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HAM Analysis of Selected Wooden-Framed Walls

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Abstract. In this paper, heat and moisture regime of the selected wooden-framed walls is analyzed. This walls meet the nearly-zero energy buildings recommendations. Totally, there are seven different compositions. They differ with thermal insulation (such as mineral wool, phenolic foam, sheep wool, etc.) and outer surface (coating, aerated cladding). The fragments are installed in two air conditioned rooms. This enables the possibility to maintain indoor boundary climate conditions constant or change dynamically. The outdoor climate is real, one of the wall faces east and one towards the south. Each fragment contains several sensors: thermocouple, relative humidity, both through the composition on contact with different materials and heat flow on inner surface. It is pavilion type of measurement and results can be interpreted for a whole climate season. Based on the measurements it is possible to calibrate the numerical model and set-up non-steady simulations. Conclusion about coupled heat-moisture transport through fragments will be made further.

1. Introduction

The interest in timber structures is significantly higher in the European Union than in Slovakia. The highest share of timber constructions is in Scandinavia 70%, in Germany 50%, in Austria 45%. There is some scepticism about these buildings, which have the market share only about 10 %, masonry buildings are still dominating. Energy savings is not only priority of the government [1] but also of the households [2]. In the area of thermal protection, more requirements were implemented in the standards and acts [1]. Nowadays, wooden buildings have significant potential in area of low energy, passive and zero energy buildings. The Department of building engineering and urban planning is dealing with the wooden structures for long time. Its laboratories and equipment are being constantly upgraded to better conduct research in the area of coupled heat-moisture transport in the building envelopes [3]. Realized long-term measurements are compared and evaluated with help of simulation made with WUFI software.

Two laboratory rooms of pavilion type (real outdoor climate, changeable indoor climate) are used, which differs with orientation. More different wall compositions were made (totally 8, 2 are the same with different orientation). The walls differs with thermal insulation, outdoor surface, use of vapour barrier [4].

In this paper are evaluated two selected walls with different orientation and similar composition. Evaluation is focused on the temperature and relative humidity courses during the winter and spring time period. Measured courses are compared with HAM simulation. Also the non-steady *U*-value courses are shown.

2. Comparison of experimental measurements and simulations

The WUFI Pro 5.1 [5] software was used to evaluate the hygrothermal behaviour of selected sandwich walls. The following boundary conditions were used in simulations. For the indoor environment, a constant temperature of 20 °C and a constant relative humidity of 50% were entered. For the external environment, the actual climatic conditions in the city of Zilina, which are obtained from the own meteorological station, have been entered. The meteorological station is located on the roof of the building, where the experimental research of the pavilion is. Using the local microclimate is very important [6]. The values are recorded throughout the year. Continuous data collection is at hourly interval. For this article has been selected one week, specifically from March 2 to 7. During the first days, the temperatures reached negative values. Later, they were positive, but not above 5 °C. The lowest temperature was -12.7 °C on March 4, 2018, at 8:00. Average relative humidity was about 60%.

The comparisons are processed on two selected walls (Figure 1), which have the same exterior and interior finishes. On the outside, it is a plaster and the inner surface is made of OSB boards. The individual parts of the wall fragments differ in the used insulating materials. Properties of individual used materials are summarized in Table 1. Both structures are diffusely open.

Table 1. Material properties of used materials.

Material	Description	d (m)	λ (W/(m.K))	ρ (kg/m^3)	c (J/(kg.K))	μ (-)
Silicone plaster	Weber 0R1E, light beige	0.0020	0.86	1600	920	130
Glass fibre	Blown-in insulation – Insulfit	0.22	00.043	35	940	1
Glass fibre	Façade board – Clima	0.1	0.034	148	1030	1
Sandwich insulation	Facade board (20 mm basalt fiber + 80 mm graphite polystyrene board) – Twinner	0.1	0.033	25	1100	30
Phenolic insulation	Kingspan Kooltherm K5	0.040	0.021	35	1400	35
OSB board	OSB board 3	0.012	0.13	650	1700	50

