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Mundt Petersen, Solof; Harderup, Lars-Erik

Published in:
Proceedings of the 9th Nordic Symposium on Building Physics - NSB 2011

2011

Link to publication

Citation for published version (APA):
Mundt Petersen, S., & Harderup, L.-E. (2011). Comparison of measured and calculated temperature and relative humidity with varied and constant air flow in the facade air gap. In J. Vinha, J. Piironen, & K. Salminen (Eds.), *Proceedings of the 9th Nordic Symposium on Building Physics - NSB 2011* (Vol. 1, pp. 147-154). Tampere University of Technology.

Total number of authors:
2

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LUND UNIVERSITY

PO Box 117
221 00 Lund
+46 46-222 00 00

Comparison of measured and calculated temperature and relative humidity with varied and constant air flow in the façade air gap

S. Olof Hägerstedt, M.Sc. [1]
Lars-Erik Harderup, Ph.D. [1]

[1] Lund University, Building Physics, Sweden

KEYWORDS: *Comparison, measurements, moisture, WUFI 5.0, calculations mould*

SUMMARY:
Calculation of relative humidity and temperature in an early stage of the design process is important to avoid moisture damages in wooden walls. Previous studies show that a sufficient air flow in the air gap behind the façade panel is important to ensure a moisture safe construction. This study investigates if blind WUFI 5.0 calculations with a varied air flow in the air gap behind the façade give a better correlation to measured values compared to calculations with a constant air flow. Calculations for two cases are compared to measured values in single family house. The results show that calculations with a wind dependent air flow does not necessary give better correlation to measured values compared to calculations with a constant air flow. However, the calculated values are confirmed with measured values during the warm period and there are deviations in the outer part of the wall during the cold period. Variations in measured values at the same depth in different places in the studied wall are larger compared to differences between calculated values with or without a wind dependent air flow in the façade air gap.

1. Introduction

1.1 Background

Higher demands for more energy efficient buildings in Sweden has led to more thickly insulated houses (BBR 16 2008). Thicker insulation can increase the risk of moisture and mould damage in the outer part of wood walls when organic material becomes more exposed to high levels of relative humidity. The regulations also require that the critical parts of the construction with respect to moisture should be investigated and modified during the design phase (BBR 16 2008). In order to handle this, there is a great need of validated calculation methods and models that are missing today.

This study is a part of a larger research project called "The future wooden houses" where climate conditions in wood framed walls are studied. The project will investigate and validate calculation tools and calculation methods to be used in the moisture safety design process. In this study, WUFI 5.0 (WUFI) was used as calculation tool. The studied house is a newly built single family wood-framed house located outside a small town on the Swedish West coast.

Previous studies with the moisture calculation program WUFI 5.0 show good correlations between measured and calculated values (Hägerstedt 2010 A). Hägerstedt (2010 A) showed that applied air flow in the air gap behind the façade panel is of great importance for the result. In those studies the airflow is constant and differences in compliance may be implied when the climate shifts between seasons (Hägerstedt 2011). Further studies show that the airflow in the air gap behind the façade panel varies depending on wind and thermal conditions and therefore can be different in different places in the air gap behind the façade (Falk 2010) (Nore 2009).

1.2 Aim

The aim of this study is to investigate the correlation between measured and calculated values for temperature and relative humidity in a Swedish standard wood-framed construction. This study includes an investigation to determine if a wind dependent flow of air changes per hour, ACH, in the air gap behind the façade panel, affects calculated climate conditions in the wall compared to if a constant ACH is applied.

The study also investigates if WUFI 5.0 is an appropriate moisture safety calculation tool by comparing measured and calculated values for temperature and relative humidity. Differences between measured temperature and relative humidity at the same wall depth but at different places in the same wall are also presented.

1.3 Limitations

This study does not contain detailed information about functions, parameters and boundary conditions in the calculation program besides differences in used ACH in the air gap behind the façade. Lack of data has not been possible to affect since measurements are made in a real house project. The house construction and location have also determined other boundary conditions in the study.

