

# Etude synthèse sur l'amélioration de l'isolation thermique des matériaux de construction

## Synthesis study on thermal insulation improvement in construction materials

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### Abstract

Improving thermal insulation of buildings envelopes can reduce their energy consumption and related CO<sub>2</sub> emissions considerably. Searching for new and innovative insulation materials is therefore a key challenge. This work presents a synthesis study on series of experiments showing the addition effect of different additives on plaster and cement composite thermal properties. The results obtained using the box method show a significant improvement of thermophysical properties with the increase of additives incorporation rate. From an energy and environmental point of view, the results of the annual simulations carried out for a typical building located in Meknes indicated that the use of the proposed materials has economic and environmental benefits.

### Résumé

L'amélioration de l'isolation thermique des enveloppes de bâtiment peut réduire considérablement leur consommation d'énergie et les émissions de CO<sub>2</sub> associées. La recherche des matériaux isolants nouveaux et innovants constitue donc un défi majeur. Ce travail présente une étude synthèse sur des séries d'expériences montrant l'effet de l'ajout des différents additifs sur les propriétés thermiques d'un composite de plâtre et de ciment. Les résultats obtenus en utilisant la méthode des boîtes montrent l'amélioration significative des propriétés thermophysiques avec l'augmentation du taux d'incorporation des additifs. D'un point de vue énergétique et environnemental, les résultats des simulations annuelles réalisées pour un bâtiment typique situé à Meknès ont montré que l'utilisation des matériaux proposés a des avantages économiques et environnementaux.

**Mots clés :** *plâtre, ciment, additifs, propriétés thermophysiques, efficacité énergétique.*

**Keywords:** *plaster, cement, additives, thermophysical properties, energy efficiency.*

### 1. Introduction

As part of Morocco's efforts to reduce energy consumption, the Energy Efficiency Program is developing a building energy efficiency code that includes improvements to the

thermal characteristics of materials and choosing the right materials [1].

During the last decades, the use of materials offering several advantages, such as availability, recyclability, low cost or free, clean, good thermomechanical and ecological performance has been considerably noticed. As well as, several researches have been made in this direction and whose objective is to improve the thermal performance of existing or innovative materials through the addition of additives in order to obtain a thermally efficient composite [2-5].

This study gives an overview of an innovative waste management method that can generate considerable energy savings in the building sector. A series of experiments were carried out by mixing either the plaster matrix or the cement matrix with different percentages of additives such as alfa [3], coffee grounds [2] and ashes [4, 5].

Initially, the thermal properties of the resulting composite materials were characterized using the box method. Subsequently, annual simulations were conducted to demonstrate the benefits of using the proposed materials in a residential building located in Meknes. Finally, ecological assessments have been studied to quantify the annual quantities of avoidable CO<sub>2</sub> emissions related to the use of these proposed materials.

### 2. Methods and devices

#### 2.1. Thermophysical properties measurement

The measurement principle consists in producing a known unidirectional heat flow, through the sample to be tested, placing it between a hot and a cold environment, and then taking the measurements after obtaining the steady state (Figure 1).

Once the steady state is established, the thermal conductivity  $\lambda_s$  is given by:

$$\lambda_s = \frac{e}{S(T_H - T_C)} \left[ \frac{V^2}{R} - c(T_B - T_A) \right] \quad (1)$$

Where  $e$  is the sample thickness (m),  $U$  the heating resistor voltage (V),  $R$  the heating resistor value (Ohm),  $C$  the box loss coefficient (W/°C) and  $S$  the sample area (m<sup>2</sup>).  $T_A$  and  $T_B$  are the ambient and internal temperatures of the box B (°C);

$T_H$  and  $T_C$  are the hot and cold faces temperatures respectively ( $^{\circ}C$ ).

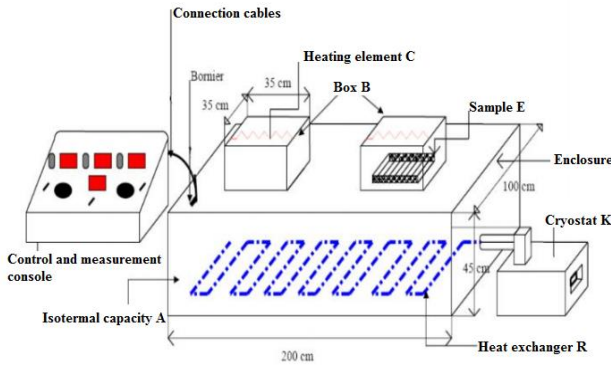


Fig.1: EI700 measuring cell.

