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Modelling cavity ventilation behind brick veneer cladding: how reliable are the common assumptions?

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Abstract

Throughout the years, different numerical HAM-simulation tools have been developed to assess and predict the heat, air and moisture response of building components. But, though commercially available and commonly applied in building practice, still, several simplifications and shortcomings exist in the common models. Probably the most important one, is the fact that most tools neglect or strongly simplify air transport, focusing only on heat and moisture transport. Especially for the analysis of wood frame constructions, these simplified models may cause a large discrepancy between simulation results and real performance. This study aims at a comparison of the outcomes of numerical HAM-simulations for wood frame constructions with experimental data of real test cases. In particular, the focus of this paper is on cavity ventilation behind brick veneer. Therefore, a simplified version of a wood frame wall with brick veneer cladding is studied in this paper. Different common modelling assumptions are compared. Furthermore, a detailed measuring campaign has been conducted at the VLIET test building of the KU Leuven to validate the different modelling approaches. By verifying the results of the numerical simulations by the data of real test cases, the reliability of the modelling assumptions can be analysed. The results of this study clearly show that simplified assumptions on cavity ventilation in HAM-models might cause large discrepancies between simulation results and in-situ measurements.

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Keywords: cavity ventilation, HAM-simulation, brick veneer, wood frame constructions

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1. Introduction

Due to the increasingly stringent energy efficiency requirements, wood frame houses – often as passive or low-energy houses – become more and more popular across Europe. However, compared to countries with a wood frame tradition, in other countries the wood frame building components might be exposed to different climatic conditions and moreover, often different compositions of the wall are used. For example in Belgium wood frame construction is typically finished with brick veneer cladding. Such cladding systems have a high buffer capacity for wind driven rain but are only poorly ventilated compared to siding or rendered systems. The type of cladding may have an important impact on the hygrothermal performance, and thus the risk of early failing by mould growth and wood rot. Consequently, various researchers have investigated cavity ventilation in building enclosures. Yet the results of these studies are not always conclusive and are sometimes even contradictive. For example, while North American studies [e.g.1] emphasized the necessity of cavity ventilation, European studies questioned its effectiveness to remove moisture [e.g. 2,3]. Künzel [4] attributed this contradiction to differences in the applied materials. Traditional masonry cavity walls in Europe are less vulnerable to high moisture contents compared to timber frame buildings in North America. As a consequence, Künzel [4] stated –based on numerical simulations- that cavity ventilation is less important in masonry building envelopes compared to timber frame construction.

These contradictive findings in the international literature are in addition likewise caused by the physical complexity of cavity ventilation, and thus, the difficulty to implement cavity ventilation in a correct way in HAM-simulations. Large deviations in the assumed air change rates can be noticed between different numerical studies. For example, while the numerical study of Burch & Tenwolde [5] applied only a constant air change rate of 6 ACH, Künzel et al. [4] used a ventilation rate of 50 ACH and Salonvaara et al. [6] varied the ventilation rate between 1.5-150 ACH. On the other hand, field tests reported mean air change rates between 144 – 576 ACH in the cavity ventilation of a North facing test wall for wind speed of 0.69-2.12 m/s [7]. Also, CFD investigations documented higher values (500-1500 ACH) for wind speeds of 0-8m/s [7].

To simplify the problem, several model assumptions can be found in the international literature to account for cavity ventilation in HAM-simulations. These methods range from: (1) the omission of ventilation effects [8], (2) effective cladding diffusion permeance [9,10], (3) the removal of the cladding system [11], (4) the application of constant air change rate [4,12] and (5) simplified coupled implementations [14]. The simplicity of the proposed methods may result in large uncertainties on the final results.

The aim of the present paper is to evaluate the reliability of the common assumptions when modelling cavity ventilation. Therefore, the outcomes of numerical HAM-simulations for wood frame constructions with brick veneer cladding will be compared with experimental data of real test cases.

2. Methodology

In the VLIET-test building in Leuven (Belgium) [15,16], in-situ measurements on ventilation behind a typical brick veneer cladding have been conducted. The configuration of the wall is shown in Figure 1. The width of the brick veneer is 9 cm. Instead of a real wood frame wall, a simplified version of the inner structure, composed of an extruded polystyrene panel with a thickness of 12 cm is applied as a thermal, vapour and airtight break at the inside. The cavity depth is 4 cm. The top and the bottom of the brick veneer cladding are provided with two open head joints. The size of each open head joint is 3.5x1.5x9 cm³. More information on the set-up can be found in [17]. The wall is equipped with a grid of sensors to measure temperature, relative humidity and air pressure differential, as shown in Figure 1.

