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1. Introduction

Structural components and parts of buildings are not only exposed to thermal stress, but also to hygric stress. After the building has been completed, building components often still contain a considerable amount of building moisture.

Therefore, using CLT is advantageous, as the driest possible structures can be obtained by using this product.

Building components must be sufficiently protected from all types of moisture. Excessive moisture content can **reduce solidity and thermal insulation**. At the same time however, wood requires a minimum level of moisture (particularly in the case of visible panels) in order to reduce drying cracks.

Figure 1 shows the different effects of moisture which a building must be protected from.

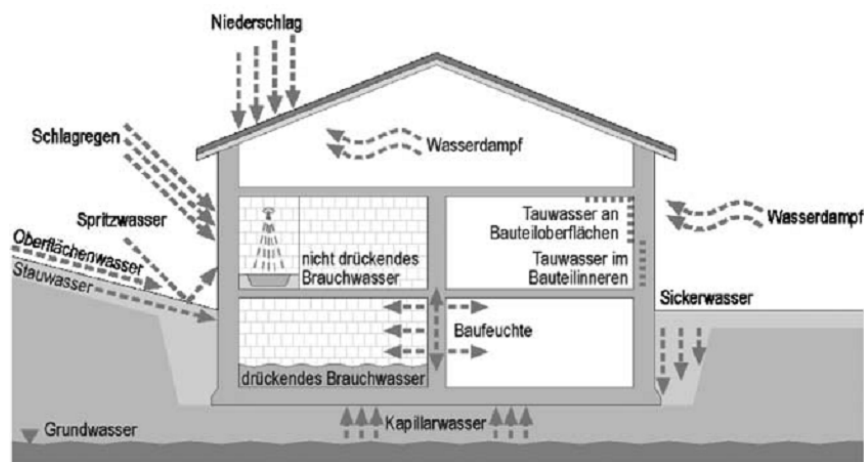


Fig. 1: Typical moisture conditions of a building (Fischer *et al.*, 2008)

As the load-bearing structure and the insulation layer are clearly separate on CLT panels, the structural and physical aspects of the design can be considered separately. CLT offers a further advantage in that, besides the

load-bearing structure, it also has a significantly higher thermal mass in comparison to other wood construction systems. With 3 layers and more, CLT panels are airtight.

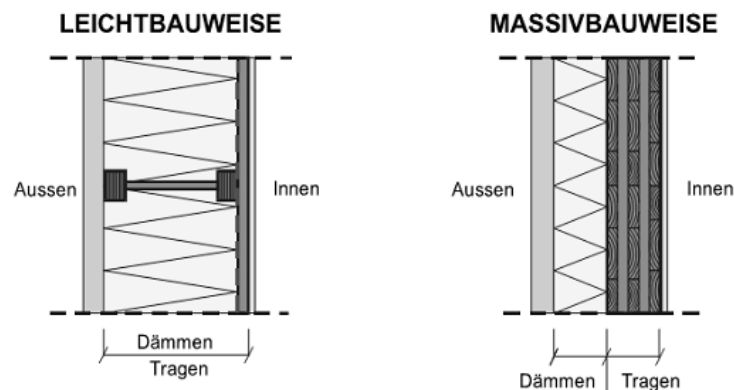


Fig. 2: Comparing lightweight wood construction with solid wood construction (Graz Technial University, 2008)

2. Reasons for moisture protection

For building owners and occupants, moisture protection is necessary or advisable for the following reasons:

a) Room usability

Rooms require a precisely defined indoor climate which means that uncontrolled levels of humidity must be avoided. Damp building materials can be the source of germs and odorous substances.

b) Building heat insulation

Increased moisture in the building means that the thermal conductivity of the building's materials increases and more energy is required to heat the building. More energy is also required to remove damp air and condensation.

c) Preserving the building structure

Managing a building's exposure to moisture is essential for preserving the building's structure. Most structural damage can be traced back to the impact of water.

3. Diffusion

Diffusion is the movement of tiny single particles (atoms, ions, molecules), caused by the thermal self-motility (Brownian motion) of these tiny particles.

In the same way as heat flow, water vapour also flows

- according to the drop in temperature from warm to cold or
- according to relative humidity from moist air to dry air.

This diffusion flow occurs in the air and also in porous building components containing air pockets. The more impermeable a building component, the greater its diffusion resistance. Damp materials are more permeable to water vapour diffusion.

