Finalisation of the European approach to assess the fire performance of facades

Steering group meeting – April 20th, 2021

Agenda

9:30 Short update on the project
   – Proposal on wood cribs and combustion chamber
   – Results from wood crib tests
   – Test program for next step

10:30 Discussion

11:30 Break

11:45 Falling parts

12:15 Discussion

13:15 AOB
Update on the project
General content of the project

• Theoretical round robin => Completed
• Initial testing activities
• Experimental round robin
• Analysis and fine-tuning of the assessment method
Update on the project

• Comments Handling Document updated and available on the web (4 documents so far)

• Assessment method updated where needed changes and improvements are highlighted. The document is available on the web.

• A proposal on the wood cribs and combustion chamber has been developed from the analysed wood crib tests.

• Tests on falling parts have started.

• Delay in the project due to several factors (pandemic, technical problems).
Wood crib tests

• Aim to define the wood crib characteristics to be used
  – Wood density, species, geometry, specific surface, calorific value, surface treatment (planned/sawn), moisture content

• Measurement of heat exposure
  – Fuel consumption, temperature measurements, heat flux measurements

• The wood to be used shall be easily accessible in most MS
Main points - Proposal

• Keep the medium wood crib as specified in DIN.

• Change wood species for the large crib.

• Change the test rig in order to accommodate for more flexible mounting of test specimen.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Medium test</th>
<th>Large test</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wood species</strong></td>
<td>Spruce (Picea abies)</td>
<td>Spruce (Picea abies)</td>
</tr>
<tr>
<td><strong>Cross section of sticks</strong></td>
<td>$40 \times 40 \text{mm}^2 \pm 1 \text{mm}$</td>
<td>$47 \times 47 \text{mm}^2 \pm 3 \text{mm}$</td>
</tr>
<tr>
<td><strong>Length of sticks</strong></td>
<td>$500 \pm 5 \text{mm}$</td>
<td>Long: $1500 \pm 5 \text{mm}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Short: $1000 \pm 5 \text{mm}$</td>
</tr>
<tr>
<td><strong>Nominal density of crib</strong></td>
<td>$475 \pm 25 \text{kg/m}^3$</td>
<td>$500 \pm 100 \text{kg/m}^3$</td>
</tr>
<tr>
<td><strong>Weight of crib</strong></td>
<td>$30 \pm 1.5 \text{kg}$</td>
<td>$350 \pm 20 \text{kg}$</td>
</tr>
<tr>
<td><strong>Number of sticks per layer and number of layers</strong></td>
<td>6 sticks per layer</td>
<td>Long: 10 sticks/layer</td>
</tr>
<tr>
<td></td>
<td>The number of layers and number of sticks in the top layer are adjusted so the weight of the crib is within the tolerances.</td>
<td>Short: 15 sticks/layer</td>
</tr>
<tr>
<td><strong>Joining of sticks</strong></td>
<td>Nailing</td>
<td>Nailing</td>
</tr>
<tr>
<td><strong>Moisture content</strong></td>
<td>$11 \pm 2 %$</td>
<td>$11 \pm 2 %$</td>
</tr>
<tr>
<td><strong>Surface finish</strong></td>
<td>Planed</td>
<td>Sawn or planed</td>
</tr>
<tr>
<td><strong>Floor for crib</strong></td>
<td>Grating</td>
<td>Solid</td>
</tr>
<tr>
<td><strong>Size of combustion chamber</strong></td>
<td>Width x Height x Depth $1.0 \times 1.0 \times 0.8 \text{m}^3$</td>
<td>Width x Height x Depth $2.4 \times 2.2 \times 1.3 \text{m}^3$</td>
</tr>
<tr>
<td></td>
<td>Opening dimension $1.0 \times 1.0 \text{m}^2$</td>
<td>Opening dimension $2.0 \times 2.0 \text{m}^2$</td>
</tr>
<tr>
<td></td>
<td>No apparent lintel</td>
<td>200 mm height lintel at the top of the opening</td>
</tr>
</tbody>
</table>
Proposal

• The initial aim was to have as similar as possible characteristics of the fuel source for the medium and large heat exposure tests.

