Ventilated Air Cavity – Annual Evaluation

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Abstract. The restricting regulations in European legislation lead to significant changes in building designs in order to reduce energy consumption. Possible approach to this phenomenon is to design passive wooden houses which provide high thermal resistance whilst maintaining relatively small structure thickness. Scientists engaged in these wooden structures focus nowadays on issues linked to the timber-framed wall structures, amongst others durability, heat capacity, or summer overheating. This paper focuses on measurements of a light-weight wooden wall assembly with ventilated air cavity which is one of possible solutions not only to reduce the influence of weather changes, but also to reduce overheating of interior space. This specific assembly is implemented in pavilion research of Department of Civil Engineering and Urban Planning within UNIZA campus in Zilina, Slovakia. It summarizes annual measurements of temperature and relative humidity in the sample center and near the wooden studs. Contribution describes the potential of using ventilated air cavity to maintain steady conditions thorough whole year.

Keywords: Ventilated air cavity · Passive wooden houses · Annual measurements · Temperature · Relative humidity

1 Introduction

Air cavities are a spread method to maintain steady conditions within envelope structures [1–4] as well as to increase the acoustic resistance [5].

This contribution focuses on the thermal performance of such structures. Creation of double-skin facade is advantageous due to the synergic effect of convection and radiation within the air cavity. Analyzes of these cavities is rather rare because of their varying results. In [2] the authors aim their interest towards investigation of their thermal resistance. The conclusion of their research is that the thermal resistance of the ventilated cavity can be 9 times the thermal resistance of the cladding.

This paper describes a wall fragment of such light-weight passive wooden house using ventilated air cavity to protect the internal environment from overheating. It follows the previous publication [6].

2 Methodology and Boundary Conditions

The pavilion laboratory of UNIZA contains three separate rooms. One of them contains window samples, the other two have built in timber-framed wall fragments designed

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for passive wooden houses [7]. The scope of this paper is one of the wall segments with eastern orientation. Figure 1 shows eastern wall assembly with 5 different wall structures.

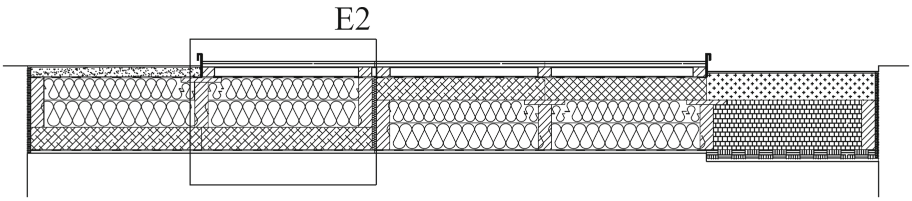

Fig. 1. Experimental wall structure with eastern orientation

Sensors for temperature and relative humidity are on the interfaces of various materials and within the room itself to monitor interior conditions. Specifically, NTC thermistors with accuracy of ±0,2 °C for temperature measurements and capacity probes with accuracy of ±2% for relative humidity. Data is gathered by multimeter Fluke Hydra III.

The weather station for external boundary conditions is located on laboratory roof to ensure corresponding values.

2.1 Exterior Climate

Figure 2 shows mean monthly exterior air temperature and rain during year 2019. According to the graph, the rain reached its maximum in May, although June reported in average highest temperatures.

