

**THE INTERNATIONAL RESEARCH GROUP ON WOOD PROTECTION**

**Section 2**

**Test methodology and assessment**

**Introduction of the COST FP 1303 Cooperative Performance Test**

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# Introduction of the COST FP 1303 Cooperative Performance Test

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## ABSTRACT

COST Action FP 1303 “Performance of bio-based building materials” successfully started in October 2013 and an ambitious program was set up for the four year programme. COST Actions provide an excellent opportunity for collaborative research, e.g. in the frame of Round Robin tests.

The idea of this respective test was to distribute a fairly simple test set up to as many places in Europe as possible in order to collect performance data reflecting the range of climatic exposure conditions. Furthermore we wanted to consider performance in its manifold meaning, i.e. optical, aesthetical, moisture and functional performance and durability. In contrast to traditional Round Robin tests aiming on comparative evaluation and validation of results from different test laboratories, this initiative aims on collecting performance data under climatically different exposure conditions. Therefore it was required to provide weather data from the respective test sites to allow establishing relationships between climate conditions and the following measured, which shall be evaluated regularly: decay, discolouration, development of mould and other staining fungi, corrosion, formation of cracks and moisture performance (if data logging device is included). Further details about the test and the first outcomes are presented in this paper.

**Keywords:** wood, performance, moisture content, degradation, Norway spruce, thermally modified wood, English oak

## 1. INTRODUCTION

There is an increasing need for consideration of performance classification for wood and other bio-based building materials, as evidenced by the European Construction Products Regulation, as well as by warranty providers and end user demands for information. In the frame of several European research projects this issue has been addressed and emphasized by CEN /TC 38 in recent years (Kutnik *et al.* 2014).

The development of performance-based design methods for durability requires that models are available to predict performance in a quantitative and probabilistic format. During the last decade great progress has been made, in that the wood sector caught up with other competing areas such as the steel, concrete, and polymer sector. The relationship between durability determined in laboratory or field tests and the performance under in-service conditions needs to be quantified in statistical terms and the resulting prediction models need verification and adaptation according to performance in real life (Brischke and Thelandersson 2014). The availability and accessibility of performance data is a basic prerequisite for

both modelling and performance classification, but is still limited. Therefore a joint initiative has been set up between participating groups within COST Action FP1303 “Performance of bio-based building materials”.

This COST action started in October 2013 and an ambitious program was set up for the four year programme. Among this a collaborative field test was planned. As we learned from earlier Actions it is valuable to start with such cooperative activities as early as possible in the life of an Action. This allows harvesting results within the run-time of the Action and helps to initiate discussions during workshops and meetings.

A Cooperative Performance Test has been organized in the frame of this COST Action as decided during the first workshop in Paris in January 2014. The idea was to distribute a fairly simple test set up to as many places in Europe as possible in order to collect performance data reflecting the range of climatic exposure conditions. Furthermore, the test aimed on considering performance in its manifold meaning, *i. e.* optical, aesthetical, moisture and functional performance and durability. In contrast to traditional Round Robin tests aiming on comparative evaluation and validation of results from different test laboratories, this initiative aimed on collecting performance data under climatically different exposure conditions. Therefore it was required to provide weather data from the respective test sites to allow establishing relationships between climate conditions and the following parameters, which were evaluated regularly:

- Fungal decay
- Discolouration
- Development of mould and other staining fungi
- Corrosion
- Formation of cracks
- Moisture performance (optional)

The results expected from this cooperative performance test shall contribute to a better understanding of performance aspects of bio-based materials in the building sector under the influence of geographical and climatic differences. Furthermore, it shall enable the participants to estimate their own location in terms of exposure severity and performance to be expected.

## **2. EXPERIMENTAL**

### **2.1 Principle set up**

A folding table with boards made from three different materials, *i.e.* Norway spruce, English oak and thermally modified Norway spruce (Table 1) served as easy shippable and ready-to-use test object (Fig. 1). The boards were fixed with partly stainless and partly ordinary steel screws. The table was available in three different versions:

- Version A: Performance table with the three materials mounted; including data logging device for recording temperature and wood MC (8 channels)
- Version B: Performance table with 3 materials mounted, no data logger
- Version C: Performance table, blank rig for testing extra materials according to personal/regional preferences (delivered only in addition to version A or/and B)

Table 1. Obligatory wood species used for the performance test.

| Wood species                     | Botanical name     | Oven dry density [g/cm <sup>3</sup> ] |
|----------------------------------|--------------------|---------------------------------------|
| Norway spruce                    | <i>Picea abies</i> | 0.465                                 |
| English oak                      | <i>Quercus</i> sp. | 0.708                                 |
| Thermally modified Norway spruce | <i>Picea abies</i> | 0.435                                 |



Fig. 1. Performance folding table.

