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Control of moisture safety design by comparison between calculations and measurements in passive house walls made of wood

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ABSTRACT

The use of passive house technique has been used in a new wood framed building in Sweden. Besides the positive effect of reduced energy need, highly insulated wooden houses often have a higher risk of moisture and mould problems. The reason is that critical positions is more exposed to higher relative humidity compared to ordinary houses with thinner insulation. To investigate if an external wall has been correctly designed and constructed it has been investigated both with hourly measurements and by calculations with WUFI 5.0.

The aim of this study is to investigate the result of the moisture design process and the way changes in the design influence the moisture safety with real climate conditions. The study also investigates if WUFI 5.0 is a reliable tool to use in the construction design process. This was investigated by comparisons between measured and calculated relative humidity and temperature in different positions in an exterior wooden wall from April 2009 to October 2010.

In the original design the outer wooden studs have no protecting layer from the ventilated air gap behind the façade. Results from calculations with WUFI 5.0 shows that it is sufficient with a thin protecting thermal insulation on the outside of outer studs to considerably improve the moisture conditions in the outer parts ot the wall. If we never want the relative humidity to be above the critical level, at least 87 mm of insulation have to be applied on the outside of the wooden studs.

Comparisons between measurements and calculations show that WUFI 5.0 can be a reliable tool in moisture design of highly insulated wood framed walls. To get safe results it is important to use reliable climate and correct assumption about the air flow in the air gap behind the façade material.

KEYWORDS

moisture, measurements, WUFI, comparisons, mould

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1 INTRODUCTION

1.1 Background

The use of passive house technique in new wood framed buildings increases in Sweden. Besides the positive effect of reduced energy need passive house often have a higher risk of moisture and mould damages. The reason is that critical positions with organic material in the frame becomes more exposed to higher relative humidity compared to ordinary houses with thinner insulation. In order to minimize risk for moisture damages in a new passive house made of wood experts were given the opportunity to implement moisture design and suggest changes throughout the design phase of a major wood build project. This paper show possibilities to use the one dimensional heat and moisture calculation program WUFI 5.0 [WUFI] in the moisture design process and the effects it could result in concerning moisture safety.

1.2 Aim

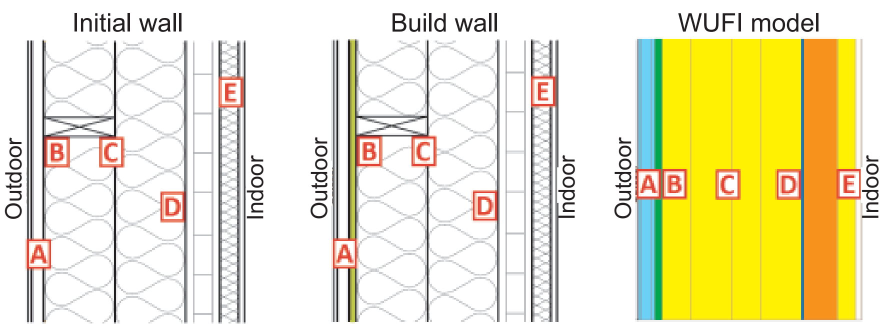
The aim of this study is to use real climate conditions and show how changes in the design will influence the moisture safety, and consequences if no changes are made. Another aim is to investigate if WUFI 5.0 is a reliable tool to use in the moisture design process. This is demonstrated with comparisons between measured and calculated relative humidity and temperature in different positions in a highly insulated exterior wooden wall in an apartment building in Sweden, in 2009.

1.3 Limitations

The limitations in this study are primarily related to conditions for the measurements. Project schedule, production plan, construction type and building location only admit data for one design in one location. The limited duration of the measurements also affects the reliability of the results. The study does not include detailed information about parameters and functions used in the calculations.

2 METHOD

During the moisture design process [Mjörnell, K. 2007] a number of calculations was carried out for an initial proposal of wall construction, shown as “Initial wall” in Fig. 1. One challenge in the moisture design process was to protect the outside of the wood studs, position B, from mould growth. This was made by adding a insulation board on the outside of the wood studs, shown in “Build wall” in Fig. 1. Conditions in the design phase limited the thickness of the insulation board to 17 mm. To study moisture conditions in the wall and to compare with results from WUFI 5.0, measurements have been carried out in positions B to E in the modified wall, shown as “Build wall” in Fig. 1.