The same wall configuration is modelled in the simulation program Delphin [18] for a period between February 21th until March 31th in 2014. Two different modelling strategies to incorporate cavity ventilation are applied. First, a 1D model is constructed, without considering air flow in the cavity. Subsequently, a 2D simulation model with a constant ventilation rate in the cavity is studied.

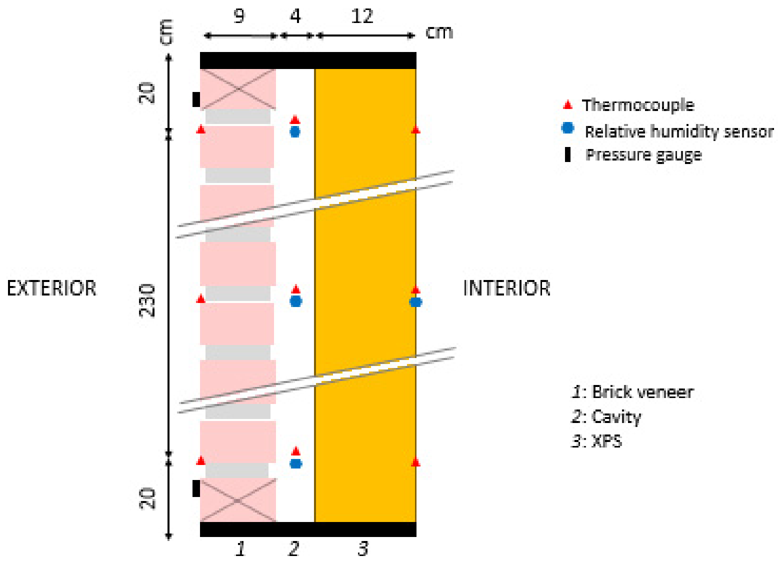

Figure 1: Configuration of the wood frame wall with brick veneer cladding

The exterior surface temperature measured at mid-height of the wall in the VLIET-test building and the exterior vapour pressure (measured by a weather station on site) are imposed on the simulation model as exterior boundary conditions. The interior surface temperature and relative humidity measured at mid-height are imposed on the simulation model as interior boundary conditions. In this paper, only a northeast oriented wall is considered. Since northeast oriented façades hardly receive any sun or rain in Belgium, direct solar radiation and wind-driven rain is not taken into account in the simulation models.

The following sections will discuss the two different modelling strategies of cavity ventilation applied in this study.

2.1. One-dimensional simulation model

In this strategy no cavity ventilation effects are taken into account. An equivalent heat conductivity is considered in the air layer of the one-dimensional simulation model. According to [19], the thermal resistance of the cavity is set to 0.18 m²K/W. Hence, the equivalent heat conductivity implemented in Delphin equals 0.22 W/mK. The water vapour diffusion resistance factor of the air in the cavity is set to 1.

2.2. Two-dimensional simulation model with a constant ventilation rate in the cavity

In the two-dimensional simulation model cavity ventilation air flow is treated as a fully developed laminar flow. As a consequence a linear relation between the pressure drop and the air flow is assumed within the cavity. The open head joints are taken into account in the simulations by increasing the air permeability of the top and bottom row of the control volumes in the outer leaf of the Delphin model. By adjusting the pressure difference between the top and bottom of the outer leaf the simulations were repeated for 5 different constant air change rates (0 ACH, 1 ACH, 10 ACH, 20 ACH, 100ACH). The heat transfer coefficient respectively the vapour transfer coefficient inside the cavity is set to 2 W/m²K and 2 s/m, according to [13].

3. Results

The in-situ measured conditions at the top and bottom of the cavity are compared to the outcomes of the numerical HAM-simulations according to the two different models. The period of March 17th until March 25th in 2014 is studied.

3.1. One-dimensional simulation model

In Figure 2, the temperature and vapour pressure in the cavity obtained by the 1D simulation are compared with the in-situ measurements and the outside conditions. The temperatures resulting from the simulation are a good approximation of the reality. Most of the time, the error made is around 0.5°C and 1°C, compared to the bottom and

