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The effect of temperature on thermal performance of fumed silica based Vacuum Insulation Panels for buildings

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Abstract

Vacuum Insulation Panels are characterized by very low thermal conductivity, which makes them alluring for building and civil sectors. However, considering the structure and composition of these materials, their application in buildings may be defined by a number of issues which need to be properly taken into account. The real performance of VIPs can be influenced by the boundary conditions (e.g. temperature) at which they work during their operation. In this paper experimental analyses aimed at characterising the relationship between the centre of panel thermal conductivity and average temperature were carried out. The experiments were performed on two VIP samples with different thickness. Moreover a comparison with non-evacuated panels and a traditional insulating material was performed.

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Keywords: Vacuum Insulation Panels; fumed silica pressed board, thermal conductivity; temperatures; guarded heat-flux meter.

1. Introduction

In the last years Vacuum Insulation Panels (VIPs) are gaining relevant interest in the building sector and, in particular, in the energy efficient refurbishment of buildings, where space saving is becoming an important aspect to be considered in the selection of insulating materials.

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Vacuum Insulation Panels (VIPs) are generally composed by silica powder, a core material of polyurthane foams or glass/mineral fibres, and a sealed barrier envelope in which a certain vacuum degree (generally between 0.1 and 10 mbar) is created.

The heat transfer mechanism in porous media (such as the VIPs core) is generally described in the literature [1,2,3,4] as the sum of the contribution of the solid thermal conductivity (λ_s), the radiative thermal conductivity (λ_r), the gaseous thermal conductivity (λ_g) and the coupling effect (λ_{cpl}), as shown in Eq.1:

$$\lambda_{tot} = \lambda_s + \lambda_r + \lambda_g \left(+ \lambda_{cpl} \right) \tag{1}$$

The basic principle of VIPs technology is to evacuate the core material to reach pressure values low enough to obtain Knudsten number $Kn \geq 1$ (the Knudsten number is calculated as the ratio of the mean free path of the gas molecule and the characteristic size of the porous media). In this way the gaseous thermal conductivity (λ_g) can be neglected and the resulting total thermal conductivity mainly depends on the contribution of the solid conduction and the infra-red radiation in the pores.

The application of VIPs in the building sector may be characterised by a series of issues which need to be properly faced and analysed in order to investigate their impact and to find potential solutions. In particular, the evaluation of the actual thermal performance of VIPs, when they are used in real building applications, could be very different from the performance measured in laboratory in terms of centre of panel thermal conductivity.

The following two main phenomena influencing the performance of VIPs have been investigated in literature in the last few years: i) the thermal bridging effect determined by the relatively higher thermal conductivity of envelope and/or materials used to couple the panels, and ii) the ageing effect.

The thermal bridging effect in VIPs was widely discussed in literature at both material/component level [5,6,7] and building level [8,9,10,11].

The service life of VIPs when they work in real building applications remains a key issue to face. The ageing mechanism could produce a rapid decay of total thermal conductivity due to the increase in pressure and moisture content inside the panel over time [12,13]. Several works were focused on the prediction of VIPs service life, and on the development of linear model for the determination of the increase in moisture content [14].

A further aspect to be properly investigated is the effect of relatively high temperatures on the actual thermal performance of panels. VIPs can reach high temperatures when they are exposed to the external environment (e.g. in sun-exposed façade VIPs could work at temperatures also higher than 60°C). Temperatures in the range 30 – 60°C (typical in building applications) could negatively affect the thermal conductivity of VIPs and this phenomenon needs to be further investigated through experimental analyses. Moreover, it can be observed that at constant pressure the main factor which determines an increase of the total thermal conductivity is assumed to be the radiative contribution [15].

In this paper, results of numerical simulations and experimental campaigns conducted by means of a Guarded Heat Flux Meter apparatus (GHFM) on fumed silica based VIPs are presented. The objective of this research activity is to experimentally demonstrate that, also in the typical range of values in building applications, the centre of panel thermal conductivity of fumed silica VIP is influenced by the boundary temperature at which it can work [16]. For this purpose, a preliminary numerical analysis was conducted to find the area of influence of the edge and lateral thermal losses effects for the analysed VIPs. This kind of analysis is useful to verify that a correct measurement of centre of panel thermal conductivity can be performed considering exclusively the centre of panel area. After that, a set of measurements of centre of panel thermal conductivity of different VIPs were carried out, considering different temperatures of hot and cold plates of GHFM while maintaining the same temperature difference. Moreover, the same analysis was conducted for non-evacuated insulating materials (fumed silica pressed board and extruded polystyrene – XPS) in order to investigate the different thermal behaviour of thermal conductivity as a function of average temperature.