Wall from outside:
8 mm Concrete board[1]
30 mm Air gap 40 ACH[2]
(17 mm Insulation board)[3,4]
170 mm insulation/studs[3,4]
170 mm insulation/studs[3,4]
1 mm Vapour retarder[2]
82 mm Massive wood[2]
45 mm Insulation/studs[3,4]
13 mm Gypsumboard[5]

Figure 1. Initial wall without insulation board and Build wall with insulation board (green). Air gap A and measuring positions B to E. Calculation model with insulation board, air gap A and calculated positions B to E. [1. Hedenblad, G. 1996, 2. IBP, 3. IEA Annex 24, 4. Paroc, 5. Krus, M. 1996].

As a first case conditions for positions B to E in the initial wall were calculated in WUFI 5.0 with real climate as boundary conditions. To get a similar model to the wall that was built, a 17 mm insulation board was added, as shown as "WUFI model" in Fig. 1, and calculations in position B to E were repeated. Calculated results from the initial wall and the built wall were analysed. Since 17 mm of board was not enough to avoid critical relative humidity levels a number of calculations were carried out to investigate the minimum thickness of the board to avoid critical relative humidity levels.

To validate the calculations and show the possibilities to use WUFI 5.0 in the design process calculations of relative humidity and temperature for position B to E are compared with measured values. The comparisons are blind, i.e. measured results have not been available until calculations were completed. Calculations and measurements have been carried out and compared hour by hour. The agreement between measured and calculated relative humidity and temperature are presented and analysed.

Measurements are carried out at sixth floor in the north façade at different distances from the outside, shown as position B to E in Fig. 1. The north façade is supposed to be the most critical regarding the risk of moisture related problems. It is also less exposed to short wave radiation, which is excluded in the calculations. Measuring sensors have been applied during the production at the same time as constructions were controlled for deviations to drawings. Measurements of temperature and relative humidity have been carried out every hour using a wireless Protimeter Hygro Trac system [Sandberg, K. et al. 2011; GE Sensing 2006]. Measurements in position B to E started 2009-05-01 and are still running.

Boundary conditions and a model for the calculations are shown in Fig. 1 as "WUFI model" and set to match build wall and measured conditions. The house is built under a tent so no initial construction moisture is added in the calculations. According to the height and earlier studies the air flow in the air gap, position A, are set to 40 air changes per hour [Hägerstedt & Arfvidsson 2010]. Used outdoor boundary conditions are taken from SMHI, Swedish meteorological and hydrological institute, at a climate station nearby [SMHI]. All indoor boundary conditions are based on measurements from October 2009 to October 2010. The apartment, where the indoor climate is measured, has not been inhabited during the measurement period. Lack of in- and outdoor climate conditions are replaced with relevant data [Hägerstedt O. 2010, A, in press]. Periods with lack of outdoor climate data are shown in the top of Figs. 4 to 8. Lack of temperature and relative humidity are shown separated because of its impact.

A complete detailed method description with defined sources of error is given in a separate report [Hägerstedt, O. 2010, in press].

2.1 Sources of error

The main sources of error can be summarized as follow: Lack of measured boundary conditions for parts of the time and lack of some material data. Possible defects in WUFI´s physical model, convergence errors and bad correspondence between material data used in calculations and real material is also treated as possible errors. In the one dimensional model wooden beams have been neglected, as shown in Fig. 1, which is a simplification. The use of field measurements both as boundary conditions and as a part of the comparison also creates unknown possible sources of error.

3 RESULTS - MOISTURE DESIGN

In this report only results from the most moisture critical position on the outside of the wall studs, position B, is presented. Other positions, C to E, are not so exposed to moisture critical conditions. Complete results for all positions are shown on the webpage www.framtidenstrahus.se.

A critical relative humidity limit, as a function of temperature [Zedlbauer, K. 2001], is shown as a green line for the initial wall in Fig. 2 and for a test calculation with 87 mm board in Fig. 3. Difference between the critical and calculated relative humidity at specific times for each case are shown in the bottom of Figs. 2 and 3. The level of critical relative humidity as a function of temperature [Sedlbauer, K. 2001] for one studied case is also added in Figs. 2 and 3. Specific time and difference between critical and actual relative humidity is also shown.