2. Method

In order to see if there are climatic variations in different parts of the wall, temperature and relative humidity was measured at three different places at the same depth, depth B. In the following section, measurements for temperature and relative humidity at two depths are compared with calculated values from a model with a constant ACH in the air gap behind the façade and another set of calculations with a wind dependent ACH in the air gap. Note that only the main boundary conditions are described as this study focuses on the correlation between measurements and the two blind calculations with different ACH conditions in the air gap. A complete method description with more detailed boundary conditions and limitations are given in Hägerstedt (2010 C).

To show the variation in the local climate conditions in the same wall, temperature and relative humidity were measured and compared at three different points in the wall at the same depth. The three measurement points B.1, B.2, and B.3 are placed as shown in Figure 1, and are located close to wood studs behind the 30 mm outer massive insulation mineral wool board as shown in Figure 2.

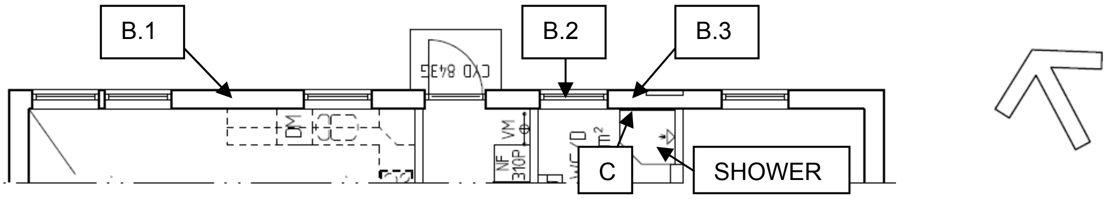

FIG 1. Location of measured places and positions, B.1, B.2, B.3 and C in the North-North West wall.

Measured temperature and relative humidity in positions B.3 and C are compared every hour with the same values from two different calculation models. The measured positions B.3 and C are located at the same point but at different depths in the wall, as shown in Figures 1 and 2 "Built wall". The first calculation model has a constant 30 ACH in the air gap, position A in Figure 2, and the second has a wind dependent ACH in the air gap, position A in Figure 2. Besides the variations in ACH, used calculation models are made to mimic real conditions.

In order to have the same conditions as in the design phase, all calculations with WUFI 5.0 are made blind, i.e. measured values have not been available until they were compared to calculations. The first calculation model has a constant air flow of 30 ACH (Hägerstedt 2010 A) in the air gap behind the façade, position A, in Figure 2. The second calculation model has a wind dependent ACH in the same air gap. The wind dependent ACH has two modes. If the wind blows away from the façade or is below 1 m/s there are 10 ACH in the air gap. If there is a wind higher than 1 m/s in any direction towards the façade the ACH is 100 ACH (Nore 2009). Although the 100 ACH normally is too low it will not have a big influence on the result as long as the flow can remove penetrated moisture (Hägerstedt 2010 A).

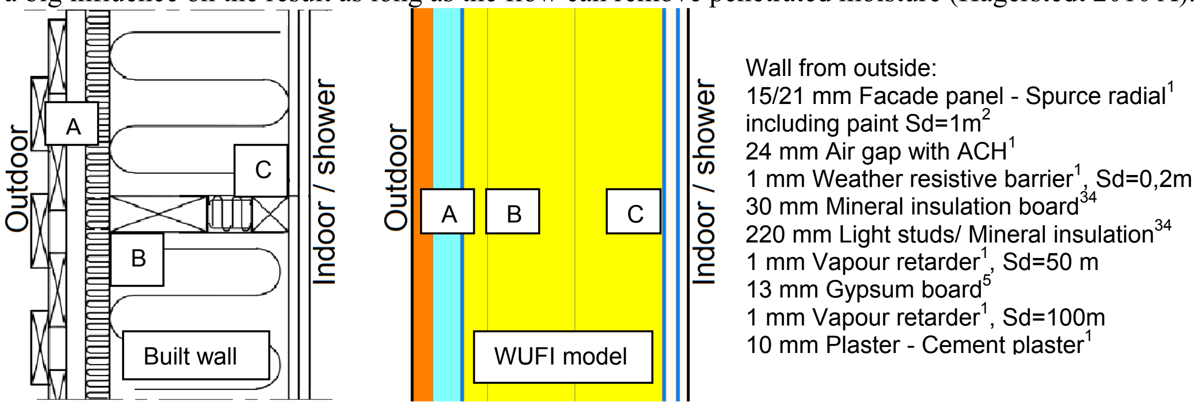

FIG 2. Built wall and WUFI model of wall. Air gap A and measured depth/ positions B and C. (1. IBP) (2. Nevander 1994) (3. IEA Annex 24 1996) (4. Paroc 2002) (5. Krus 1996)

