

Comparison of Field Measurements and Calculations of Relative humidity and Temperature in Wood Framed Walls

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Abstract: Energy efficient wood frame buildings give besides a number of positive effects also risks for moisture damages. To avoid moisture damage in wood houses some parts of the Swedish construction industry use WUFI 1D calculation tool in the design phase. The purpose of this study is to demonstrate the coupling between measured and WUFI 1D calculated values of relative humidity and temperature. The first step presents a comparison between measurements and blind calculations of relative humidity and temperature at different positions in a wooden wall with an air gap. In the second step has boundary conditions for calculated values been adjusted in order to achieve better agreement. The result of the comparisons between calculated and measured values are analyzed. The general conclusion of this study is that it is of great importance to apply a correct airflow in air gap. Results also show that it is possible to obtain reliable calculated values with a proper flow in the air gap.

Keywords: Moisture, Wood framed houses, WUFI, Relative humidity.

Introduction

Background

New laws and demands from consumers have increased the interest in well insulated wood frame houses. Besides a number of positive effects of reduced energy need there are also risks with well insulated wood frame houses. Critical parts of the building envelope become more often exposed to higher relative humidity than before. That provides increased probability for the occurrence of mould growth. To minimize the risk of moisture damages the Swedish wood house industry need a user friendly and reliable moisture calculation tool. This paper show the possibilities to use WUFI 1D to calculate the moisture performance for Swedish conditions.

Aim

The purpose of this study is to demonstrate the coupling between measured values of relative humidity and temperature compared with the same parameters calculated in WUFI 1D. The intension is to show if WUFI 1D is a tool that is suitable for the Swedish house industry during the design of wooden framed houses.

Limitations

The limitations for the measurements in this study are governed by the project schedule and building location. Measuring period, instrumentation and production schedule allows only data for one design and one building section, exposed to central Swedish climate, to be presented. This study does not deal with detailed information about functions and parameters used in the calculation program.

Method

In this chapter is a briefly method description given. A complete detailed method description with defined sources of error is given in a separated report (Hägerstedt, O. 2010, in press)

Relative humidity and temperature has been measured at different positions in a wall. Calculations of relative humidity and temperature have been carried out for the same positions with WUFI 1D 4.2 (WUFI 2009). Measured and calculated values for the relative humidity and temperature are then compared hour by hour in two steps. The first step is a blind comparison. In the second step the boundary conditions for calculated values have been adjusted in order to get better agreement. The comparisons between calculated and measured values are analyzed.

Measurements are carried out in the northwest facade for different depths in positions A to D as shown in figure 1. Northwest facade has been chosen because it often becomes the most moisture critical. This facade is also exposed to least amount of short wave radiation, which is a missing boundary condition. Measurements of temperature and relative humidity have been carried out every hour using a wireless Protimeter Hygro Trac system (Fjellström, P. et al. 2009; GE Sensing 2006; Hoogenboom, C. 2009). Measurements in position A to D, started 2008-11-08.

