Wooden wall research: comparison of pavilion laboratory and climate chamber measurement

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Abstract. With advance in the thermal protection, sustainability, low carbon, energy consumption etc. is the advance in the building envelopes important. Department is working in the research of lightweight timber-framed walls for several years. There are developed and tested several wall structures in the pavilion type laboratory - exposed to the real outdoor climate and controlled indoor climate. In this paper is made comparison of the selected wall composition, with aerated air cavity on the outdoor surface. Comparison is made with the pavilion laboratory wall and fragment of same composition in the climate chamber. With use of own weather station, recorded outdoor climate can be exactly modeled in the chamber. Also temperature and relative humidity courses were compared during same day. More test were evaluated in the climate chamber and analyzed.

1 Introduction

The equipment of the department was constantly upgraded for several years and nowadays includes top laboratory instruments and computational devices that enable to analyze and evaluate complex heat and humidity transfer through building structures.

The research at the Department is oriented to lightweight column sandwich structures, which are suitable for use for nearly zero energy buildings. In a pavilion laboratory with possibility to set-up the indoor environment are totally eight types of lightweight sandwich wall evaluated. These are exposed to the conditions of a real outdoor climate during the year. Individual wall compositions differ with use of building materials (thermal insulation, surface finishing, diffuse open and closed structures) and orientations (east, south).

Departments' climate chamber located in Research Centre of University of Zilina allow laboratory measurement of the same composition with use of the "guarded" hot box or without it. According to [1], the climate chambers are primarily designed to obtain data of the thermal and technical behavior, the state of the building envelope elements under the influence of real ambient climate conditions. In the chamber (consisting of outdoor and indoor), it is possible to combine the effects of temperature differences, water vapor pressures, air filtration, solar radiation, precipitation, etc.

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Last possibility of design evaluation are use of dynamic modeling and computational simulations of monitored structures using simulation programs (ESP-r, WUFI Pro, WUFI 2D) [2, 3]. As the input for simulation are correct outdoor boundary conditions needed. These should be accurate, with high precision, consisting with all required climate parameters (such as diffuse solar radiation) and close to the location. For this purpose, detached experimental weather station is located on the roof of pavilion laboratory building [4]. Detailed description of the measuring devices and the measurement methodology is elaborated on [5].

The aim of the research is to obtain a comprehensive overview of heat and moisture (HAM) transport in the selected wall compositions annually. This includes the load bearing columns as thermal bridges, overheating, wind-driven rain on the joints, environmental aspects, etc. Another important reason is the creation of data sets for the comparative case studies, HAM simulation validation of measurement etc. In this area of research, department has long-term experience [5-8].

Because of the limited extent of the paper, results of the research are limited to the evaluation of two wall compositions with different orientation.

2 Selected wall compositions

Selected wall composition is one of the two compositions which have two different orientation. This wall composition is oriented towards east (V4) and south (J5) in the pavilion laboratory. Outdoor surface consists of aerated wooden cladding and indoor surface consists of OSB board. It is a diffuse closed construction and insulation is combined from glass and mineral wool.

Fig. 1. Composition of wall sample for climate chamber with location markers for the sensors (V4, J5).

Manufactured sample of the wall composition for measurement in the climate chamber has dimensions 1210 mm x 1460 mm. The perimeter of the sample is made from 25 mm thick OSB board, total thickness of the sample is 320 mm. In the middle is located column with dimension 60 x 220 mm. Detailed composition of the wall with material properties is described in the Table 1. Sensors (combined temperature and humidity sensors) are located

in the middle of the insulation part and around the column and position are marked in Fig. 1. These sensors are placed in each layer. In addition, also heat flux plates are incorporated within the composition.

Table 1. Structure of the selected wall.