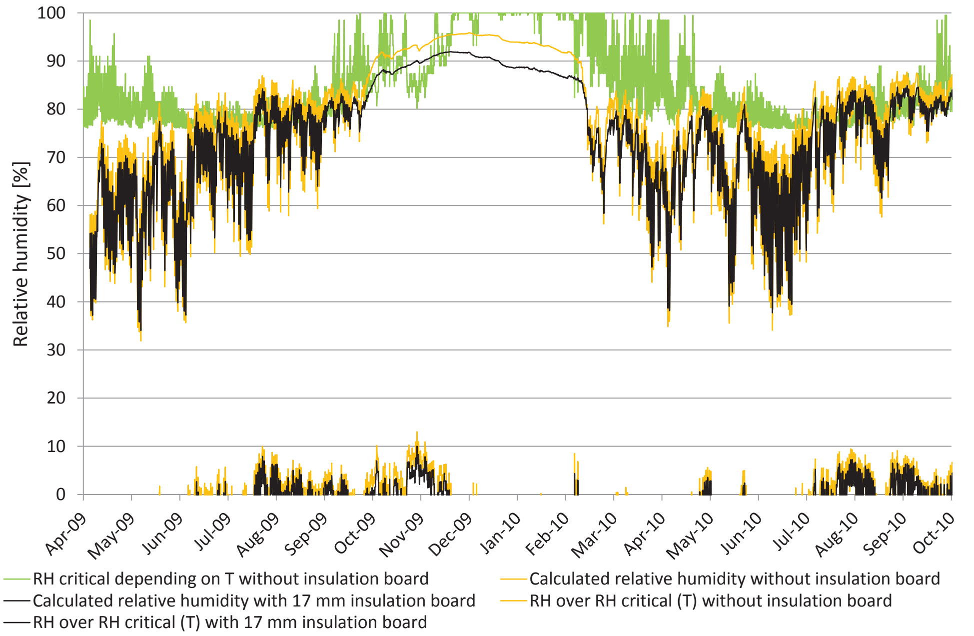


Figure 2. Position B. Calculated RH without insulation board and exceeded to critical RH (yellow). Critical RH level as a function of temperature for calculated RH without insulation board (green). Calculated RH with 17 mm insulation board and exceeded to critical RH (black).

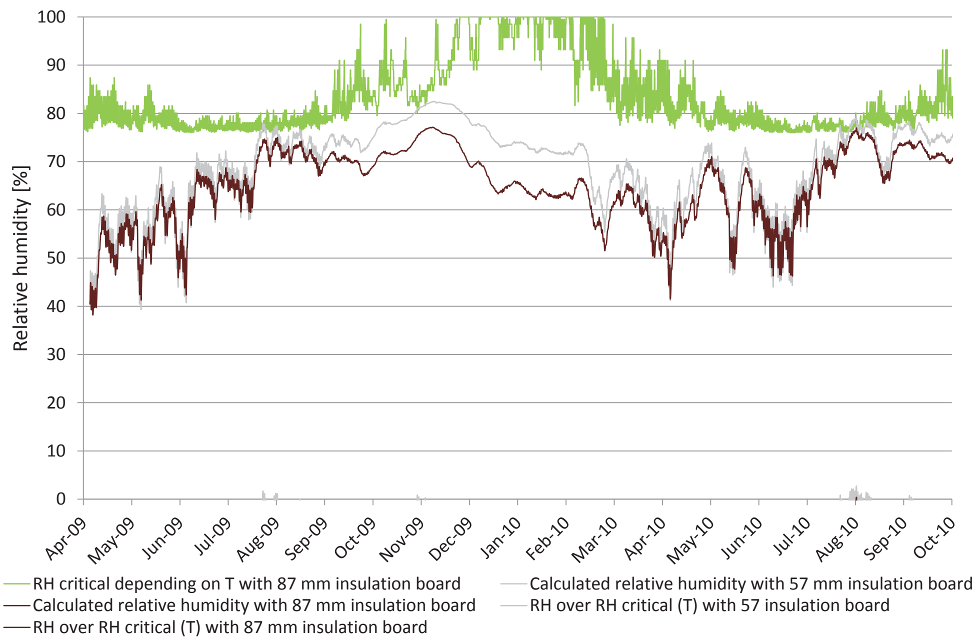


Figure 3. Position B. Calculated RH with 57 mm insulation board and exceeded to critical RH (grey). Critical RH level as a function of temperature for calculated RH with 87 mm insulation board (green). Calculated RH with 87 mm insulation board and exceeded to critical RH (dark red).

