Influence of Weather Changes on Thermo-technical Behaviour of Selected Wooden House Wall Assemblies

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Abstract. Wooden houses became perspective in the building industry. The University of Žilina owns pavilion research, in which the light-weight wooden based envelope structures are tested. They are designed for almost zero-energy buildings. The structures vary in the used materials and their order. This paper deals with the analysis of their performance during exterior boundary conditions changes. The best performance in relation relative humidity has the structure V2, in which is used wooden cladding, ventilated air cavity and thermal insulations Steico Protect and Isover Multimax 030. In terms of the overheating is the structure V5 desired, with light beige render and thermal insulations Isover Twinner, Isover Insulfit and Kingspan Kooltherm.

1. Introduction
The consumption of the non-renewable nature sources, formed by biological and geological processes for ages [1], is becoming unbearable. Woodard and Milner [2] summarised the advantages of using wood in the building industry. It is a natural material, which consumes a small amount of primary energy for its production. Wood is light to recycle, is reusable and biodegradable. For the building industry, it provides a significant advantage by minimalizing of thickness by integrating the thermal insulation within the load bearing structure. The constructions analysed in this paper are designed to fulfil the legislative requirements for the almost zero-energy buildings [3].

2. Analysed constructions and boundary conditions
The light-weight wooden envelope structures referred in this article are embedded within the pavilion research of the University of Žilina, further described in [4]. Two wall systems are built within this research, one oriented to the east, the other one to the south. Both of them consist of 5 different wall assemblies with different materials or different order of the materials. This paper deals with the wall systems oriented to the east – figure 1. The applied materials and their main characteristics are listed in table 1.
Each structure V1 – V5 is equipped with the temperature and relative humidity probes as shown in figure 2. The temperature is measured with NTC thermistors (T) with the accuracy of ±0.2°C. The relative humidity with the capacity probe (H) with the accuracy of ±2%. The data are stored on digital recorder Fluke Hydra III.

The structures are exposed to the real external boundary conditions measured with the weather station within the research. The air conditioning provides constant internal boundary conditions. Evaluated are the measurements for the period 20.05.2019 – 02.06.2019, in which were reached significant divergences in the external air temperature and relative humidity – figure 3.

Table 1. Materials of wall structures and their main characteristics in alphabetical order

| Layer                          | d [m] | λ [W/(m.K)] | ρ [kg/m³] | c [J/(kg.K)] | μ [-] |
|--------------------------------|-------|-------------|-----------|--------------|-------|
| Adhesive render + meshcloth    | 0.005 | 0.90        | 1660      | 900          | 20    |
| Isover Insulfit                | 0.220 | 0.043       | 35        | 940          | 1     |
| Isover Multimax 030            | 0.220 | 0.03        | 64        | 940          | 1     |
| Isover TF Profi                | 0.100 | 0.036       | 100       | 1020         | 1     |
| Isover Twinner                 | 0.120 | 0.033       | 25        | 1100         | 30    |
| Isover Vario KM Duplex UV      | 0.00005 | 0.35     | 1600      | 1470         | 10000 |
| Kingspan Kooltherm K5          | 0.040 | 0.021       | 35        | 1400         | 35    |
| OSB 3 P + D                    | 0.012 | 0.13        | 650       | 1700         | 50    |
| Silicone render Weber HN8C     | 0.002 | 0.86        | 1600      | 920          | 130   |
| Silicone render Weber OR1E     | 0.002 | 0.86        | 1600      | 920          | 130   |
| Steico Protect                 | 0.040 | 0.048       | 265       | 2100         | 5     |
| Steico Protect                 | 0.100 | 0.045       | 230       | 2100         | 5     |
| Wooden cladding                | 0.028 | 0.18        | 400       | 2510         | 157   |

Note:  

- d – thickness, λ – thermal conductivity, ρ – bulk density, c – specific heat capacity, μ – water vapor diffusion resistance factor.
Figure 2. Analysed wall structures with probes placement – temperature T and relative humidity (H)
Within the mentioned period was the temperature of 7.1°C to 32.8°C. The relative humidity was between 27% and 99%. The first cooling and thereby rising of the relative humidity occurred 22.05. and especially on 23.05. On the contrary, the other day the temperature rose by 10°C and simultaneously the relative humidity decreased. The second cooling started at 28.05. and lasted to 31.05.2019.

