THE BEHAVIOUR OF SPECIAL OSB BOARDS UNDER FIRE CONDITIONS

The influence of OSB board's fire coating on the fire resistance of light timber frame assemblies

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Abstract

The paper is focused on the influence of fire resistant coatings used on OSB boards on the fire resistance of entire light timber frame wall assemblies. Two fire tests were performed in the fire test laboratory of PAVUS, a.s. in Veselí nad Lužnicí. The fire tests were performed on a load bearing wall. The wall dimensions were 3.0 (depth) x 3.0 (height) m. According to EN 1995-1-2, the calculation for fire paints and coatings is not possible. The aim of the paper is the determination of the influence of this type of coating on the OSB board's charring rate, the determination of the start of charring of a timber stud and the fire resistance of the whole construction.

Keywords: light timber frame wall assemblies, nominal fire, charring depth, charring rate, fire coating

1 INTRODUCTION

The timber industry has developed a lot of new types of wood-based materials for buildings in recent years. By their composition or surface treatment, these new products contribute to fire resistance. There are a lot of requirements for timber structures in terms of fire safety in the Czech Republic. The paper is focused on the behaviour of an OSB board with a fire protection coating. The coating consists of a cement-based mixture of magnesium oxide, reinforced by fibreglass with a thickness of 1.7 (± 0.3) mm. For the OSB board, see Fig. 1, according to EN 1995-1-2, the calculation for fire paints and coatings is not possible. There is a conservative approach in the case of calculating the contribution to the fire resistance of a wooden construction using this type of boards, where the surface layers are neglected.

a) b) c)

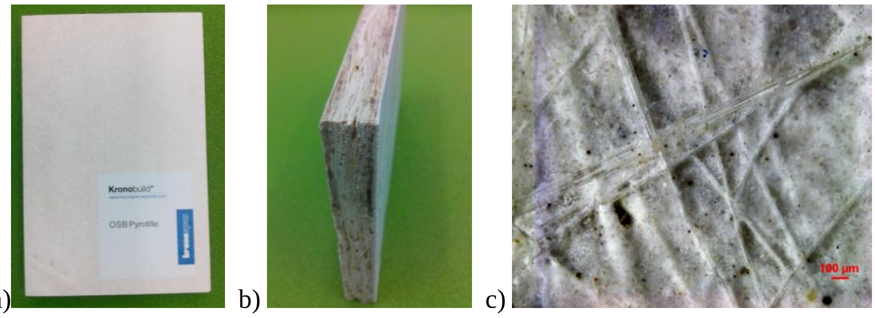

Fig. 1 The OSB board specimen with a fire resistant coating: a) side with a coating, b) OSB board in section, c) fire protection coating – microscopic picture, at 40x magnification

2 FIRE TEST OF A WALL ASSEMBLY WITH ONE-LAYER OSB BOARDS

One OSB board (according to EN 300, OSB 3) with a fire resistant coating was used on the fire exposed side (board thickness of 15 mm + coating 1.7 mm (± 0.3)), while an OSB board without any surface finish (15 mm) was used on the fire unexposed side. The gaps between the timbers studs were completely filled by rock wool. In Fig. 2, the composition of the test specimen can be seen. There were 20 pieces of thermocouples used inside the specimen for measuring temperature.

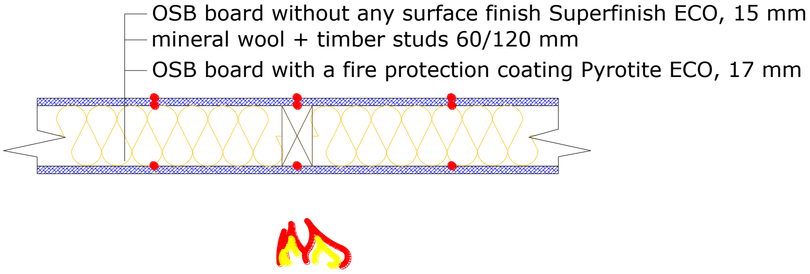

Fig. 2 The composition of the test specimen

2.1 Calculation of t_{ch}, t_f, d_{char} according to EN 1995-1-2

The charring starting time t_{ch} of the timber member for claddings made of OSB boards:

$$t_{ch} = \frac{h_p}{\beta_0} - 4 = \frac{15}{0.797} - 4 = 14.8 \text{ [min]} \qquad (1)$$

where h_p is the thickness of the board; β_0 – the charring rate of the OSB board for a one-dimensional charring rate.

