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Study of thermal behaviour of clay wall facing south

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Abstract

Sustainable development includes socio-economic and environmental targets and concerns all sectors of human activity. The main reasons for green building are to reduce energy consumption, green house gases emission, water use, waste production etc. The choice of materials used for the construction of a building has a direct impact on the environment. A material with a low life-cycle cost (LCC) and high technical performance reduces the impact of the building on the environment. Cob is a traditional material with a low LCC; its thermal performances are studied here and compared with the thermal performances of stone walls and of insulated concrete block walls. A first type of simulation concerns a wall model with an interior temperature set at 19 °C and a second type of simulation concerns a whole building, the wall model is then coupled with a zone model. Three types of buildings are simulated: a conventional building and two efficient buildings. One of the efficient buildings is a block of flats that is part of the European programme CEPHEUS: Salvatierra. The simulations show that, for south-facing walls, the thermal behaviour of a 50-cm-thick cob wall is about the same as that of insulated concrete blocks wall with 7.5 cm of insulation. With a 5-cm-thick insulation added, the thermal behaviour of a south-facing cob wall is then about the same as that of an insulated dense concrete block wall with 15 cm of insulation. Cob is, thus, a traditional material that can be used in modern constructions.

Keywords: Sustainable building; Clay; Thermal behaviour; Environmental impacts; Thermal inertia; Energy saving

1. Introduction

At the World Summit on Sustainable Development in Johannesburg, 2002, the world's nations reaffirmed their commitment to fostering sustainable development. Sustainability includes both the satisfaction of our present needs and the ability for future generations to satisfy theirs. It includes socio-economic and environmental targets and concerns all sectors of human activity.

Throughout its lifetime (construction, use, dismantling), a building has a direct impact on the environment through resource and energy consumptions. Some obvious reasons for green building are to reduce energy consumption, green house gases emission, water use, waste production etc. The environmental impact of a building depends on the choices made during the different phases of the building's life. The choice of materials used for the construction of the building has a strong environmental impact. As a matter of fact, a material with a low life-cycle cost (LCC) and with high technical performance allows to reduce the building's impact on the environment.

This study concerns a local traditional material: cob. In the first part, we will present the cob material and a review of its environmental qualities.

Then, we will present the numerical models and the computing configurations used for the thermal behaviour study. The first type of simulation concerns a wall model with an interior temperature set at 19 °C. In the second type of simulation, the wall model is coupled with a zone model and the simulation concerns the whole building. Three buildings are simulated: a conventional building and two efficient buildings.

Finally, the interest of cob is evaluated by comparing the results obtained with a cob wall to the results

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Nomenclature

a_E, a_P, a_W	Finite volume coefficients
C	Thermal capacity ($J\,kg^{-1}\,K^{-1}$)
h_{ext}	Exterior global heat transfer coefficient ($W\,m^{-2}\,K^{-1}$)
h_{int}	Interior global heat transfer coefficient ($W\,m^{-2}\,K^{-1}$)
I_s	Incident solar radiation ($W\,m^{-2}$)
N	Frequency (Hz)
n	Normal unit vector to the boundary Γ
t	Time (s)
T	Temperature (°C or K)
T_0	surface temperature of wall (exterior)
T_{amb}	ambient exterior temperature
vol	control volume
α	Thermal diffusivity ($m^2\,s^{-1}$)
α_{sol}	solar absorptivity
Γ	boundary of the control volume
λ	Thermal conductivity ($W\,m^{-1}K^{-1}$)
ρ	Density ($kg\,m^{-3}$)

obtained with other traditional walls (stone walls) and with modern walls (insulated concrete blocks walls).

One of the efficient buildings is a block of flats that is part of the European programme CEPHEUS [1]: Salvatierra [2].

2. Presentation of cob

Cob is a local traditional material of the Rennes basin in Brittany, France. This material is made of raw clay reinforced with animal or vegetal fibres (here, straw fibres) [14]. The cob blocks are also stabilised with a low quantity of cement (between 3% and 5% of clay mass) [3,4].

Traditionally, cob is pressed in situ. Nowadays, manually compacted blocks of cob are prefabricated and naturally dried (stored outdoors, exposed to weather). The blocks are then laid directly onto the wall.

As far as resource consumption is concerned, cob has a low environmental cost:

(i) clay is a locally available resource that is far from being exhausted,
(ii) straw comes from an annual plant, it is a renewable resource,
(iii) cement quantity is insignificant [5],
(iv) cob is a recyclable material,
(v) manufacturing and transport are low-energy consuming (like other local materials [13]).

From a thermal behaviour point of view:

(i) thick cob walls have a high thermal mass. So, they provide a high level of thermal comfort,
(ii) cob has a low thermal conductivity ($0.4\,W\,m^{-1}\,K^{-1}$) compared with concrete (1.5–$2.5\,W\,m^{-1}\,K^{-1}$) and stone (1–$3\,W\,m^{-1}\,K^{-1}$),
(iii) cob is dark and hence has a high solar absorptivity.

The following study aims at verifying that these thermal properties are performant enough to consider that cob is environmentally friendly.

3. Numerical models

3.1. Wall model

The numerical model is based on finite-volume equations.

Patankar [6] integrates the energy conservation equation over a control volume:

$$\int_{\Gamma}\int_{t}^{t+dt} -\lambda\,\overrightarrow{\text{grad}}\,T\,\vec{n}\,dt\,d\Gamma = \int_{\text{vol}}\int_{t}^{t+dt} \rho C \frac{\partial T}{\partial t}\,dt\,d\text{vol}. \quad (1)$$

The temperature distribution is assumed to be linear between nodes (Fig. 1).

In order to integrate the right-side term of Eq. (1), Patankar considers that the temperature is uniform all

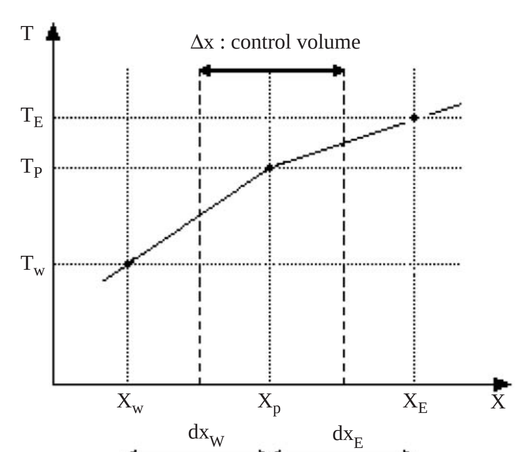

Fig. 1. Temperature distribution.