• It has been shown that this will be difficult to achieve, and at the same time have a cost-effective test procedure.
Proposal

• The crib for the medium heat exposure test is much smaller and more sensitive to changes in density, and probably also to cross-sectional dimensions of the sticks, and therefore stricter tolerances and requirements are proposed.
Proposal

• The crib for the large heat exposure crib is proposed to be made of spruce, which is a deviation from BS 8414 which states pine.

• The tests show that with spruce the HRR and temperatures are significantly lower compared with cribs of pine.

• Although, the spruce cribs are shown to be in accordance with the tolerances and the target values given in BS 8414.

• Other full-scale tests with real fires also show that the values on HRR and temperatures reached with spruce cribs are representative for a severe fire.
Proposal

• In both the medium and large heat exposure tests it is proposed to use a target weight of the wood crib, i.e. the number of sticks to be used as in BS 8414 is not defined.

• For the large heat exposure, a method for determining the number of layers to be used in the crib is proposed. It is a probabilistic approach that includes a sampling of some material from the batch of sticks on which the density and dimensions are measured.

• A simple calculation is then made, and the number of layers needed in the crib can be determined.
Wood crib tests
Initial testing activities

**Objective:** to determine the sensitivity of the test method to variations of its main parameters and, consequently, define the specifications to be imposed on these parameters in order to ensure a robust method
Initial testing activities

- Literature survey
- Define the test program
- Design of a simple test rig
- Perform the tests
- Analyse the test results
- Update the assessment method
Initial testing activities - fuel

• Parametric tests on wood cribs
  – Wood species
  – Density
  – Geometrical tolerances
  – Moisture content

• Measurements
  – Mass loss rate
  – Heat release rate
  – Flame behaviour
  – Heat flux and temperature at different positions
## Test program – medium exposure wood crib tests

<table>
<thead>
<tr>
<th>Test reference</th>
<th>Total mass</th>
<th>Wood species</th>
<th>Surface finish</th>
<th>Mean wood density [kg/m³]</th>
<th>Moisture content [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>B0</td>
<td>32.19</td>
<td>Spruce</td>
<td>Planed</td>
<td>390</td>
<td>Average</td>
</tr>
<tr>
<td>B1</td>
<td>32.25</td>
<td>Spruce</td>
<td>Planed</td>
<td>542</td>
<td>Average</td>
</tr>
<tr>
<td>B2</td>
<td>34.02</td>
<td>Spruce</td>
<td>Planed</td>
<td>413</td>
<td>Average</td>
</tr>
<tr>
<td>B3</td>
<td>31.96</td>
<td>Spruce</td>
<td>Sawn</td>
<td>389</td>
<td>Average</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Property</th>
<th>Target value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stick section</td>
<td>47 (±2) mm square</td>
</tr>
<tr>
<td>Stick length / number per layer</td>
<td>517 (±10) mm / 6 sticks</td>
</tr>
<tr>
<td>Total mass</td>
<td>(33 ± 1.5) kg</td>
</tr>
<tr>
<td>Species</td>
<td>Spruce (Picea abies)</td>
</tr>
<tr>
<td>Forced ventilation</td>
<td>400 m³/h, 4 min after ignition</td>
</tr>
</tbody>
</table>
1 Masonry  
2 Wood crib  
3 Fireproof blanket

4 Additional air  
5 Top opening of the combustion chamber  
6 Grating (thickness 30 mm)
Effect of density/specific surface

HRR (t) - KW versus Time (min)

Test reference | Average wood density [kg/m³]
---|---
M0 | 390
M1 | 542
M2 | 413
M3 | 389
# Test program – large exposure wood crib tests