3. Results
Because of the nonhomogeneous basis of the structures, the heat transfer coefficient is calculated according to the current legislative [5] with the results listed in table 2.

| Structure | Heat transfer coefficient U [W/(m².K)] |
|-----------|----------------------------------------|
| V1        | 0.120                                  |
| V2        | 0.122                                  |
| V3        | 0.122                                  |
| V4        | 0.114                                  |
| V5        | 0.099                                  |

3.1. Structure V1
The temperature and relative humidity within the structure V1 are displayed in figure 4 and figure 5. The temperature curves show the reaction of the materials to the outer conditions. The first two days was the temperature of exterior layers significantly higher than the temperature of the exterior air. This phenomenon may be caused by solar radiation. The following days during the cooling, the curves almost copy the temperature of the outer air. The warming caused the surface temperature of 50°C, while the air temperature was under 30°C. The relative humidity near to the exterior – Steico Protect copies the outer air. The relative humidity of the interior materials is rather constant within 40 to 52%.
Figure 4. Temperature curves of structure V1 20.5. – 2.6.2019

Figure 5. Relative humidity curves of structure V1 20.5. – 2.6.2019
3.2. Structure V2
Figure 6 and 7 shows the temperature and relative humidity of the V2 structure. Similar to the V1, V2 shows a significant response to the outer climate. In this case, the temperature of the exterior surface is 2°C lower than in the previous example. The temperature of Isover Multimax surface is even 5°C lower compared to the V1. The relative humidity within the structure is rather constant by around 70%. Within the interior materials is the relative humidity between and 50%.

**Figure 6.** Temperature curves of structure V2 20.5. – 2.6.2019

**Figure 7.** Relative humidity curves of structure V2 20.5. – 2.6.2019
3.3. Structure V3

The exterior surface of the structure V3 has the same probe of the exterior surface temperature as V2 because they both possess the same exterior cladding. The temperature curves – figure 8 – is similar to the structure V2. By comparison with V2, in V3 are the materials in a different order, which causes the 1°C lower temperature in the middle. The relative humidity – figure 9 – at the surface of Steico Protect tends to vary which may be caused by the ventilated air cavity. In the middle of the construction is the relative humidity 10% lower than in V2. The highest values occur 8 hours earlier than in the V2.

Figure 8. Temperature curves of structure V3 20.5. – 2.6.2019

Figure 9. Relative humidity curves of structure V3 20.5. – 2.6.2019
3.4. Structure V4
The exterior surface temperature – figure 10 – is the same as in the previous cases – V2 and V3. The temperature by the air cavity is however compared to them 1 – 2°C lower. In the middle is the temperature of greater amplitude and is mostly 2°C higher by the maximal temperature of 23°C and 1°C lower by the minimal temperature 16°C. The relative humidity – figure 11 – is of greater amplitude, too, and moves from 45% to 83%.

![Figure 10. Temperature curves of structure V4 20.5. – 2.6.2019](image)

![Figure 11. Relative humidity curves of structure V4 20.5. – 2.6.2019](image)
3.5. Structure V5

The exterior surface temperature of V5 – figure 12 – is the lowest above all mentioned constructions. Its temperature is 5°C lower compared to V1, while the only difference between both surfaces is the colour. In comparison to V2 – V4 is the temperature 2°C lower. The temperature in the middle almost copies the curves of V1. By low exterior temperatures is this temperature 1°C – 1.5°C lower than in V2 – V4. The maximal relative humidity – figure 13 – reaches 85% by exterior relative humidity 83%. The extremes occur 5 hours earlier than in V4 and 10 hours later than in V3.

![Figure 12. Temperature curves of structure V5 20.5. – 2.6.2019](image)

![Figure 13. Relative humidity curves of structure V5 20.5. – 2.6.2019](image)
4. Conclusions
It can be stated that all the structures have almost constant curves of temperature and relative humidity of the interior materials. This is caused by the modified interior climate by air conditioning.

The highest relative humidity was measured in the structure V4. The most preferred in regards of relative humidity is V2 with wooden cladding with a ventilated air cavity and thermal insulation Steico Protect and Isover Multimax 030. The structure V5 is the only diffuse-open construction mentioned in this paper. The relative humidity is in this case in the interior materials higher than in 4 other structures – around 60%. The closest measured relative humidity is similar to the V2 – V4. No condensation zone occurs in the selected structures.

On the other hand, in regard to temperature, the structure V1 showed the highest temperature on the surface and also within the structure. In concern of the overheating is the structure V5 most advantageous. There is a light-beige surface and shows the lowest surface temperature above all the other structures. The best performance in terms of heat accumulation shows the layer Steico Protect (V1, V3) and Isover TF Profi (V4) which is also in agreement with their specific heat capacity – table 1.

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