Thermal diffusivity is measured in the second box. The principle is to illuminate the samples by two incandescent lamps power (1000 Watt) for a few seconds. The temperature elevation of the sample is recorded as a function of time and the points for which we have: 1/2, 1/3, 2/3 and 5/6 of the temperature maximum value are identified. We then look for the values of the corresponding time and deduce the material thermal diffusivity by the average of the three values calculated by the following expressions:

$$\alpha_1 = \frac{e^2}{t_{5/6}^2} [1,15 t_{5/6} - 1,25 t_{2/3}] \quad (2)$$

$$\alpha_2 = \frac{e^2}{t_{5/6}^2} [0,76 t_{5/6} - 0,926 t_{1/2}]$$

$$\alpha_3 = \frac{e^2}{t_{5/6}^2} [0,618 t_{5/6} - 0,862 t_{1/3}]$$

$$\alpha_{exp} = \frac{\alpha_1 + \alpha_2 + \alpha_3}{3} \quad (3)$$

## 2.2. Energy and environmental calculation

### 2.2.1. Energy requirements

The building annual heating and cooling requirements are calculated by building energy simulation software TRNSYS, adopting reference temperatures for heating and cooling: 20  $^{\circ}C$  in winter and 26  $^{\circ}C$  in summer.

The specific annual energy requirements of the building related to thermal comfort ( $B_{th,c}$ ) are determined according to the following formula:

$$B_{th,c} = \frac{B_h + B_c}{TAC} \quad (4)$$

Where  $B_h$  and  $B_c$  are the annual energy requirements for heating and cooling related to the thermal comfort of the studied building expressed in (kWh/m<sup>2</sup>.yr), and TAC is the total living area conventionally conditioned expressed in m<sup>2</sup>.

### 2.2.2. Environmental assessment

The avoided CO<sub>2</sub> emissions (in kg/yr) as an environmental indicator can be calculated using the following equation:

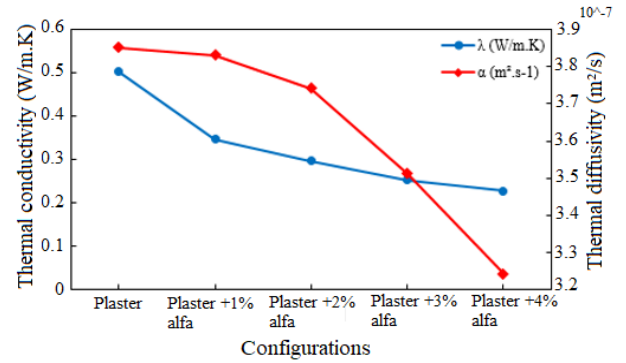
$$Q_{av.co_2} = ES * EF \quad (5)$$

Where ES represents the energy savings (kWh/yr) and EF the grid emission factor (0.74 kg of CO<sub>2</sub>/kWh for Morocco).

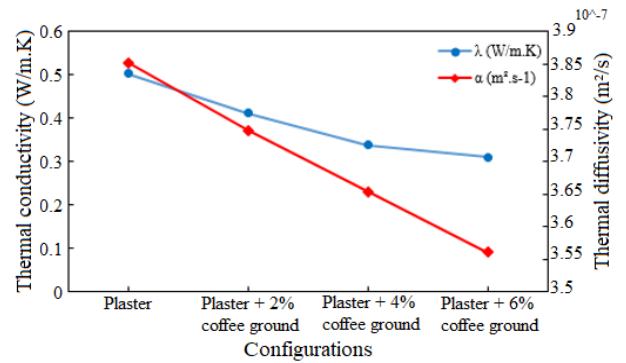
## 3. Results and discussions

### 3.1. Measurement results

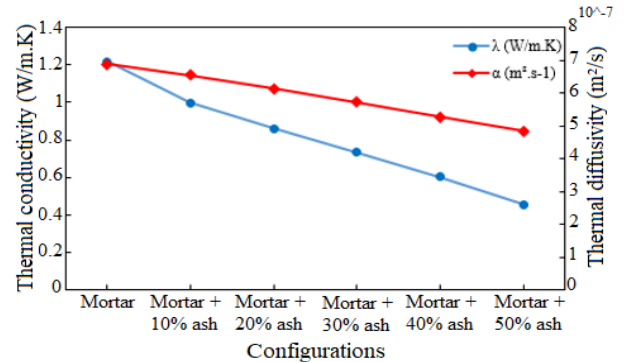
The characterization is made by the EI700 device which is specially designed to simultaneously determine the thermal conductivity and diffusivity of materials by the box method. Figure 2 summarizes the average results of measuring the different samples thermophysical properties.