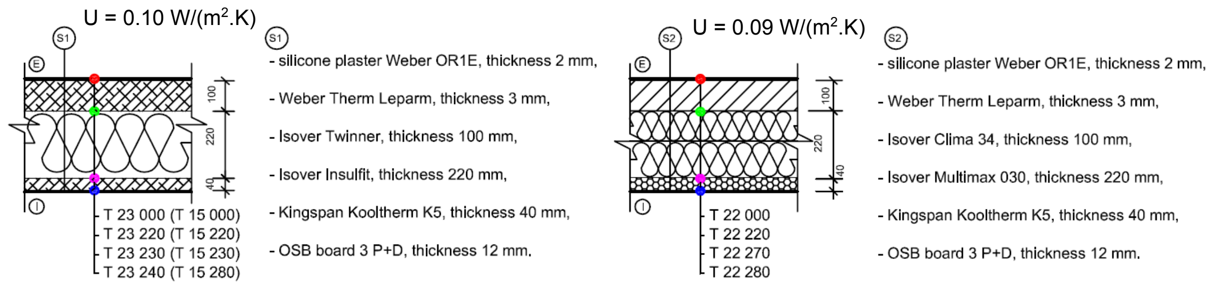

Figure 1. Sandwich walls with sensors names. Left composition is oriented towards south and east (names in brackets), Right composition only towards south

The measured and simulated temperature profile in the fragment section of the experimental wall "S1" is shown in Fig. 2. Figure 3 also represents measured and simulated temperature data but part of experimental wall fragment "S2". The horizontal axis shows the time and the temperature on the vertical axis.

The comparison of measured and simulated results in selected diffusion open constructions shows a relatively good match. During the day the temperatures are almost the same as in the night, depending on the depth of storage of the individual sensors from the exterior. The greatest temperature differences occur during the day on the outer surface, in the plaster. From the graphs, it is possible to read how the weather changed during the selected days. It is best to see on curves that represent temperature on the outer surface. At the beginning of the week, the weather was cloudy, which changed to sunny for the next two days when the surface temperature was above 20 °C.

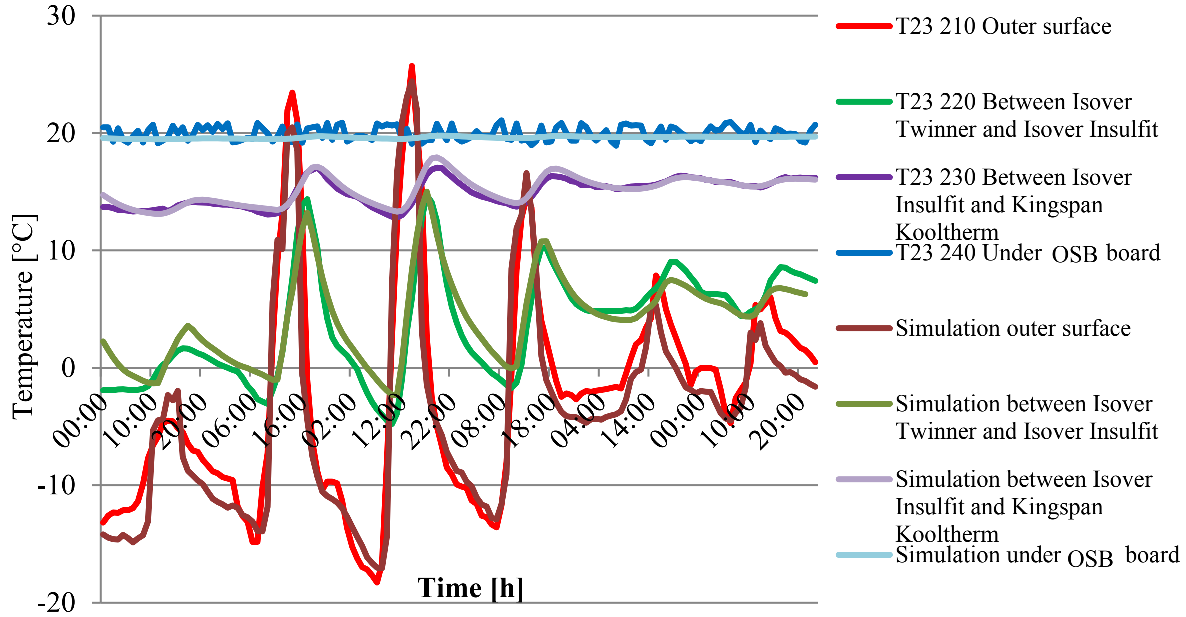

Figure 2. Graphically compared experimental measurement results with simulated results of the experimental wall fragment section "S1" during one chosen week

