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Influence in Connection of a Vapor Barrier in Critical Detail of Composite Structures

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Abstract

Influence of connection vapor barrier in a critical detail of composite structures is directed to the humidity temperature evaluation of a design detail, focusing on the risk of mold growth. Detail corner of the building is elected with a variation of the connection of vapor barrier on the concrete skeleton. The thesis describes the course of moisture in those points of structure describing the possibility of the occurrence and growth of fungus.

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Keywords: Composite structures, vapor barrier, humidity, temperature, mold grow

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1. Introduction

The composite structure, respectively. Composite structures, the trend in the construction of houses, civil and industrial buildings. It applies where there is an object used a combination of two (or more) different technologies or methods of construction. One technology ensures the stability of the building, while the other is applied to the wall structure. A typical example, which is already anchored in our several years, monolithic reinforced concrete skeleton construction filled brick blocks. In contrast, the atypical example of timber in which the supporting function is performed by a reinforced concrete frame. This type of composite construction is widespread in the Nordic countries.

Combining design, wood-based panels and assembled or monolithic reinforced concrete frame is achieved the benefits of both technologies simultaneously. The wood used for façade construction provides insulating properties, determines its appearance and fully exercises its lightness and functionality. Subtle concrete skeleton eliminates the limited lifespan of wood in stressed areas of construction and construction also gives the maximum flexibility in the design of the facade and interior layout. The big advantage compared to traditional composite construction Wooden buildings are fire resistant.

Today's trend in construction is determined by the passive and low-energy standards, which determine high requirements for buildings and their construction. In a particular the thermal technical requirements for circuit design, object orientation to the world side, assessment of environmental construction, airtightness of the building and more. For composite structures it is risky especially the connection of different structural systems due to the different physical properties of the materials used.

For proper functionality of the thermal envelope of buildings with composite structures it is important to ensure the proper realization of vapor layer and its connection to the concrete skeleton. When correctly performed at critical contact structures in the details of construction, there is an increased flow of water vapor diffusion, which are produced in the internal environment of the building. Increased flow and change of seasons has resulted in condensation of water vapor in the structure. Increasing humidity in the structure has resulted in the formation of thermal bridges (areas with an increased heat flow), volume changes of wooden structures, decrease the effect of an airtight envelope of buildings and ultimately creates the risk of mold growth.

2. The risk of mold grow

In porous materials, which also include wood and materials made of wood-based, it is contained always certain amount of water. Depending on temperature, relative humidity and ambient air pressure. The water is physically bound. If the timber, respectively. wood element for some time located in an environment with a temperature and humidity, then the moisture is stabilized at the so-called. the equilibrium moisture. In building practice can have equilibrium moisture wide range (from about 6% of the room up to 25% or more in the external environment in the winter). [2]

The equilibrium moisture of wood embedded in the envelope of a timber frame affects some basic physical properties:

- With the increasing wood humidity reduces its compressive strength in the fiber direction and modulus of elasticity.
- With increasing humidity increases the risk of attacks by biological pest wood (wood decaying fungi, wood-destroying insects, rot and mold).
- Changing the humidity makes changes in the shape of the cross section of wood. It's very unpleasant property and the use of wood is necessary to take it into account.
- When unregulated or more multiple drying can create cracks in the wood, which reduce the resistance of the relevant timber member, thereby restricting its use.

2.1. The risk of mold growth, according to ČSN 73 1702 Design, calculation and assessment of wooden constructions - General rules and rules for buildings

Table 1. The equilibrium moisture of wood construction materials (Table. F. 3 - ČSN 73 1702) [3]

	1	2	3	4
1	**Class of use**	**1**	**2**	**3**
2	**Wood moisture**	5 - 15 % [a)]	10 - 20 % [b)]	12 - 24 %

[a)] For most coniferous wood is not exceeded medium equilibrium moisture content of 12% in use class 1.
[b)] For most coniferous wood is not exceeded medium equilibrium moisture content of 20% in use class 2.

- Class of use 1: The risk of attack wood surface by fungi or wood-decaying fungi is negligible. Wood may be over the lifetime maximum moisture of 20%.
- Class of use 2: Humidity of Solid wood exceeds 20% occasionally. Allows infestation by wood decaying fungi.
- Class of use 3: Humidity of Solid wood is often above 20%. Wood often susceptible to infestation by wood decaying fungi.

