Comparison of condensation risk calculations in wooden framework constructions by two different methods

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Summary

The paper analyzes the possibility of interstitial condensation in wooden carcass wall using two different calculation methods. As the result of the calculations the defects of the chosen construction were shown. These defects lead to the condensation on wooden framework and in time will lead to the deterioration of wooden structure. The paper also shows the rare case, in which the calculation methods give different results, and analyses the reasons of it.

Keywords: condensation, wooden carcass construction

1. Introduction

The wooden constructions traditionally are widely used in Latvia. In the recent years the new building technologies and typical structures of other countries came into use in Latvia. Not all of them are suitable for Latvian climate with all year round high relative humidity of outside air. That fact caused the special attention to the wooden details of building elements in Latvian Building Code LBN 002-01 “The thermal performance of building envelopes”[1]. The Building Code states that condensation on wooden details of building elements is not allowed. That means that in wooden constructions condensation risk has always to be calculated. At the same time the Building Code does not specify the methods that should be used for the calculation. So the calculation of interstitial condensation may be done by the traditionally used in Latvia method of Fokin-Vlasov and by the method of EN ISO 13788 [2]. The methods use different coefficients: vapour transfer coefficient and vapour transfer resistance factor. The paper will show common and different features of the methods on the example of widely used wooden framework construction.

2. Estimation of condensation risk in wooden framework construction

2.1 Short description of calculation methods

It is a well known fact that condensation of water vapour occurs when water vapour pressure exceeds saturated water vapour pressure. Usually the water vapour and saturated water vapour distribution is shown graphically. The saturated water vapour pressure depends only on the temperature distribution in the construction and it is calculated similarly in both methods. The differences of the methods are connected with the calculation of water vapour distribution in the construction. In method traditionally used in Latvia water vapour pressure distribution is shown in the cross section of element drawn proportionally real element thickness d, m.
Water vapour distribution in element is found by Equation 1:

\[ p_x = p_i - \frac{R_{tv}}{\sum R_{tv}}(p_i - p_e), \text{ Pa} \]  

(1)

where \( p_i \) is water vapour pressure of the inside air, Pa,

\( p_e \) is water vapour pressure of the outside air, Pa,

\( R_{tv} \) is the sum of water vapour resistance of all previous layers, \( \text{m}^2\cdot\text{h}\cdot\text{Pa}/\text{m} \),

\( \sum R_{tv} \) is total water vapour resistance of the element, \( \text{m}^2\cdot\text{h}\cdot\text{Pa}/\text{m} \).

Water vapour resistance of individual layer:

\[ R_{tv} = \frac{d}{\delta}, \text{ m}^2\cdot\text{h}\cdot\text{Pa}/\text{m} \]  

(2)

where \( d \) is thickness of the layer, m,

\( \delta \) is vapour transfer coefficient (vapour permeability of the material), mg/m·h·Pa.

Accordingly to the EN ISO 13788 method water vapour pressure distribution (\( p_x \) and \( p_{sat} \)) is shown with the thickness of the layer equivalent to the water vapour diffusion-equivalent air layer thickness \( s_d \), m.

Water vapour diffusion-equivalent air layer thickness is thickness of motionless air layer that has the same water vapour resistance as the material layer:

\[ s_d = \mu \cdot d, \text{ m} \]  

(3)

where \( \mu \) is water vapour resistance factor,

\( d \) is thickness of the layer, m.

In the drawing water vapour saturated pressure depends on the temperature distribution in the element. Water vapour pressure of the inside and outside air is connected by the straight line. If there is need for the precise pressures at the conjunction of the material layers, water vapour pressure distribution may be calculated as following:

\[ p_x = p_i - \frac{s_d}{s_{d,n.}}(p_i - p_e), \text{ Pa} \]  

(4)

where \( p_i \) is water vapour pressure of the inside air, Pa,

\( p_e \) is water vapour pressure of the outside air, Pa,

\( s_d \) is the sum of water vapour diffusion-equivalent air layer thicknesses of all previous layers, m,

\( s_{d,n.} \) is total water vapour diffusion-equivalent air layer thicknesses of the element, m.

The water vapour resistance factor and water vapour transfer coefficients are interconnected values as water vapour resistance factor shows how many times water vapour transfer coefficient of material layer is smaller than the water vapour transfer coefficient of motionless air [3]:

\[ \mu = \frac{\delta}{\delta'}, \]  

(5)

where \( \mu \) is water vapour resistance factor,

\( \delta \) is water vapour transfer coefficient of material layer, mg/m·h·Pa,

\( \delta' \) is water vapour transfer coefficient of motionless air, mg/m·h·Pa.

So generally both calculation methods have to give the same results.

2.2 Calculation of the interstitial condensation in wooden carcass construction

The comparison of the calculation methods will be done on the example of the wooden carcass construction shown in the Figure 1. The distance between carcass elements in both layers is 600 mm. The most dangerous place for condensation is the conjunction of the carcass and the insulation layer as here the temperature distribution is the same as temperature distribution in wooden carcass but the water vapour resistance of insulation is much smaller. In that place the condensation of the water is possible on the surface of wooden carcass. The calculations of the temperature and water vapour pressure distribution will be done for the inside air temperature +18°C and outside air
temperature -20°C that corresponds to the design temperature for heating. The temperature
distribution was calculated using the Cobra programme and it is shown in Figure 2.

Calculations by both methods (Table 1) with the thickness of main insulation layer up to 175 mm
had shown that condensation will occur near the carcass after water vapour.