<table>
<thead>
<tr>
<th>Test reference</th>
<th>Wood species</th>
<th>Surface finish</th>
<th>Wood density [kg/m³]</th>
<th>Moisture content [%]</th>
<th>Stick section</th>
<th>Solid plate/grating</th>
<th>Chamber volume</th>
<th>Nailing</th>
</tr>
</thead>
<tbody>
<tr>
<td>L0 (BS8414)</td>
<td>Pine</td>
<td>Sawn</td>
<td>490</td>
<td>11.5 %</td>
<td>50x50</td>
<td>G</td>
<td>Large</td>
<td>Yes</td>
</tr>
<tr>
<td>L1</td>
<td>Spruce</td>
<td>Planed</td>
<td>492</td>
<td>10.0 %</td>
<td>47x47</td>
<td>S</td>
<td>Large</td>
<td>Yes</td>
</tr>
<tr>
<td>L2</td>
<td>Spruce</td>
<td>Planed</td>
<td>411</td>
<td>10.0 %</td>
<td>47x47</td>
<td>G</td>
<td>Large</td>
<td>Yes</td>
</tr>
<tr>
<td>L3</td>
<td>Spruce</td>
<td>Planed</td>
<td>547</td>
<td>10.5 %</td>
<td>47x47</td>
<td>G</td>
<td>Large</td>
<td>Yes</td>
</tr>
<tr>
<td>L4</td>
<td>Pine</td>
<td>Planed</td>
<td>485</td>
<td>11.7 %</td>
<td>47x47</td>
<td>G</td>
<td>Large</td>
<td>Yes</td>
</tr>
<tr>
<td>L5</td>
<td>Spruce</td>
<td>Planed</td>
<td>447</td>
<td>8.7 %</td>
<td>47x47</td>
<td>G</td>
<td>Large</td>
<td>Yes</td>
</tr>
<tr>
<td>L6</td>
<td>Spruce</td>
<td>Planed</td>
<td>465</td>
<td>14.5 %</td>
<td>47x47</td>
<td>G</td>
<td>Large</td>
<td>Yes</td>
</tr>
<tr>
<td>L7</td>
<td>Spruce</td>
<td>Planed</td>
<td>447</td>
<td>10.0 %</td>
<td>47x47</td>
<td>S</td>
<td>Large</td>
<td>Yes</td>
</tr>
<tr>
<td>L8 (BS8414)</td>
<td>Pine</td>
<td>Sawn</td>
<td>501</td>
<td>11.5 %</td>
<td>50x50</td>
<td>S</td>
<td>Standard</td>
<td>No</td>
</tr>
</tbody>
</table>
Instrumentation: HRR & MLR
Instrumentation: temperatures and heat fluxes
Instrumentation: temperatures and heat fluxes
Video & pictures
Results

Synthesis of HRR30

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>L0 (BS 8414)</td>
<td></td>
</tr>
<tr>
<td>L1-AD+Plate</td>
<td></td>
</tr>
<tr>
<td>L2-LD</td>
<td></td>
</tr>
<tr>
<td>L3-HD</td>
<td></td>
</tr>
<tr>
<td>L4-Pine</td>
<td></td>
</tr>
<tr>
<td>L5-8.7 %</td>
<td></td>
</tr>
<tr>
<td>L6-14.5 %</td>
<td></td>
</tr>
<tr>
<td>L7-LD+Plate</td>
<td></td>
</tr>
<tr>
<td>L8 (BS 8414) + Plate</td>
<td></td>
</tr>
</tbody>
</table>

HRR (kW) vs. Time (min)
Results
Results – Pictures- example of L3
Results – different collapsings (examples L2 vs L1)

<table>
<thead>
<tr>
<th>Crib ref</th>
<th>Collapsing</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>L0 (BS 8414)</td>
<td>23 min 46s</td>
<td>Grating</td>
</tr>
<tr>
<td>L1</td>
<td>Slowly start from 26 min</td>
<td>Solid board</td>
</tr>
<tr>
<td>L2</td>
<td>22 min 42s</td>
<td>Grating</td>
</tr>
<tr>
<td>L3</td>
<td>27 min 40s</td>
<td>Grating</td>
</tr>
<tr>
<td>L4</td>
<td>22 min 25s</td>
<td>Grating</td>
</tr>
<tr>
<td>L5</td>
<td>23 min 54s</td>
<td>Grating</td>
</tr>
<tr>
<td>L6</td>
<td>26 min 03s</td>
<td>Grating</td>
</tr>
<tr>
<td>L7</td>
<td>Slowly start from 23 min 30s</td>
<td>Solid board</td>
</tr>
<tr>
<td>L8 (BS 8414)</td>
<td>Slowly start from 23 min 15s</td>
<td>Solid board</td>
</tr>
</tbody>
</table>
Effect of species