## 2.2 Exposure conditions

The test sites for exposure of the performance table had to meet the following requirements:

- Typical free exposure (avoiding canopies and vicinity to buildings and other shading elements)
- Standard test site (if available) to allow for further comparison with your running tests
- Safety (against vandalism, thievery, storm, and other catastrophes, which might occur at the site)
- Fixation with the ground, *e.g.* with steel angles.
- Steel box with data loggers positioned below the table or on a nearby holder. Leakage should be prevented.

## 2.3 Documentation

### 2.3.1 Documentation of exposure site

The following information of the respective exposure site was collected:

- Geographical position (GPS coordinates)
- Height above sea level
- Photographs showing the performance table and the surrounding showing the four compass directions

### 2.3.2 Documentation of exposure conditions

For interpretation of the results detailed information about the respective exposure conditions were required. In particular the weather parameters corresponding to the exposure period were requested as follows:

- Precipitation
- Average air temperature
- Minimum and maximum air temperature
- Average relative humidity

If available also the following parameters were considered valuable:

- Wind speed
- Wind direction
- Global irradiance

In order to obtain these data the closest weather station, which might be an official, private or even own station was used.

### 2.3.1 Documentation of results

All results and all other relevant data were requested in an Excel sheet template that has been delivered with the performance table. Results and documentation reports are requested regularly.

## 2.4 Assessment and evaluation

### 2.4.1 Fungal decay

The specimens were inspected once a year regarding the onset and progress of fungal decay. Therefore the screws were loosened and the specimens removed from the rig to allow inspection from all sides. Decay was assessed by visual inspection combined with a pick-test using a pointed knife. The knife should be pricked into the specimens and pulled out again to inspect the surface strength as well as the fracture depth and splinter characteristics for the rating pursuant to EN 252 (2012). The rating scheme according to EN 252 (2012) is shown in

Table 2.

Table 2. Decay rating scale according to EN 252 (2012)

| Rating | Classification  | Definition                                                                                                                                                                                                                                       |
|--------|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0      | No attack       | No change perceptible by the means at the disposal of the inspector in the field. If only a change of colour is observed, it shall be rated 0.                                                                                                   |
| 1      | Slight attack   | Perceptible changes, but very limited in their intensity and their position or distribution: changes which only reveal themselves externally by superficial degradation, softening of the wood being the most common symptom.                    |
| 2      | Moderate attack | Clear changes: softening of the wood to a depth of at least 2 mm over a wide surface (covering at least 10 square centimetres) or by softening to a depth of at least 5 mm over a limited surface area (covering less than 1 square centimetre). |
| 3      | Severe attack   | Severe changes: marked decay in the wood to a depth of at least 3 mm over a wider surface (covering at least 25 square centimetres) or by softening to a depth of at least 10 mm over a more limited surface area.                               |
| 4      | Failure         | Impact failure of the stake in the field.                                                                                                                                                                                                        |

Additionally, on the basis of visible characteristics the type of decay should be identified. Information how to distinguish the main decay types (brown rot, white rot, soft rot and tunnelling bacteria) can be found in CEN/TS 15083-2 (2005) – Annex D. Typical examples of the main decay types are shown in Fig. 2 and Fig. 3.





Fig. 2: Left: Beech. Failure after 0.5 years exposure. Visual inspection showed typical signs of white rot: whitish discoloration, long-fibred splinter, fibred fracture. Right: Southern yellow pine. Failure after 0.5 years exposure. Visual inspection showed typical signs of brown rot: brownish discoloration, brittle/cubical splinter, cross-checking texture



Fig. 3: European ash. Failure after 0.5 years exposure. Visual inspection showed typical signs of soft rot: shell-shaped splinter, attack on the outer wood shell, clean fracture.



## 2.4.2 Discoloration

### *CIE L\*a\*b\* colour measurements - colorimeter*

Colour measurements were recorded at three points on the upper surface of each specimen with a colorimeter. The measuring points were marked on each specimen through cross lines. The positions were centrally between the long sides of the specimens and 30 mm from the end-grain and in the middle of the specimen as shown in Fig. 4.



Fig. 4. Positions for measuring L\*a\*b\* colour values.