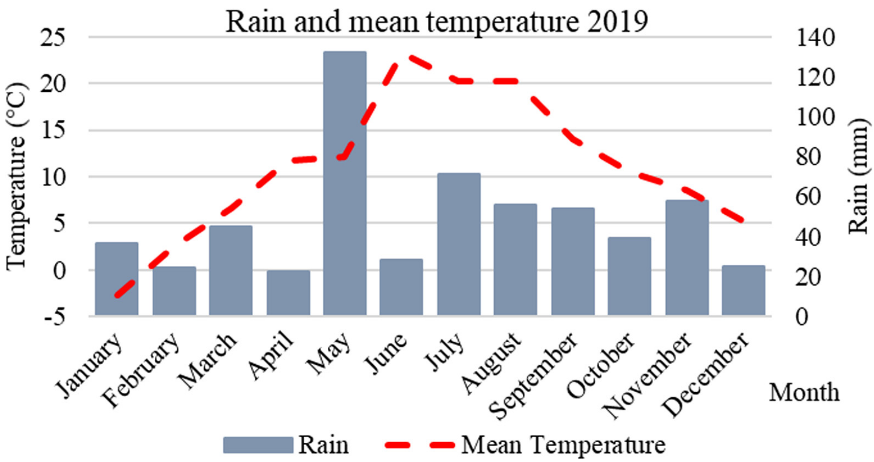

Fig. 2. Rain and mean temperature during 2019

Figure 3 presents solar radiance intensity – direct and diffuse – measured by the weather station. Correspondingly to the temperature, the intensity reached its peak during June.

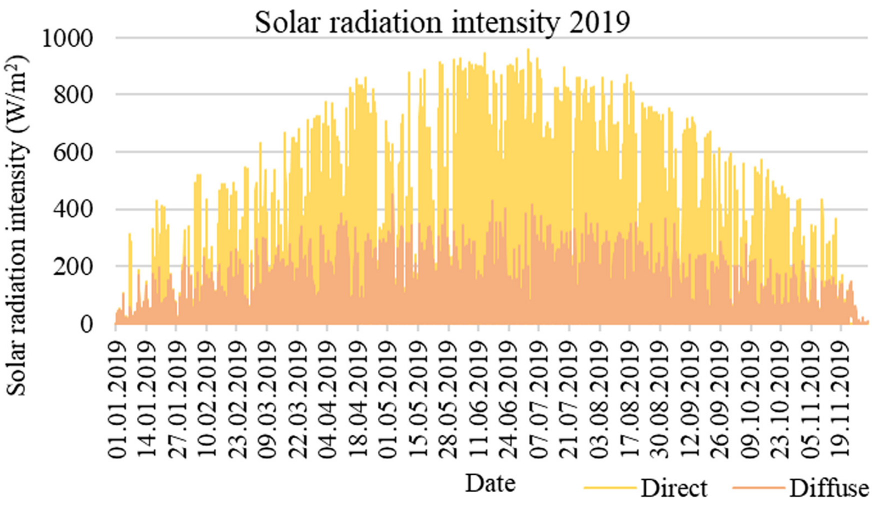

Fig. 3. Solar radiation intensity 2019

Last but not least, Fig. 4 shows wind speed and direction during this year. The predominant wind direction was southwest with speed between 0,2 to 0,7 m/s.

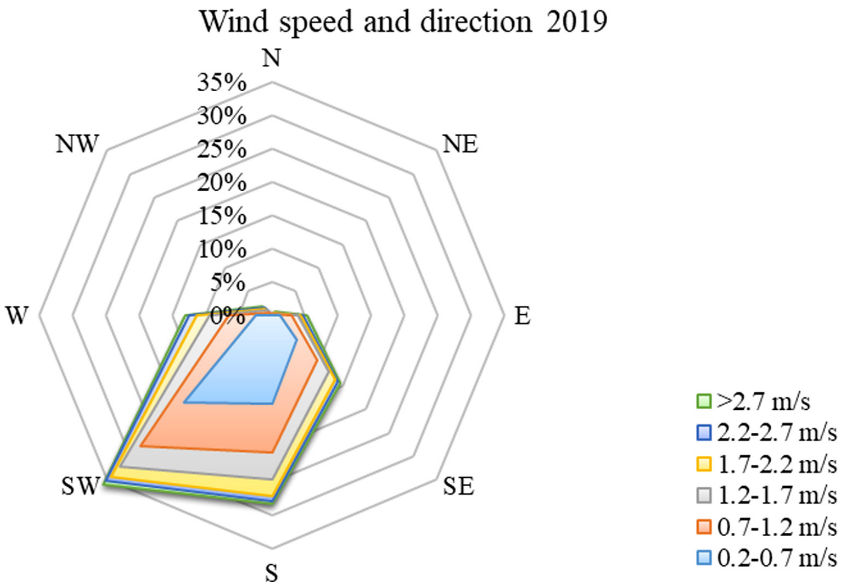

Fig. 4. Wind speed and direction diagram 2019

2.2 Interior Conditions

The sensors for interior temperature and relative humidity measurements are placed in the center of eastern laboratory. Figure 5 shows these measurements during the year 2019. The intention was to keep the interior climate stable which was disabled due to unreliable ventilation system. On the other hand, this error enabled us to see the wall behavior in more realistic conditions.