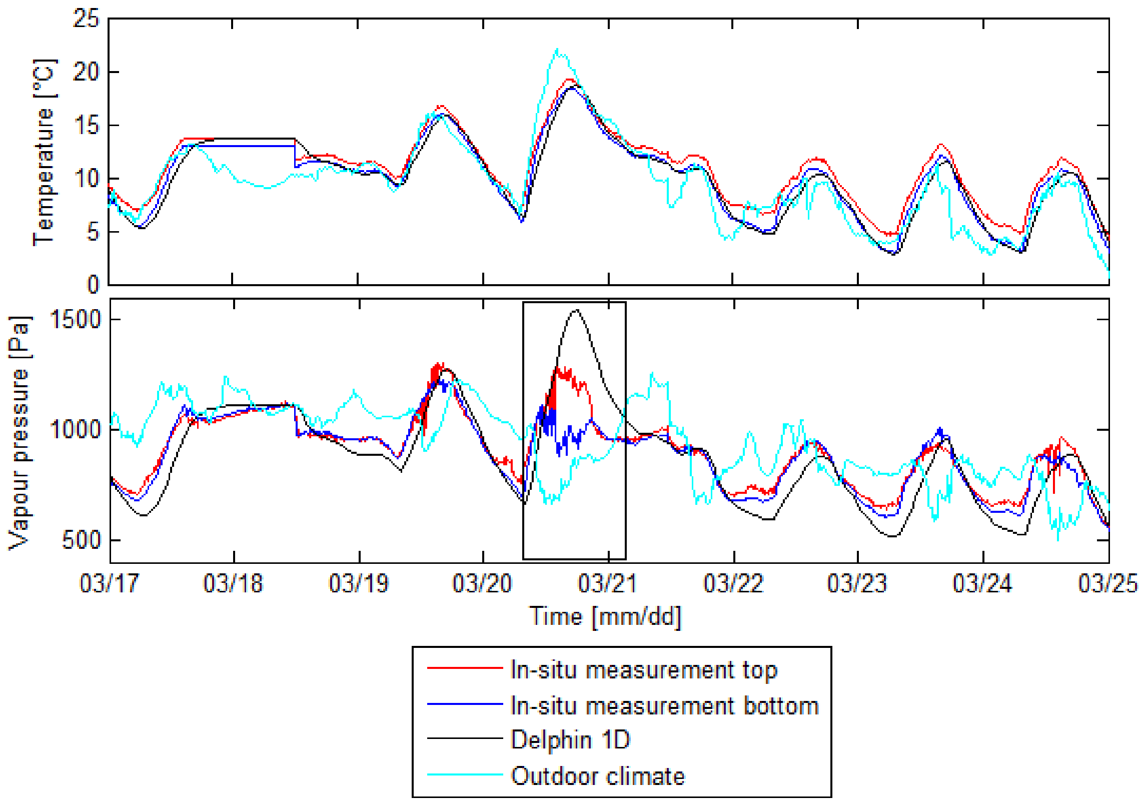

Figure 2: 1D simulation results compared to in-situ measurements

top temperature respectively. On the other hand, the simulated vapour pressure follows the same trend as the in-situ measured vapour pressure. Though, at some moments large discrepancies occur, as designated by the black square in Figure 2. At that moment, there is a relatively large difference between the vapour pressure measured at the top and the bottom of the cavity, which can be explained by a significant air flow in the cavity.

3.2. Two-dimensional simulation model with a constant ventilation rate in the cavity

In Figure 3 the temperatures and the vapour pressures in the cavity obtained by the 2D simulation are compared with the in-situ measurements and the outside conditions.

The temperatures resulting from the simulation are again a good approximation of the reality.

Different ventilation rates give significant differences in vapour pressure. The outcomes of simulations with low ventilation rates are comparable with the outcomes of the 1D simulation, as can be expected. At the moment when larger differences are observed for the vapour pressure at the top and the bottom of the cavity, the simulation results assuming an ACH of 50 and 100 perform much better than the 1D simulation results. Though, at the other moments, the agreement between the results of the 1D simulation model and of the 2D simulation models which take into account a low ACH is much better than the agreement with the results of the 2D simulation models with high ACH. These results indicate that there is a clear need for a simulation model which takes into account a variable ventilation rate in the cavity.