The measurements were taken in L\*a\*b coordinates, as established by the Commission Internationale de l'Enluminure (CIE) in 1976, where  $L^*$  determines the lightness,  $a^*$  and  $b^*$  determine the chromatic coordinates on the green-red and blue-yellow axis, respectively. First measurements were performed at University Ljubljana before shipment of the specimens. Second measurement to determine initial values were performed immediately upon the delivery of the table (= before exposure and storage in the lab). The measurements were conducted every week during the first four weeks of exposure, every 4 weeks during the first six months, and later on twice a year. Measurements were determined on the dry surface, at least 2 hours after the last rainfall. In case that there was snow or ice on the table, measurements were postponed. To determine colour changes over time the distance in colour space  $\Delta E$  was determined according to Equation 1:

Equation 1: Distance in colour space  $\Delta E$

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

$;\Delta E = \text{distance in color space [-]}$   
 $;\ L^* = \text{lightness [-]}$   
 $;\ a^* = \text{chromatic coordinate of the red-green axis [ ]}$   
 $;\ b^* = \text{chromatic coordinate of the yellow-blue axis [ ]}$

## 2.4.3 Surface disfigurement due to mould and staining fungi

For easy evaluation of surface disfigurement due to fungal growth the following criteria adapted from EN 152 (2011) were used (Table 3). Therefore the upper and lower surface of the test specimens was examined visually for the presence of mould and staining fungi.

Table 3. Fungal disfigurement rating scale

| <b>Rating</b> | <b>Classification</b>  | <b>Definition</b>                                                                                              |
|---------------|------------------------|----------------------------------------------------------------------------------------------------------------|
| 0             | no disfigurement       | No surface disfigurement can be detected visually on the surface.                                              |
| 1             | Slight disfigurement   | The surface exhibits only a few individual small colonies none larger than 1.5 mm in width and 4 mm in length. |
| 2             | Moderate disfigurement | The surface is colonized up to a maximum of one third of the total area.                                       |
| 3             | Severe disfigurement   | More than one third of the surface area is colonised.                                                          |

#### 2.4.4 Corrosion

Corrosion was assessed according to the adopted procedure described by Jermer and Andersson (2005). Each fastener was washed in ethanol and weighed before being fixed in the wood sample. There were two types of fasteners used, galvanized and stainless steel screws.

#### *Intermediate assessments*

In parallel with the visual assessment of fungal decay the fasteners were inspected regarding corrosion. All fasteners on the upper surface were removed and inspected visually according to the rating scheme presented in Table 4.

Table 4. Assessment of corrosion attack (Jermer and Andersson 2005)

| <b>Rating</b> | <b>Description</b>   | <b>Definition</b>           |
|---------------|----------------------|-----------------------------|
| 0             | No attack            |                             |
| 1             | Insignificant attack | <5 % of surface attacked    |
| 2             | Slight attack        | 5-50 % of surface attacked  |
| 3             | Serious attack       | 50-95 % of surface attacked |
| 4             | Completely attacked  | >95 % of surface attacked   |

#### *Final evaluation*

After 3 years of exposure, fasteners will be replaced with new ones. The old ones will be analysed according to the following procedure. The metal loss is calculated and expressed as metal loss (%) and as depth of corrosion (mm). In order to determine the metal loss and depth of corrosion the corrosion products had to be eliminated. Thus the fasteners will be pickled, cleaned and then weighed. Pickling and cleaning will be performed as follows:

- 1.) 5 min pickling in Clark's solution: Concentrated hydrochloric acid with an additive of 20 g/l antimony oxide and 20 g/l stannic chloride
- 2.) 2 min cleaning in hot water
- 3.) 10 s rinsing in hot running water
- 4.) Drying with a clean paper tissue
- 5.) Dipping for 30 s in 96 % ethanol
- 6.) Drying with a clean paper tissue
- 7.) Storage for at least one hour in a desiccator. To equalize the temperature, storage shall be done in the same room as the weighing

Equation 2: Metal loss due to corrosion [%]

$$MeL = \frac{(m_{initial} - m_{pickled})}{m_{initial}} \times 100 \text{ [%]}$$

;  $MeL$  = metal loss [%]

;  $m_{initial}$  = initial mass of screws [g]

;  $m_{pickled}$  = mass after pickling [g]

Equation 3: Corrosion depth [mm]

$$d_{corrosion} = \frac{1}{2} \times (\phi_{initial} - \phi_{pickled}) [mm]$$

;  $d_{corrosion}$  = depth of corrosion [mm]

;  $\phi_{initial}$  = initial diameter [mm]

;  $\phi_{pickled}$  = diameter after pickling [mm]

#### 2.4.5 Crack formation

The formation of cracks on the upper surface of the specimens was determined using the following three measures:

- Total crack length (total length of cracks with length of more than 5 mm)
- Number of cracks (longer than 5 mm)
- Mean maximum crack width

The length of cracks can be easily determined using a ruler. For measuring the crack width a crack measuring gauge (Fig. 5) was used. The maximum width of each single crack (longer than 5 mm) was recorded to determine the mean maximum crack width. The sides and the lower surface of the specimens will not be considered. Specimens were inspected regarding the formation of cracks before exposure (initial state) and then every 3 months.

