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Vacuum Insulation Panels: thermal bridging effects and energy performance in real building applications

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Abstract

Due to their very low thermal conductivity, Vacuum Insulation Panels (VIPs) have recently seen a fast development and an increasing penetration in building thermal insulation market.
However, there is still a lack of knowledge about their performance when actually applied in buildings. In fact, the thermal bridging effects that occur in VIP junctions are not easily evaluable while produce a reduction of the global thermal performance.
In this paper, the linear thermal transmittances related to VIP junctions considering different joint materials between VIPs panels and different wall configurations were assessed through a 2D numerical analysis. Finally, through a quasi-steady state simulation, a parametric building case study was analysed, with the aim to evaluate the influence of the thermal bridging effects on the overall building energy need.
The results shows that the thermal bridging effect due to VIPs assemblies have not a negligible influence on the overall building energy performance.

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Keywords: Vacuum Insulation Panels; Simulation; Thermal bridge; Joint; Building energy performance; Building application.

1. Introduction

Acting on the existing building stock is a mandatory strategy to reduce the energy consumption at the global scale, firstly because about 40% of the overall energy consumption can be attributed to buildings [1], secondly because many of these buildings are more than 20 years old (70-90% in the EU) [2].

Super insulation materials can give a solution to this issue, since their thermal conductivity is 5-10 times lower

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than traditional insulation materials, allowing to refurbish existing building envelope with small insulation thickness increments [3]. In recent year, Vacuum Insulation Panels were studied by several researchers. VIPs technology is still poorly adopted, despite many positive aspects, because of the high costs, short durability (with respect of the building life) and lack of knowledge about thermal behaviour in real building applications (especially for the thermal bridging effects [4], [5]).

Nomenclature

λ	Thermal conductivity	[W/mK]
λ_{eq}	Equivalent thermal conductivity of VIP assembly	[W/mK]
λ_{fict}	Fictitious thermal conductivity	[W/mK]
λ_{COP}	VIP Centre Of Panel thermal conductivity	[W/mK]
λ_{pro}	VIP thermal conductivity declared by producers	[W/mK]
R_i	Thermal resistance of inner bounding layers	[m^2K/W]
R_e	Thermal resistance of outer bounding layers	[m^2K/W]
R_i+R_e	Total thermal resistance of the bounding layers	[m^2K/W]
ψ	Linear thermal transmittance due to thermal bridge	[W/mK]
l	Thermal bridge length	[m]
A	Panel area	[m^2]
P	Panel semi-perimeter	[m]
d	Layer thickness	[m]
$\dot{Q}$	Heat flow	[W]
θ_{up}	Higher set point temperature	[K]
θ_{low}	Lower set point temperature	[K]
$\Delta\theta$	Difference between higher and lower set point temperature	[K]
S	Non adiabatic walls surface	[m^2]
V	Single room apartment volume	[m^3]
S/V	Aspect ratio	[m^{-1}]

1.1. State of the art and aims

Kalnæs and Jelle [6] state that *“VIP consists of a porous core enveloped by an air and vapour tight barrier which is heat sealed”.* Many studies were carried out on VIPs, particularly on its main components, which mainly consist on core material [7] and envelope [8]. These studies were focused on the increasing of thermal conductivity for vacuum loss (due to gas permeation over time) and damaging risk (e.g. puncturing).

Other studies were focused on the thermal bridging effects related to the envelope materials [9], the air gaps or structural joints between the panels and the VIPs assemblies at building scale. A universal conclusion from these researches demonstrate the crucial importance to properly consider the thermal bridging effects in order to correctly assess VIPs thermal performance. The higher the thermal resistance of the insulation layer, the greater is the importance of thermal bridging effects. Even if many studies on this issue were carried out, few investigations were done on thermal bridging effects at the building scale, considering the VIP panels coupled with other materials and inserted in a multi-layered wall [4], [5].

In this paper, thermal bridging effects of VIP panels coupled with a number of different joint materials were assessed, also taking into account several multilayer wall configurations.

In the study, the thermal conductivities of VIP panels and the structural joint materials were first evaluated through an experimental campaign (in accordance with [13]). Then, the linear thermal transmittance and the equivalent thermal conductivity of each configuration was assessed through a 2D numerical analysis (in accordance with [12]). Finally, in order to evaluate the influence of the thermal bridging effect on the heating energy need of a building archetype, a case study was considered and a quasi-steady state simulation was performed according to EN