The charring starting time is (according EN 1995-1-2) the same as the failure time of the cladding for fire resistant claddings made of wood-based panels.

a) The calculation without the charring rate reduction after reaching t_a or a charring depth of 25 mm

The charring of wood from one side is assumed for the calculation of the charring rate of a timber stud with dimensions of 60/120 mm (the cavities are completely filled by mineral wool):

$$\beta_{n1} = k_s \cdot k_3 \cdot k_n \cdot \beta_0 = 1.1 \cdot 1.53 \cdot 1.5 \cdot 0.65 = 1.645 \text{ [mm/min]} \qquad \text{for} \quad t \geq t_f \qquad (2)$$

where k_s is the cross-section factor; k_3 - the post-protection factor; k_n - a factor for converting the irregular residual cross-section into a notional rectangular cross-section; β_0 - the one-dimensional design charring rate.

The charring depth obtained by calculation in the 52nd minute:

$$d_{char,0} = (t - t_{ch}) \cdot \beta_n = (52 - 14.8) \cdot 1.645 = 61.15 \text{ [mm]} \qquad (3)$$

b) The calculation with the charring rate reduction after reaching t_a

The charring rate obtained by calculation is the same as a) (β_{n1} = 1.645 mm/min).

The failure time of claddings t_f is equal to the charring starting time t_{ch}. Increasing charring started after the failure of the cladding and went on until the time t_a, where the charring depth was 25 mm.

$$t_a = \frac{25}{\beta_n} + t_f = \frac{25}{1.645} + 14.8 = 30.02 \text{ [min]} \qquad (4)$$

The charring depth obtained by calculation in the 52nd minute:

$$d_{char,0} = (t_a - t_{ch}) \cdot \beta_{n1} + (t - t_a) \cdot \beta_{n2} = (30.02 - 14.8) \cdot 1.645 + (52 - 30.02) \cdot 1.07 = 48.57 \text{ [mm]} \qquad (5)$$

2.2 Results of the fire test

The fire test was terminated in the 53rd minute due to a large deflection wall outside the furnace, and weak leakage of gray smoke was observed from the joints between the boards in the upper half of the specimen. There was a risk of the construction's collapse. The development of temperatures (average values) in each layer can be seen in the graph, Fig. 3, including the temperature on the unexposed side.

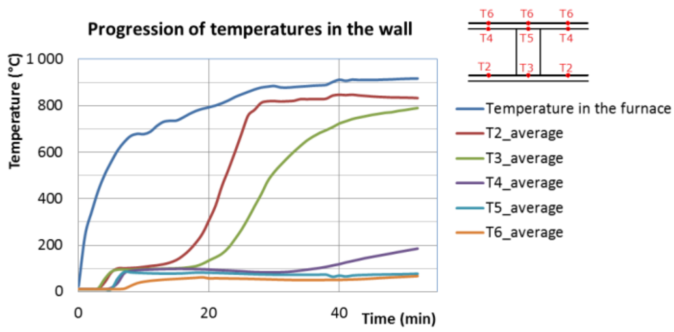

Fig. 3 The measured temperature of thermocouples during the fire test (average values)

2.3 Evaluation

The graph (Fig. 4) displays the dependence of the charring depth on time. The red line shows calculated values obtained by EN 1995-1-2 (see chap. 2.1). The green colour represents the values obtained by the fire test - charring starting time of timber studs (t_{ch}), and the green point on the graph represents charring depth measured after the fire test (d_{char}). The red dashed line shows a constant charring rate (according to chap. 2.1, a), while the red dotted line shows the charring rate, which reduces charring after reaching a depth of 25 mm (calculated according to chap. 2.1, b).

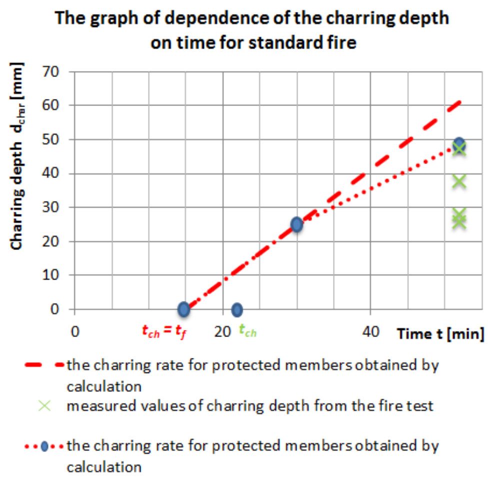

Fig. 4 The graph of the charring depth dependence on time, comparison between calculation and the fire test

In Fig. 5, there are pictures of timber studs cut up after the fire test. It shows the comparison between the calculation (red line) and the real (green line) charring depth.
The start of charring of the timber stud was assumed in the 15th minute on the basis of calculated results. On the basis of temperatures measured inside the specimen during the fire test, the start of charring of timber studs was determined in the 23rd minute. Therefore, the difference between these starting charring times is 8 minutes. The fire coating likely contributes to the fire resistance of the structure. However, it is generally known that calculation methods are always on the safe side, therefore, conservative.