In order to derive deviations, vapour content is calculated from measured and calculated temperatures and relative humidity using the saturation vapour content (Nevander 1994). Measurements and calculations are carried out on a North-North West façade because it is generally the most moisture critical and is less exposed to short wave radiation that affects thermal air transport in the air gap.

Measurements for temperature and relative humidity have been carried out every hour using a wireless Protimeter Hygro Trac system (Sandberg 2011) (GE Sensing 1996). Measurements started 2009-02-02, the same day as the house was mounted and are still running. A great number of measurement sensors have been applied during production at the same time as the constructions were controlled for deviations to drawings.

Calculations for temperature and relative humidity have been made every hour using WUFI 5.0. Climate is from SMHI, Swedish meteorological and hydrological institute (SMHI). Losses of complete hourly climate data and radiation data led to that the nearest climate station not could be used. Differences between local outdoor measured temperature and relative humidity and used outdoor boundary conditions for temperature and relative humidity are shown in the results.

Indoor temperature boundary conditions are based on measurements during the periods 2009-03-12 to 2009-06-10 and 2010-04-28 to 2010-11-30. During the periods with lack of indoor climate data the temperature is assumed to be 22°C, based on known indoor climate data. Periods with a lack of indoor boundary temperature are shown in Figures 4 and 6. Indoor relative humidity has been set to 99 percent because there is a shower with tiled walls and previous studies show a constant wet plaster behind the tiles (Jansson 2006).

3. Measurement result in depth B

3.1 Comparison between measurements in the places B.1, B.2 and B.3

Figure 3 shows measured relative humidity and temperature in the places B.1, B.2 and B.3. The aim is to show if the climate conditions at the same depth in different places in the same wall deviates from each other. The three upper lines show measured relative humidity and the three lower lines shows measured temperature for the same places. The three lines in the middle show vapour content calculated from measured values.

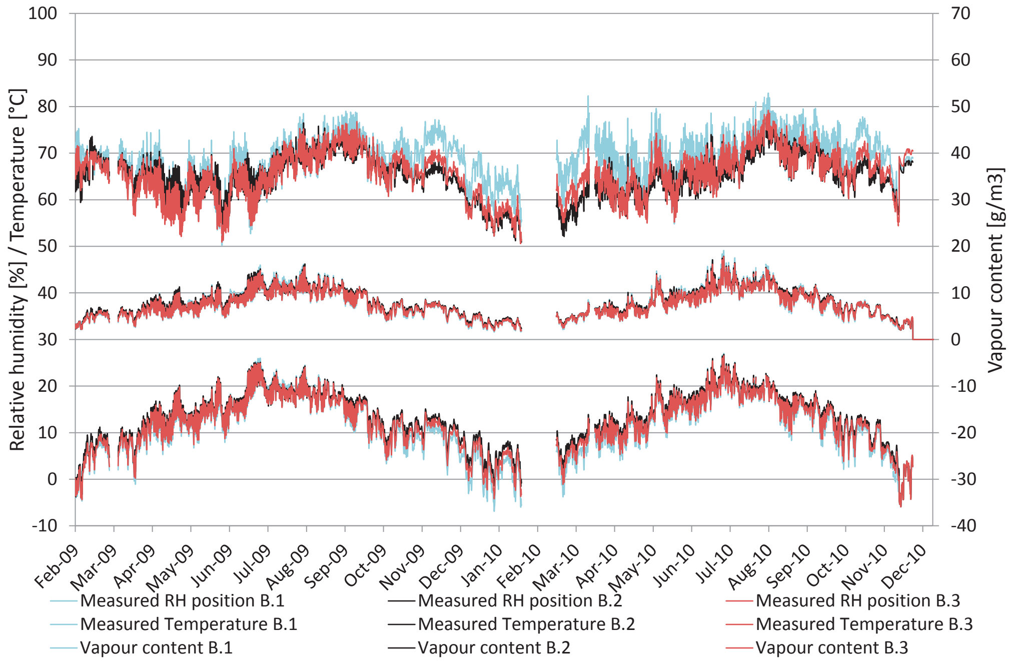

FIG 3. Depth B – Measured relative humidity and temperature at B.1, B.2 and B.3. Vapour content is calculated from RH and T. B.1 light grey B.2 black and B.3 dark grey.