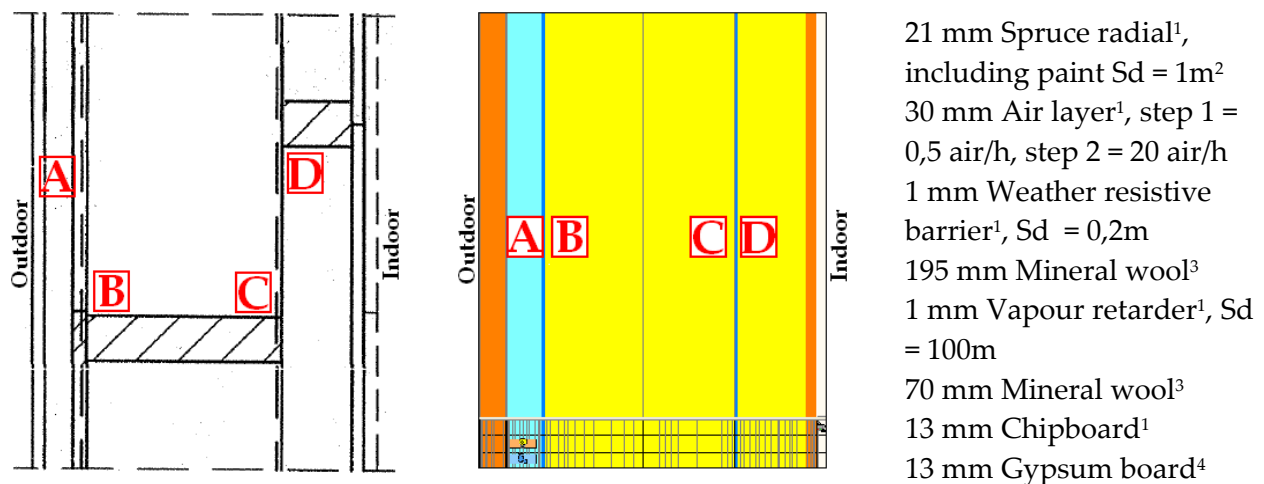


Figure 1: Wall construction, measuring positions (A to D) and calculation model showing calculated positions (A to D). (1. IBP, 2. Nevander, L. et al. 1994, 3. IEA Annex 24 1996 4. Krus, M. 1996)

Boundary conditions in the calculation model are set to match measurement conditions. Applied outdoor climate for calculations are taken from SMHI, Swedish meteorological and hydrological institute, at a climate station nearby. Lack of data for longer periods has been replaced with the previous year's values for the period. Measured indoor climate have been possible to use for indoor boundary conditions from 2009-04-07. Previous period has constant values of 22°C and 40% relative humidity in calculations. Monitor position has also been changed 2009-09-23. Periods of significant lacks of climate data are shown in result charts.

Sources of error

Losses of climate data are the biggest sources of error. The constant conditions in the air gap are also of importance. Those losses in boundary conditions are bigger in a normal design phase and not reasonable to solve in context of this project. Deficiencies in WUFI physical model and bad coincides between calculated material and real material is seen as a part of the limitations. The loss of wooden beams in the 1D model, as show in figure 1, is also difficult to affect.

Result Blind Test

In order to limit the report only characteristic comparisons between blind calculated and measured values are presented. A short written result explanation is presented for all positions. Complete results are presented on the website www.framtidenstrahus.se.

Comparison between blind calculated and measured values for relative humidity and temperature for position C are shown in chart 1 and for position D in chart 2.

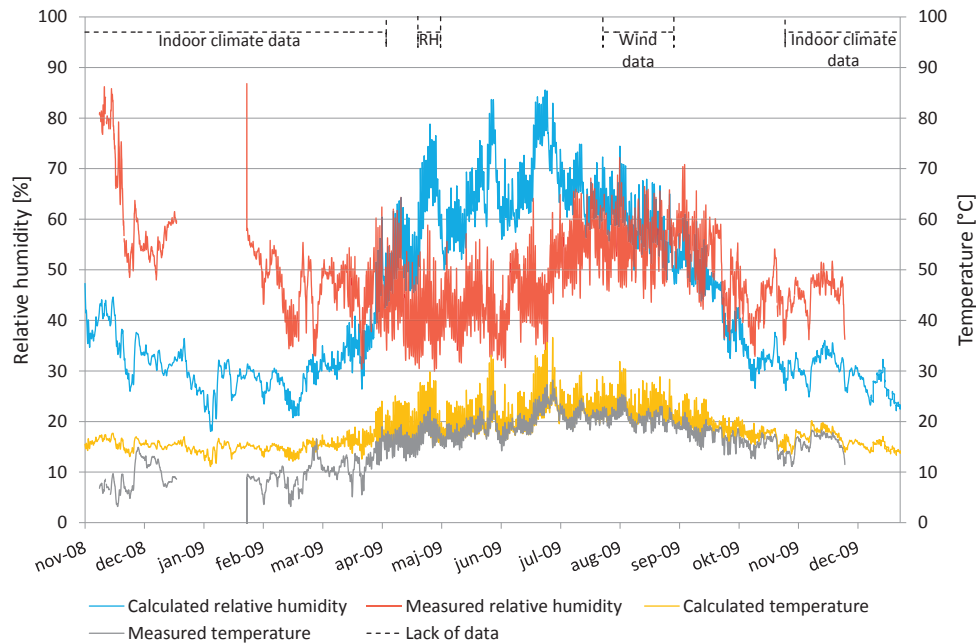


Chart 1: Position C. Relative humidity: Blind calculated (blue), measured (red). Temperature: Blind calculated (yellow), measured (grey). Periods without measured boundary conditions are shown in top.