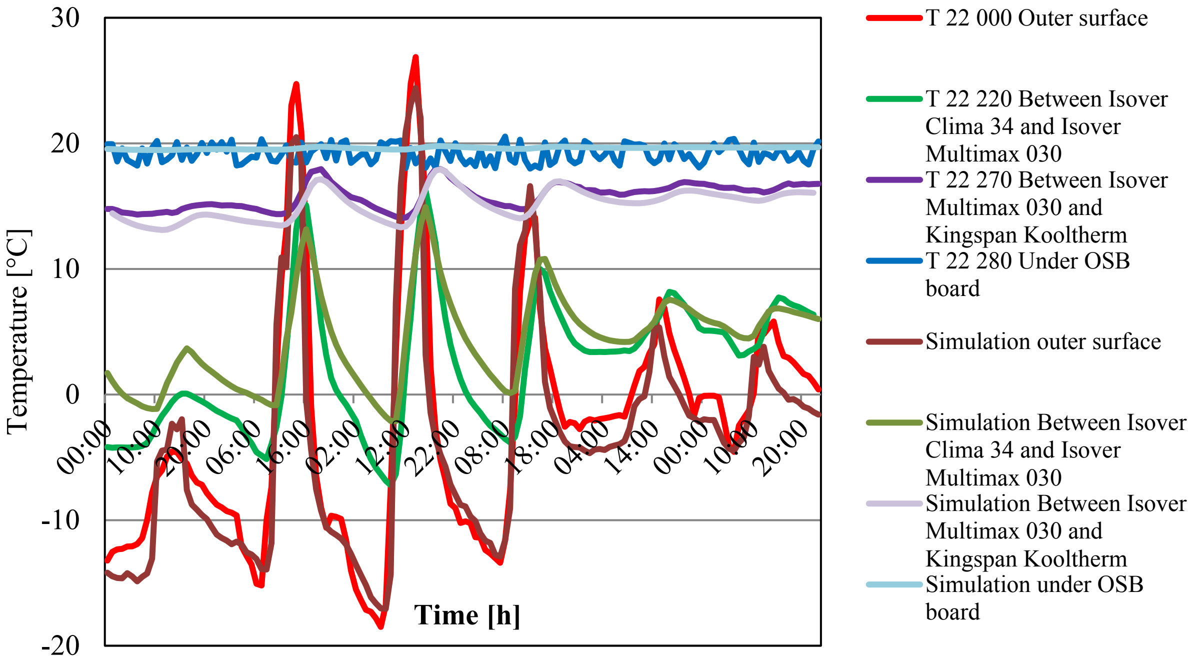

Figure 3. Graphically compared experimental measurement results with simulated results of the experimental wall fragment section "S2" during one chosen week

The weather worsened at the end of the week, which can be deduced from the graphs where the surface temperature dropped significantly over the sunny days. Curves showing the temperature below the MDF board are still in the simulations, given that the internal temperature was entered as a 20 °C constant. While the measured values of the temperatures oscillate around the temperature of 20 °C. These measurements are partly influenced by the air conditioning units located in the room to provide stationary conditions. Based on the curves shown in figures 2 and 3 the phase shift of the temperature in the construction from the exterior side towards the interior is well visible.

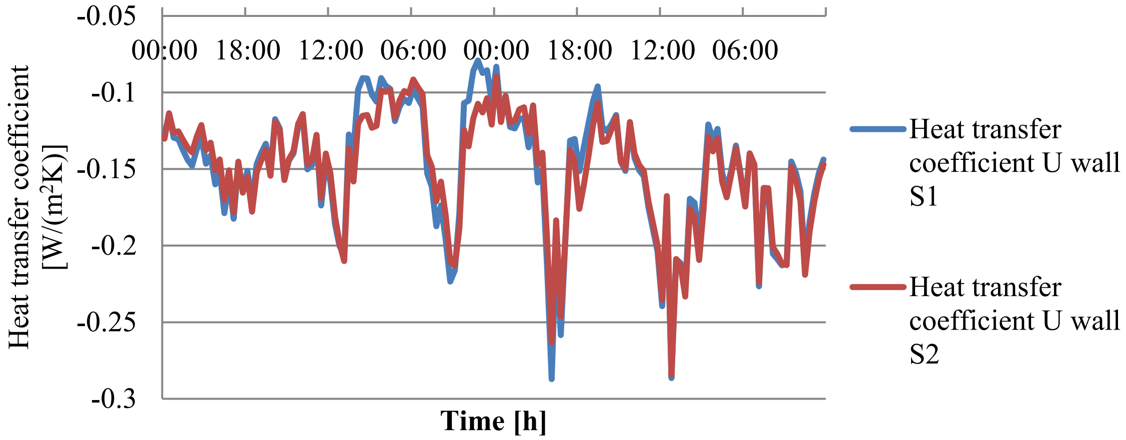

Figure 4. Heat transfer coefficient wall "S1" and "S2"