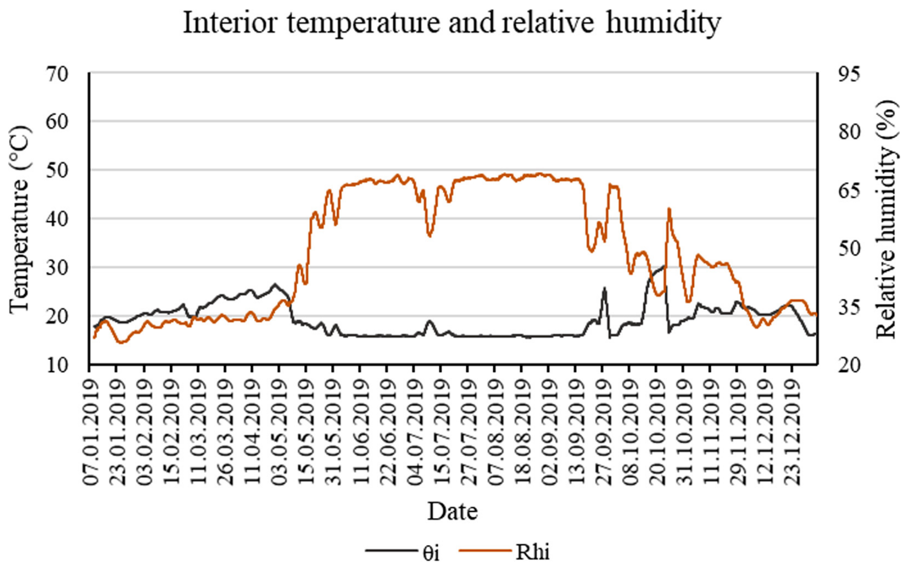

Fig. 5. Interior temperature and relative humidity in eastern laboratory

3 Wall Fragment

The laboratory is highly insulated to ensure elimination of additive heat flow through the structures. Interior and exterior boundary conditions are described in previous section. Following text focuses on materials within the assembly, their properties and sensor placement.

Figure 6 displays materials order and probes placement for temperature θj and relative humidity Rh.

From exterior the layers are: wooden cladding (28 mm), ventilated air cavity (40 mm), adaptive vapor barrier Isover Vario KM Duplex UV, thermal insulation of glass fibers Isover Multimax 030 (220 mm), thermal insulation of wooden fibers Steico Protect (100 mm), another layer of Isover Vario KM Duplex UV, finished with OSB 3 P + D (12 mm). Table 1 contains main physical characteristics of these materials.

More complex characteristics are stationary and nonstationary properties shown in Table 2.