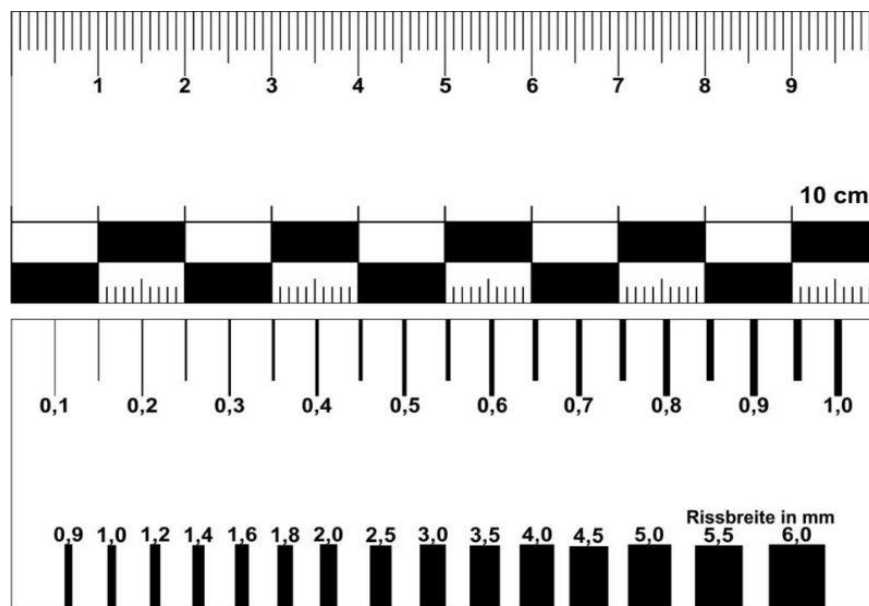


Fig. 5. Crack measuring gauge.

#### 2.4.6 Moisture content and temperature (optional)

Version A of the performance table was equipped with moisture content sensors, a Thermofox datalogger and a connected gigamodule (Scantronik Mugrauer GmbH, Zorneding, Germany) for electrical resistance measurements and recordings. Data loggers were connected with the test specimens. Electrodes were fixed to the wood with insulated fasteners as shown in Fig. 6. Therefore, the moisture content was recorded only in the central part of the specimen

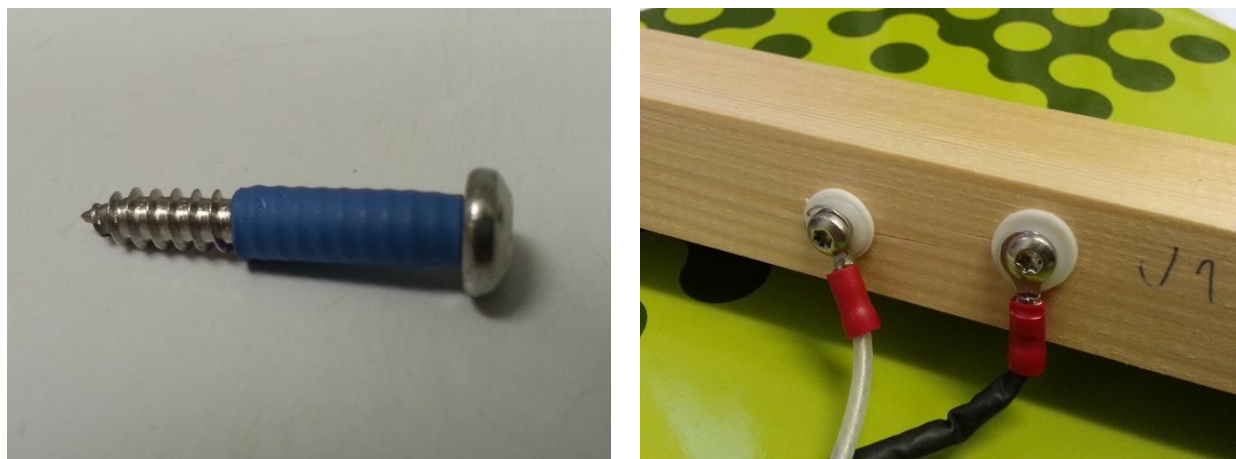


Fig. 6. Isolated fasteners (left) used for fixing electrodes on wood specimens (right).

There were eight electrodes mounted to the wood; first three in the Norway spruce, second three in thermally modified spruce, and the last two in English oak. Temperature was measured and recorded in the least dense (thermally modified Norway spruce) and the densest material only (English oak).