**Table 1. Temperature and vapour pressure distribution with insulation layer 175 mm**

<table>
<thead>
<tr>
<th>Nr</th>
<th>Layer</th>
<th>d, m</th>
<th>( \theta ), °C</th>
<th>( \delta_{\text{sat}} ), Pa</th>
<th>( R_{\text{es}} ), m²·h·Pa/m</th>
<th>( p_{\text{v}} ), Pa</th>
<th>( p_{\text{x}} ), Pa</th>
<th>( \mu )</th>
<th>( s_{\Delta} ), m</th>
<th>( p_{\Delta} ), Pa</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Finishing</td>
<td>0,013</td>
<td>16,1</td>
<td>1828,9</td>
<td>-</td>
<td>0,156</td>
<td>1213,9</td>
<td>10</td>
<td>0,13</td>
<td>1235,7</td>
</tr>
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<td>2</td>
<td>Insulation</td>
<td>0,05</td>
<td>9,3</td>
<td>1170,9</td>
<td>0,72</td>
<td>0,069</td>
<td>1203,4</td>
<td>1</td>
<td>0,05</td>
<td>1235,7</td>
</tr>
<tr>
<td>3</td>
<td>Vapour barrier</td>
<td>0,0002</td>
<td>9,3</td>
<td>1170,9</td>
<td>-</td>
<td>7,3</td>
<td>92,6</td>
<td>-</td>
<td>75</td>
<td>54,4</td>
</tr>
<tr>
<td>4</td>
<td>Insulation</td>
<td>0,175</td>
<td>-18,7</td>
<td>182,32</td>
<td>0,72</td>
<td>0,243</td>
<td>55,6</td>
<td>1</td>
<td>0,175</td>
<td>51,7</td>
</tr>
<tr>
<td>5</td>
<td>Wind protection</td>
<td>0,02</td>
<td>-20</td>
<td>102,74</td>
<td>0,72</td>
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<td>51,37</td>
<td>1</td>
<td>0,02</td>
<td>51,4</td>
</tr>
</tbody>
</table>

Graphically the results are shown in Figure 3.

**Fig. 1 Cross section of element**

**Fig. 2 Temperature distribution**

**Fig. 3 Vapour pressure distribution by a) EN ISO 13788 method; b) traditional method**
Calculation with the thickness of insulation 200 mm is shown in Table 2. Here the methods give different results. If by the traditional method there is no condensation, by the EN ISO method the condensation exists. But both values are rather close to the saturated water vapour pressure.

Table 2. Temperature and vapour pressure distribution with insulation layer 200 mm

<table>
<thead>
<tr>
<th>Nr</th>
<th>Layer</th>
<th>d, m</th>
<th>θ, ºC</th>
<th>p_{sat}, Pa</th>
<th>Traditional method</th>
<th>EN ISO 13788</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>δ, mg/m·h·Pa</td>
<td>R_{v}, m²·h·Pa/m</td>
</tr>
<tr>
<td>1</td>
<td>Finishing</td>
<td>0,013</td>
<td>16,2</td>
<td>1202,9</td>
<td>0,156</td>
<td>1237,7</td>
</tr>
<tr>
<td>2</td>
<td>Insulation</td>
<td>0,05</td>
<td>10,0</td>
<td>1277,3</td>
<td>0,72</td>
<td>0,069</td>
</tr>
<tr>
<td>3</td>
<td>Vapour barrier</td>
<td>0,002</td>
<td>10,0</td>
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<td>-</td>
<td>98,3</td>
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<tr>
<td>4</td>
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<td>0,200</td>
<td>-14,4</td>
<td>174,1</td>
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<td>0,243</td>
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<tr>
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<td>Wind insulation</td>
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<td>-20</td>
<td>102,74</td>
<td>0,72</td>
<td>0,028</td>
</tr>
</tbody>
</table>

The differences in calculation results have to be attributed to the limitation of methods due to the known simplification of physical processes and to the differences in the sources of material’s properties. As both vapour transfer coefficient and vapour resistance factor are experimentally found values, its precision depends on the quality of measuring equipment. One of the mistake sources definitely is the value of motionless air water vapour transfer coefficient that very much depends on the air velocity. In German normative literature it is assumed as 1.6·10^{-10} kg/m·s·Pa but in EN ISO standard it’s value is 2·10^{-10} kg/m·s·Pa (0,72 mg/m·h·Pa). Recalculating the materials’ properties [4;1] by the Formula 5 the authors had found that the values in many cases differ up to 2-4 times. It is not possible in this paper to find out which method is more reliable although the authors would prefer the traditional method as it is not connected with the doubtful motionless air.

3. Conclusions

1. The most dangerous place for condensation in wooden carcass construction is the conjunction of the carcass and the insulation layer as here the temperature distribution is corresponds to the temperature distribution in wooden carcass but the water vapour resistance of insulation is much smaller. Accordingly to the in Latvian Building Code LBN 002-01 “The thermal performance of building envelopes” condensation on wooden details of building elements is not allowed.

2. In the construction selected as the calculation example, vapour barrier is situated not near the inside surface, but after 5 cm thick insulation layer. This constructive decision leads to the condensation of water vapour on wooden carcass near the vapour barrier. The condensation occurs with main insulation layer thicknesses up to 175 mm (total insulation layers’ thickness 245 mm). Although design heating temperature occurs for relatively short periods, in time the condensation will lead to the mould growth and deterioration of the wood.

3. Comparison of calculation methods show that both methods may be used for the check of interstitial condensation in wooden constructions. Although in some rear cases as in this construction with the main insulation layer thickness of 200 mm, the calculation results differ (Table 2). The reason of that mainly lays in differences of experimental data of vapour transfer coefficient and vapour resistance factor. In practice it is not possible to use Formula 5 for data recalculation, and this is probably partly the result of the uncertainties connected with the water vapour transfer coefficient of the motionless air.

4. References