2.2. The risk of mold grow, according to ČSN EN 335-1 Durability of wood and wood-based materials

The influence of the environment is classified using classes use according to the hazards of wood biotic pests. [1]

Table 2. Classes use according to ČSN EN 335-1 for solid wood [1]

Class of use	Terms and conditions of use (exposure to wood)	Description of exposure to moisture in the operating conditions	The incidence of biotic factors
1	Interior, covered	Drought, max. 20%	Wood-destroying insects
2	Interior or covered	Occasionally > 20%	Wood-destroying insects, wood-decaying fungi
3	3.1 Exterior, without touching the ground, protected	Occasionally > 20%	Wood-destroying insects, wood-decaying fungi
	3.2 Exterior, without touching the ground, unprotected	Often > 20%	
4	4.1 Exterior, with touching the ground and/or fresh water	predominantly or permanently > 20%	Wood-destroying insects, wood-decaying fungi, wood-destroying insects
	4.2 Exterior, touching the ground (permanently) and/or fresh water	Permanently > 20%	
5	In seawater	Permanently > 20%	Wood-destroying insects in parts under the water, wood-destroying insects, wood-decaying fungi, wood-destroying insects

3. Analysis model – WUFI-2D

Hydrothermal calculation of critical detail was conducted in a computer program WUFI 2D. Simulation was set at 10 years. However, the assessments always used the last three years of simulation, which ensures steady thermal and moisture in the plot structure. WUFI-2D is a computer program for the calculation of the simultaneous heat and moisture transport in multi-layer building components. It has repeatedly been validated by comparison with experimental results. The humidity model in WUFI is a simulation tool to calculate moisture problems in structures without a coupled thermal simulation. [5] WUFI computational numerical model was based on the thesis H. M.Künzel. This model is based on the following system of differential equations:

$$\frac{dH}{dT}\frac{\partial T}{\partial t} = \nabla \cdot (\lambda \nabla T) + h_v \nabla \cdot \left(\delta_p (\varphi p_{sat})\right) \quad (1)$$

$$\frac{dw}{d\varphi}\frac{\partial \varphi}{\partial t} = \nabla \cdot \left(D_\varphi \nabla_\varphi + \delta_p \nabla (\varphi p_{sat})\right) \quad (2)$$

Where
λ Heat conductivity of moist material [W/(m.K)],
δ_p Water vapor diffusion coefficient in air [kg/(m.s.Pa)],
D_φ Coefficient of capillary moisture transport [kg/(m.s)],
h_v Evaporation enthalpy of water [J/kg],
p_{sat} Water vapor partial pressure [Pa],
θ Temperature [°C],
φ Relative humidity [-].

Spread of moisture in the structure is affected by variable edge conditions, and therefore in the structure occurs to accumulation of moisture. Amount moisture accumulated described curve called equilibrium moisture (sorption isotherm). In the porous materials is spread of moisture in the liquid phase due to capillary forces [7]. Distribution of moisture in structures affects varying temperature and relative humidity of external and internal air and precipitation, which impinge on the outer surface of the packaging building structure.

Künzel numerical model unlike stationary standardized procedures allows [6]:

- dynamically simulate the propagation of heat and moisture in building structures,
- take into account the dependence of the thermal conductivity coefficient of the material the quantity moisture in the material,
- take into account the dependence of diffusion resistance factor on the amount of moisture in material,
- consider the spread of liquid moisture in porous materials,
- include absorption driving rain on the outer surface of the structure.

4. Critical detail of composite construction

4.1. Description of construction

Critical detail composite structure was chosen as the corner detail exterior walls. It is a composite structure, where is the support structure ensures reinforced concrete with inset wall of wooden constructions such as "Two by Four". Compositions wooden wall is chosen as a diffusion-open with a ventilated air gap on the side exterior.