### 2.5 Measurement intervals - summary

The schedule for measurements and assessment given in Table 5 was followed:

Table 5. Assessment schedule for performance tests.

| Test/Assessment                         | Period           | Interval       |
|-----------------------------------------|------------------|----------------|
| Fungal decay                            | full             | every 6 months |
| Mould / stain                           | first 6 months   | every 4 weeks  |
|                                         | from month 7 on  | every 6 months |
| Crack formation                         | full             | every 3 months |
| Colour measurements                     | first 4 weeks    | every week     |
|                                         | first 6 months   | every 4 weeks  |
|                                         | from months 7 on | every 6 months |
| Corrosion visual                        | full             | every 6 months |
| Corrosion final                         | after 3 years    | -              |
| MC recordings (read out of data logger) | full             | every 3 months |

## 3. FIRST OUTCOMES AND DISCUSSION

### 3.1 Location of the COST FP 1303 performance test tables

In total, 28 research institutions and industrial partners are participating, wherefore the performance tables were wide spread through Europe (Fig. 7, Table 6). Therefore, 17 tables of version A (equipped with

moisture logging sensors), 14 tables of version B (without moisture logging sensors) and 16 tables of version C (blank rig) were manufactured.



Fig. 7. Distribution of partners within the COST FP 1303 Cooperative Performance Test.

The performance tables were exposed September 2014. A detailed guideline for all assessments was prepared together with Excel forms to enable easy comparison of the results. Data from the test will be available to the public, most likely through the IRG-WP Durability database at a later stage.

Table 6. List of partners.

| <b>Partner</b>                                                                                                   | <b>Abbreviation</b> | <b>City</b>          | <b>Country</b> |
|------------------------------------------------------------------------------------------------------------------|---------------------|----------------------|----------------|
| Holzforschung Austria                                                                                            | HFA                 | Wien                 | Austria        |
| UGent - Woodlab                                                                                                  | UGE                 | Gent                 | Belgium        |
| Danish Technological Institute                                                                                   | DTI                 | Taastrup             | Denmark        |
| Tallinn University of Technology                                                                                 | TAL                 | Tallinn              | Estonia        |
| Estonian University of Life Sciences, Institute of Forestry and Rural Engineering, Departement of Rural Building | TAR                 | Tartu                | Estonia        |
| Groupe ESB École supérieure du bois                                                                              | NTE                 | Nantes               | France         |
| Thünen-Institut für Holzforschung                                                                                | HAM                 | Hamburg              | Germany        |
| MPA Eberswalde, Materialprüfanstalt Brandenburg GmbH                                                             | MPA                 | Eberswalde           | Germany        |
| BASF Wolman GmbH                                                                                                 | SIN                 | Sinzheim             | Germany        |
| Gutachtenbüro Rapp                                                                                               | ARA                 | Hannover             | Germany        |
| Leibniz Universität Hannover, Institut für Berufswissenschaften im Bauwesen (ibw)                                | HAN                 | Hannover             | Germany        |
| Robert Ott - Sachverständiger für Holzschutz und Holzschäden                                                     | OTT                 | Gammertingen         | Germany        |
| TU München, Holzforschung München                                                                                | MUN                 | München              | Germany        |
| CNR IVALSÀ                                                                                                       | ITA                 | Florence             | Italy          |
| Norwegian Forest and Landscape Institute                                                                         | ÅS                  | Ås                   | Norway         |
| Norwegian Institute of Wood technology                                                                           | OSL                 | Oslo                 | Norway         |
| Poznań University of Life Sciences Institute of Chemical Wood Technology                                         | POL                 | Poznań               | Poland         |
| LNEC                                                                                                             | LIS                 | Lisbon               | Portugal       |
| University of Ljubljana, Biotechnical Faculty                                                                    | ULJ                 | Ljubljana            | Slovenia       |
| Silvaproduct d.o.o.                                                                                              | SIL                 | Ig                   | Slovenia       |
| Área de Innovación y Tecnología, Centro de Innovación y Servicios Tecnológicos de la Madera                      | SCV                 | San Cibrao das Viñas | Spain          |
| Tecnalia R&I                                                                                                     | TEC                 | Azpeitia - Gipuzkoa  | Spain          |
| SP Technical Research Institute of Sweden                                                                        | BOR                 | Borås                | Sweden         |
| SP Technical Research Institute of Sweden                                                                        | OSQ                 | Stockholm,           | Sweden         |
| Lund University, Division of Structural Engineering                                                              | LUN                 | Lund                 | Sweden         |
| Berner Fachhochschule - Architektur, Holz und Bau                                                                | BIE                 | Biel-Bienne          | Switzerland    |
| Building Research Establishment (BRE)                                                                            | BRE                 | Garston              | UK             |
| Bangor University, BioComposites Centre                                                                          | BNG                 | Bangor               | UK             |

### 3.2 Decay and corrosion of fasteners

Preliminary results, reported in this paper, were obtained after 12 weeks of exposure only. As expected, fungal decay did not occur after such a short exposure period. Fungal decay as well as the corrosion of the fasteners will be reported after one year of exposure.

### 3.3 Colour changes

Colour is one of the most frequently used indicators for monitoring of the changes due to the weathering. Colour reflects the changes of chemical structure of wood main components. One of the most important weaknesses of the colour is the fact, that colour changes appear due to various abiotic (UV, weathering, *etc.*) and biotic (staining fungi, degrading fungi, algae, *etc.*) factors.