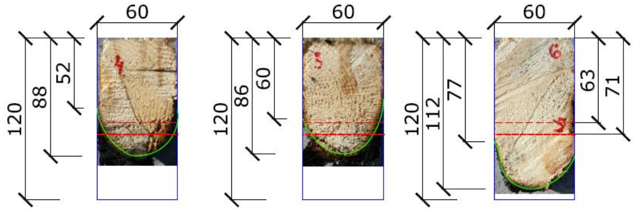

Fig. 5 Timber studs after the fire test; green line - real charring depth, red dashed line - calculation according to EN 1995-1-2 (2.1a), red dotted line - calculation according to EN 1995-1-2 (2.1b)

3 FIRE TEST OF A WALL ASSEMBLY WITH TWO-LAYER OSB BOARDS ON THE FIRE EXPOSED SIDE

In the second fire test, two OSB boards (according to EN 300, OSB 3) with a fire resistant coating were used on the fire exposed side to increase the fire resistance (board thickness of 15 mm + coating 1.7 mm (± 0.3)). One OSB board without any surface finish (15 mm) was used on the fire unexposed side. The gaps between the timbers studs were completely filled by rock wool. In Fig. 6, the composition of the test specimen can be seen. There were 22 pieces of thermocouples used inside the specimen for measuring temperature.

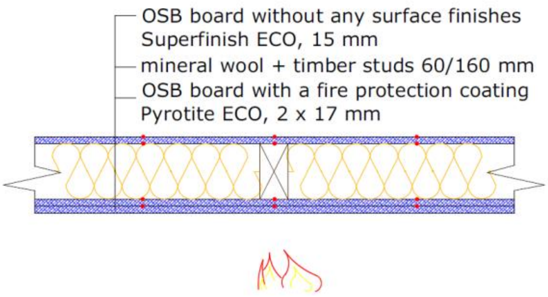

Fig. 6 The composition of the test specimen

3.1 Calculation of t_{ch}, t_f, d_{char} according to EN 1995-1-2

The charring starting time t_{ch} of the timber member for claddings made of OSB boards:

$$t_{ch} = \frac{h_p}{\beta_0} - 4 = \frac{30}{0.690} - 4 = 39.5\,[\text{min}] \tag{6}$$

a) The calculation without the charring rate reduction after reaching t_a or a charring depth of 25 mm

The charring of wood from one side is assumed for the calculation of the charring rate of a timber stud with dimensions of 60/160 mm (the cavities are completely filled by mineral wool):

$$\beta_{n1} = k_s \cdot k_3 \cdot k_n \cdot \beta_0 = 1.1 \cdot 2.42 \cdot 1.5 \cdot 0.65 = 2.596\ [\text{mm/min}] \qquad \text{for} \qquad t \geq t_f \tag{7}$$

The charring depth obtained by calculation in the 82nd minute:

$$d_{char,0} = (t - t_{ch}) \cdot \beta_n = (82 - 39.5) \cdot 2.596 = 113.0\ [\text{mm}] \tag{8}$$

b) The calculation with the charring rate reduction after reaching t_a

The charring rate obtained by calculation is the same as a) (β_{n1} = 2.596 mm/min).

The failure time of claddings t_f is equal to the charring starting time t_{ch}. Increasing charring started after the failure of the cladding and went on until the time t_a, where the charring depth was 25 mm.

$$t_a = \frac{25}{\beta_n} + t_f = \frac{25}{2.596} + 39.46 = 49.09\ [\text{min}] \tag{9}$$

The charring depth obtained by calculation in the 82nd minute:

$$d_{char,0} = (t_a - t_{ch}) \cdot \beta_{n1} + (t - t_a) \cdot \beta_{n2} = (49.09 - 39.46) \cdot 2.596 + (82 - 49.09) \cdot 1.07 = 61.37\,[\text{mm}] \tag{10}$$

3.2 Results of the fire test

The fire test was terminated in the 83rd minute due to a large deflection wall outside the furnace, when cracking inside the specimen was heard on the fire unexposed side, and weak leakage of grey smoke was observed from the joints between the boards in the upper half of the specimen. Both of the OSB boards on the fire exposed side were charred and fell off; though the insulation was without greater damage.

