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Interaction of materials and humidity of wood based construction walls

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Abstract: *Interaction of materials and humidity of wood based construction walls.* The indoor environment quality is significantly affected by absolute humidity content. Material composition of wood based structure is one of the most important factors that affect indoor environment quality. The article compares the impact of different material composition of building envelope to interior humidity in winter. Calculation is carried out to determine the diffusion flux. Variation of two different materials (oriented strand board – vapour retarder, vapour barrier) was applied in the material composition. The final values of the interior humidity influenced by diffusion flux were compared to the impact of natural ventilation. The calculation results confirmed that material composition hasn´t significant impact on the interior humidity.

Keywords: water vapour, diffusion, humidity, vapour retarder, vapour barrier

INTRODUCTION

The air humidity is expressed by the degree of saturation of air with water vapour (***Chmúrny 2003***). *Relative humidity (RH)* is the ratio of actual vapour pressure of the air-vapour mixture to the pressure of saturated water vapour at the same dry-bulb temperature multiplied 100 (***Bradshaw 2006***). RH causes discomfort due to inhalation of dry air in winter. In winter it is necessary to maintain RH greater than 30%. RH under 30% causes health problems like dry skin and eyes (***Sunwoo et al. 2006***). One of the most significant factors influencing RH is material composition of the building envelope, in terms of the vapour permeability. However, application of vapour barriers instead of vapour retarders and absence of moisture-buffering materials lead to the increase of RH of interior as well as to higher moisture loads on construction (***Mlakar et al. 2013***). ***Kalamees et al.*** (***2008***) in its research indicates that the impact of the building structure vapour permeability didn´t show significant differences in the average daily amplitude of the interior RH in winter.

The aim of the paper is to compare and quantify the effect of material vapour permeability (vapour barrier, vapour retarder) on the interior RH. Furthermore, this impact is compared to the effect of the natural ventilation on interior humidity microclimate.

MATERIAL AND METHODS

Wood building structure with the floor space 113.0 m^2 was selected for the experiment. The building envelope is formed by a vapour permeable structure (Fig. 1 – A). The vapour retarder of this structure is composed of OSB (Oriented strand board), type OSB-3 Egger with thickness 15 mm. The alternative material (vapour barrier) was selected to compare the effect of material composition on interior RH. The vapour barrier Airstop VAP creates diffusion layer of the vapour impermeable structure (Fig. 1 – B). The values of thermal properties used in calculation of the diffusion flux was selected according to STN 73 0540-3. The measurement was carried out in interior and exterior conditions in winter from 1 February 2014 to 28 February 2014. The climatic data (RH, interior and exterior air temperature) were recorded with TFA 30.3015 DTHL Klima Logger in one hour interval.

Chmúrny (***2003***) states that the air temperature is key indicator for evaluating the room thermal environment. It is usually assessed at 1.5 m above the floor (***Chmúrny 2003***).

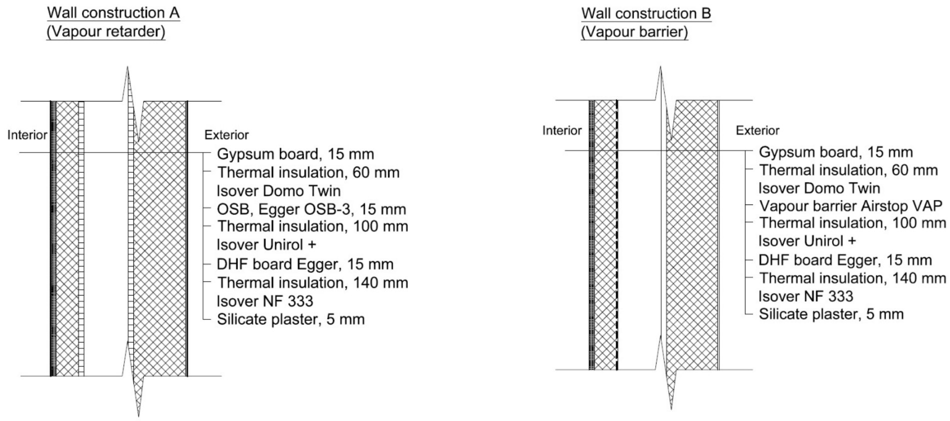

Fig. 1 Test wood based structure (A - vapour permeable structure, B - vapour impermeable structure)