As can be seen from Table 7, the first colour changes appeared during the first week of exposure. Colour changes appeared on all wood species tested. Intensity of colour and colour changes depends on the actual weather conditions. However, determination of colour was not possible on all the proposed terms, because colour measurements should be performed on dry specimens only.

Table 7: Colour changes of Norway spruce (NS), English oak (O) and thermally modified spruce (TM) during exposure on different locations across Europe.

| Location | Wood species | Period of exposure (weeks)  |      |      |      |      |      |      |      |      |      |     |      |      |      |      |      |      |      |      |      |      |
|----------|--------------|-----------------------------|------|------|------|------|------|------|------|------|------|-----|------|------|------|------|------|------|------|------|------|------|
|          |              | 0                           |      |      | 1    |      |      | 2    |      |      | 3    |     |      | 4    |      |      | 8    |      |      | 12   |      |      |
|          |              | CIE $L^*a^*b^*$ color value |      |      |      |      |      |      |      |      |      |     |      |      |      |      |      |      |      |      |      |      |
|          |              | L                           | a    | b    | L    | a    | b    | L    | a    | b    | L    | a   | b    | L    | a    | b    | L    | a    | b    | L    | a    | b    |
| ULJ      | NS           | 82.7                        | 5.0  | 20.6 | 76.2 | 9.0  | 36.0 | 78.3 | 6.9  | 28.9 | 76.6 | 7.7 | 29.0 | 75.1 | 7.8  | 27.4 | 70.0 | 6.2  | 20.0 | 64.4 | 6.9  | 16.7 |
|          | O            | 61.6                        | 7.4  | 21.0 | 32.5 | 10.4 | 15.4 | 53.7 | 6.7  | 19.5 | 56.1 | 6.6 | 19.3 | 56.1 | 6.5  | 18.4 | 55.2 | 4.1  | 12.3 | 48.6 | 2.9  | 11.0 |
|          | TM           | 45.6                        | 8.1  | 16.6 | 45.7 | 13.2 | 27.9 | 63.3 | 7.7  | 26.1 | 64.1 | 7.5 | 25.8 | 63.9 | 7.1  | 24.2 | 55.0 | 3.6  | 15.9 | 50.9 | 4.1  | 8.6  |
| SIL      | NS           | 84.3                        | 4.2  | 19.6 | 78.3 | 7.8  | 34.9 | 68.0 | 10.2 | 34.4 | 78.8 | 7.5 | 28.6 | 76.9 | 7.5  | 27.2 | 73.9 | 7.2  | 17.8 |      |      |      |
|          | O            | 46.0                        | 8.9  | 17.5 | 43.6 | 8.1  | 18.0 | 45.0 | 8.8  | 20.3 | 59.4 | 6.4 | 18.6 | 59.9 | 6.1  | 17.2 | 58.8 | 5.0  | 10.0 |      |      |      |
|          | TM           | 62.4                        | 7.3  | 20.6 | 46.8 | 12.6 | 26.4 | 61.2 | 9.2  | 27.5 | 65.9 | 7.4 | 24.5 | 65.2 | 6.8  | 22.4 | 55.0 | 4.1  | 13.0 |      |      |      |
| HAN      | NS           | 82.3                        | 4.3  | 21.6 | 74.8 | 8.1  | 32.1 | 72.6 | 8.0  | 30.5 | 71.6 | 9.3 | 30.6 | 71.2 | 8.8  | 27.8 | 67.5 | 7.2  | 19.2 | 64.6 | 6.4  | 16.5 |
|          | O            | 63.9                        | 7.8  | 21.4 | 63.0 | 7.9  | 26.2 | 63.7 | 7.3  | 24.7 | 63.6 | 7.6 | 24.7 | 64.5 | 6.3  | 20.6 | 60.5 | 3.8  | 14.6 | 58.0 | 2.8  | 12.0 |
|          | TM           | 42.1                        | 9.9  | 19.1 | 46.0 | 8.5  | 20.5 | 45.1 | 7.4  | 19.2 | 49.9 | 8.1 | 18.6 | 51.3 | 7.6  | 16.4 | 52.3 | 5.2  | 10.9 | 51.3 | 4.4  | 8.9  |
| DTI      | NS           | 78.5                        | 0.8  | 30.7 |      |      |      |      |      |      |      |     |      |      |      |      |      |      |      | 55.3 | 7.3  | 34.9 |
|          | O            | 63.0                        | 6.0  | 25.5 |      |      |      |      |      |      |      |     |      |      |      |      |      |      |      | 40.0 | 5.0  | 17.7 |
|          | TM           | 44.6                        | 2.7  | 25.1 |      |      |      |      |      |      |      |     |      |      |      |      |      |      |      | 32.1 | 4.4  | 21.3 |
| BOR      | NS           | 83.7                        | 4.5  | 22.8 | 68.6 | 2.3  | 24.0 | 66.6 | 3.2  | 22.6 | 53.2 | 5.5 | 22.4 | 56.6 | 3.0  | 17.5 |      |      |      |      |      |      |
|          | O            | 65.9                        | 7.9  | 22.2 | 57.7 | 3.2  | 19.3 | 56.5 | 2.6  | 17.8 | 33.7 | 4.7 | 11.9 | 47.4 | 0.0  | 11.8 |      |      |      |      |      |      |