Figure 4 shows the progress of the heat transfer coefficient of the two tracks. In both cases, these are apparently non-stationary. For wall composition "S1" the average coefficient of heat transfer is 0.149 W / (m^{2}K). For this structure, the average heat transfer factor between 00:00 and 06:00 during the selected week is 0.127 W / (m^{2}K). The wall composition "S2" has an average heat transfer coefficient of 0.150 W / (m^{2}K) and is from 0.00 to 06.00 in the selected week 0.162 W / (m^{2}K). Heat transfer coefficient measurement rules were respected [7].

3. Selected experimental measurements of temperature and relative humidity

This section contains example of measurements for the "S1" wall structure. This section is oriented to the south and east. The temperature and relative humidity values are from the middle of the experimental wall height. Measuring period is from 12.10.2018 to 18.10.2018, which is the autumn climate period.

Figures 5 and 6 show south-facing wall courses, figures 7 and 8 east facing courses. Figures 5 and 7 show the temperature courses for selected positions and Figures 6 and 8 relative humidity courses.

From figures containing temperature courses, it can be seen that the difference in the temperature peaks on the outer surface is about 8 to 10°C between southern and eastern orientation. Low peaks is lower by about 2 to 3°C.

The phase shift of the temperature between the two orientations is about 3 hour. The surface temperature of the south-facing wall reaches higher values compared to the east-facing wall. It can also be seen that in the east-facing wall, the outside temperature is higher than the temperature between the Isover Twinner and Isover Insulfit layers, while in the Southern orientation it is the opposite. From the relative humidity courses, the phase shift can be read as well as the temperature graphs. In the southern orientation, the relative humidity between the Isover Twinner and Isover Insulfit position is significantly lower than in the eastern orientation and decreases in the evenings, along with the position below the MDF board below air humidity in the interior. The humidity values at the Isover Twinner and Isover Insulfit in the eastern orientation are higher than the relative humidity of the outside air. This strange behavior will need further investigation.