3.3 Evaluation

The graph (Fig. 7) displays the dependence of the charring depth on time. The red line shows calculated values obtained by EN 1995-1-2, see chap. 3.1. The green colour represents the values obtained by the fire test - charring starting time of timber studs (t_{ch}), and the green point on the graph represents charring depth measured after the fire test (d_{char}). The red dashed line shows a constant charring rate (according to chap. 3.1, a), while the red dotted line shows the charring rate, which reduces charring after reaching a depth of 25 mm (calculated according to chap. 3.1, b).

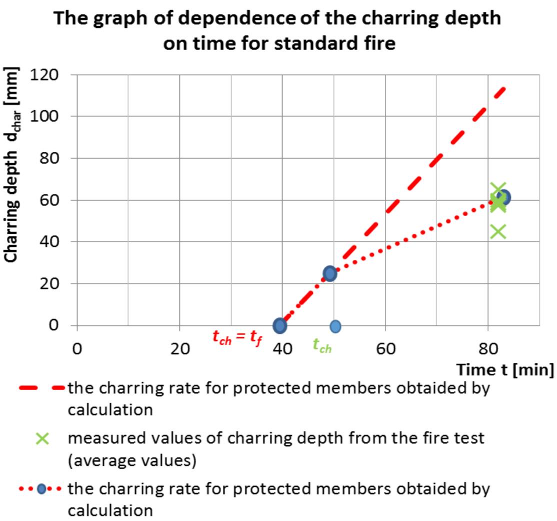

Fig. 7 The graph of the charring depth dependence on time, comparison between calculation and the fire test

In Fig. 8, there are pictures of timber studs cut up after the fire test. It shows the comparison between the calculation (red line) and the real (green line) charring depth.

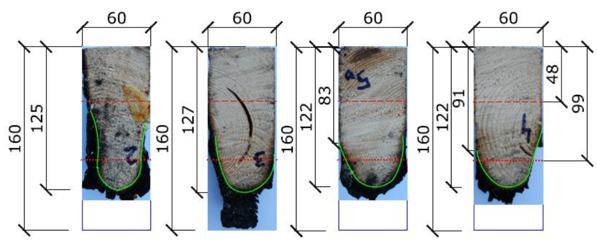

Fig. 8 Timber studs after the fire test; green line – real charring depth, red dashed line – calculation according to EN 1995-1-2 (3.1 a), red dotted line –calculation according to EN 1995-1-2 (3.1 b)

4 CONCLUSIONS

The calculation was performed for both fire tests by two methods using EN 1995-1-2. While the first method (see chapter 2.1 a), 3.1 a) is totally in accordance with Annex C (EN 1995-1-2), the second method (see chapter 2.1 b), 3.1 b) assumes reducing the charring rate after reaching a certain charring depth (Fig. 3.3, EN 1995-1-2). The second method compared with the first method is more accurate and gives better results as can be seen from Table 1. Therefore, it is assumed that the charring rate of these very subtle elements (load-bearing timber studs) also reduces after reaching a certain depth. After the fire protection falls off, a large increase in the charring rate occurs compared to an unprotected element (by up to 4 times in the second fire test) according to Annex C (EN 1995-1-2).

Table 1 Comparison between the values obtained by the fire test and normative calculation

<table>
<tr><th>test / calculation</th><th>t_{ch} (min)</th><th>t_f (min)</th><th>β_0 (mm/min) OSB board</th><th>β_0 (mm/min) timber stud</th></tr>
<tr><td>1st fire test</td><td>23</td><td>0.739</td><td>1.19</td><td>34.5 (average)</td></tr>
<tr><td rowspan="2">EN 1995-1-2</td><td rowspan="2">14.8</td><td rowspan="2">0.797</td><td>1.645</td><td>61.15</td></tr>
<tr><td>1st phase: 1.645
2nd phase: 1.07</td><td>48.57</td></tr>
<tr><td>2nd fire test</td><td>49</td><td>0.694</td><td>1.74</td><td>57.4 (average)</td></tr>
<tr><td rowspan="2">EN 1995-1-2</td><td rowspan="2">39.5</td><td rowspan="2">0.797</td><td>2.596</td><td>113</td></tr>
<tr><td>1st phase: 2.596
2nd phase: 1.07</td><td>61.37</td></tr>
</table>

The fire protection coating contributes to the fire resistance of wall assemblies. The calculation according to EN 1995-1-2 is conservative and does not allow including the impact of coating. Thus, it is necessary to develop new computational methods for new materials. Fire tests are an integral part for creating and developing new computational methods that need to be examined and evaluated in detail.

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