3.2 Measurements results in position B.1, B.2 and B.3

Overall there is a correlation between measured values at all three points. However, there is a stronger correlation between values for B.2 and B.3, which are located close to each other. The largest deviations between measured temperatures and relative humidity occur during the period October -09 to April -10 and October -10 to November -10. Vapour content calculated from measured relative humidity and temperatures show good correlation for all three places. This means that the reason for deviations in relative humidity are due to different temperatures. The influence of thermal bridges, different air flows in the air gap or a higher indoor temperature could be possible explanations.

4. Comparison of measured and two cases of calculated values

This section shows comparisons of measured and calculated relative humidity and temperature in positions B.3 and C with a constant ACH and a wind dependent varied ACH in the air gap. Calculations are carried out for two different cases with a constant air flow of 30 ACH, position A, and a wind dependent air flow of 10 or 100 ACH, in the air gap, position A. Position B.3 and C are located in the same area but at different depths as shown in Figures 1 and 2.

The results are shown in Figures 4 and 6. The three upper lines show measured and calculated relative humidity while the three lower lines show measured and calculated temperature. Calculated values, in black and light grey should correlate to the measured ones presented in dark grey.

In order to explain the causes of deviations, vapour content based on presented relative humidity and temperature are shown in Figures 5 and 7. Those figures also include differences between local outdoor climate data (three hour measurement data) and used outdoor boundary conditions in the calculations (one hour measurement data). A high positive or negative value means a big difference between real outdoor climate conditions and used conditions in the calculations. At the bottom of Figures 4 to 7 are the used ACH for the calculation case with a wind dependent ACH shown. At the top of Figures 4 and 6 periods with lack of data in indoor climate and assumed temperatures of 22 degrees are shown.

4.1 Measured and two cases of calculated relative humidity and temperature in position B.3

Measured temperature and relative humidity compared to the same calculated values for two cases with constant 30 ACH and a wind dependent ACH of 10 or 100 ACH in the air gap behind the façade.