- L1 - Spruce
- BS 8414 - Pine

- L2 - Spruce, low density
- L3 - Spruce, high density
- L4 - Pine, average density
Effect of moisture content

- L2 - Medium moisture content
- L5 - Low moisture content
- L6 - High moisture content
Effect of density – medium crib

- M0 - Low density
- M1 - High density
- M2 - Low density
- M3 - Low density

Effect of density – large crib

- L2 - Low density
- L3 - High density
Effect of surface finish – medium crib

- M2 - Planed surface
- M3 - Sawn surface

Effect of surface finish – large crib

- L0 - Sawn surface
- L4 - Planed surface
Effect of floor design – large crib

![Graph showing the effect of floor design on heat release rate (HRR) over time. Red line represents L2 - Grated floor, and blue line represents L7 - Solid floor.](image-url)
Effect of cross-section dimensions – large crib

- L0 - 50x50 mm²
- L4 - 47x47 mm²
Modelling possible differences of geometry between regular and proposed combustion chamber
Large fire tests with timber constructions performed outdoors – severe fire
Summary of test results

- Wood species have an significant effect
- Density have a significant effect for the medium crib, but not for the large crib
- Moisture content have an effect, mainly on the initial phase of the heating
- Surface finish does not have any effect
- The type of floor have an significant effect (large wood crib)
- The cross sectional dimension does not have any significant effect, within the tolerances used
Still missing information

• Effect of specific surface of the wood crib – when the number of sticks can vary, it may have an effect

• Change of position of the large wood crib in order to prevent falling parts to damage the crib

• ...
Next step according to the plan

- Test with full size rigs
- Average tests – repetition three times
- Effect of wind speed
- Uplift of rig
- Position of secondary opening
To be discussed – uplift of rig

- When testing with the large heat exposure the rig must be uplifted in order to avoid ignition of combustible falling materials.
- An uplift will give rise to new requirements for the testing labs – increase height of the test halls, more complicated installation of the cribs in the combustion chamber.
- It is proposed to look for alternative solutions to assess flamespread downwards by burning falling parts.
To be discussed – missing information

- The effect of specific surface
- It is proposed to make tests with different specific surface instead of the uplift tests
Proposed next step

- Effect of specific surface – high and low
- Average tests – with medium specific surface
- Effect of wind

- Meeting with steering group before continuing with test of secondary opening position
Discussion
Falling parts
Overview

- Why assessing falling parts?

- Challenges in assessing falling parts

- Requirements for measurement of falling parts

- Video measurements - overview

- Weight measurements - experiments

- Conclusions
Why assessing falling parts?

- Falling parts in facade fires endanger fire fighters and escaping inhabitants
- Burning falling parts may spread fire downward
- Several building regulations of MS have regulations for falling parts

- Three aspects mostly are addressed in building regulations:
  - Weight of the part (limits vary between 1 kg and 5 kg)
  - Size of the part (less than 1 m²)
  - Burning / not burning
Challenges in assessing falling parts

- Parts may fall down during the whole test time (the timing is not foreseeable)

- Parts might be damaged when hitting the floor

- Parts might be burning and consumed further after falling

- Parts might be ignited by the burning wood crib

- If crib is extinguished parts might be hit by water (changing the weight of the part)

- If extinguishment of part is necessary weight is changed
Requirements for measurements of falling parts

- Size and weight of the falling part shall be assessed

- It should be possible to measure the size of the falling part during the test, ideally when falling down

- 3D measurement of the part would allow weight assessment as specimen is known
What failure criteria shall be used for falling parts?

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Member States</th>
<th>Stakeholders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Weight and flaming</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Weight and distance</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Size</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Large pieces</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Size and flaming</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Project team decides</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>More discussions needed</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>No opinion/comment</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
3 D video recordings

- Full movement can be captured in falling
- 3D figure is created electronically
- Several cameras and good lighting
- Expensive technique
Digital image correlation 1

- Two cameras in two fixed positions

- Assessment of movement with reference points
Digital Image Correlation 2

- Two possibilities:
  - Assessing the specimen on the wall and changes there: specimen has to be marked with something to give the cameras and software points to correlate to
  - Assessing parts that fall down, easier to assess, maybe with pixel counting