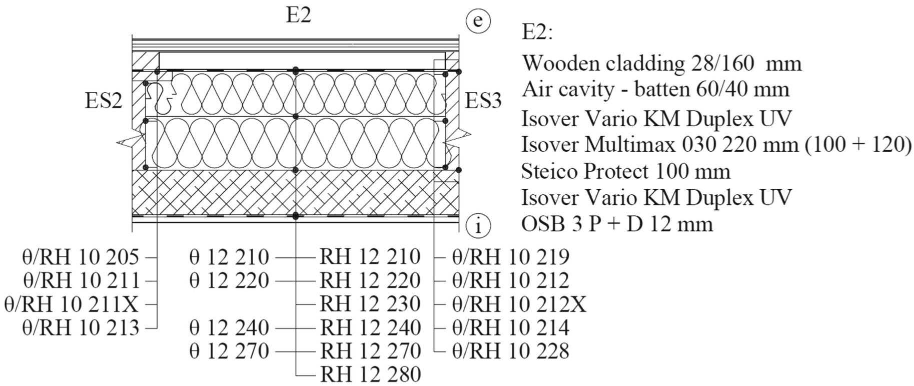

Fig. 6. Horizontal section of wall assembly with sensors placement

Table 1. Material characteristics

Material	d (m)	ρ (kg/m^3)	λ (W/(m.K))	μ (-)	c (J/(kg.K))
Wooden cladding	0,028	400	0,180	157	2510
Isover Vario KM Duplex UV (adaptive vapour barrier)	0,0002	364	0,350	100000	1470
Isover Multimax 030 (glass fibres)	0,220	64	0,030	1	940
Steico Protect (fibrewood)	0,100	265	0,048	5	2100
OSB 3 P + D	0,012	650	0,130	50	1700

Note: d – thickness, ρ – bulk density, λ – thermal conductivity, μ – water vapor diffusion resistance factor, c – specific heat capacity

Table 2. The main properties of the structure.

Name	R_T ((m^2.K)/W)	U (W/(m^2.K))	ν (-)	ψ (h)
E2	7,99	0,125	248,8	10,3

Note: R_T - thermal resistance, U – heat transfer coefficient, ν – thermal damping factor, ψ – phase shift of thermal oscillation.

4 Results

Laboratory equipment records temperature and relative humidity in 15 min intervals. To provide comprehensive and clear results of annual measurements are the measurements reduced to trend lines with period of 200. The following graphs show comparison of these parameters in three depths of the wall – from exterior (e), in the middle (without any other indication), and from the interior (i). Moreover, the results are presented near the wooden studs (ES = eastern stud) and in the center between them.

Figure 7 describes the temperature in mentioned placements with sensor indicators in order to preserve their localization.

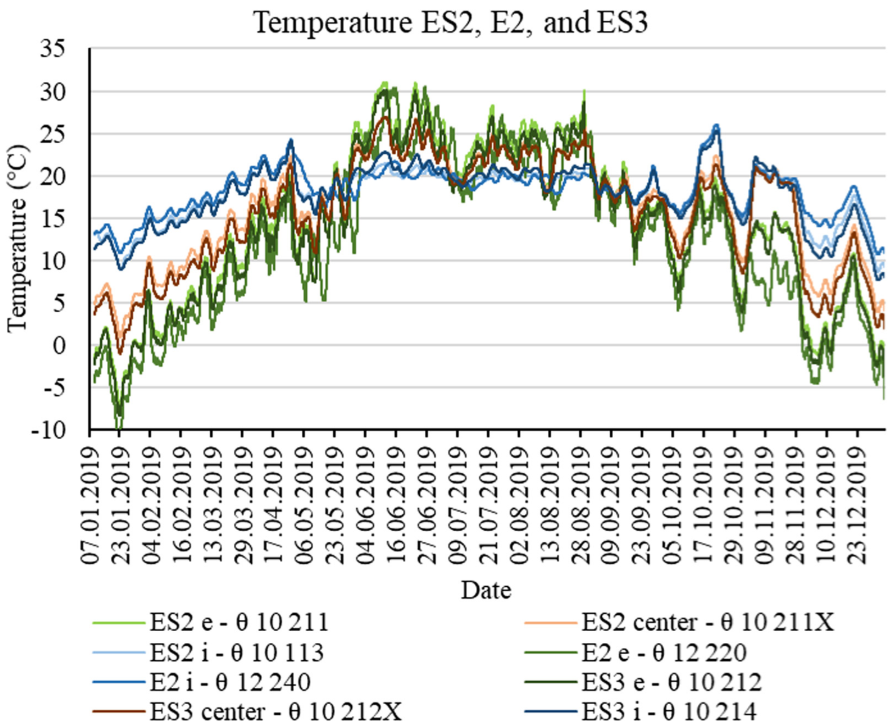

Fig. 7. Temperature of eastern stud 2 (ES2), eastern wall 2 (E2), and eastern stud 3 (VS3)

The temperature is almost identical almost throughout the whole year in both cases of wooden studs. This, beside others, confirms legitimacy of the measurements. Small differences are implied due to different wall assemblies from the other side of each stud.

