Charring analysis for timber frame assemblies with cellulose cavity insulation and Aquastone board
(1 appendix)

General
This report is a result of non-loaded model scale fire test with different beam configurations insulated with cellulose fiber insulation and covered by Aquastone board from Wekla AB on the fire exposed side.

Model scale test was made on 20th of October 2015 in a model furnace at SP Wood Building Technology in Stockholm.

The results of the fire test together with analysis is given in this report. Charring scenario of timber beams is analyzed.

This report is confidential. The publishing of the results is allowed only with permission by Wekla AB.

Reference number
5P07616-02
Internal test number of SP Wood Technology’s model scale test furnace: 105
1 Introduction

TT ORIGINAL is a cellulose fibre insulation. Non-load bearing floor test was conducted at the model scale furnace of SP Wood Building Technology in Stockholm.

A test was sponsored by Wekla AB.

The scope of the presented test was to investigate the effect of TT ORIGINAL and Aquastone board on charring of studs and joists in timber frame assemblies.

This study is a pre-study for the research programme Väx Med Skogen.

2 Materials

For the test specimens timber graded to C24 was used. Cellulose fibre insulation and magnesium board were used to investigate the performance of the insulation material and its coaction with the timber beams in the protection phase before failure of the cladding.

All specimens were built at SP Wood Building Technology and conditioned in a controlled climate chamber at 20 °C and 65% RH before the fire tests.

2.1 Timber

Four timber beams with different cross-sections were tested in the specimen. Rectangular sections 45x150 mm and 45x137,5 mm. I-beams with heights 150 mm and 137,5 mm.

See Figure 6 to Figure 10 for the layout and measures for the beams.

Timber with strength grade C24 was used.

2.2 Insulation

Tests were done with cavity insulation with a nominal density of 30 kg/m³.

The insulation material was manufactured and installed by blowing to the test specimen by Svenska Termoträ AB.

2.3 Boards, fasteners and additional material

Wekla Aquastone® boards with thickness 9 mm were used. Density of the board was measured 953 kg/m³. Board consists of magnesiumoxide, sulphate, silicate and EPS according to the producer (www.wekla.com).

Self-drilling screws with lengths 55 mm and a nominal diameter of 3,0 mm were used to fasten boards to the test specimens. Distance between the screws was 300 mm.
Wooden particle board with thickness of 19 mm was used on the unexposed side.

To keep the specimens as air-tight as possible an aluminium tape was attached in the joints at the non-exposed side as well as on the sides of the specimens.

For temperature measurements different types of thermocouples type K were used. Crimped junctions with a contact length of about 3 mm were used for internal temperature measurements while the length was about 5 mm for measurements of the non-exposed surface of the gypsum plasterboard on the fire exposed side. For measurements at the non-exposed surface thermocouples according EN 1363-1 were used.

3 Fire test TT1C

3.1 General

Fire test was conducted at model scale furnace of SP Wood Building Technology. Test was done to study the influence of the insulation material and the cladding on the charring of a timber member.

Non-loaded test was performed with horizontal test specimen with outer dimensions 1,2 x 1,2 m. Fire exposed surface was 1,0 x 1,0 m.

The aim of the non-loaded tests was to measure charring at protected and unprotected phase with different beam configurations.

Figure 1. Building of test specimen. Insulation installed.
Figure 2. Test specimen placed on the furnace. Unexposed side.

Figure 3. Test specimen placed on the furnace. Exposed side.
The fire exposure was started and the temperature in the furnace was increased following the standard fire temperature-time curve according to ISO 834. Recorded data for furnace temperature and pressure can be found in Clause 3.3. The recorded temperature-time curves during the tests can be found in Figure 17.

Test time was 60 minutes. After that the burners were turned off, the specimen removed from the furnace and the fire was extinguished with water. The time elapsed from turning off the burners, breaking the boards and extinguishing the fire was around 7 minutes.

Figure 4. Plan of test specimen.
3.2 Location of the thermocouples

All thermocouples were type K. Thermocouples were set in the loaded timber members in different arrangements:
The holes (depth 23 mm) for the wires were drilled from and perpendicular to the wide side of the member. Thermocouple wires were crimped (twisted length 3 mm) and tested for contact before inserting.

A number of thermocouples were also placed on the sides of cross-section to measure the recession of the insulation.

Figure 5. Cross-section of test specimen.

Figure 6. Cross-section of test specimen. Definition of beams. Location of thermocouples.
Figure 7. Location of thermocouples of beam A.

Figure 8. Location of thermocouples of beam B.
Figure 9. Location of thermocouples of beam C.

Figure 10. Location of thermocouples of beam D.
3.3 Furnace data

Furnace temperature and pressure during the fir test are presented in Figure 11 and Figure 12.