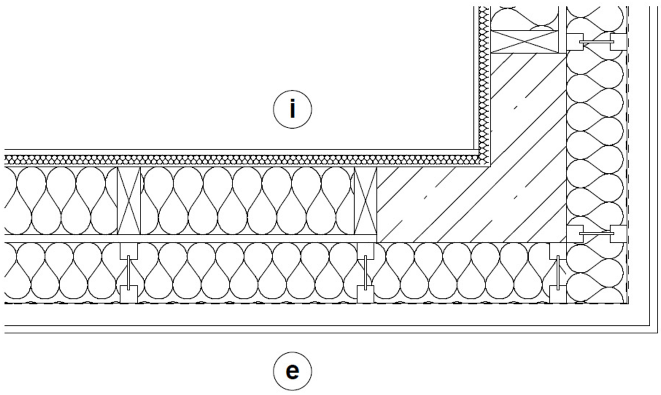

Fig. 1. The critical detail of the corner exterior walls of composite construction.

4.2. Definition of used materials

Table 3. Table of materials and their physical properties (composition away from the interior).

Material	Layer thickness d [mm]	Coefficient of thermal conductivity λu [W/(mK)]	Diffusion resistance factor μ [-]
Gypsum board	15	0,32	16
Installation space, wooden lath 50/30 mm + Heat insulation, Mineral wool	30	0,04	1,3
Vapor barrier	0,2	2,3	50000,0
Wooden posts „Two by Four“ 60/180 mm + Heat insulation, Mineral wool	180	0,04	1,3
Gypsum board	18	0,32	16
Heat insulation, Mineral wool + „Steico“ beam	160	0,04	1,3
Weather resistive barrier	0,1	2,3	500
Air ventilated layer	60	0,337*	2,7
Facade from spruce	20	0,23	4,3

Comment:

** Coefficient of thermal conductivity, dry state, temperature 10°C*

5. Assessed variations of detail

Variations assess of critical details are designed with influence on the completion of the vapor layer which also performs the function airtight. The first variation (Fig. 2. (a)) is focused on the wrong implementation of the vapor barrier to leave an air gap on the wooden post structure "two by four". Another variance connection vapor barrier (Fig. 2nd (b), Fig. 2 (c), 2 (d)) are designed as right solution for moisture and vapor barrier and airtight exterior walls. Thermal technical assessment was carried out at three points on a wooden post:

- Point_1 – Wooden post in contact with the reinforced concrete skeleton structure on the interior side.
- Point_2 - Wooden post in contact with the reinforced concrete skeleton structure on the exterior side
- Point_3 - Wooden post in contact with the thermal insulation.

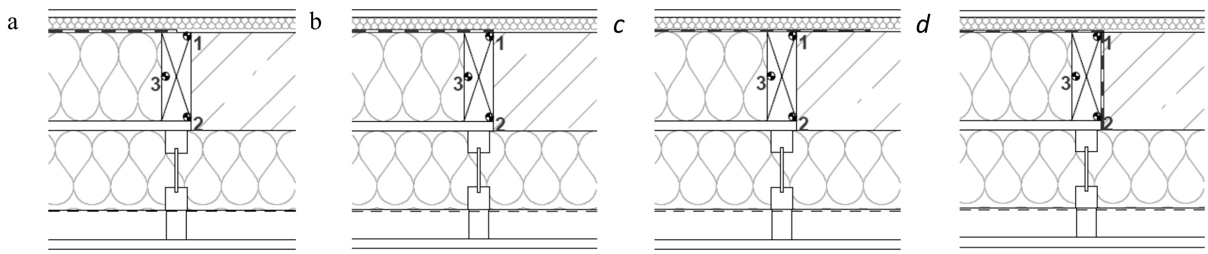

Fig. 2. (a) Termination of vapor barrier on a wooden pillar system "Two would" Four " (b) Termination of vapor barrier at the contact of a wooden pillar system of" Two by Four "and the pillar concrete skeleton (c) Termination of vapor barrier on the pillar of concrete skeleton (d) Location vapor barrier between the components' Two by Four "and reinforced concrete frame.

6. Graphical outputs- Comparison

6.1. Relative Humidity / Temperature

The graphs show that the temperature distribution in the points is almost identical. Fluctuations in relative humidity is not large enough to affect the heat flux. The critical point, susceptible to increase the value of relative humidity is Point1. (Fig. 3.) The values of relative humidity are approaching the limit of 80% for internal environment No.3 (living room). If a long-term increase, or irregular fluctuations in relative humidity in the interior, increases the risk of mold and infestation by wood decaying fungi or decaying insects (in the case in connection vapor barrier on a wooden pillar "Two by Four"). Relative humidity values at points point2, point3 has almost the same relative humidity regardless on termination of vapor barrier.