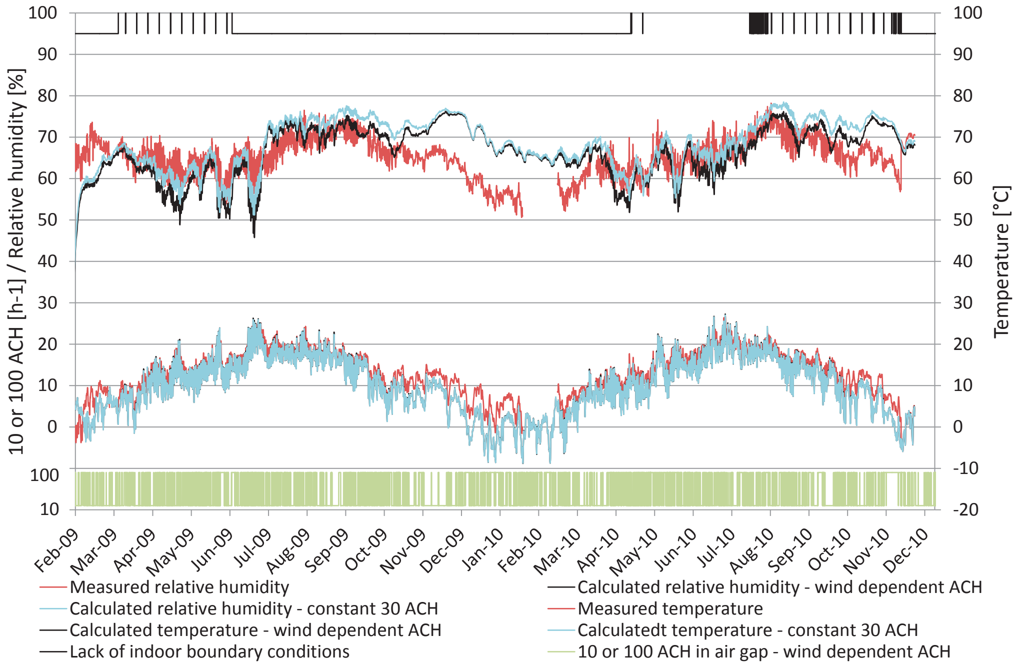

FIG 4. Position B.3-Relative humidity/ Temperature outside of the wood studs: Measured (dark grey), calculated with 30 ACH in the air gap (light grey), calculated and wind dependent ACH in the air gap (black), 10 or 100 ACH (light grey in bottom). Periods with lack of indoor data (black in top).

Figure 5 shows vapour content from measured and calculated values in Figure 4. Differences between local measured outdoor climate (3 h data) and used boundary conditions in calculations (1 h data).

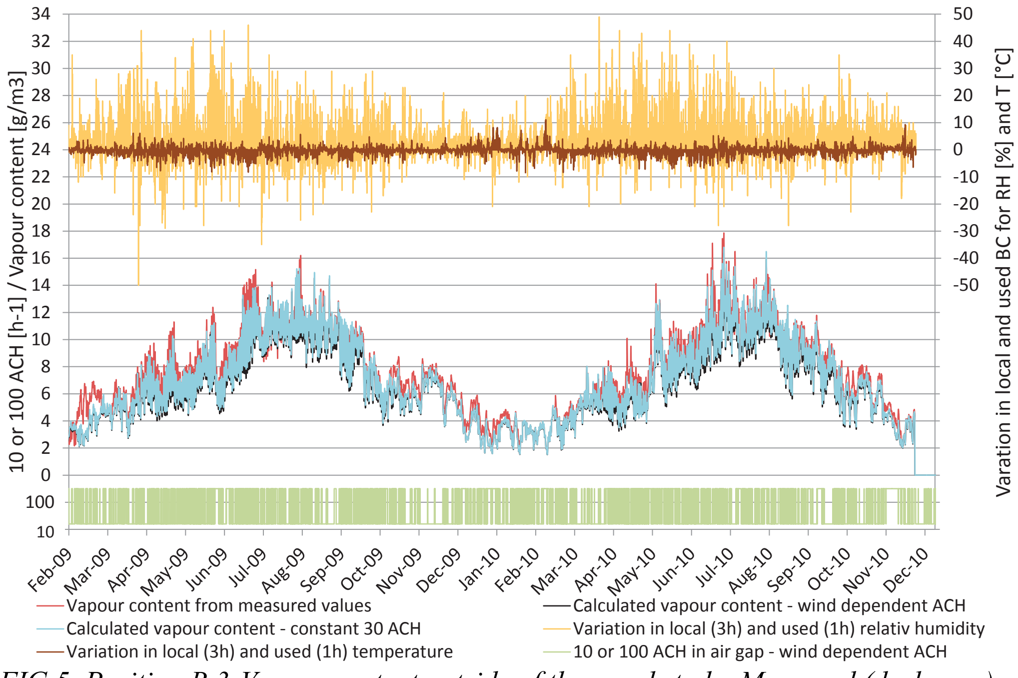

FIG 5. Position B.3-Vapour content outside of the wood studs: Measured (dark grey), calculated with constant 30 ACH in the air gap (light grey), calculated and wind dependent ACH in the air gap (black). Variation in local outdoor T /RH (3h) and used T/RH in calculations (1 h) (in top black/grey).

4.2 Measured and two cases of calculated relative humidity and temperature in position C

Measured temperature and relative humidity compared to the same calculated values for two cases with constant 30 ACH and a wind dependent ACH of 10 or 100 ACH in the air gap behind the façade.