![Furnace temperature graph](image1)

*Figure 11. Furnace temperature.*

![Furnace pressure graph](image2)

*Figure 12. Furnace pressure.*
3.4 Observations

The Wekla Aquastone board did not fall down during the entire test. There was a crack observed that appeared on 24th minute. See also Figure 14

After removing the board when extinguishing, the insulation was observed to be on place and the colour of the insulation was black.

Figure 13. Test specimen mounted on the furnace. Fire exposed side.

Figure 14. Specimen after removing from the furnace.
Figure 15. Test specimen after removing of board.

Figure 16. Test specimen after removing of board.
3.5 Temperatures

Temperatures measured in the specimen during the fire test can be found on Figure 17 and Figure 18.

Figure 17. All thermocouple measurements.

Figure 18. Temperatures measured by TC 27 to TC 33.
4 Analyse

4.1 Start time of charring

The start time of charring of the beams is given in Table 1.

Beams B and D had two protective layers for wood – Aquastone board and stripe of gypsum plasterboard, Type A with thickness 12.5 mm.

Table 1. Start times of charring and failure times.

<table>
<thead>
<tr>
<th>Beam</th>
<th>Start time of charring $t_{ch}$ [min]</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>14.3</td>
</tr>
<tr>
<td>B</td>
<td>48.8</td>
</tr>
<tr>
<td>C</td>
<td>15.3</td>
</tr>
<tr>
<td>D</td>
<td>47.7</td>
</tr>
</tbody>
</table>

The start of charring time is measured by thermocouples.

4.2 Residual cross-sections

After the fire test was terminated the specimen was removed from the furnace and extinguished within 4 minutes.

The residual cross-sections were cut and the charring depth measured.

See Figure 19 to Figure 23.
Figure 19. Charred beams.

Figure 20. Residual cross-sections from beam A.
Figure 21. Residual cross-sections from beam B.

Figure 22. Residual cross-sections from beam C.
Figure 23. Residual cross-sections from beam D.

Table 2. Charring depths and remaining heights of beam cross-sections in the middle of span.

<table>
<thead>
<tr>
<th>Beam</th>
<th>Height of cross-section</th>
<th>Remaining height of cross-section</th>
<th>Charring depth in the middle of cross-section width</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>h [mm]</td>
<td>h_f [mm]</td>
<td>d_{char,m} [mm]</td>
</tr>
<tr>
<td>A</td>
<td>150</td>
<td>108</td>
<td>42</td>
</tr>
<tr>
<td>B</td>
<td>137,5</td>
<td>127</td>
<td>10,5</td>
</tr>
<tr>
<td>C</td>
<td>150</td>
<td>108</td>
<td>42</td>
</tr>
<tr>
<td>D</td>
<td>137,5</td>
<td>125</td>
<td>12,5</td>
</tr>
</tbody>
</table>

4.3 Charring rate

The charring rate is measured by thermocouples during the test and by measuring the residual cross-section after the test.

As the temperature for charring is regarded 300°C.
Figure 24. Charring of the beams along the vertical axle of the cross-section. Thermocouple measurements.

Table 3. Charring rates.

<table>
<thead>
<tr>
<th>Beam</th>
<th>Charring rate at protected phase, charring depth from 0 to 6 mm $t_{ch}&lt;t&lt;t_{fr}$ [mm/min]</th>
<th>Charring rate at protected phase, charring depth from 6 mm to the final $t_{ch}&lt;t&lt;t_{fr}$ [mm/min]</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.58</td>
<td>1.01</td>
</tr>
<tr>
<td>B</td>
<td>0.60</td>
<td>3.75</td>
</tr>
<tr>
<td>C</td>
<td>0.47</td>
<td>1.12</td>
</tr>
<tr>
<td>D</td>
<td>0.76</td>
<td>1.48</td>
</tr>
</tbody>
</table>

4.4 Load-bearing capacity

Load-bearing capacity based on test results are presented in Table 4.

Rough calculations of bearing capacity are added as Annex B.

Beam height is chosen 150 mm for the load-bearing capacity for all beams.

Calculations are made with reduced cross-section method according to the European technical guideline “Fire Safety in Timber Buildings”.

Table 4. Load-bearing capacities for bending

<table>
<thead>
<tr>
<th>Duration of test</th>
<th>Beam</th>
<th>30 min</th>
<th>60 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>M [kNm]</td>
<td>A</td>
<td>2,89</td>
<td>1,58</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>2,73</td>
<td>2,29</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>3,52</td>
<td>0,32</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>3,37</td>
<td>2,49</td>
</tr>
</tbody>
</table>

References