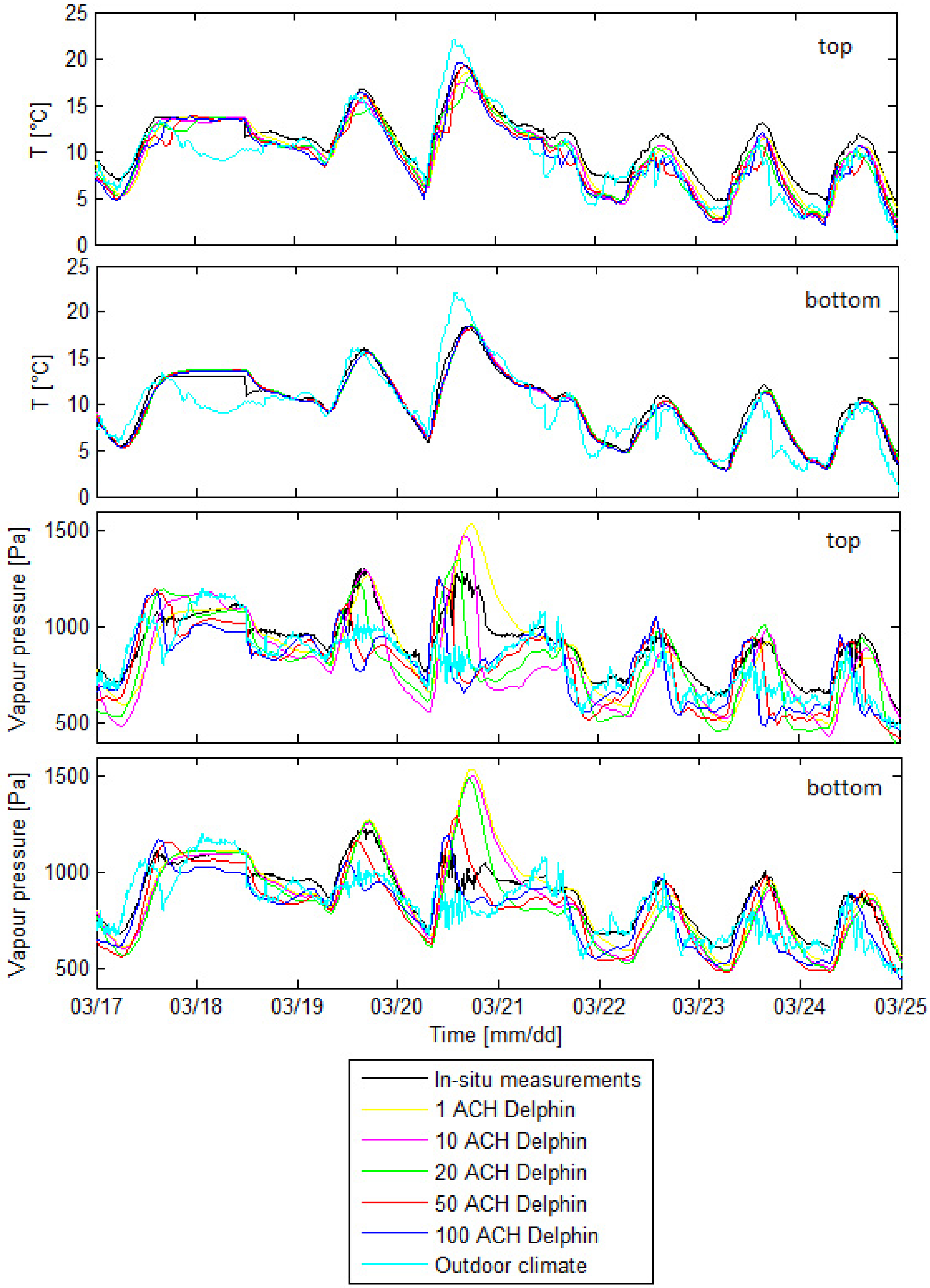

Figure 3: 2D simulation results compared to in-situ measurements at the top and bottom of the cavity (constant ventilation rate)

4. Discussion and conclusions

In this paper, a northeast oriented wood frame wall with cavity ventilation behind brick veneer is modelled and simulated in the Delphin software. Both, a 1D model as well as a 2D model with constant ventilation rate are studied. The conditions in the cavity of the wall resulting from these simulations are compared with real test cases in the VLIET-test building in Leuven.

Regarding temperatures, all models more or less approximate the real situation well. However, when comparing vapour pressure in the cavity, more significant differences between the results of the different simulation models are observed. Firstly, overall the outcome of the 1D simulation –without cavity ventilation– does agree rather well with the in-situ measurements, though at some moments large discrepancies occur. The 2D simulation model considers multiple constant ventilation rates of the cavity. The outcomes of these simulations show that at some moments the conditions in the cavity are better predicted by taking into account a high ACH, however, at other moments the simulation results according to low ACH or even the 1D simulation results are much closer to the real conditions in the cavity.

This comparison between in-situ measurements and simulation results shows that at this moment, the simplifications and assumptions made in the simulation models are not reliable to predict the actual moisture conditions in the cavity. Therefore, there is a need for an in-depth simulation model taking into account a variable ventilation rate in the cavity.

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