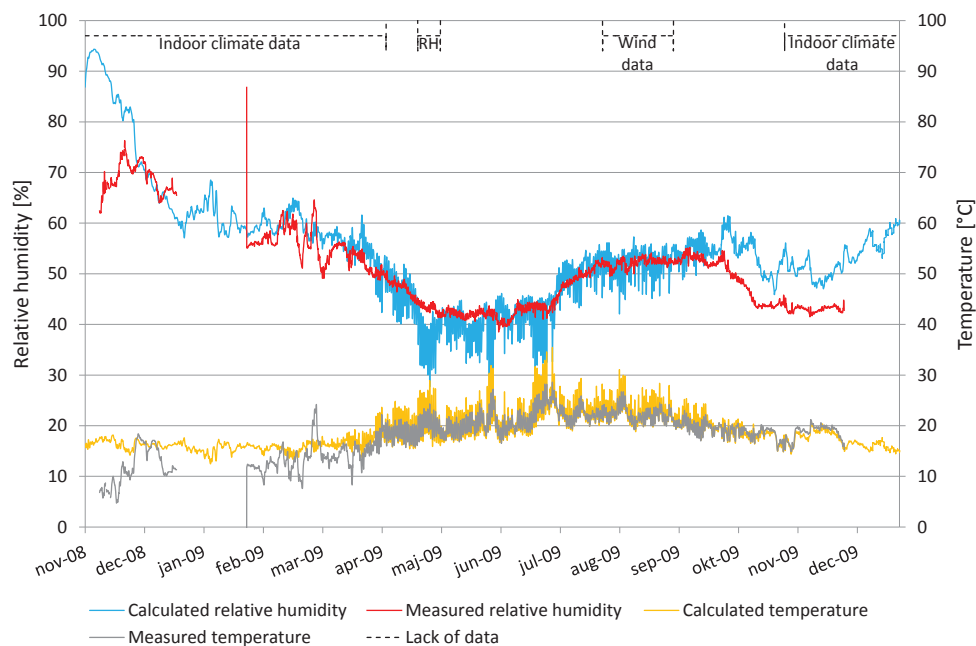


Chart 2: Position D. Relative humidity: Blind calculated (blue), measured (red). Temperature: Blind calculated (yellow), measured (grey). Periods without measured boundary conditions are shown in top.

Results for position C, as shown in chart 1, are characteristic for positions A, B and C outside the vapour barrier. Estimated and measured values follow each other for temperature but do not comply for relative humidity. Comparison of blind calculated and measured values in position D, as shown in chart 2, complies in both temperature and relative humidity.

Analysis Blind Test

Estimated and measured relative humidity does not match for positions at the cold side of the vapour barrier. At the same time there is a good correlation between calculated and measured temperature for all positions and relative humidity on the warm side of the vapour barrier.

This means that outdoor temperature and complete indoor climate seem to be correct applied. The relative humidity generally follows the temperature. That means that the reason for the mismatch of the relative humidity in position A, B and C has to do with additional or removed moisture outside the vapour barrier. The two possibilities for this in the calculation model are the amount of construction moisture or the airflow rate in the air gap behind the panel. Construction moisture should be dried out early in the calculation and is affected by the airflow in the air gap. The conclusion is therefore that the bad compliance in relative humidity in positions A, B and C depends on incorrect estimated airflow.

Adjustment of airflow

The airflow of 0,5 air changes/h, used in blind calculations, is taken from previous studies (Wadsö, L. 1986) and are assumed because of the horizontal wood strips in the air gap. Used airflow can be improperly adopted because the measuring points are located near a corner and a window which create leaks. The air in the air gap could also move more horizontally than expected.