Humidity is an important parameter for evaluating the quality of indoor environment. The density of water vapour per unit volume of air is called *absolute humidit* and the amount of water vapour in unit volume of air is determined by it . The amount of water vapour in the air depends on air temperature, thus the values of absolute humidity were derived according to EN ISO 13788. *Relative humidity* is the ratio of water vapour partial pressure p_d to partial pressure of saturated water vapour p_{sat}. RH is expressed as a percentage. In winter the indoor air dries out and RH usually drops below 30%. ***Wyon et al.*** (***2002***) have shown that long exposure to low humidity 5 – 15%, at air temperature 22°C has a negative effect on eyes and skin. When RH remains constant or grows above 25% the negative effect on human health is unknown. Firstly were calculated values of the partial pressure of saturated water vapour p_{sat} according to STN 73 0540-3. The values of p_{sat} are based on measured values of air temperatures. Consequently we used the measured values of RH and air temperature to calculate water vapour partial pressure p_d.

Diffusion of water vapour is equalization process of water vapour partial pressure by the interaction of molecules between two different environments. During evaluated winter period the diffusing water vapour moved from the environment of higher to the environment of lower pressure p_d. Furthermore, this process may be defined as the move of water vapour from the environment of higher to the environment of lower air temperature. Each structure is resistant to diffusion of water vapour. This property is called value of water vapour diffusion resistance R_d. R_d values of structures A, B (Fig. 1) were calculated in the programme TEPLO 2014 according to EN ISO 13788. The diffusion flux density was determined by the equation:

$$g_d = \frac{\delta}{d} \cdot (p_{dsi} - p_{dse}) = \frac{p_{dsi} - p_{dse}}{R_d} \qquad (1)$$

Where: g_d – diffusion flux density of water vapour [kg.m^{-2}.s^{-1}], δ – diffusion constant of water vapour [s] or [kg.m^{-1}.s^{-1}.Pa^{-1}], p_{dsi}, p_{dse} – partial pressure of water vapour on internal and external surface of structure [Pa], d – thickness of structure [m], R_d – value of water vapour diffusion resistance [m.s^{-1}] or [m^2.s.Pa.kg^{-1}].

RESULTS AND DISCUSSION

The effect of different permeable materials in vapour permeable and impermeable structure was assessed in terms of the diffusion flux from interior. The effect of vapour retarder and vapour barrier in the structure is determined using values of diffusion flux shown in Table 1. More significant loss of water vapour is due to natural ventilation compared to diffusion flux through the structure A, B (Table 1). Values of average RH and water vapour in the course of one week in February when the external air temperature drops to the value 0 – 5 °C are shown in Table 1 as well. Our calculations of water vapour losses by natural ventilation are carried out with standard value of minimum air exchange n= 0.5 h^{-1} according to STN 73 0540-2.

Tab. 1 Values of interior humidity, losses of water vapor by diffusion (diffusion flux) and effect to the humidity of interior

Day	**Average daily RH [%]**	**Diffusion flux (A), [g/day]**	**Diffusion flux (B), [g/day]**	**Loss of water vapour due to natural ventilation [g/day]**	**The final value of RH due to diffusion flux (A) [%]**	**The final value of RH due to diffusion flux (B) [%]**	**The final value of RH due to natural ventilation [%]**
12/2/2014	40.50	432.78	61.07	10474.67	40.23	40.49	32.91
13/2/2014	37.10	416.86	58.83	10053.76	36.84	37.09	29.94
14/2/2014	37.00	383.75	54.15	8717.60	36.77	36.99	30.96
15/2/2014	36.50	438.35	61.86	10615.76	36.24	36.49	29.15
16/2/2014	40.80	407.09	57.45	9843.93	40.55	40.79	33.82
17/2/2014	42.20	453.58	64.01	10975.41	41.93	42.19	34.60
18/2/2014	40.10	432.36	61.01	10364.76	39.83	40.09	32.63

A- Vapour permeable structure
B- Vapour impermeable structure

Table 1 shows significant effect of vapour barrier in vapour impermeable structure. Application of a vapour barrier in the structure of building envelope can eliminate the diffusion flux to the exterior in winter. This may prevent the decrease of RH in the interior. However, the use of OSB as well as vapour retarder has little effect on the interior RH. ***Kalamees et al.*** (***2008***) in its research indicates that the impact of the building structure vapour permeability did not show significant differences in the average daily amplitude of interior RH in winter. Figure 4 shows little effect of the structure permeability on the changes of interior RH.