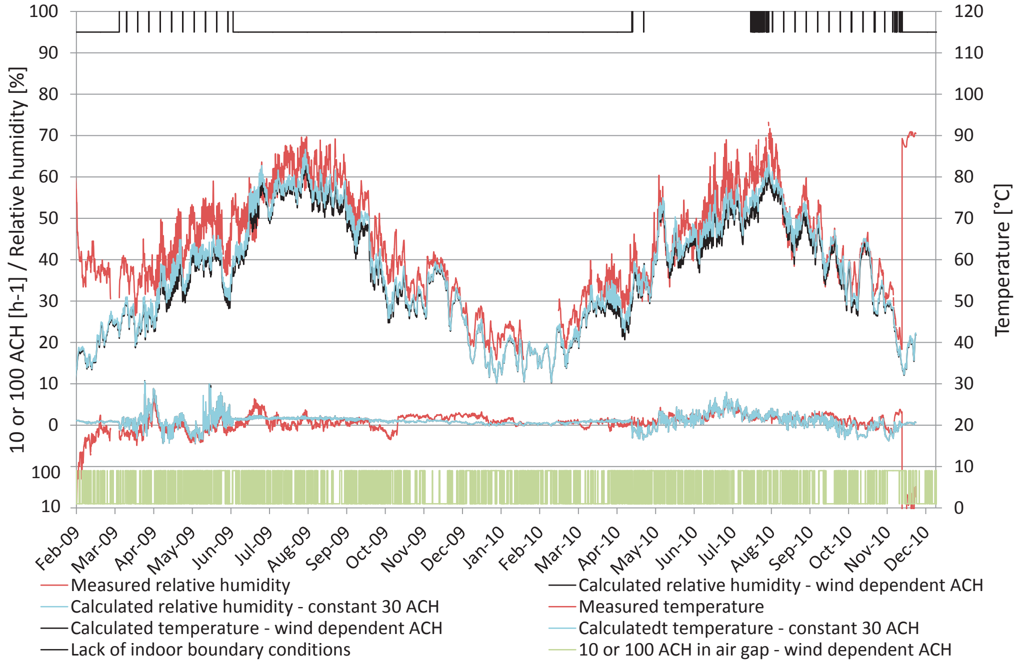

FIG 6. Position C-Relative humidity/ Temperature outside of the wood studs: Measured (dark grey), calculated with 30 ACH in the air gap (light grey), calculated and wind dependent ACH in the air gap (black), 10 or 100 ACH (light grey in bottom). Periods with lack of indoor data (black in top).

Figure 7 shows vapour content from measured and calculated values in Figure 6. Differences between local measured outdoor climate (3 h data) and used boundary conditions in calculations (1 h data).

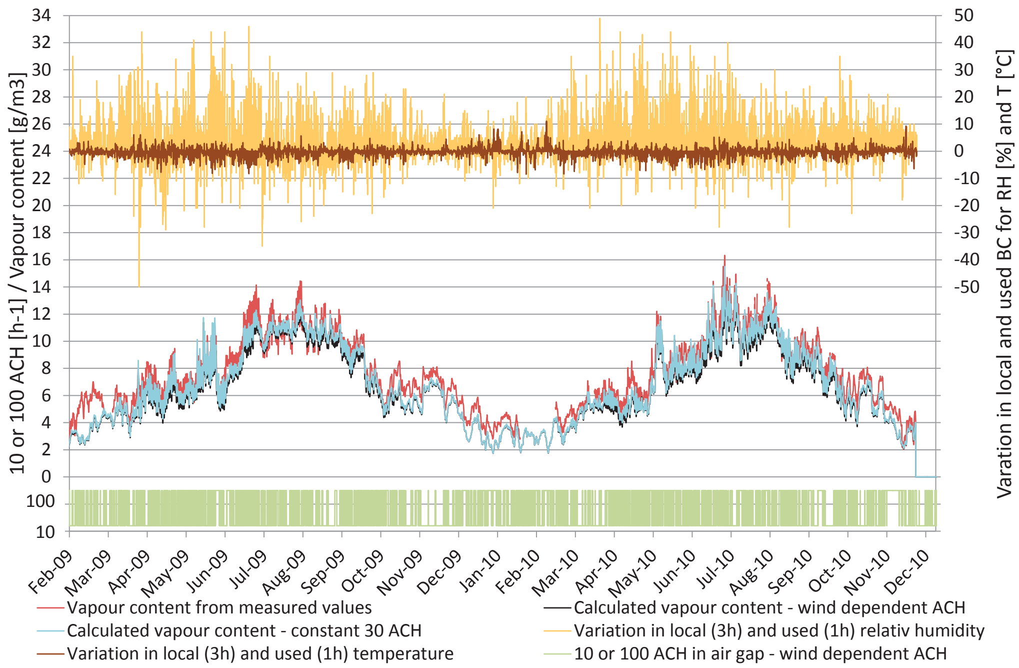

FIG 7. Position C-Vapour content outside of the wood studs: Measured (dark grey), calculated with constant 30 ACH in the air gap (light grey), calculated and wind dependent ACH in the air gap (black). Variation in local outdoor T /RH (3h) and used T/RH in calculations (1 h) (in top black/grey).

