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The impact of workmanship on the thermal performance of cavity walls with rigid insulation boards: where are we today?

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Abstract

Even small air paths around the insulation layer in cavity walls may result in a significant reduction of its thermal resistance. This topic of air flow patterns bypassing the insulation layer has been studied in detail from the '80s and '90s on and let to clear recommendations for building practice [1]. However, the question remains to which extend the proposed research results of that time are adopted in today's building practice and if so, to which extent they are still valid for current building techniques. The overall aim of the present article is to gain insights into the current installation quality of the insulation layer in cavity walls in Belgium. Moreover, the present article targets to quantify at the same time the impact of workmanship inaccuracies on the thermal performance of these building elements.
In a first step the current building practice is mapped in relation to the installation quality of rigid insulation panels in cavity walls in Belgium. A high number of building construction sites has been visited and the installation methods and accuracy are documented. The outcome of this work provides an overview of the configuration of typical air leakage paths in and around the rigid insulation boards in cavity walls for today's building practice.
In the second step of the research, the air flow resistances of the observed air flow paths (e.g. air gap between inner leaf and insulation board, tongue and groove connection of the insulation boards,…) have been measured in laboratory conditions. The characterization of these air flow resistances allows modelling the thermal behaviour of these elements in a following step. Numerical simulations, taking both heat and air transport into account, have been conducted to assess the performance of today's levels of workmanship. Based on this numerical parameter study, recommendations are proposed to obtain optimal thermal performance in cavity walls.

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Keywords: cavity wall; rigid insulation; air flow resistance; thermal performance; laboratory; numerical

1. Introduction and problem statement

Masonry cavity walls are the favored building method in Belgium, Denmark, The Netherlands and United Kingdom for several decades. Cavity walls were historically designed as a solution to avoid rain penetration in these windy wet

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regions. The rain tightness in these walls is based on separating two screens with an air cavity: 1) the outer leaf acts as a water buffer, 2) the air cavity works as a capillary break and drainage plane and 3) the inner screen takes up the function of air barrier. After the first energy crisis of 1973 cavity walls were provided with insulation panels. These panels – with a typical thickness of 5 to 8cm - were attached at the cold side of the inner masonry leaf. Theoretical U-values of around 0.4 W/m²/K were common for that time. Soon after, however, research on the performance analysis of these building components illustrated that the thermal performance of especially rigid board insulated cavity walls were highly depending on the installation quality of the insulation layer. From the late '80s onwards several researchers have been investigating the influence of air flow patterns bypassing the insulation layer in case of poor workmanship [2],[3],[4]. For example, Lecompte [1] proved with laboratory work that an air layer of 10mm between insulation and inner leaf can almost double the heat transport through this element by natural convection. Field measurements in Belgium by Hens. et al. [5] document that the U-value of a cavity wall in which the rigid insulation panel is poorly installed may increase up to three or four times the design value. Unfortunately, however, the authors only make a distinction between "good installation" and "poor installation" and did not document the actual geometry of the air paths around the rigid insulation board of the cavity wall tested.
In addition to these field and laboratory measurements also a few authors applied numerical simulation to investigate the impact of air flow on the thermal performance of cavity walls [3],[1]. These models apply hydraulic network simplifications for building components for which the coupled heat and air transport equations are solved. The simulation results found in [2] are in line with the measured values documented in [1] and [5]. The simulation results indicate that small air channels with a width of 2mm can even decrease the thermal performance by 10 to 50% for a temperature difference of 20°C across a cavity wall with a rigid insulation panel of 5cm.
Based on numerical and laboratory investigations Lecompte emphases in [2] that air looping and wind washing behind the insulation layer should be avoided by all means in cavity walls. He proposes to apply rigid boards with a soft backside to realise a perfect connection with the inside leaf or, alternatively glue the rigid insulation boards against the leaf. Other measures proposed by Lecompte [2] are sealing the cavity or sealing all joints (see Fig. 1).

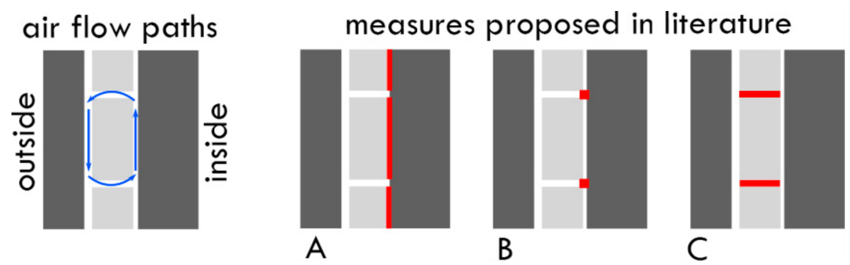

Fig. 1. Left) air flow bypassing insulation layer and right) measures proposed by Lecompte [2] : A) avoid cavity by applying soft insulation material or glue between rigid board and masonry, B) seal cavity, C) seal all joints.

The research results on the thermal performance of cavity walls with rigid insulation panels are straightforward; avoid air paths by all time. Measures to avoid these air flow paths are summarized in Fig. 1. However, the main research questions of the present paper are 1) to which extend these recommendations are adopted in today's building practice, 2) to which extent these previous recommendations are still valid in the light of the current building practice, and 3) which thermal performance levels are reached in the current building practice. The major overall objective of the present paper is to gain information on the impact of air flows on the thermal performance of the cavity walls in today's building practice and provide adjusted recommendations if needed. This is done by combining a survey of building sites with laboratory measurements and numerical simulation.

2. Field investigations: mapping current state of workmanship

A campaign with building site visits was organized in the period 2012-2016 to gain insights in the installation quality levels currently reached in practice. The results are documented in three consecutive master thesis projects at the Building Physics Section of the KU Leuven [6], [7] and [8]. First, 60 building sites of 55 different contractors have been qualitatively studied by Saelen [6]. The aim of the work was to give a global idea of the installation quality and