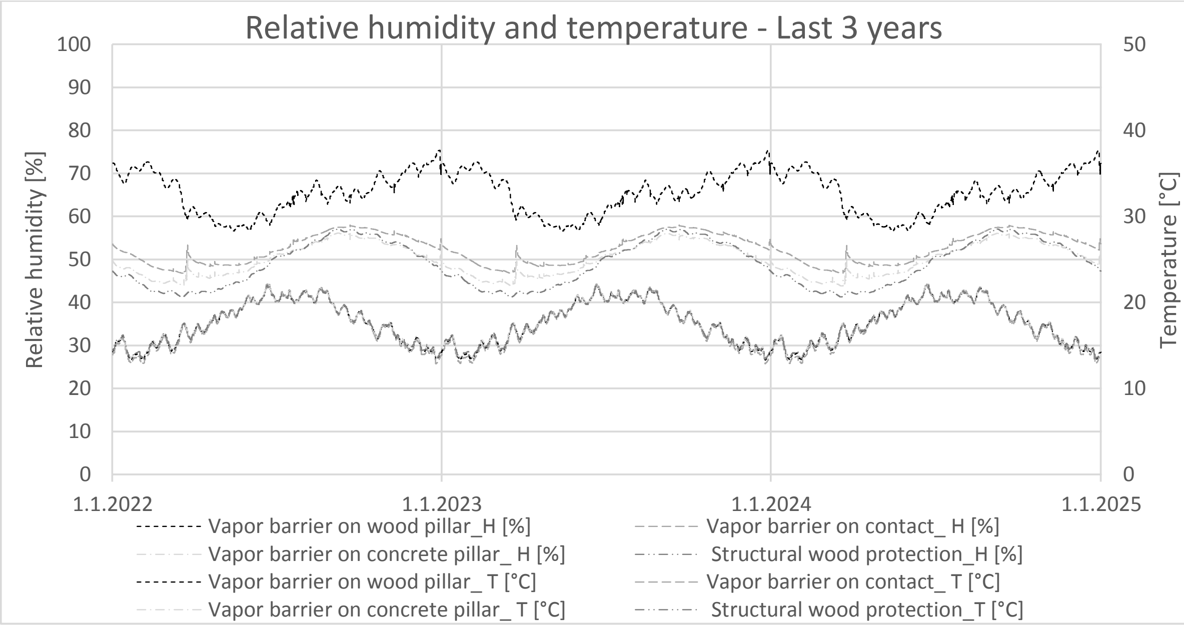

Fig. 3. Comparison of Temperature and Relative humidity in Point_1 on wooden pillar.