4 RESULTS - VALIDATION OF CALCULATIONS

Comparison between calculated and measured relative humidity and temperature are presented.

4.1 Position B - Outside of the wood studs

Comparison between calculated and measured relative humidity and temperature are show in Fig. 4. In Fig. 5 a more detailed comparison from March 2010 to June 2010 is shown.

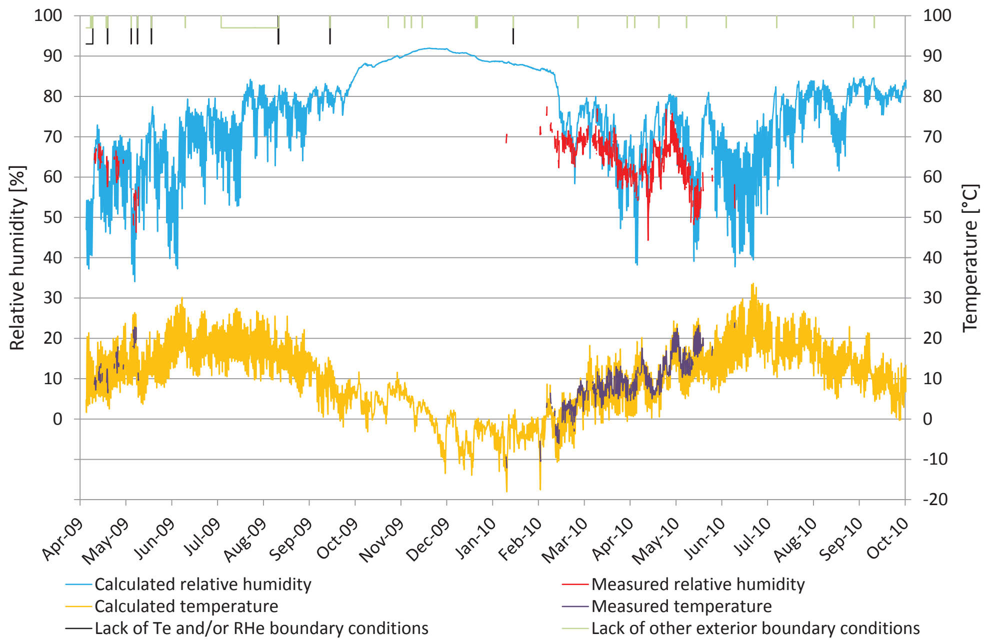


Figure 4. Position B - Outside of the wood studs. Relative humidity: Calculated (blue), measured (red). Temperature: Calculated (yellow) measured (purple). Lack of boundary condition (green/black).