We can observe the correlation between the values of the diffusion flux and water vapour pressure difference for the entire research period (Fig. 2). The increase of the water vapour pressure difference causes the increase of the diffusion flux values for both types of structures A and B. However, the increase of water vapour losses due to diffusion flux does not cause changes in the interior RH.

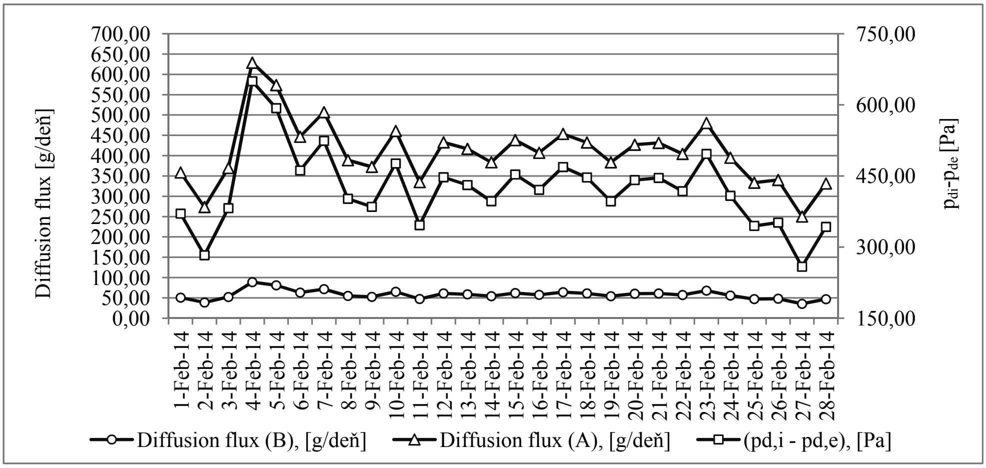

Fig. 2 Correlation between diffusion flux and water vapor pressure difference
Where: (p_{di}-p_{de}) – water vapour pressure difference between interior and exterior [Pa].

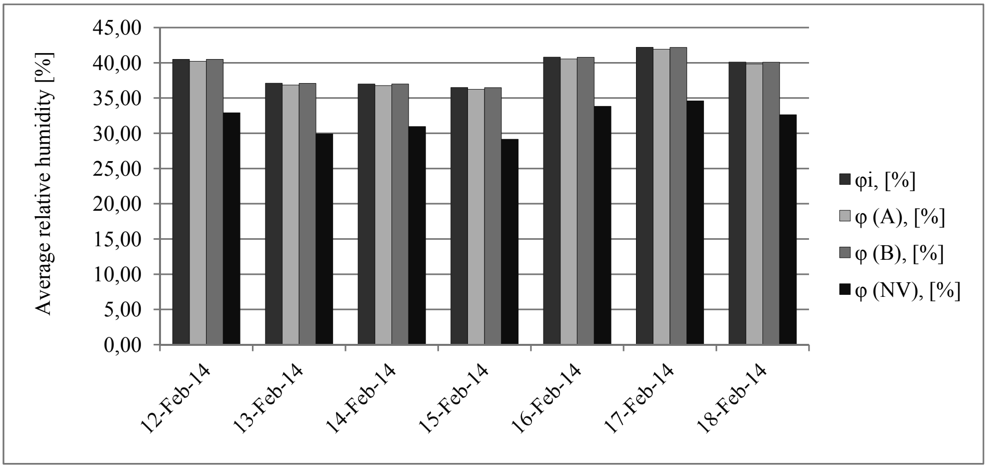

Fig. 3 The average values of the humidity as per type of structure and natural ventilation
Where: φi – The average value of interior RH in [%], φ (A), (B) – The average value of interior RH influence by diffusion flux through A and B structure in [%], φ (NV) – The average value of interior RH influence by natural ventilation.