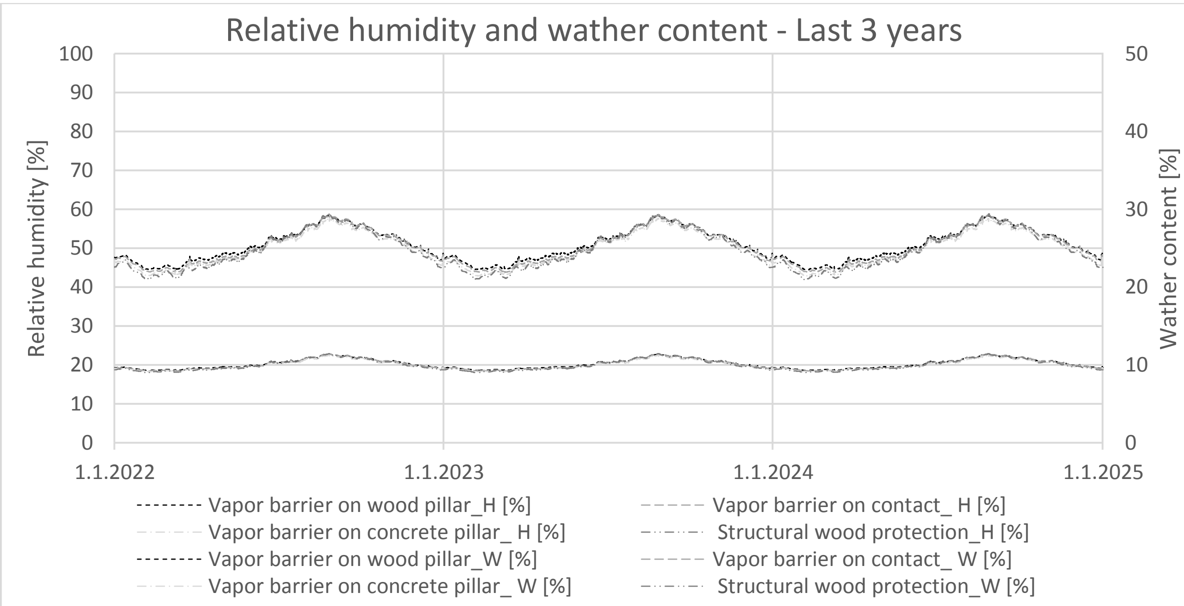

Fig. 4. Comparison of Temperature and Relative humidity in Point_2 on wooden pillar.

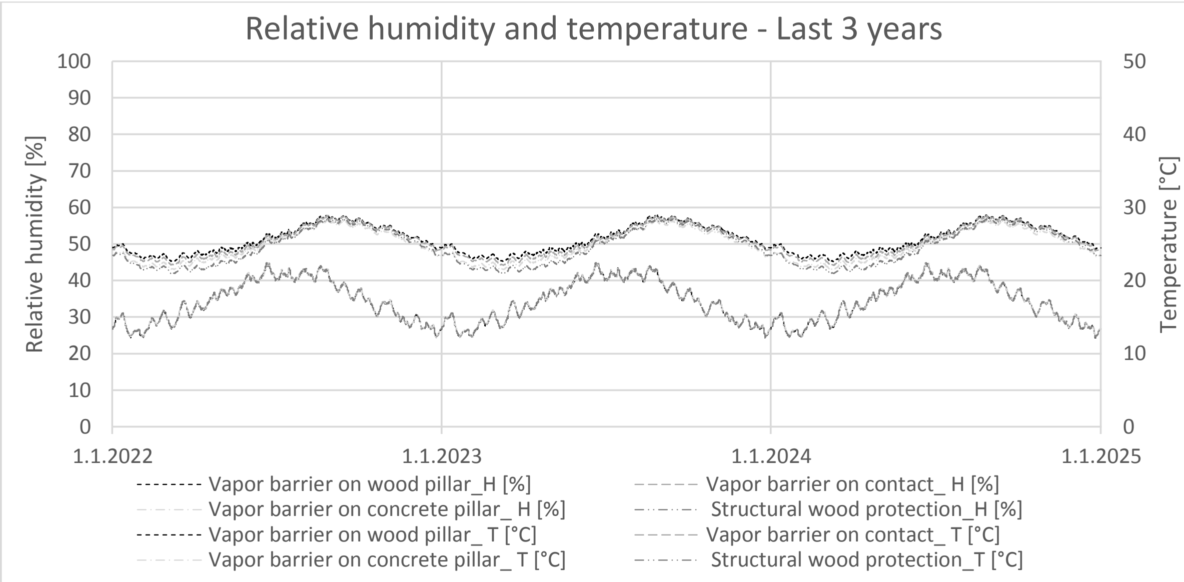

Fig. 5. Comparison of Temperature and Relative humidity in Point_3 on wooden pillar.

Depending on the composition of the structure may occur over time to evaporate the water built. However, if the layer of the high moisture enclosed between the additional layers with high diffusion resistance to evaporation of water will never occur during the use of the building. For perimeter structures is increasing the moisture due to water vapor diffusion. In the case of timber elements that leads to serious negative effects - to attack one of the biological wood pests, and to their destruction. [4] Proper design open to diffusion tracks peripheral walls does not prevent the passage of water vapor diffusion out of the structure.