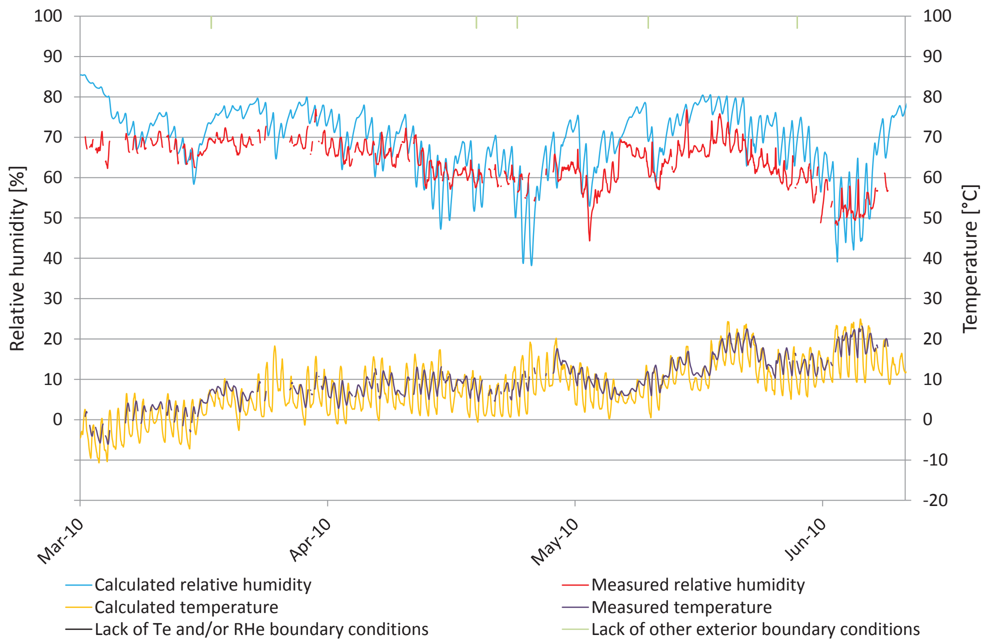


Figure 5. Position B - Outside of the wood studs. Relative humidity: Calculated (blue), measured (red). Temperature: Calculated (yellow) measured (purple). Lack of boundary condition (green/black).

4.2 Position C - In the middle of insulation

Comparison between calculated and measured relative humidity and temperature are show in Fig. 6. Unfortunately there is an extensive lack of measurements in position C.

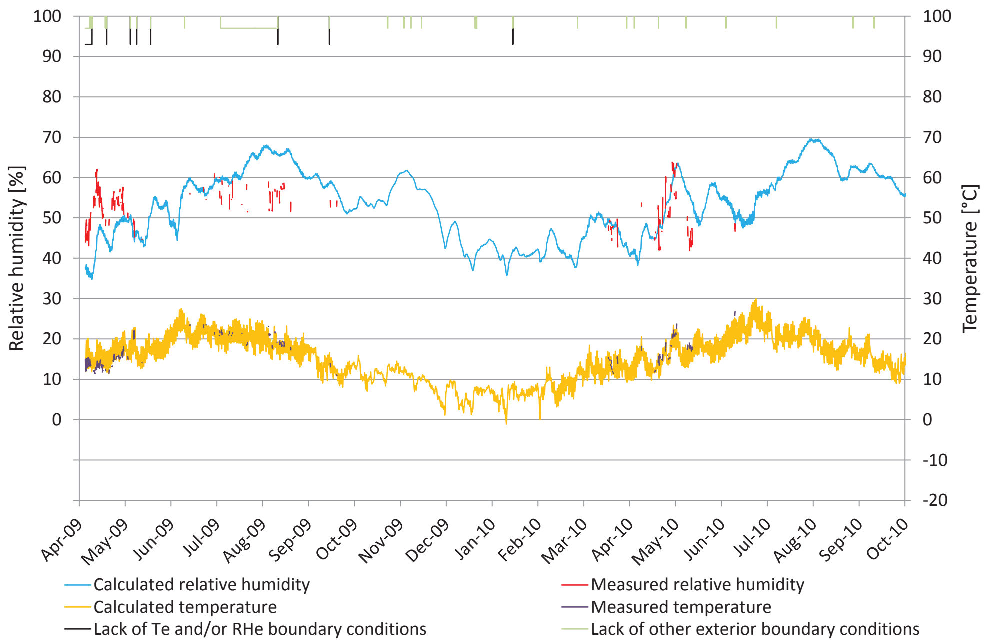


Figure 6. Position C - The middle of insulation. Relative humidity: Calculated (blue), measured (red). Temperature: Calculated (yellow) measured (purple). Lack of boundary condition (green/black).

4.3 Position D - Cold side of the vapour retarder

Comparison between calculated and measured relative humidity and temperature are show in Fig. 7.

