$, the system is obtained 5

$\varphi_{ext}(t_1)$ $\frac{dT_{ext}(t_1)}{dt}$ $T_{ext}(t_1)$ 1
$\varphi_{ext}(t_2)$ = pcd
: $\frac{dText(t_2)}{dT}$ $T_{ext}(t_2)$ 1 1/R
. *Cst*
: : :
$\varphi_{ext}(t_N)$ $\frac{dT_{ext})(t_N)}{dT}$ $T_{ext}(t_N)$ 1 (7)

or

$\boldsymbol{\varphi} = \mathbf{YB}$ (8)

where $\boldsymbol{\varphi}$ denotes the vector of observations of flux density, B the vector of parameters to be estimated and Y the sensitivity matrix the vector parameter.

With contact measurements, the problem of measurement noise reduces the sensitivity of the measuring equipment. In this case, they are quite loyal. To prove (see Figures 5 and 6) comments flow and external temperature are in phase and even variations, even sensitive environment are displayed. It is then possible to say that the observations φ_{ext} and T_{ext} are known with good accuracy, and the sensitivity matrix is no measurement noise. Under these conditions, the Gauss-Markov (Beck and Arnold 1977) provides an optimal estimator of ***B*** is given by:

$\boldsymbol{B} = Y^T.\ Y)^{-1}\ Y^T\varphi$ (9)

The optimal parameter B is then calculated for each of the five days starting temperature data and the measured flow density. The results can be read in Table 3.

Table 3 Estimated values of storage capacity

Days	J1	J2	J3	J4	J5
Capac Wh/(m²^2.K)	309.87	244.89	385.5675	337.14	367.84
Capa Wh/(m^2.K)	25.82	20.4 1	32.13	28. 10	30.65

The alternation of day and night is 24. If the wall could absorb energy, it is necessary due to solar activity. But the path of the sun each day is 12 hours. The sun rises every day at about 6am and going to bed at around 18am. So, the values in the second row of Table III represent the cumulative energy absorbed by the wall during the 12 hours solar activity that lasts a day. To arrive at the dynamic storage capacity, it was enough to divide the values of the second line 12. The values can be read from the last line of Table III. An average of the last line is

$$Capa = 27.4219\ Wh/(m^2.K) \qquad (10)$$

Results and Discussion

This simple method described in this paper was used to estimate the transmission coefficient and the storage capacity of the wall. The found values for the coefficient of transmission and storage capacity of the wall. The found values for the coefficient of transmission and storage capacity are respectively 0.2327W/(m_2.K) and 27.4219Wh/(m_2.K) against U = 0.18W/(m_2.K) and C_p=29Wh/(m_2.K). Is the coefficient, a deviation of 0.0527 W/(m_2.K) and for the storage capacity *1.5781 W h* / (m_2. K) of a standard. But it must be remembered that, because no external disturbance is felt to be done inside, weather experiment failed to the wall of implementing all these layers. This explains the relative increase of the transmission coefficient found from the theoretical. In other words, the wall still has to overcome resistance, equivalent to that of the layers of the wall that have not yet been affected by external forces. The same reasoning holds for energy. The difference noted in relation to the theoretical value corresponds to the storage capacity of the wall layers that have not yet been requested.

Conclusion

The method is simple, easy to implement and inexpensive. However, the data are not easy to interpret. It remains to be properly defined experimental conditions in order to determine these parameters accurately. Because, so far, the controversy remains about the proposed theoretical values. They actually correspond to the true values of the wall? Indeed, the data (J3), the third day it rained almost all day, could be interpreted as a loss of much of the energy stored by the wall in favor of the outside. And in this case, the parameters of the wall as simply those obtained J3) namely 0.0499 W / (m^2.K) for the transmission coefficient and 32.1306 W / (m^2.K) for the storage capacity. It should therefore associated with this study the influence of meteorological parameters (wind, rain, humidity, pressure etc.). In this way the method can become decision-making tools necessary for development. On the other hand a deepening of the method could be in the future a great way to auscultation thick materials. Implementation, for example, an infrared camera, allows auscultation of a larger area, and the game spreads transmission coefficients, exposing a thermal bridge. It is also important to note that the measurements were made where the sensor is placed. The results are worth it for the whole wall? The latter concern could be partially resolved if the sensor is placed in several well-chosen locations. An average of the results would be an indicator of the general state of the wall.

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