6.2. The risk of mold grow

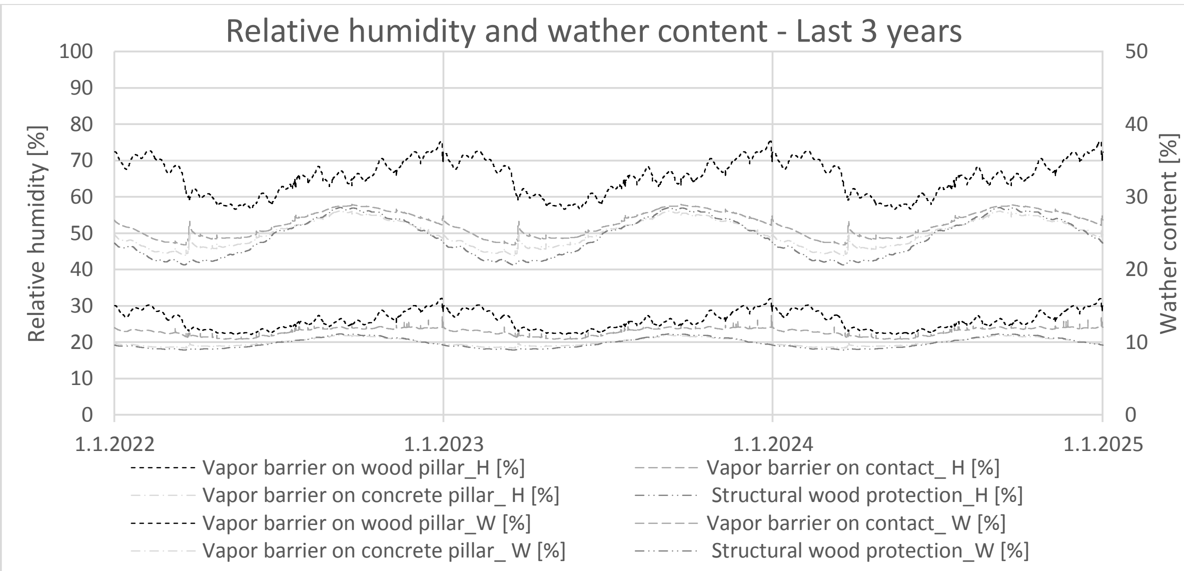

Fig. 6. Comparison of Water Content in Mass in Point_1 on wooden pillar

The equilibrium moisture content in wood, located in the heated interior can move in the range of 8 ÷ 12%. When increasing the moisture content of wood, the wood element can be attacked by:

- Wood-destroying fungi – moisture of wood 18–20 % or higher (about 85–90 % of relative humidity) and temperature in range 2 - 40 °C.
- Wood-destroying insect – moisture of wood 12 % or higher (about 60 % of relative humidity) and temperature under 10 °C.

7. Summary - conclusion

Due to the effect physical degradation factors on wood is change of wood humidity, which occurs due to changes in relative humidity of the surrounding environment. There are changes in the dimensions of the wood, the material created internal tension and can cause warping wood or disruption or destruction of the entire structure. This also applies to cases where the wood is combined with another type of material having different thermal in particular, a structure where the wood is combined with another type of material having different thermal expansion and with a different sensitivity to changes in humidity (e.g. Reinforced concrete, metals, or various kinds of wood).

In wooden structural elements, if they exhibit values of equilibrium moisture is not in terms of the risk of mold growth usually no problem. Problems arise when there is an increase of moisture.

In case of incorrect connection of vapor barrier, ie. Connection of vapor barrier on a wooden pole (Fig. 2. (a)) and connection a vapor barrier at contact a wooden pillar and concrete skeleton (Fig. 2 (b)), there is a risk of wood-boring insects. Moisture on the surface of the wooden post is between 12% to 16% during the time of 10 years. Moisture in the range 12% to 16% on the surface of the wood element occurs at a relative ambient humidity of 70% to 75%.

In a properly conducted vapor barrier ie. Completion of the vapor barrier on the column concrete skeleton (Fig. 2 (c)), and the location of the vapor barrier between the structural elements of "Two by Four" and concrete skeleton (Fig. 2 (d)) there is a significant decline moisture on the surface of a wooden post. Humidity value of 9% to 11% corresponding to a relative humidity of 40% to 60%. Wooden element is naturally resistant to all biotic pests.

For further modeling and assessment of critical detail is offered to select a variation of a diffusion-sealed envelope, the application of thermal insulation system ETICS. When incorrectly made vapor barrier and increase the diffusion resistance layer thermal envelope, is projected to increase condensation of vapor diffusing in structural timber construction.

8. Acknowledgements

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