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Field study on the air change rate behind residential rainscreen cladding systems: A parameter analysis

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ABSTRACT

The article at hand presents the results of an extensive field study in which the air change rate behind rainscreen claddings has been measured. In total eight different full-scale test walls have been tested. The main parameter variations are: 1) the cladding system (brick veneer and sidings), 2) orientation (South-West and North-East) and 3) area of ventilation openings. To increase the reliablity of the results four measuring techniques to determine the air change rate have been applied. The accuray and applicability of these methods have been discussed in a previous paper. The current article focusses on the impact of the three abovementioned parameter variations on the overall air change rate. Moreover their effect on the hygrothermal conditions in the cavities will be outlined.

The results show that the cavity ventilation for brick veneer (1–10 ACH) is two order of magnitude lower than behind sidings (100–1000 ACH). This difference also reflects on the drying potential of both systems. The vapour content behind the sidings follows closely the outer climate. In contrast the vapour pressure behind brick veneer can be significantly higher than the outer climate which is induced by its moisture buffer capacity and its low ventilation rate.

1. Introduction

Ventilated wall claddings are widely applied to protect the building envelope from rain water ingression [1].

Rainscreen cladding serves as a drainage layer and a capillary break between the outer climate and the inner structural elements. In addition, cavity ventilation behind the cladding system promotes the evacuation of trapped moisture by means of convection. In contrast to the straightforward process of gravity-driven drainage of rain water to avoid water penetration, the convective removal of moisture is a complex process influenced by many parameters (e.g. ventilation rate, the material properties of the system, the indoor and climate conditions and the configuration of the cavity). A number of experimental studies have been investigating cavity ventilation behind rainscreen cladding for specific configurations. For example, a Danish study by Gudum [2] applied a tracergas technique based on the injection of nitrous oxide to study the ventilation rate behind a plexiglass cladding layer. A similar method, but based on carbon dioxide tracer gas, has been used in New-Zealand by Basset and McNeil [3] to study the ventilation rate behind brick veneer. TenWolde et al. [4], on the other hand, established a methodology to determine the ventilation rate based on the measured air pressure differences across the rainscreen cladding. In addition, several scholars measured cavity ventilation by using anemometry methods [e.g. 2,5]. A thorough study on cavity ventilation behind rendered cladding panels with anemometry is documented by Falk and Sandin [5]. The air change rate in their experiment was studied with an omnidirectional anemometer in the middle of the cavity. Falk and Sandin described that the air flow direction in these cavities changes with a high frequency induced by unstable wind pressures. These changing flow conditions could not be quantified with the applied omnidirectional anemometer. As a remedy theses authors developed a method to compensate for these changing flow conditions in the calculation of the air change rate. Their method is based on calibration periods with known flow direction in the cavity (periods with low wind velocities and high levels of solar radiations resulting in upward flow). Also Labat et al. [6] applied anemometry to measure the ventilation rate behind a wooden cladding. Their focus was however limited to solar dominated periods avoiding the difficulties of changing air flow direction related to dynamic wind

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Nomenclature

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ACH	Air change rate (1/h)
C_p	Pressure coefficient (−)
I	Irradiance (W/m²)
n	Flow exponent (−)
h	Height (m)
Q	Air flow rate (m³/s)
T	Temperature (K)
U	Velocity (m/s)
P	Pressure (Pa)
RH	Relative humidity (%)

Abbreviations

OHJ	Open head joint
HAM	Heat, Air and Moisture
SW	South West
NE	North East

Subscripts

av	average (in time)
b	buoyancy
ex	exterior
hor	horizontal
c	cavity
m	average (in space)
out	outdoor
v	vapour

effects. Sandin [7] measured - in addition to the electronic measuring techniques – the air change rate with smoke visualisation on brick veneer cladding. Though this method revealed interesting insights in the air flow pattern behind brick veneer, it was difficult to derive accurate air change rate levels for this type of cladding system.

The above documented field measurements correspond to a wide range of methods to determine cavity ventilation levels. However, only few of these works verified the accuracy and applicability of the proposed techniques. Moreover, the tests have been conducted for a wide range of cladding systems and materials impeding a straightforward comparison between the different documented methods.

In addition to the remaining questions regarding the effectiveness of cavity ventilation, its implementation in building component HAM-models remains a topic of debate. Today several cavity ventilation models are implemented in HAM-tools ranging from 1) the omission of ventilation effects [8], 2) effective cladding diffusion permeance [9,10], 3) neglecting the cladding system [11], 4) the application of a constant air change rate [12,13], 5) simplified coupled implementations [14] and 6) fully-coupled models [15]. Yet the impact of these ventilation models on the obtained outcome – which can be large – is hardly validated with experimental data.

In order to study the impact of cladding design decisions on its ventilation rate and subsequent its hygrothermal consequences, a full scale test setup has been built in Leuven, Belgium. In total eight test walls have been constructed. The walls are applied to investigate the accuracy of the existing measuring methods and to verify the impact of several design options on the overall cavity ventilation and hygrothermal conditions. In a previous article the accuracy and applicability of the applied experimental measuring techniques are documented for *in-situ* test walls with brick veneer and sidings systems [16]. The results illustrated that the methods based on pressure differential and anemometry have the widest applicability and highest accuracy. This study further revealed that for low ventilation rates (<10 ACH) the anemometer measurements were biased by local buoyancy effects induced by thermal bridging effects of the sensors. As a consequence the study advises to apply the method based on measuring the pressure differential instead of anemometry for cladding with low ventilation rate such as brick veneer. For wall cladding with higher ventilation rates, such as sidings or (rendered) façade panels both methods perform equally.

The aim of the present work is to study the impact of the cladding configuration on its overall air change rate. The test setup applied in Ref. [16] has been used here to investigate the influence of following parameters:

- Cladding system: brick veneer and fibre cement sidings
- Orientation
- Ventilation openings

Moreover the present work documents the hygrothermal conditions in the cavity for the different configurations.

First, the experimental test-setup will be briefly outlined focussing on the measuring techniques applied in the present paper. Second, the theoretical driven potentials for cavity ventilation will be discussed and verified with the measured data. Thereafter the impact of the three design parameters on the overall cavity ventilation rate will be examined. In addition the influence of these parameters on the hygrothermal conditions within the cavity will be discussed in the final section of this paper. This will result in recommendations to include cavity ventilation in building component HAM-models.

2. Experimental test-setup and measuring methods

2.1. Global test wall configuration

Field measurements on cavity ventilation are performed at the VLIET-test building of KU Leuven, Belgium. This test building has measuring sections, oriented to the Northeast and the Southwest. In Belgium, Southwest is the direction of prevailing winds, wind-driven rains and solar irradiation. Northeast oriented façades, on the other hand, hardly receive any sun or rain. The building is equipped with a weather station positioned at the ridge of the sloped roofs module and a weather station in the nearby open field. Both stations register the outside climate conditions on a minutely basis (humidity, temperature, wind direction and speed, global solar irradiation, horizontal rainfall). More information on the building's geometry, location and orientation can be found in Refs. [17,18].

Eight individual walls have been studied in this test building. Fig. 1 illustrates the configuration of the test walls which are installed on both the North East oriented and South West oriented test bays of the building. For both orientations two separated walls are finished with brick veneer cladding and two are executed with fibre cement sidings. The test walls have a height of 2.7 m and a width of 0.9 m. For all the test walls a cavity depth of 4 cm was applied. In walls A, brick veneer with a thickness of 9 cm is used in which a grid system is provided at the bottom and top allowing to change the number of open head joints. The number of open head joints in this system could be varied from 0 to 30 openings per metre with the configuration of each opening being