Material	d	λ	ρ	c	μ
	[m]	[W/(m.K)]	[kg/m ³]	[J/(kg.K)]	[-]
Wooden cladding with impregnation	0,028	0,18	400	2510	157
Air cavity	0,040	0,444	1010	1,2	0,25
Vapor membrane “intelligent”	0,00005	0,35	60	1470	100000
Mineral thermal insulation	0,100	0,36	100	1020	1
Glass fiber insulation	0,220	0,03	64	940	1
Vapor membrane “intelligent”	0,00005	0,35	60	1470	100000
OSB board	0,0012	0,13	650	1700	50

3 Results

For comparison the pavilion and climate chamber measurement was selected one day, 25.04 17:00 - 26.04.2018 15:00. This day is from the mild (spring) season of the year, with lower influence of the heat accumulation. One of the reason for selection was the technical limits of the chamber. During this period, the weather was cloudy, which means that the direct solar radiation was low that day. Results of the selected period for the pavilion wall is shown in Fig. 2 for temperature and relative humidity courses. Exterior air temperature was measured by weather station. At the beginning, surface temperature was 23 ° C and dropped to 11 ° C. The temperature below the OSB plate was around 19 ° C.

Fig. 3. Temperature and relative humidity courser measured in the experimental wall in a pavilion center.

In terms of temperatures, measurement in the pavilion wall showed that the air conditioning unit did not maintain a constant temperature of the indoor climate, which

oscillates around 1 °C. The influence of the exterior climate (temperatures varied from 25 °C to 7 °C, cloudy sky) is obvious on the outer layers of the wall. The temperatures on the exterior cladding and in the air cavity follow the course of the outside temperature. Courses toward interior have smaller amplitude and are closer to the indoor air course.

In terms of the relative humidity of the indoor air, its values also oscillate about 10%. Courses in the individual layers respond accordingly to the external climate (temperature, relative humidity) with the highest values of relative humidity on the exterior surface and in the air cavity.

Results from the measurement in climate chamber are in Fig. 4 and 5. Boundary conditions are the same as in Fig. 3: outdoor air temperature and relative humidity are based on the measurement by the weather station. Indoor boundary conditions were kept constant with values based on the measurement. To study the differences in the courses were simulated three identical cycles.

Fig. 4. Temperature courses in the wall fragment measured in climate chamber.

Fig. 5. Relative humidity courses in the wall fragment measured in climate chamber.

Achieved temperatures are similar to the pavilion research, surface temperatures and under the OSB board, which was around 19 ° C. The temperature and humidity courses follow the trend curves of measurement under real conditions in pavilion. Both measurements have proven trouble-free thermal-moisture behavior in the selected time period. Comparison of wall temperatures with different orientations showed that surface temperatures for the south orientation was partially affected by solar radiation. This southern wall reached higher temperatures compared to the wall having the eastern orientation.

For the testing in the climate chamber were chosen several different regimes. One of them consist of constant indoor air temperature and constant outdoor air temperature with one hour steps from 10 °C up to -20 °C and then to 35 °C. The steps are 5 and 10 °C.

Temperature courses for the position in the middle of the wall and on the column are in Fig. 6. From the temperature courses in the wall composition, it can be stated that these respond to the outdoor temperature changes accordingly. The outer parts of the wall follow the outdoor temperature and on the other hand, sensors within the composition are still in the positive values. There is also phase shift observable.

Fig. 6. Temperature courses for the middle position (top) and around the wall column (bottom).

Fig. 7. Relative humidity courses for the middle position (top) and around the wall column (bottom).

Relative humidity courses for the same test are in the Fig. 7. Relative humidity in the outdoor chamber was not controlled, which is caused by the use of negative temperatures, the chamber cannot control humidity in this case. Highest relative humidity is detected on the outer membrane next to the air cavity, also higher values are between insulation layers during the heating up the wall.

4 Conclusion

In this paper, partial results of the HAM lightweight wood-based sandwich construction are described. Departments' equipment allows to simulate measured real outdoor climate in the climate chamber. This enable possibility to investigate various compositions such as experimental wall in this paper. Comparing the results of the pavilion research together with the results from the climate chamber allow to draw exact conclusions in the future. The existence the weather station make possibility to set-up similar boundary condition and create a database of external climate data set to use them in simulation tools. This will be investigated in the next step.

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