Calculations with varied airflows are therefore made and compared with measurements from the air gap. Comparison shows that 20 air changes/h is a more reasonable value in terms of the whole year. During colder periods of the year, a lower flow of about 10 air changes/h give a better agreement. By changing the airflow in the air gap during the year gives the possibility to obtain very good correlations in all points over the whole year. A higher number of air changes than 20 air changes/h does not affect the calculated results significant.

Note that the airflow in both initial blind and adjusted calculations is constant during the calculation period, which itself gives rise to a source of error. It is not possible to further measure or study changes of airflow in context of this project.

Result with Adjusted Airflow

In the following comparisons the airflow in the air gap behind the wood panel are adjusted to 20 air changes/h in all calculations. In order to limit the report a characteristic period is chosen for each position to show the comparison between calculated and measured values. This is a short period for some positions and the entire period for other positions. Complete results are presented on the website www.framtidenstrahus.se. Results from this study are summarized and discussed in the analysis section.

In order to show the influence of the amplitude in calculated values carts have been extended with 12 hourly averages.

Position A – Air gap

Calculated and measured relative humidity and temperature in position A are shown in chart 3.

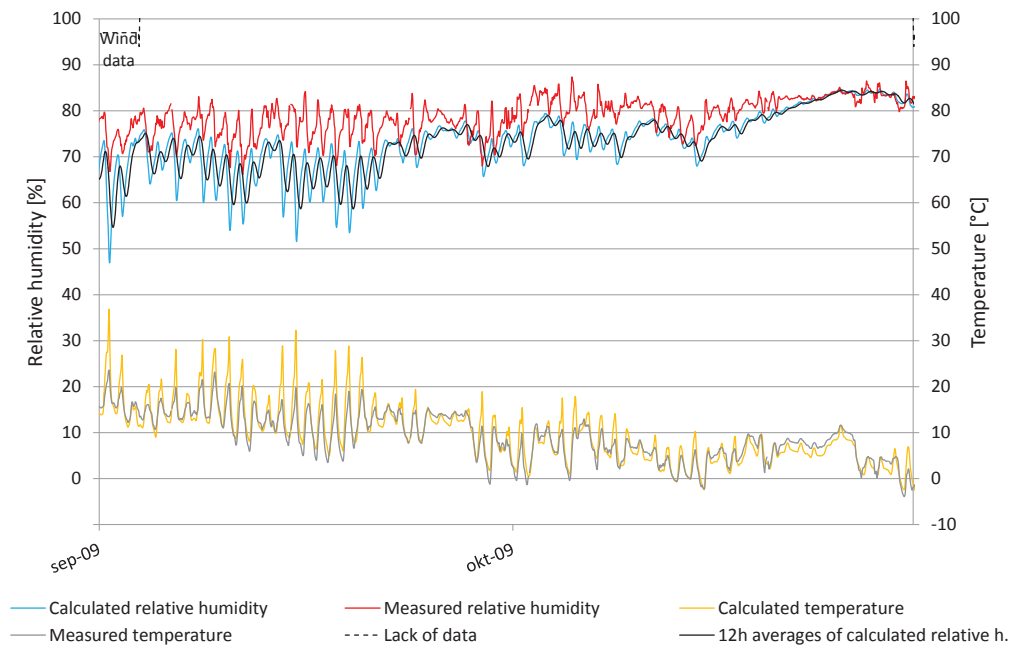


Chart 3: Position A – Air gap. Period: September - October. Relative humidity: Calculated (blue), measured (red). Temperature: Calculated (yellow), measured (grey). Periods without measured boundary conditions are shown in top. 12 hourly averages for calculated relative humidity (black).

Position B – Outside frame

Calculated and measured relative humidity and temperature in position B are shown in chart 4.