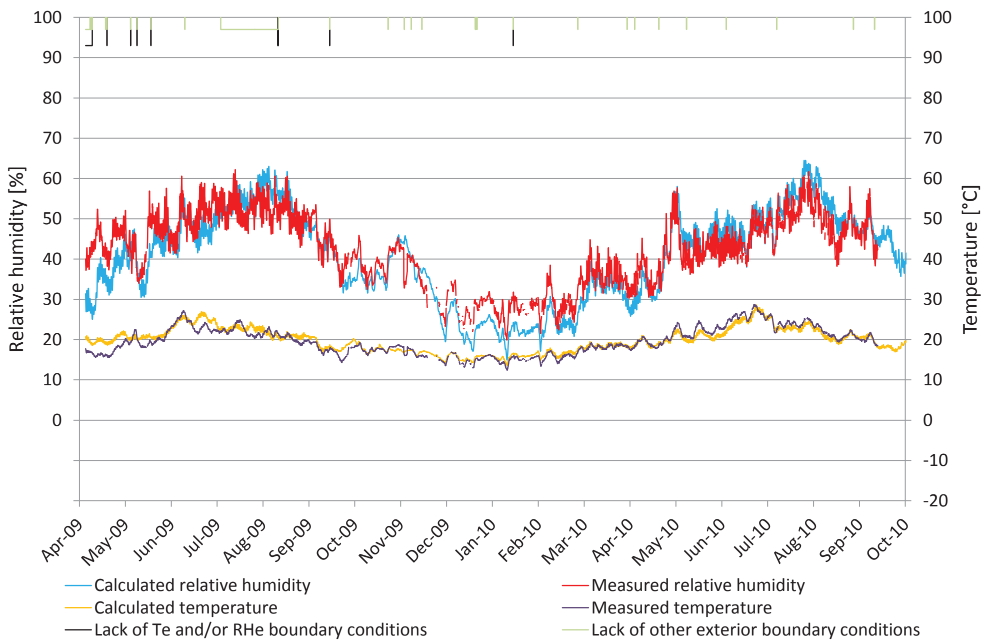


Figure 7. Position D - Cold side of vapour retarder. Relative humidity: Calculated (blue), measured (red). Temperature: Calculated (yellow) measured (purple). Lack of boundary condition (green/black).

4.4 Position E - Installation layer on the warm side of the vapour retarder

Comparison between calculated and measured relative humidity and temperature are show in Fig. 8.

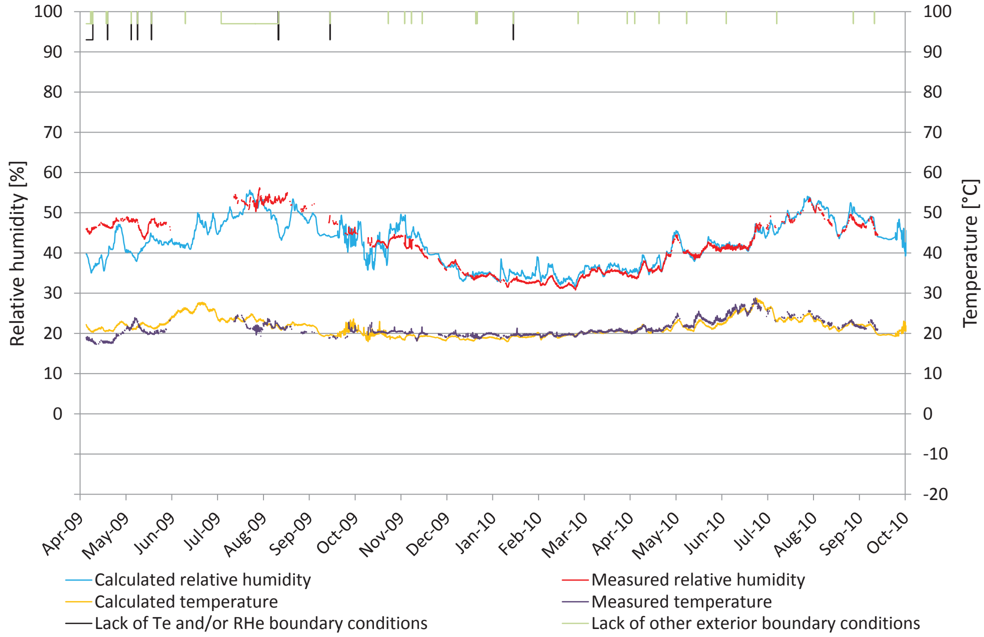


Figure 8. Position E - Installation layer on the warm side of the vapour retarder. Relative humidity: Calculated (blue), measured (red). Temperature: Calculated (yellow), measured (purple). Lack of boundary condition (green/black).

5 ANALYSIS

The evaluation, as shown in Fig. 1, shows that an extra 17 mm insulation board improves the moisture conditions in position B. However, the evaluation also shows that 17 mm is insufficient to protect the exterior part of the wooden studs from moisture damages.