|          | TM           | 43.8                        | 9.1  | 18.4 | 41.7 | 2.3  | 24.0 | 44.0 | 2.2  | 11.3 | 28.1 | 4.8 | 8.1  | 43.7 | 1.3  | 9.2  |      |      |      |      |      |      |
| OSQ      | NS           | 83.6                        | 4.6  | 21.7 |      |      |      | 76.5 | 6.9  | 30.7 | 75.7 | 8.4 | 31.1 | 74.5 | 8.3  | 28.3 |      |      |      | 62.1 | 6.9  | 21.2 |
|          | O            | 63.6                        | 7.7  | 22.1 |      |      |      | 65.0 | 7.3  | 25.5 | 64.8 | 7.4 | 24.9 | 64.1 | 6.6  | 21.9 |      |      |      | 54.1 | 2.6  | 13.6 |
|          | TM           | 42.1                        | 9.7  | 18.1 |      |      |      | 49.8 | 7.7  | 20.1 | 50.6 | 8.0 | 19.3 | 51.7 | 7.5  | 17.0 |      |      |      | 48.7 | 5.1  | 11.3 |
| AS       | NS           | 80.4                        | 4.0  | 21.9 | 76.2 | 7.0  | 30.0 | 75.8 | 7.3  | 29.0 | 75.7 | 7.1 | 26.5 | 75.7 | 7.3  | 25.9 | 72.1 | 6.4  | 18.9 | 57.6 | 10.0 | 33.7 |
|          | O            | 62.5                        | 7.7  | 21.6 | 64.5 | 8.0  | 25.8 | 65.9 | 7.5  | 24.7 | 67.4 | 6.7 | 21.6 | 68.0 | 6.5  | 20.7 | 63.2 | 3.8  | 14.9 | 33.7 | 7.6  | 17.4 |
|          | TM           | 43.3                        | 8.0  | 17.0 | 50.0 | 7.0  | 19.3 | 53.1 | 6.8  | 18.4 | 54.9 | 6.6 | 17.5 | 56.0 | 6.4  | 16.7 | 57.8 | 5.4  | 12.0 | 31.7 | 10.8 | 15.7 |
| HFA      | NS           | 79.9                        | 6.1  | 22.9 |      |      |      |      |      |      | 74.1 | 5.6 | 21.2 | 69.9 | 9.7  | 25.8 | 57.2 | 5.8  | 15.4 | 58.4 | 5.2  | 13.0 |
|          | O            | 64.0                        | 7.9  | 23.1 |      |      |      |      |      |      | 60.9 | 8.1 | 23.4 | 59.8 | 7.3  | 21.3 | 54.2 | 4.0  | 13.6 | 48.9 | 4.5  | 10.3 |
|          | TM           | 44.4                        | 10.7 | 19.5 |      |      |      |      |      |      | 51.9 | 9.6 | 19.7 | 55.1 | 9.2  | 19.4 | 50.0 | 6.6  | 12.3 | 49.1 | 5.5  | 10.2 |
| BIE      | NS           | 81.3                        | 4.6  | 22.1 | 74.9 | 8.1  | 31.1 | 72.2 | 8.5  | 30.6 | 69.9 | 8.7 | 28.0 | 66.4 | 7.5  | 23.3 | 58.6 | 5.5  | 15.3 | 56.3 | 4.8  | 12.9 |
|          | O            | 63.1                        | 8.0  | 21.8 | 63.7 | 8.1  | 26.1 | 62.8 | 8.2  | 27.4 | 63.5 | 8.0 | 26.4 | 60.2 | 6.6  | 23.7 | 51.4 | 3.7  | 14.6 | 47.4 | 2.8  | 11.9 |
|          | TM           | 42.8                        | 9.7  | 19.7 | 47.9 | 8.3  | 20.1 | 50.2 | 8.2  | 20.2 | 51.2 | 8.6 | 19.2 | 51.6 | 7.8  | 17.2 | 49.8 | 5.1  | 11.2 | 48.8 | 4.3  | 9.2  |
| OSL      | NS           | 81.2                        | 4.6  | 23.2 | 74.8 | 6.8  | 29.9 | 74.7 | 7.9  | 32.6 | 74.1 | 8.9 | 31.8 | 73.9 | 8.7  | 29.0 | 67.4 | 10.1 | 34.5 | 66.7 | 8.8  | 24.7 |
|          | O            | 63.8                        | 8.8  | 22.3 | 46.9 | 7.3  | 20.5 | 64.2 | 9.2  | 27.5 | 63.7 | 9.4 | 24.9 | 65.0 | 8.1  | 23.8 | 50.0 | 12.1 | 29.6 | 56.6 | 5.2  | 17.3 |
|          | TM           | 43.1                        | 9.5  | 20.2 | 62.5 | 8.9  | 25.6 | 48.5 | 7.8  | 21.8 | 48.7 | 8.7 | 20.9 | 51.0 | 7.6  | 19.6 | 38.6 | 11.8 | 23.6 | 47.9 | 6.8  | 14.8 |
| BNG      | NS           |                             |      |      | 76.6 | 7.0  | 31.7 | 76.4 | 7.9  | 31.5 | 75.5 | 9.2 | 33.3 | 76.9 | 7.8  | 27.0 | 70.6 | 9.4  | 32.8 | 72.9 | 6.8  | 18.4 |
|          | O            |                             |      |      | 58.5 | 10.1 | 28.8 | 63.1 | 8.8  | 28.8 | 60.5 | 8.5 | 24.2 | 65.4 | 8.1  | 25.0 | 52.4 | 11.7 | 29.9 | 64.0 | 5.7  | 16.6 |
|          | TM           |                             |      |      | 50.3 | 8.1  | 21.4 | 53.9 | 8.4  | 21.9 | 52.2 | 8.7 | 20.1 | 57.6 | 7.4  | 18.4 | 46.7 | 11.5 | 25.0 | 61.5 | 5.1  | 10.5 |
| ITA      | NS           | 82.2                        | 4.6  | 23.2 | 74.0 | 8.7  | 33.1 | 72.9 | 9.7  | 35.4 | 72.2 | 9.7 | 39.0 | 70.4 | 10.2 | 28.9 | 68.0 | 8.3  | 21.5 | 61.1 | 5.7  | 14.5 |
|          | O            | 61.8                        | 8.5  | 22.7 | 59.9 | 8.8  | 26.2 | 60.8 | 9.6  | 29.2 | 62.8 | 8.8 | 26.9 | 61.5 | 7.7  | 22.0 | 58.6 | 5.4  | 17.6 | 48.4 | 2.6  | 11.0 |
|          | TM           | 42.4                        | 9.8  | 18.6 | 48.0 | 8.1  | 19.4 | 43.0 | 11.0 | 23.9 | 50.9 | 8.7 | 20.8 | 52.1 | 8.1  | 17.6 | 53.8 | 6.5  | 13.9 | 44.9 | 5.7  | 11.6 |