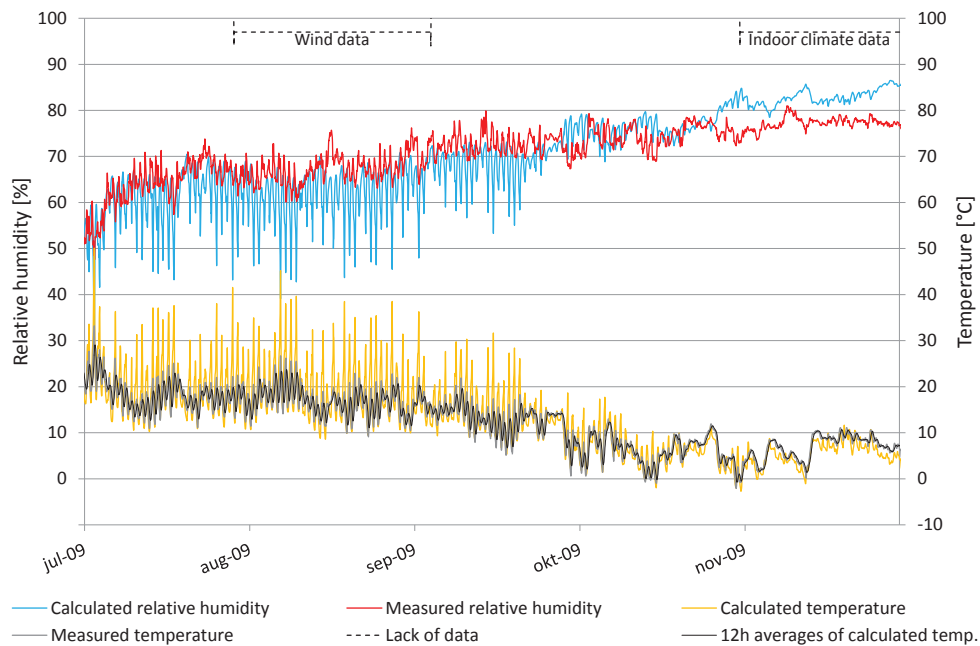


Chart 4: Position B – outside frame. Period: July - November. Relative humidity: Calculated (blue), measured (red). Temperature: Calculated (yellow), measured (grey). Periods without measured boundary conditions are shown in top. 12 hourly averages for calculated temperature (black).

Position C – Cold side of vapour retarder

Calculated and measured relative humidity and temperature in position C are shown in chart 5.

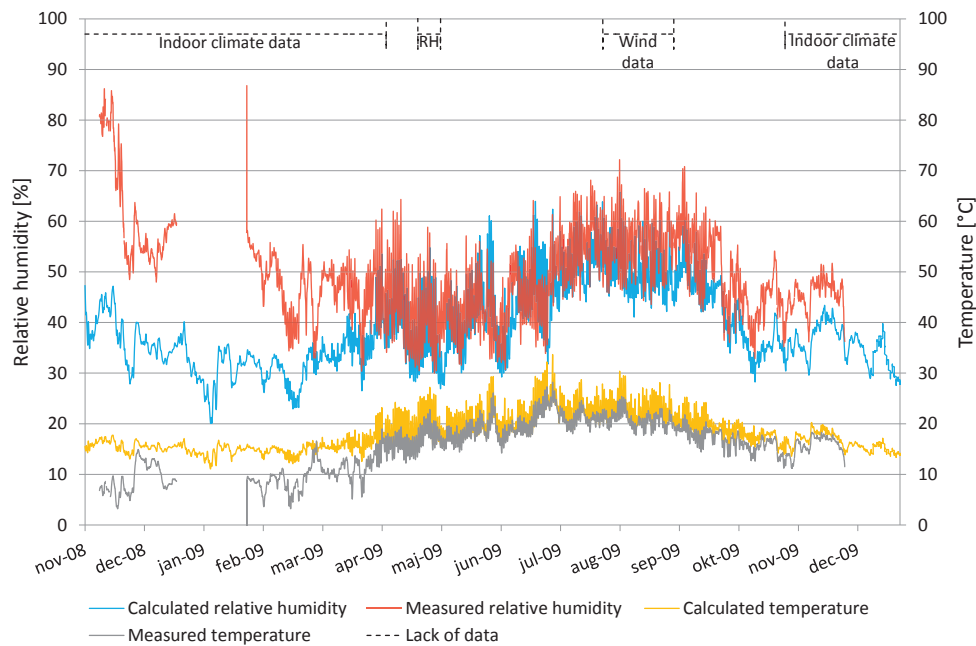


Chart 5: Position C – Cold side of vapour retarder. Period: November 2008 – December 2009. Relative humidity: Calculated (blue), measured (red). Temperature: Calculated (yellow), measured (grey). Periods without measured boundary conditions are shown in top.