- Challer radiatic
Photogrammetry

- Possible use of pictures (photographs), drone videos
Stripe projection

- Stripes or grid with beamer in fixed position

- Two cameras in fixed positions

- With the images and the grid, size can be assessed, problem is the third dimension; the method works good in two dimensions
## Different possible techniques

<table>
<thead>
<tr>
<th>Technique</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D full video capture of the dynamic fall</td>
<td>Full realistic 3D assessment of the falling part in falling</td>
<td>Expensive and elaborate method with several cameras and software, software might not be able to adjust for variable lighting due to flames</td>
</tr>
<tr>
<td>Digital image correlation</td>
<td>Easier to install, pixel counting or markers movement assessment</td>
<td>Software might not be able to work with flames and hot air</td>
</tr>
<tr>
<td>Photogrametry</td>
<td>3D volume assessment from pictures</td>
<td>Flames might be modelled as well</td>
</tr>
<tr>
<td>Stripe projection</td>
<td>Easier to install, only 2 cameras and beamer</td>
<td>If part is burning flames would maybe be counted as part</td>
</tr>
</tbody>
</table>
Challenges for assessment methods

- Flames in front of the specimen
- Flames when part is burning
- Change in part when damaged due to hitting the floor
- Hot air (air movement)
- Third dimension
Weight assessment

- Experiments were performed at BAM on March 25th 2021 between 13:40 and 16:10 h with a scale and a plate on top and a software to record the weight development with time.

- 16 experiments were performed outside (wind influence).

- The following equipment was used:
  - Scale: 150 kg with 1 g, Kern DS 150 K1
  - Weights:
    - 13 metal balls, 2 pieces with about 40 g and 20 mm diameter
    - 2 pieces with about 180 g and 35 mm diameter
    - 9 pieces with about 500 g and 50 mm diameter
  - Plate with stone wool on top, height of scale with plate and stone all: about 20 cm
Test set-up

![Test set-up image](image1)

![Test set-up image](image2)
• 16 experiments with different weights and combinations of weights have been performed. The height from where the weights have been dropped have been varied as well.

• In the following table the experiment plan is shown. In experiments 3, 5 and 11 the weight bounced from the scale to the floor. These experiments have been done again, experiment 4, 6 and 12 respectively.

• The height from the top of the test set-up to point from which the weights have been dropped have been varied from 0.5 m to 1.8 m.
### Experiments

<table>
<thead>
<tr>
<th>No</th>
<th>time</th>
<th>height</th>
<th>weight</th>
<th>2 weights at the same time</th>
<th>2 weights, each one after the other</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15:23</td>
<td>1 m (1,20 m über Boden)</td>
<td>1082 g</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>15:37</td>
<td>0,5 m</td>
<td>1082 g</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>15:45</td>
<td>1,5 m</td>
<td>1082 g</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>15:46</td>
<td>1,5 m</td>
<td>1082 g</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>15:47</td>
<td>1,8 m</td>
<td>1082 g</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>15:48</td>
<td>1,8 m</td>
<td>1082 g</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>15:51</td>
<td>1 m</td>
<td>1082 g</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>15:53</td>
<td>1 m</td>
<td></td>
<td></td>
<td>1082 g and 534 g with 5 s between</td>
</tr>
<tr>
<td>9</td>
<td>15:54</td>
<td>1 m</td>
<td></td>
<td></td>
<td>1082 g and 534 g with 10 s between</td>
</tr>
<tr>
<td>10</td>
<td>15:56</td>
<td>1 m</td>
<td>534 g</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>15:57</td>
<td>1,5 m</td>
<td>534 g</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>15:58</td>
<td>1,5 m</td>
<td>534 g</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
One weight

![Experiment 1](image1.png)

![Experiment 2](image2.png)

![Experiment 4](image3.png)
Two weights

Experiment 8

Experiment 9
Weight bouncing off the scale to the floor
Conclusions

- The method seem to be useful to assess falling parts.

- However, some fluctuations around the time when the weight has been dropped can be seen and they are more if the height is greater or if two parts together are being dropped.

- For one falling part or even two with time between them (of 5 or 10 s) the plateaus seem to be distinctive and an assessment seems to be possible.
Discussion
AOB
Questions and comments

• You are also welcome to send your questions or comments after the meeting (email to Johan and Heikki)