About breathing and dynamic structures in building envelopes

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In general, buildings and building components are often thought as static, passive structures. However, the continuous daily or yearly cyclic variations for example in air relative humidity - as well as local changes in indoor air conditions - impose dynamic variations also on and in structures, such as exterior walls. Local indoor air changes can be caused, for example, by moisture released from shower or sauna in form of water vapor. A "breathing" structure consists of hygroscopic materials, which are able to bind moisture from humid air. In case of changes in the relative humidity of surrounding air, there is a certain material-dependent delay before a hygroscopic material layer reaches the same humidity level as the air. This principle of moisture buffering is shown in Figure 1 below.

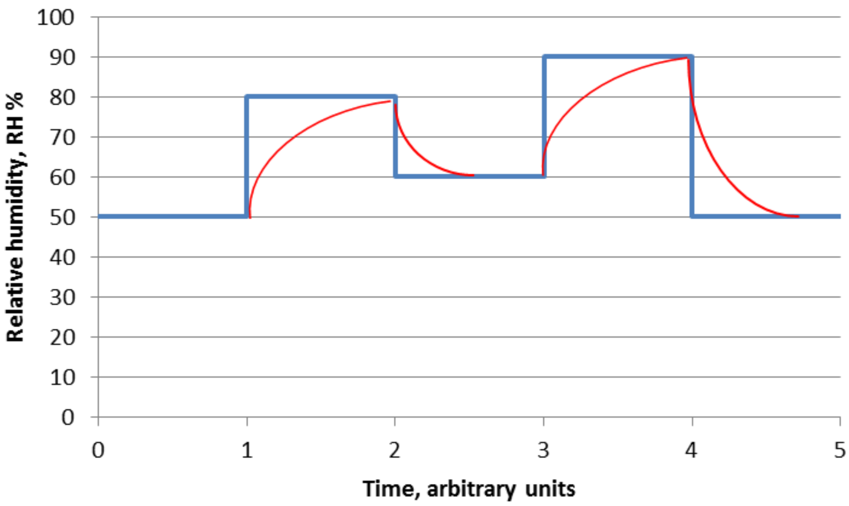

Figure 1. A schematic of moisture buffering phenomenon, where the blue line is showing the step-changes in relative humidity of surrounding air. Red line shows the theoretical change in moisture content of a hygroscopic material, following the humidity changes of air with a material-specific delay.

Usually in modern constructions, HVAC (Heating, Ventilation and Air Conditioning) systems are used to counteract the variations in indoor climate, but it is in principle possible to design building structures to aid in this task, resulting effectively in more even indoor air quality with less energy consumption by the auxiliary equipment. Hygroscopic building materials such as wood can dampen air humidity variations, if a few prerequisites are fulfilled.

To achieve any significant buffering or dampening effect in the indoor conditions, the buffering layers must be massive enough, and also have a direct enough contact with the indoor air. For example, thermal insulation materials are usually lightweight and not in direct contact with the indoor air. Already a thin layer of plastic or paint on a hygroscopic material will effectively hinder the dampening effect. Also, as mentioned for example by Ojanen [1], humidity buffering wall structures need to be airtight and to follow the good building practices to achieve the desired effects. An air-leaky structure is likely to cause energy consumption increase by the HVAC systems as uncontrolled air flows will enter the building and mix with the indoor air.

This implies directly that; as the term says; thermal insulation is present in the structures for insulation purposes, not to cause any buffering effect against quick humidity changes. In addition, the thermal performance of insulation materials is declared in dry state, and any significant amount of moisture bound in the insulation always compromises the thermal conductivity of the material. [2]

In addition, a common misunderstanding is that a hygroscopic material as a part of exterior wall or roof constructions would have a humidifying impact on the indoor air conditions, for example during winter season when air is in general dry. However, even if any significant amounts of moisture are bound in the construction materials, moisture transfer will occur via diffusion to the direction of lower water vapor content. In practice this means that moisture possible bound in thermal insulation layers will move outwards in the structure, though possibly somewhat slower than if a non-hygroscopic wall material was used (Figure 2).

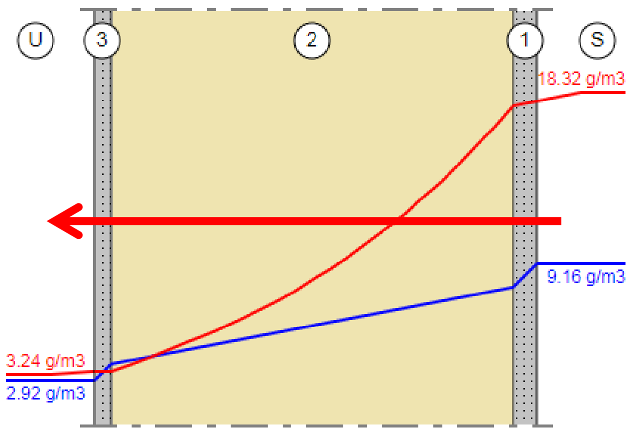

Figure 2. A schematic of a wall structure with inside (S) at 21°C and 50% relative humidity, outside (U) at -5°C and 90% relative humidity. The wall consists of inner (1) and outer (3) gypsum sheets with a thermal insulation layer (2) between them. Red line shows the maximum water vapor content in air as g/m^3 corresponding to a relative humidity of 100%, while the blue line shows the actual water vapor content. Red arrow points the direction of water vapor movement towards lower water vapor content by diffusion.

References

[1] T. Ojanen, ”VTT-R-04783-17: Moisture performance of stone wool insulation products, ” VTT Technical Research Centre of Finland Ltd, Espoo, 2017.

[2] H.-P. Mattila, ”Moisture Behavior of Building Insulation Materials and Good Building practices,” Paroc Group Oy, 2017.