Position D – Warm side of vapour retarder

Calculated and measured relative humidity and temperature in position D are shown in chart 6.

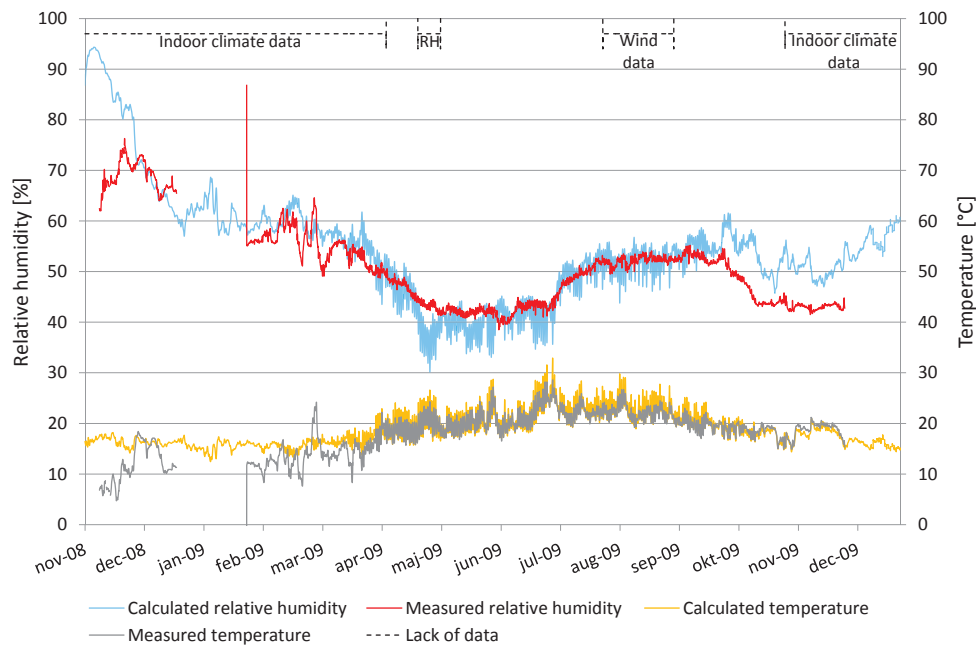


Chart 6: Position D – warm side of vapour retarder. Period: November 2008 – December 2009. Relative humidity: Calculated (blue), measured (red). Temperature: Calculated (yellow), measured (grey). Periods without measured boundary conditions are shown in top.

Analysis – with adjusted airflow

Besides some individual periods, and the size of amplitude for daily values, there is a good correlation between calculated and measured temperature in all studied positions. By adding the mean value for every 12 hours on calculated temperature, as shown in chart 4, the daily amplitude size is reduced and gives a perfect agreement with measured values.

Apart from some individual periods, and the size of amplitude for daily values, calculated and measured relative humidity follows each other. Calculated values of relative humidity are constantly five to ten percent lower compared to measured values for positions A, B and C, outside the vapour barrier. The mean value for every 12 hours in calculated relative humidity, as shown in chart 3, reduce the size of the daily amplitude to corresponds to the measured amplitude.

Deviations between calculated and measured values outside the vapour barrier during the cold period could, as mentioned earlier, be remedied by reducing the airflow in the air gap. The effort to identify the impact of outdoor climate on the conditions in the air gap was not possible to do within the context of this project.

The lack of boundary conditions for relative humidity in the end of April could be noticed in position C and D, as show in chart 5 and 6.

Especially position C and D shows a bad correlation between calculated and measured values for both relative humidity and temperature until indoor climate is applied 2009-04-01 in the calculations. Position C and D are closer to the inside and therefore more affected of the lack of boundary conditions compared to positions further out in the construction. Besides the loss of boundary conditions for indoor climate during this period, the house is not inhabited, and construction moisture may retain and effect measurements.