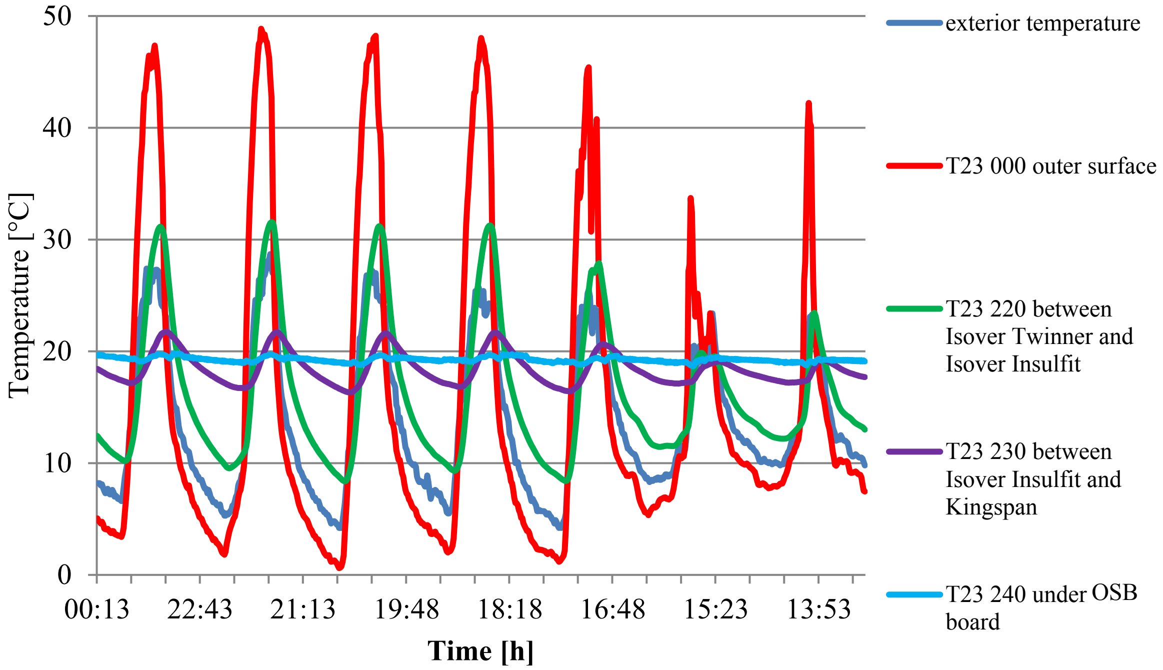

Figure 5. Temperature measurement of the experimental wall fragment section "S1" with south orientation

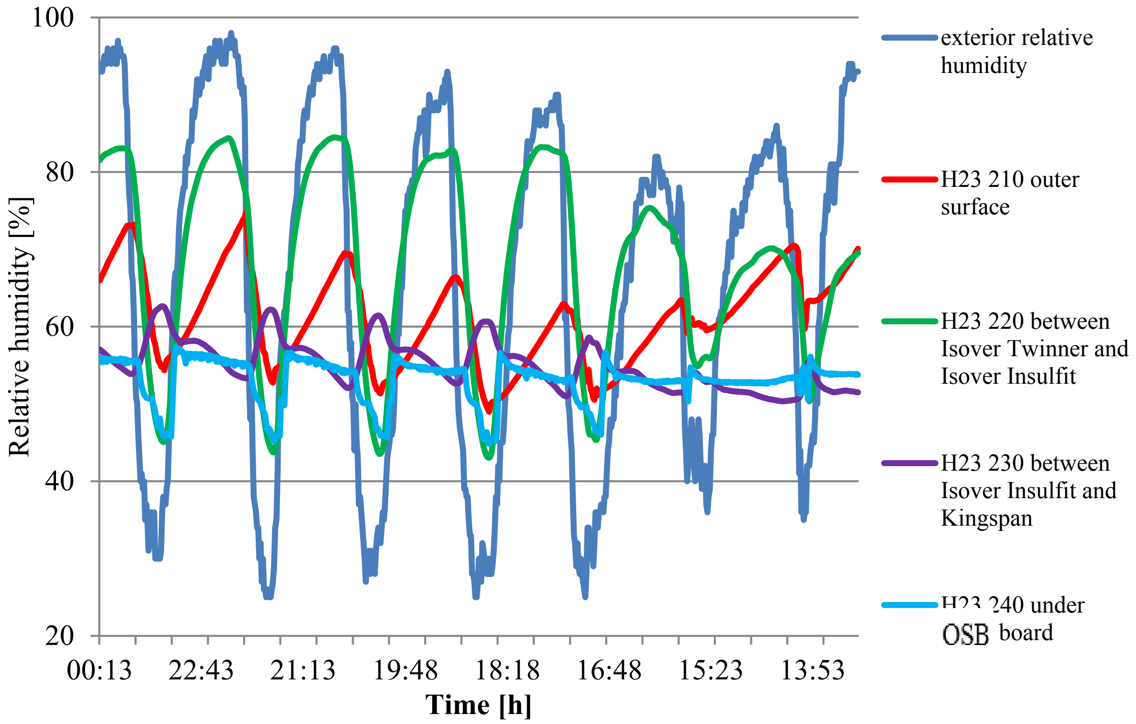

Figure 6. Relative humidity measurement of the experimental wall fragment section "S1" with south orientation