Natural ventilation caused significant decrease of the interior RH. Figure 3 shows the difference between values of RH influence by natural ventilation and the other values of RH. These differences reach in some cases even 10%. The decrease of RH at the level of 29 – 35% caused natural ventilation after water vapour losses (Fig. 3). Therefore, it is necessary to increase the water vapour saturation of interior air.

However, we need more detailed analysis for more accurate assessment of the need to increase interior RH. We can increase the RH by moisture production, caused by human operations. Indeed this analysis is not the subject of the research.

CONCLUSION

Vapour permeability of the material composition of analysed structures A and B is important parameter in terms of diffusion flux. Diffusion flux caused a minimal drop of initial RH. Table 1 shows that initial RH decreased by diffusion flux of 0.3% (structure A) and 0.01% (structure B). Comparing the effect of the water vapour permeability of vapour retarder (OSB) and vapour barrier in vapour permeable and impermeable structure we drew the conclusion that application of these materials does not have negative impact on interior RH. The concept of vapour permeable structure in terms of moisture problems in its structural composition is still safer. Calculation methods show that natural ventilation calculated with standard value of minimum air exchange n= 0.5 h^{-1} is more significant problem than diffusion flux. Initial average values of RH between 36 – 42% dropped to 29 – 35% due to natural ventilation (Fig. 3). Finally we found out that detailed analysis, taking into account building moisture production must be conducted to determine the impact of the natural ventilation on interior RH.

REFERENCES

1. BRADSHAW V. 2006: The Building Environment: Active and Passive Control Systems, 3rd Edition. John Wiley & Sons, 2006. pp. 3–106, ISBN: 978-0-471-68965-2.
2. CHMÚRNY I. 2003: Tepelná ochrana budov. 1. vydanie. Bratislava : Jaga group v.o.s., 2003. pp. 119–136, ISBN 80-88905-27-3.
3. KALAMEES T., KORPI M., VINHA J., KURNITSKI J., 2009: The Effect of Ventilation System and Building Fabric on the Stability of Indoor Temperature and Humidity in Finish Detached Houses. Building and Environment, 44, 2009. pp. 1643-1650.
4. MLAKAR J., ŠTRANCAR J. 2013: Temperature and humidity profiles in passive-house building blocks. Building and Environment, 60, 2013. pp. 185–193.
5. SUNWOO Y., CHOU CH., TAESHITA J., MURAKAMI M., TOCHIHARA Y. 2006: Physiological and Subjective Responses to Low Relative Humidity in Young and Elderly Men. Physiological Anthropology, 25(3), 2006. pp. 229-238.
6. WYON DP., FANG L., MEYER HW., SUNDELL J., WEIRSØE CG., SEDRBERG-OLSEN N., TSUTSUMI H., ANGER T., FANGER PO. 2002: Limiting Criteria for Human Exposure to Low Humidity Indoors. Indoor Air, 2002. pp. 400-405, 978-0-9721832-0-80-9721832-0-5.
7. EN ISO 13788: 2012: Hygrothermal Performance of Building Components and Building Elements - Internal Surface Temperature to Avoid Critical Surface Humidity and Interstitial Condensation - Calculation Methods.

Streszczenie: *Wzajemne oddziaływanie materiałów i wilgotność w drewnopochodnych konstrukcjach ścian.* Skład materiału w strukturach drewnopochodnych ścian jest jednym z najważniejszych czynników wpływających na jakość środowiska wnętrz budynków. W artykule porównano wpływ różnego rodzaju składu materiałowego ścian budynków na wilgotność wnętrz w zimie. Obliczenia przeprowadzono w celu określenia strumienia dyfuzji. Ostateczne wartości wilgotności wewnętrznej wpływającej na strumień dyfuzji porównano z wpływem naturalnej wentylacji. Wyniki obliczeń potwierdzają, że skład materiału, z którego zbudowana jest ściana ma znaczący wpływ na wilgotność wnętrz budynków.

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