The comparison between calculations and measurements in position D, as shown in chart 6, clearly shows that the monitor for indoor boundary conditions has been moved 2009-09-23.

The amplitude of the daily calculated values for both relative humidity and temperature are bigger than measured in all positions during the warm period. During the cold period the amplitude of calculated and measured values is equal. Lower daily amplitude obtains for positions deeper into the construction. This probably depends on a more even temperature distribution from the indoor climate. The amplitude for calculated and measured values also has a better correlation deeper into the construction. The reason for constant higher amplitude for calculated values is unknown. Installations of monitors in the wood frame with higher heat and moisture capacity may cause the amplitude of the measurements to be lower. The monitors may also have a weak ability to register rapid temperature shifts, or calculation could be more sensitive to temperature fluctuations compared to measurement. In positions A, B and D there is also higher amplitude on calculated relative humidity compare to measured. It is easy to assume that the high amplitude of the calculated temperature gives corresponding errors to calculated relative humidity. It is therefore surprising that the amplitude of the calculated relative humidity is the same as the measured relative humidity in position C, while there is a difference in amplitude of the calculated and measured temperature. By adding the floating mean value for every 12 hours on calculated values, as shown in chart 3 and 4, the amplitude is reduced which give a better correspondence to measured values.

Conclusion

The general conclusion of this study is that conditions of the airflow in the air gap behind the panel must be known to give a good correlation between calculated and measured values.

The difference in results for the relative humidity between blind calculations with airflow of 0.5 air changes/h and the calculated values with an adjusted airflow for 20 air changes/h shows the great importance using a correct air flow in the model. The use of a relevant airflow in the air space is essential for evaluation of the risk for moisture damages and mould growth. Applied airflow in the air space has a big influence in all points of the frame that are located on the outside of the vapour retarder.

Deviations and differences between calculated and measured values can be attributed to relevant sources. It is entirely possible that the airflow in the air gap behind the panel varies in a manner which gives a good correlation between calculated and measured values. Since the condition in the air gap is not measured it is not possible to confirm that this is the case. In respond to known and unknown sources of error the correlation between calculated and measured values are considered as good.

Future work on development of WUFI 1D should focus on designing a model for airflow in air gaps behind facade layer. Another solution could be to look for context in settled airflow in other studies where comparisons between calculated and measured values in facades with underlying air space made. It would have been helpful if a general model of varying airflow in air gaps could be created and applied in calculations.

References

- [1] FJELLSTRÖM, P-A.; POUSETTE, A.; SANDBERG, K. *Verification measurements in Woodbuild project. Verifieringsmätningar inom Woodbuild*, in Swedish. SP Träteknik, Skellefteå, 2010.
- [2] GE SENSING, *Protimeter HygroTrac*, Wireless environmental monitoring. 2006.
- [3] HOOGENBOOM, C. *GE Sensing Report on Calibration issues affecting HygroTrac model*. 2009.
- [4] HÄGERSTEDT, O. *Calculation and field measurement method for wood framed house*. Department of Building Physics, Lund University, Report TVBH-XXXX, 2010, In press.
- [5] IBP. Fraunhofer Institute for Building Physics. http://www.ibp.fraunhofer.de/index_e.html.
- [6] IEA Annex 24. *Heat, air and moisture transfer through new and retrofitted insulated envelope parts*. 1996.
- [7] KRUS, M. *Moisture Transport and Storage Coefficients of Porous Mineral Building Materials*. Fraunhofer IRB Verlag. 1996.
- [8] NEVANDER, L-E.; ELMARSSON, B. *Moisture guide book, Fukt handbok*. In Swedish. AB Svensk Byggtjänst 1994. Elanders Svenskt Tryck AB, Stockholm 2001.
- [9] SMHI, Swedish meteorological and hydrological institute, *Klimat data. Klimatdata*. <http://www.smhi.se/klimatdata>.
- [10] WADSÖ, L. *Air movement in brick wall facades. Luft rörelser i skalmursspalter*, In Swedish. Department of Building Materials, Lund University, Report TBBM-5009, 1996.
- [11] WUFI 4.2. http://www.hoki.ibp.fhg.de/wufi/wufi_frame_e.html. 2009.