Building physics

MOISTURE

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4. Diffusion resistance factor and s_d value

a) Diffusion resistance factor

The water vapour diffusion resistance factor μ is used to measure the impermeability of a building material to diffusing water molecules. μ is a dimensionless quantity which indicates the factor by which a material's diffusion resistance increases in comparison to the reference value. Air is used as the reference value as it generally offers the least resistance to water vapour ($\mu = 1$).

Only glass and metal can be considered impermeable to water vapour; all other materials are permeable to water vapour, even if diffusion resistance can be very high.

b) s_d value

The diffusion resistance factor μ alone is not enough to identify the impermeability to water vapour diffusion of a layer of material, rather than of the material itself. Both the type of material and the thickness of the layer must be known to understand the extent of resistance to water vapour diffusion.

Thus, the simplest definition to describe the resistance of a layer of material is derived from the product of the thickness of the layer and the diffusion resistance factor. Therefore, in building physics, the term "equivalent air layer thickness s_d " is used to measure the diffusion resistance of a layer of material.

$$s_d = \mu * d$$

The s_d value represents how thick a layer of air must be to have the same transmission resistance as the component.

CLT panels have different levels of diffusion resistance. This depends on the lamella thickness and the number of layers and adhesive joints.

$$\sum s_d = \mu_1 * d_1 + \mu_2 * d_2 + \mu_3 * d_3 + \dots + \mu_n * d_n$$

5. Holzforschung Austria's expert opinion

Holzforschung Austria's expert opinion reveals that:

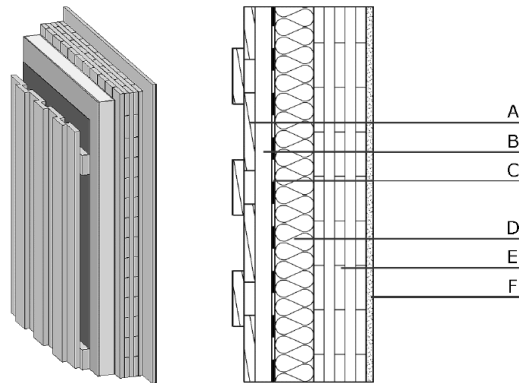
A 3-layer CLT panel exhibits the same s_d value as that of a solid wood panel made of spruce with similar strength (+ 26 mm for the bonded joint on the CLT panel).

- Dependence of the material moisture content

The bonded joint's μ value significantly decreases in damper test conditions. Porous cavities occur between the adhesive layers and capillary contacts between end grain and length grain wood. This enables faster moisture transport processes in humid climates compared with dry climates. However, this depends on the type of adhesive and the relative ambient humidity.

- The s_d value should be 5–10 m lower towards the surface than on the inside. By way of example:

Standard wall structure with ventilated façade



Baustoffangaben zur Konstruktion, Schichtaufbau
(von außen nach innen, Maße in mm)

	Dicke	Baustoff	Wärmeschutz				Brandverhaltenskl.	
			λ	μ min – max	ρ	c	EN	
A	20,0	Holz Lärche Außenwandverkleidung	0,150	50	600	1,600	D	
B	30,0	Holz Fichte Lattung	0,130	50	500	1,600	D	
C		diffusionsoffene Folie $s_d \leq 0,3\text{m}$						
D	50,0	Holzwolelehrsichtplatte (WW-MW-WW)	0,049	2 - 5	130	1,000	B	
E	78,0	Massivholz verleimt (z.B. Brettsperrholz 3-lagig)	0,130	50	500	1,600	D	
F	13,0	Gipsfaserplatte od. 12,5 mm GKF	0,320	21	1000	1,100	A2	

Plasterboard: $s_d = 0.273$ m; cross-laminated timber: $s_d = 3.9$ m; insulation: $s_d = 0.25$ m; permeable layer: $s_d \leq 0.3$ m

The structure is more impermeable towards the surface (calculated using the cross-laminated timber) and is therefore correct from a building physics point of view.

6. Significance of moisture and diffusion for CLT

With 3 layers and more, CLT panels are “airtight” but not vapour proof. This means that CLT is permeable and the adhesive bonds form vapour barriers for the insulation plane. Just like any other construction system, CLT must be protected from permanent moisture.

CLT regulates the inside air. When there is higher ambient humidity, CLT absorbs the moisture and releases it again when the level of humidity decreases.

CLT can also be described as a moisture variable vapour barrier. It is more permeable in the summer, when temperatures are high and the air humid, than in the winter when temperatures are cold and the air is drier.

8. Sources

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