4.3 Comparison between measured and calculated values in position B.3 and C

Beside the cold periods between October -09 to April -10 and October to November -10 there is a good correlation between measured and calculated values for the two different cases in position B.3. In position C, deeper into the wall, measured and calculated values correlate during the whole period.

Previous studies have indicated that there might be less correlation between measured and WUFI 5.0 calculated values in the outer part of the wall during the winter (Hägerstedt 2010 B). In this case the deviation becomes clear. The correlation in vapour content during the period show that deviations in relative humidity depend on temperature differences. Position B.1 at the same depth but at a different part of the wall, also shows the same pattern compared to other positions. The reason for the deviation cannot be determined but a higher indoor temperature compared to set boundary conditions as shown in Figure 6 could be a factor. Thermal bridges or an incorrect ACH are also possible explanations.

In position C, the measured relative humidity tends to remain a little higher compared to calculated values because of a higher vapor content, as shown in Figure 7. Correlation between measured and calculated temperatures in position C, in Figure 6, show that assumed temperature of 22°C is good. There are no differences between the two calculated cases, with constant 30 ACH and a wind dependent ACH. During certain periods the curves cover each other. This is expected because the air flow in the air gap has a lower influence of the climate conditions deeper into the wall.

The two calculated cases show good correlation with measured values during different periods in position B.3. Differences between the two calculated cases are smaller compared to the variances between B.1, B.2 and B.3. Calculated relative humidity with a constant air flow of 30 ACH tend to have higher relative humidity compared to the case with a wind dependent ACH, and would have correlated better with position B.1 in Figure 3. Differences in calculated values for the two cases shows that the ACH affect the calculated values in position B.3 but the variations could not be connected to specific periods with 10 or 100 ACH in the wind dependent case.

Differences between local outdoor measured climate data and used outdoor boundary conditions in the calculations cannot be traced to deviations between measured and calculated values. In fact the opposite, since the largest deviations in October -09 to April -10 occur when there are low differences between used boundary conditions and local measured climate.

Differences in amplitude in Figure 4 between measured and calculated relative humidity shows a notable deviation compared to previous studies. In this case the measured relative humidity has higher amplitude compared to calculated values. Normally it should be the opposite. (Hägerstedt 2011) The use of light beams with lower thermal bridges and lower thermal load might be the explanation.

Values before June -09 might not be full representative because the house was not inhabited. The initial period is probably more affected by moisture from the construction process.

5. Conclusions

Comparison between measurement places at the same depth, B.1, B.2 and B.3 show that the climate conditions in a wood framed wall near the façade can vary in different places. In this case the relative humidity varies up to 10 percent, depending on different temperatures, between the places.

In this study WUFI 5.0 tends to generate low temperatures compared to measured values in the outer part of the wall during the cold period of the year. This gives a higher calculated relative humidity compared to measured values. Besides the cold periods there is good correlation between measured and calculated values.

A wind dependent ACH in the air gap behind the façade does not necessary give better correlation between measured and calculated values. Differences between calculated relative humidity with constant 30 ACH and a wind dependent ACH in the air gap is smaller than the differences between measured values in different places at the same depth in the wall. This means that the local conditions in air gap and the wall can be of greater importance than calculations with a wind dependent ACH in the air gap, as long as the flow is high enough to dry out incoming moisture (Hägerstedt 2010 A).

The correlation between measured and calculated values, although the differences between used boundary conditions and local measured climate, shows that the calculations tend to be stable as long as outdoor climate data are similar to the local climate.

6. Acknowledgements

This study was supported by Vinnova and conducted in collaboration with SP and the wooden house company Myresjöhus AB.

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