International Journal of Thermal Sciences 50 (2011) 1543–1553

Contents lists available at ScienceDirect

International Journal of Thermal Sciences

journal homepage: www.elsevier.com/locate/ijts

Numerical analysis by FEM and analytical study of the dynamic thermal behavior of hollow bricks with different cavity concentration

K. Arendt, M. Krzaczek*, J. Florczuk

Gdańsk University of Technology, Faculty of Civil and Environmental Engineering, 80-233 Gdańsk, Narutowicza 11/12, Poland

A R T I C L E I N F O

Article history:
Received 14 October 2010
Received in revised form
27 January 2011
Accepted 28 February 2011
Available online 11 April 2011

Keywords:
Cavity concentration
Thermal performance
Hollow bricks
Heat transfer
FE method
Numerical simulation

A B S T R A C T

This paper presents the investigation results on the influence of the cavity concentration in hollow bricks on static and dynamic thermal parameters: a time lag, a decrement factor, an equivalent thermal diffusivity (ETD) and an equivalent thermal conductivity (ETC). The dynamic thermal behavior of hollow bricks is studied with an optimized cavity shape to reduce the intensity of radiation and convective heat exchange. The thermal performance assessment is based on static and dynamic thermal behavior calculated numerically. A semi-analytical method is proposed to enable calculations of thermal parameters of hollow bricks. The optimum thermal parameters of hollow bricks made from low-thermal-conductivity materials are obtained by ratios of a total cavity area to a gross brick area in the range of 30–45%. As a result, hollow bricks made from materials with relatively high thermal conductivity required a cavity concentration of 45–65% which was impossible to obtain technologically.

1. Introduction

The permanent increase of the total energy consumption in buildings results in a great human pressure on savings of earth natural resources. Since building heating and cooling contributes significantly to the global energy demand, it is crucial to improve the thermal efficiency of building materials and building technologies. At the same time, the total building energy demand reduction should still maintain the thermal comfort.

An increase of the building envelope thermal resistance is a well known method of the reduction of heat losses in buildings. However, in the last years it became apparent that it was impossible to design energy efficient buildings using the U-value as the only thermal criterion. The U-value approach, existing in many national building codes (including the Polish ones), neglects the dynamic thermal behavior of structure components, since the U-value is related to a simplified 1D steady-state heat transfer model only. This simplification leads to significant energy demand miscalculations, since the thermal inertia of building components has a profound impact on heating and cooling loads in buildings [1–3]. The effect of the thermal mass on the building energy demand depends not only on the envelope structure but also on the outdoor and indoor climate conditions [4] which cannot be neglected. Aste et al. [5] studied the influence of the thermal inertia of external walls on the energy performance in climatic conditions of Northern Italy. The authors estimated that the difference in heating demands between high and low thermal inertia walls was about 10%. However, when considering cooling demands, the difference increased up to 20%. Kossecka and Kosny [4] reported that the difference in total (heating and cooling) loads between the least and most effective walls ranged between 2.3% and 11.3% depending upon the climate. It showed that the favorable effect of the thermal mass was more pronounced in the case of large solar gains and diurnal temperature differences. Kontoleon and Bikas [6] stated that the determination of thermal inertia factors was crucial in designing of passive zones in climate zones having considerable diurnal temperature fluctuations and daily averaged outdoor temperatures close to a thermal comfort range. This conclusion was valid especially in regions with the hot and dry climate, in which buildings were prone to overheating phenomena.

One of the most effective approaches to the energy management in buildings, taking advantage of the high thermal inertia of structural components, is the idea of passive heating and cooling (called also passive solar design) [7]. The passive technologies store the solar energy mainly in external walls during a day to gradually release it overnight. In some passive solutions, the storing capabilities of external walls are coupled with an air heating function,

* Corresponding author. Tel.: +48 58 348 63 40; fax: +48 58 347 26 96.
E-mail addresses: krzysztof.arendt@pg.gda.pl (K. Arendt), marek.krzaczek@wilis.pg.gda.pl (M. Krzaczek), jaroslaw.florczuk@pg.gda.pl (J. Florczuk).

1290-0729/$ – see front matter
doi:10.1016/j.ijthermalsci.2011.02.027