The center of the assembly reports more significant discrepancies, foremost near to the exterior – in average 2 °C lower temperature which is caused by the ventilated air cavity itself. In summer period is obvious a significant temperature shifts. Towards the interior the temperature amplitude decreases. The temperature shift is nevertheless noticeable even in interior placement, where is essential influence of the interior climate conditions.

Figure 8 displays the relative humidity in surveyed zones of the structure. The linear regions are caused by the air conditioning breakdown, in some cases failure of a recording system.

Similarly to the temperature, the relative humidity doesn't show large discrepancies in terms of wooden studs. The significant divergence in results of studs and center of the assembly is foremost caused by the fact, that the studs are not directly exposed to the ventilated cavity (Fig. 6). Notable is the lower relative humidity almost throughout all year in the middle of the structure without large fluctuation.

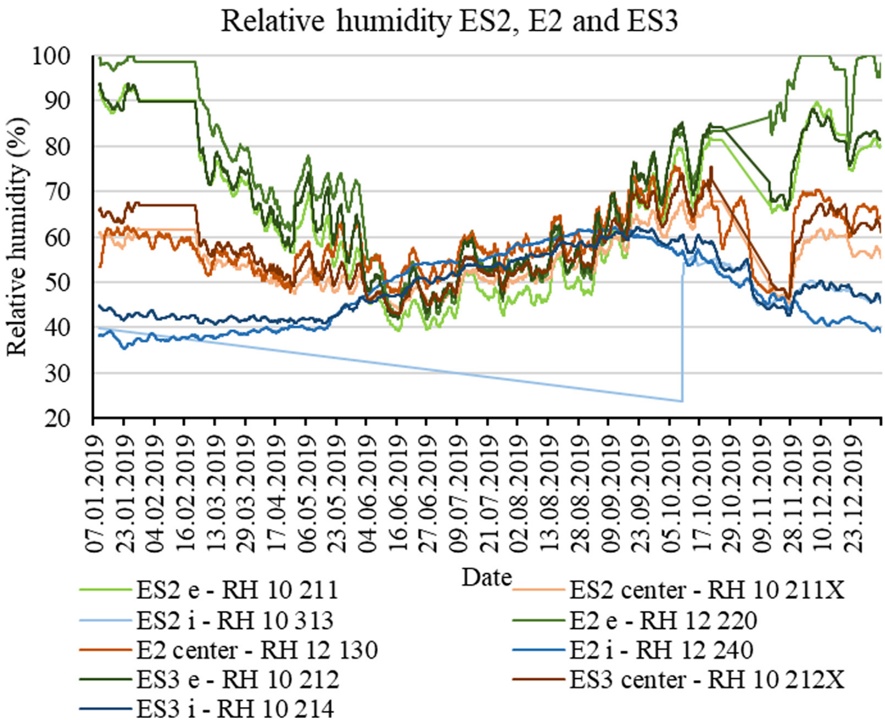

Fig. 8. Relative humidity of eastern stud 2 (ES2), eastern wall (E2), and eastern stud 3 (ES3)

5 Discussion

The advantages of passive wooden houses are unquestionable. But despite their low weight and extremely high thermal resistance there are some aspects to be aware of. One of them is summer overheating which is widely discussed. Another approach is to incorporate PCM (phase change materials) into the walls to increase heat capacity of these structures [8].

The results stated in this contribution will be further supported by following research comparing this wall assembly to one without the ventilated air cavity during the same period.

6 Conclusions

The ventilated air cavity provides weather barrier for building structures. This paper describes one of these construction, specifically timber-framed passive wall assembly, that is under research for 10 years.

The ventilated air cavity showed significant ability to maintain steadier conditions within the structure while having only minor investment requirements.

The temperature shift and reduction of 2 °C demonstrate the advantages in application of these ventilated claddings.

Relative humidity shows lower values in the center the assembly between both studs, where it's directly exposed to the cavity. Nevertheless, the influence of this cavity in terms of relative humidity is minor due to the vapor barriers used in the assembly.

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