The use of an internal airtight membrane in CLT external wall in terms of hygrothermal performance

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Abstract. This study focused on the dry-out capacity of the vapor-permeable CLT (cross-laminated timber) external wall and the impact of using an internal airtight membrane. The results of the work were obtained first from the field measurements, after which the simulation model was created and validated, and the hygrothermal performance of the wall was analyzed by a stochastic approach. The results of this showed that the CLT dries out quickly and safely in a wall assembly with a high water vapor permeability, even with the large range of initial CLT MC (13-25%). When an additional airtight layer with high vapor diffusion resistance (Sd of 244 m) is added between the insulation and the CLT, the dry-out capacity of the CLT decreases significantly and there is a high probability of mold growth on the CLT surface. The risk of mold growth can be prevented when the vapor resistance (Sd) of the airtight layer is reduced to 1.5 m in a case where initial CLT MC is up to 25% and in a case where initial MC is up to 20%, the vapor resistance of an airtight layer must be reduced to 3 m.

1. Introduction

CLT envelope works hygrothermally safe if the panel is not covered by material layers that cause moisture accumulation on the CLT surface, which in turn increases the risk of moisture damage. The most critical period is the start of the service life immediately after construction when the CLT moisture content equilibrates and the excess moisture dries out. In addition to the drying capacity, the airtightness of the building envelope must also be ensured, for which in many cases an internal airtight membrane is used. General recommendations are usually given for the use of the membrane. Mainly to use "low" water vapor resistance products. The objective of this research was to analyze the effect of the internal airtight membrane on the dry-out performance of the vapor-permeable CLT external wall and to find the parameters of water vapor resistance at which the sufficient dry-out is not prevented.

2. Materials and methods

2.1. CLT external wall

Laboratory measurements were carried out with the test walls built in the test facility and exposed to real weather conditions, in the cold and humid climate. Weather conditions (RHₑ, tₑ), indoor environment (RHᵢ, tᵢ), temperature, and relative humidity between materials layers (t&RH_L1-L4) in the test walls were measured during the test, see Figure 1. Laboratory measurements of the test walls started on the 16th of June 2018 and finished on June 30 in 2019. This paper focuses on the vapor-permeable external wall, which was insulated with 300 mm glass wool insulation and CLT used as a load-bearing element.
with a thickness of 100 mm was exposed to an indoor environment (Figure 1). The external wall was designed with a ventilated wooden cladding façade and a glass wool insulation board was used as a wind barrier. Based on the laboratory measurements the simulation model was created and validated using HAM (heat, air, and moisture) modeling software Delphin 5.9. The properties assigned to the material layers of the wall were taken from the Delphin database.

2.2. Stochastic approach

The hygrothermal performance of the wall was analyzed by a stochastic approach using both continuous and discrete random variables. For the continuous random variables, the most influential material properties in terms of hygrothermal performance were used: thermal conductivity (W/m·K), vapor diffusion resistance, and moisture content (m$^3$/m$^3$). For the discrete random variables, the presence of an internal airtight membrane, between the insulation and CLT, with fixed water vapor resistance values was used. Two main scenarios based on discrete random variables were used: the CLT wall without (scenario 1) and with (scenario 2) the internal airtight membrane (with the water vapor resistance of $S_d = 244$ m). In the first scenario, the CLT could dry out towards both indoor and outdoor environments. Hygrothermal performance of the wall was evaluated by the risk of mold growth on the material surface via a mold growth index (a numerical scale from M=1 to 6, the risk of mold occurs when index 1 is exceeded) (Viitanen et al., 2011).

3. Results and discussion

In the first scenario, it can be seen that if the remaining wall layers do not prevent the dry-out of CLT, the RH on the CLT surface quickly equilibrates even with high variability in moisture content (13-25%), see Figure 2, a and there is no risk of mold, see Figure 2, c. Figure 2, a, also shows that the results of all 100 different calculations (sub-scenarios) converge and differ little from each other after the first 6 months, where the blue line indicates the base project and the gray lines the 100 sub-scenarios. Figure 2, b, shows clearly that in the second scenario the added air barrier with high water vapor resistance has created an environment with high RH on the CLT surface and drying is slow in all sub-scenarios. This is reflected also in the mold index results where about 85% of the results of sub-scenarios exceeded the mold growth index 1, varying between 1 and 5, see Figure 2, d.

Simulating with different vapor resistance values ($S_d$) of additional internal airtight layer, it was found that in the CLT initial MC range of 13-20% there is no risk of mold on the CLT surface if the vapor resistance value is no greater than 3 m, see Figure 2, f. In the MC range of 13-25%, there is no risk of mold on the CLT surface if the vapor resistance of the additional airtight layer does not exceed 1.5 m, see Figure 2, e. These calculations are made for a wall where the CLT is exposed to the indoor environment without a finishing layer and with a thickness of 100 mm. The results showed that even if the CLT panel is open to the indoor environment, it must be ensured that the surface of the CLT panel towards insulation is not covered with a high vapor resistance layer and external drying is also allowed.
Figure 2. Dry-out performance (RH) of CLT in the external wall, analysed between the CLT and insulation, of scenarios 1 (a) and 2 (b), mold growth risk of scenarios 1 (c) and 2 (d), and when using an internal membrane at CLT MC up to 25% (e) and up to 20 % (f).

4. Conclusion

The results of this showed that the CLT dries out quickly and safely in a wall with high water vapor permeable material layers, even with the large range of initial CLT MC (13–25%). When an additional airtight layer with high vapor diffusion resistance (Sd of 244 m) is added between the insulation and the CLT, the dry-out capacity of the CLT decreases significantly and there is a high probability of mold growth on the CLT surface. The risk of mold growth can be prevented when the vapor resistance ($S_d$) of an airtight layer is reduced to 1.5 m in the case where initial CLT MC is up to 25% and in the case where initial MC is up to 20%, the vapor resistance of an airtight layer must be reduced to 3 m.

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