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Latent Heat Phenomena in Buildings and Potential Integration into Energy Balance

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Abstract

Wood as hygroscopic material has the capacity to absorb moisture and thus to moderate the indoor relative humidity (RH) in a building, resulting in lower ventilation demand. In addition, when moisture migrates in hygroscopic structures energy is released through latent heat phenomena. The diurnal variation of moisture content in wood hold a potential for contributing in the buildings energy balance. This study presents the theoretical energy savings in low energy buildings with interior wooden surfaces under different moisture protocols indoors. The requirements of the Norwegian Building Regulations (TEK10) are followed regarding the U-values of the envelope components. A hygrothermal simulation tool is employed to estimate the potential diurnal variations of moisture content in the wood structure. The latent heat released and absorbed is mathematically calculated for a reference building. The results show the potential of hygroscopic structures to save thermal energy by means of heat of sorption and to reduce the conductive heat losses through opaque building elements. The limitations of the phenomena are also discussed.

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Keywords: latent heat; moisture buffering; energy balance; hygroscopic materials; timber structure

1. Introduction

During the last two decades the moisture buffer capacity of hygroscopic structures has been extensively discussed its contribution to damping the peak and valleys of relative humidity (RH) has been reported[1,2]. Recently, a joint

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Nomenclature

d	thickness of building components [m]
d_m	moisture penetration depth [m]
t	time [s]
ρ_m	density of hygroscopic material [kg/m^3]
A	floor area [m^2]
MC	moisture content [%]
H	total latent heat of sorption released during a wetting phase [kWh]
H_m	total latent heat of bounded water [J/kg]
H_v	latent heat of vaporization of water [J/kg]
ΔH_s	differential heat of sorption [J/kg]
MBV	moisture buffer value [kg/m^2·%RH]
RH_i	relative humidity [%]
S	surface area of building components [m^2]
T_i	air temperature indoors [°C]
T_o	air temperature outdoors [°C]
T_s	surface temperature of interior wooden surfaces [°C]
U	thermal transmittance [W/m^{2}K]

Nordic project introduced a new material property, the so-called 'moisture buffer value' (MBV) which describes the ability of building materials and systems of materials to exchange moisture with the indoor environment[3]. The MBV of wood is thrice as MBV of concrete and brick, twice as of gypsum and about 20% higher than cellular concrete. Rode and Grau[4] showed that hygroscopic wall surfaces provide a noticeable effect on damping of indoor humidity variations; the higher the MBV of a material the greater the damping. Simonson *et al.*[5] showed that when the internal surfaces of a wooden apartment building were permeable, the maximum indoor RH was lower compared to the impermeable case assumed (impermeable paint). In addition, the RH dropped below 20 % for less period of time compared to the impermeable case. The results showed that hygroscopic materials, as wood, hold the potential for energy savings through reduction of ventilation rates.

Moisture buffering reveals an interesting area of the building physics that has been so far limited exploited: the latent heat of sorption. Latent heat is the amount of heat required for the phase change of substance without any temperature change in the substance. When condensation occurs from a vapor phase to a liquid phase heat is released is at a rate of 2501 J/kg of vapor condensing at 0 °C[6]. This is the latent heat of vaporization of water H_v. In typical indoor temperatures, i.e. 10 – 30 °C, it varies from 2477.7 to 2430.5 J/kg. The enthalpy of sorbed water is less than the one of liquid water and the differential heat of sorption ΔH_s has to be added at the latent heat of vaporization of water in order to equal the total latent heat of sorption H_m of bounded water in the cell walls of a wood structure. Thus, the latent heat of moisture H_m is the sum of the latent heat of vaporization of water H_v and the differential heat of sorption ΔHs, described by the following equation[6]:

$$H_m = H_v + \Delta H_s \tag{1}$$

Osanyintola and Simonson[1] showed that when a hygroscopic material, as wood, is combined with a well-controlled heating, ventilation and air conditioning (HVAC) system, the potential for direct energy savings -through latent heat- is relatively small for heating, i.e. 2% to 3% of the total heating energy, but significant for cooling, i.e. 5% to 30% of the total cooling energy. The potential indirect savings from adjusting the ventilation rate and indoor temperature, while maintaining adequate indoor air quality and comfort, are in the order of 5% for heating while they range from 5% to 20% for cooling. Woloszyn *et al.*[7] confirmed that the use of gypsum-based moisture-buffering materials, combined with a relative humidity sensitive (RHS) ventilation system, could reduce the mean ventilation rate by 30% to 40% and generate 12% to 17% energy savings while during the heating period. The combined effect of ventilation and wood, as buffering material, make it possible to maintain a stable indoor RH