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Definition of Parameters Useful to Describe Dynamic Thermal Behavior of Hollow Bricks

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Abstract

Dynamic thermal behavior of hollow bricks is attracting much interest nowadays as there is much concern on energy performance of building envelope. In fact, high thermal inertia of outer walls provides mitigation of the daily heat wave, which reduces the cooling peak load and the related energy demand. Different approaches have been used to study dynamic thermal behavior within the papers available on unsteady heat transfer through hollow bricks. Actually, the usually employed methods for calculation of unsteady heat transfer through walls are based on the hypothesis that such walls are composed by homogeneous layers, so they are not suitable for many common building components. In this framework, a study on the dynamic thermal performance of hollow bricks is brought forth in the present paper. A critical review of available data from the literature is provided. Literature data are used to propose a parameter useful to predict dynamic thermal behavior. A finite-volume method is used to solve two-dimensional unsteady thermal fields in some standard bricks with different imposed temperature solicitations, with a numerical code developed by the authors. New results are used to check the effectiveness of the proposed parameters.

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Keywords: building envelope; thermal inertia; hollow brick; block response time;equivalent thermal diffusivity; time-lag

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1. Introduction

The fundamental “Nearly Zero-Energy Building (NZEB)” concept has been introduced by the latest updates in the European directive on energy performance of buildings [1]. Considering that in UE about 40% of total final energy consumption is attributed to civil sector, the analysis of the thermal performance of building, as well as the surroundings in which it is situated, has become a determining factor [2],[3],[4] and [5]. In this frame, a special focus needs to be addressed to building envelopes, especially on the role played by the thermal inertia on the energy requirements for heating and cooling applications.

Available methods to evaluate the attitude of building envelope to reduce the effect of daily heat wave are applicable only to homogeneous layers, as reported in [6] and [7]. Thus, they are not suitable for hollow bricks.

Dynamic thermal performance of walls may be shortly described through time-lag, which is the time that passes before the peak of the outer solicitation passes inside, and decrement factor, that is the reduction in heat flux in comparison to steady state heat transfer. In a previous paper by the authors [8], it has been shown that there is a straight correlation between these two, so the present study will be focused solely on time-lag.

As far as homogeneous multi-layered walls are considered, studies by Assan and Sancaktar [9], Assan [10], and by Lakatos [11] have shown that wall thickness is the main relevant parameter for time-lag of heat wave flux, even though wall composition is much important. These results are congruent with the common assumption that high masses per unit front area of walls lead to high time-lags, as it is linearly proportional to wall thickness.

Time lag of 24 hours long sinusoidal temperature solicitation on hollow bricks is provided in some papers. Sala et al. [12] experimentally studied multilayer walls containing hollow bricks, 40 mm thick, showing a 1.5 hours time lag. Arendt et al. [13] studied by numerical simulations the influence of cavities size on time-lag and decrement factor in a 300 mm thick clay brick. Their results show that time lag was in between 14 hours and 16.7 hours, with a maximum at an intermediate cavity concentration (that is the ratio of cavities volume to full block volume). Zhang et al. [14] experimentally studied heat transfer through a 190 mm thick layer of lightweight aggregate concrete with vertical cavities of two different sizes. They found a 4.4 hours time-lag.

Nomenclature

BRT	Block response time, ratio of the square of block thickness to equivalent thermal diffusivity, [s] or [h]
c_p	specific heat, [J/kg·K]
J	radiosity of the surface, [W/m^2]
k	thermal conductivity, [W/m·K]
L	dimension of integration domain perpendicular to main direction of heat transfer, [m] or [mm] as relevant
M	front mass, [kg/m^2]
q	specific heat transfer rate, [W/m^2]
s	block thickness, i.e. dimension of integration domain along main direction of heat transfer, [m] or [mm]
R	specific thermal resistance, [m^2·K/W]
T	temperature, [K] or [°C]

Greek symbols

α	thermal diffusivity, [m^2/s] or [mm^2/s]
$\Delta\tau$	time-lag, [h]
ε	emissivity, non-dimensional
ρ	density, [kg/m^3]
τ	time, [s] or [h] as relevant

Subscripts

1	hot side of block in steady state
2	cold side of block in steady state
a	referred to air
av	volume averaged value
c	referred to cavity