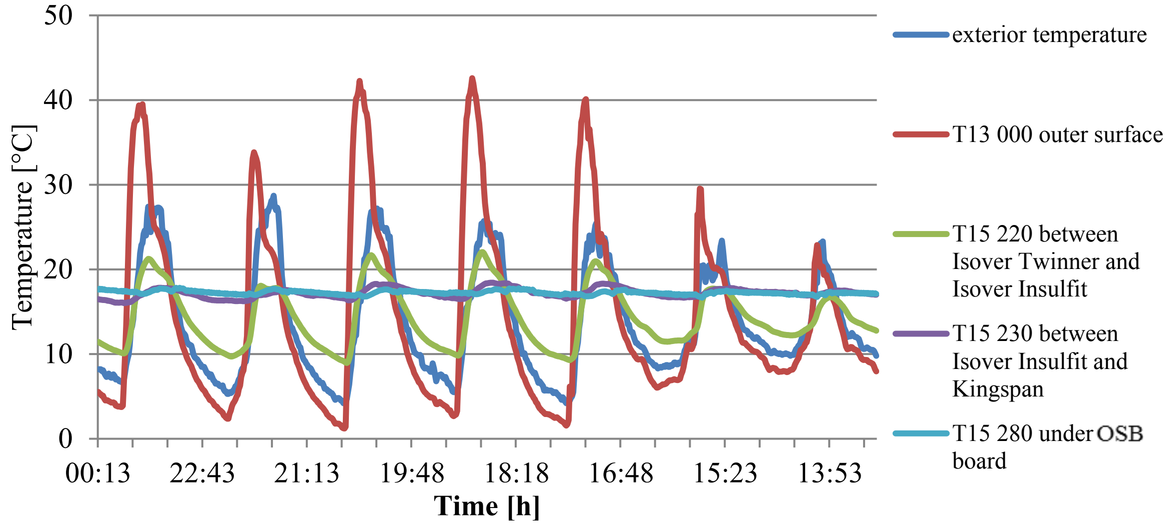

Figure 7. Experimental temperature measurement of the experimental wall fragment section "S1" with east orientation

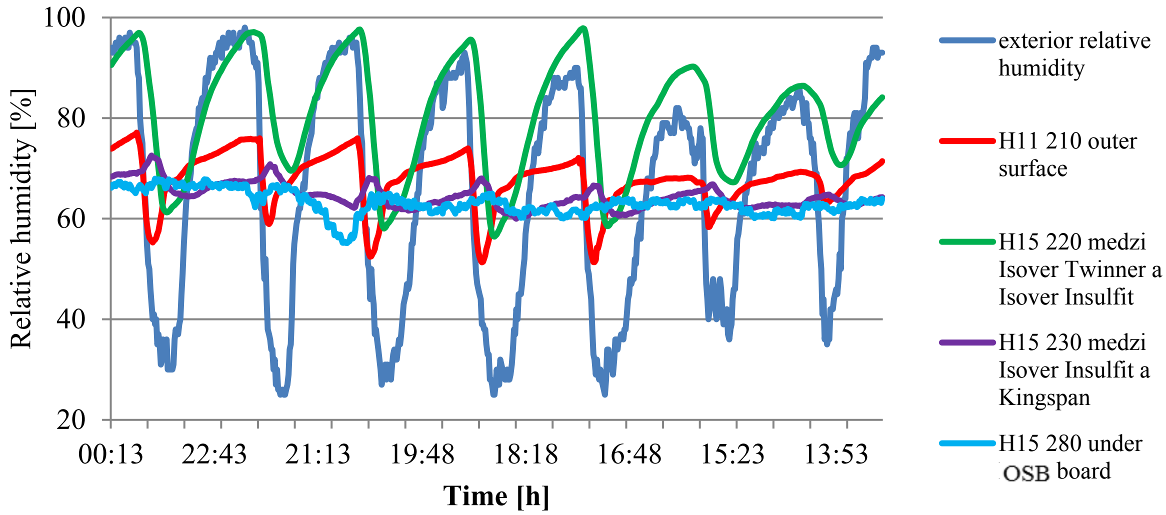

Figure 8. Experimental relative humidity measurement of the experimental wall fragment section "S2" with east orientation

4. Conclusion

This study pointed to a small temperature difference in two similar experimental wall fragments. The temperatures through the wall structure are similar. In some positions, higher temperature differences are observed. This is due to the different thermal insulation and heat-accumulation properties of the materials that have been used in the sandwich panels of wooden buildings. It also contains the passages of the heat transfer coefficients in the compared constructions.

Comparison of the measured parameters courses in the pavilion research and its simulation showed a significant match, which can be used in further research in variation of different boundary conditions in parametric studies.

The heat transfer coefficients in the compared wall compositions showed markedly non-steady courses. This could be further used to calculate more precisely heat loss through the building envelopes based on the timber framed walls.

In the selected time periods, the diffuse open compositions confirmed suitability for the realization of timber framed structures in passive buildings in terms of heat and moisture transport.

These laboratory measurements together with the simulations will be later verified by testing on samples taken in the climate chamber. Due to the different types of materials used and their combinations, it is possible to observe and compare their behaviour under the same boundary conditions from the exterior as well as from the interior.

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