Calculations in Fig. 3 shows that an 87 mm thick insulation board is needed to prevent mould growth on the outside of the wooden studs. Fig. 3 also shows that 57 mm thick insulation board reduces the risk of mould growth significantly. Not presented initial calculations with standard climate data shows a need of about 65 mm insulation board. Today the building system allows 80 mm insulation board.

The results in Figs. 2 and 3 shows that August is the most critical period although critical conditions occur in other parts of the year to. Because of defective measurements no moisture critical conditions have been measured. For all that we have to assume that mould growth on the studs may occur.

The comparison between calculated and available measured values of relative humidity and temperature in Figs. 4 to 8 shows a considerable convergence witch validates the use of WUFI 5.0. Deficiencies in measurements make positions C impossible to use and position B weaker in analyze.

Divergence in position D and E from April to October 2009 can be explained by the indoor boundary conditions. During this period the indoor boundary conditions are based on the following April to October 2010.

The amplitude of daily calculated values for both relative humidity and temperature are bigger compared to available measured ones in position B and C during the warm period. Daily amplitude of calculated and measured values in position D and E shows agreement throughout the whole period. As shown in a previous study the daily amplitude is low during the winter (Hägerstedt & Arfvidsson 2010). All used measurement sensors are located close to solid wood. In the calculation model it is only possible to take account of the solid wood structure near position D and E. The fact that calculated daily amplitude in position D and E converges with measured when solid wood is close supports the theory that nearby wood reduce the daily amplitude (Hägerstedt & Arfvidsson 2010). In the calculations model the solid wood is separated from position C by a vapour barrier. This means that the heat capacity of the wood that affects the daily amplitude but not the moisture capacity.

6 CONCLUSIONS

The first conclusion of this study is that the moisture design process has both exposed bad design and improved moisture conditions in critical positions. Unfortunately the modifications in the construction do not seem to be good enough to ensure that no moisture or mould damages will occur.
Today the wall manufacturer has change the design that will allow 80 mm thick insulation board.

The second conclusion is that WUFI 5.0 can be used as a tool in the moisture design process of passive wood framed houses with an open air gap behind the façade material. When using WUFI 5.0 in those cases it is of great importance that proper assumptions, materials, models and boundary conditions are used. The importance of accurate climate data has been shown. The study also shows that it is reasonable to believe that wooden material reduces the daily amplitude inside the wall.

REFERENCES

GE Sensing 2006, ‘Protimeter HygroTrac, Wireless environmental monitoring’

Hedenblad 1996, ‘Moisture safety in buildings. Materialdata for Moisture Calculations’. In Swedish. Byggforskningsrådet, T19:1996, Stockholm, Sweden.

Hägerstedt, O. 2010, ‘Calculations and field measurements method in wood framed hoses’, Department of Building Physics, Lund University, Report TVBH-XXXX, 2010, In press.

Hägerstedt, O. & Arfvidsson J. 2010, B, ‘Comparison of Field measurements and Calculations of relative humidity and Temperature in Wood Framed Walls’, Thermophysics 2010 – Conference proceedings, Bruno University of Technology, Faculty of Chemistry 2010.

IBP. Fraunhofer Institute for Building Physics. http://www.ibp.fraunhofer.de.

IEA Annex 24 1996, ‘Heat air and moisture transfer through new and retrofitted insulated envelops’.

Krus, M. 1996 ‘Moisture Transport and Storage Coefficients of Porous Mineral Building Materials’, Fraunhofer IRB Verlag.

Mjörnell, K. 2007 ‘ByggaF’ Method for moisture proof building process. In Swedish.

Paroc, 2002, ‘Product information - Construction book’ Produktinformation - byggboken. In Swedish.

Sandberg, K., Pousette, A. & Dahlquist, S. 2011, ‘Wireless in situ measurements of moisture content and temperature in timber constructions’. XII DBMC – Conference proceedings, Porto, Portugal 2011

SMHI, Swedish meteorological and hydrological institute, Climate data, Klimatdata www.smhi.se.

Zedlbauer, K. 2001 ‘Vorhersage von Schimmelpilzbildung auf und in Bauteilen’, Uni. Stuttgart, Dis.

WUFI 5.0, IBP Softwaer, www.wufi.com.