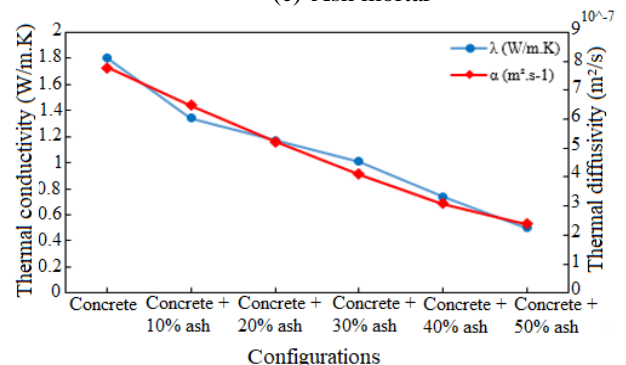
(a) Plaster with alfa



(b) Plaster with coffee grounds



(c) Ash mortar



(d) Ash concrete

Fig. 2: Variation in the conductivity and thermal diffusivity of the samples studied.

These results reveal that the higher the additives percentage, the lower the thermophysical properties namely conductivity and thermal diffusivity.

This shows that the addition of alfa and coffee grounds with small plaster portions and the replacement of cement with ashes in the mortar and concrete have a positive effect on these materials insulating power. The results presented in this work show that the proposed materials have good thermal performance compared to conventional material.

### 3.2. Simulation results

The studied structure is a mono zone of 80 m<sup>2</sup> of living space with south and west facades.

The benefits of adding additives to the plaster and cement matrix have been vigorously quantified when the proposed composites are integrated into the building envelope.

Figures 3 and 4 show the heating and cooling requirements of the building under study and the amount of CO<sub>2</sub> avoided for the different configurations.

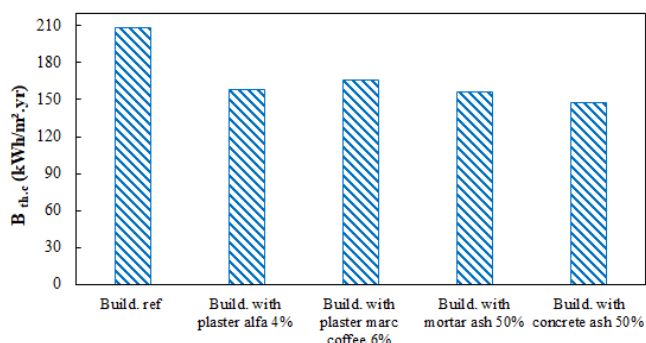


Fig. 3: The building annual energy requirements for the different configurations studied.

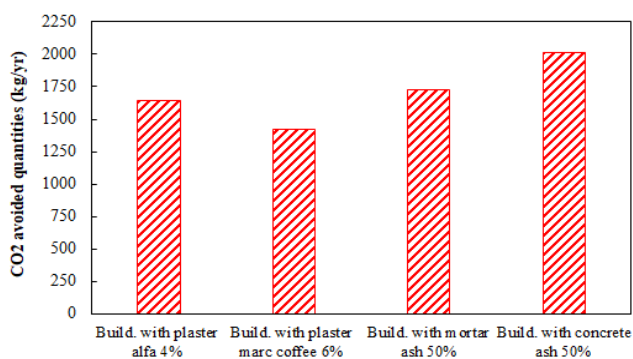


Fig.4: CO<sub>2</sub> avoided quantities for the different configurations studied.

The proposed materials have significantly reduced the energy requirements of the building studied with an average rate of 24.5% compared to the first configuration with conventional materials.

From an environmental point of view, the integration of the proposed materials in the building envelope avoids significant amounts of CO<sub>2</sub> approximately 1699.05 kgCO<sub>2eq</sub>/year on average (Fig. 4).

The effects study results of the different materials proposed were combined to formulate a building envelope design that has the minimum annual energy requirements.

The most efficient combination of parameters was selected by comparing these results against each other. The required annual energy requirements from various parameters are shown in the following table.

Table. 1: The annual energy requirements of the different configurations studied.

Buildings	B <sub>th,c</sub> (kWh/m <sup>2</sup> .yr)	CO <sub>2</sub> amount avoided (kg / yr)
Building with plaster alfa 4% + mortar ash 50%	128.86	2283.84
Building with plaster marc coffee 6% + mortar ash 50%	134.45	2122.38
Building with plaster alfa 4% + concrete ash 50%	116.74	2633.67
Building with plaster marc coffee 6% + concrete ash 50%	124.69	2404.35
Building with plaster alfa 4% + mortar ash 50% + concrete ash 50%	103.03	3029.13
Building with plaster marc coffee 6% + mortar ash 50% + Concrete ash 50%	108.98	2857.53

It can be seen that the combined effect of integrating alfa plaster, mortar and ash concrete into the building envelope resulted in the greatest energy saving of almost 50% and subsequently the larger amount avoided of CO<sub>2</sub> approximately 3029.13 kg/yr.

### Conclusion

This synthesis study presents the results of the experimental series to evaluate the influence of the additives incorporation on the thermophysical properties of conventional materials based on plaster and cement.

The data presented in this work show that the proposed materials have good thermal performance compared to conventional materials, and their integration into the building envelope contributes to significant energy savings as it reduces CO<sub>2</sub> emissions in the building.

### Références

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