Table 7 cont'd: Colour changes of Norway spruce (NS), English oak (O) and thermally modified spruce (TM) during exposure on different locations across Europe.



| Location | Wood species | Period of exposure (weeks)  |     |      |      |     |      |      |     |      |      |     |      |      |     |      |      |     |      |      |     |      |
|----------|--------------|-----------------------------|-----|------|------|-----|------|------|-----|------|------|-----|------|------|-----|------|------|-----|------|------|-----|------|
|          |              | 0                           |     |      | 1    |     |      | 2    |     |      | 3    |     |      | 4    |     |      | 8    |     |      | 12   |     |      |
|          |              | CIE $L^*a^*b^*$ color value |     |      |      |     |      |      |     |      |      |     |      |      |     |      |      |     |      |      |     |      |
|          |              | L                           | a   | b    | L    | a   | b    | L    | a   | b    | L    | a   | b    | L    | a   | b    | L    | a   | b    | L    | a   | b    |
| NTE      | NS           | 82.7                        | 3.2 | 25.5 | 77.3 | 4.5 | 33.5 | 74.5 | 5.3 | 37.7 | 72.2 | 6.1 | 38.2 | 74.7 | 5.9 | 35.3 | 71.7 | 7.3 | 20.9 | 69.3 | 3.6 | 15.9 |
|          | O            | 64.5                        | 5.3 | 24.8 | 59.9 | 6.0 | 32.6 | 61.4 | 5.8 | 33.0 | 48.8 | 8.7 | 34.2 | 62.7 | 5.6 | 30.5 | 63.4 | 5.3 | 18.6 | 62.0 | 1.9 | 13.3 |
|          | TM           | 45.0                        | 6.5 | 22.4 | 44.2 | 5.6 | 24.3 | 48.8 | 5.4 | 27.3 | 46.5 | 5.7 | 24.9 | 51.4 | 5.5 | 26.5 | 54.6 | 6.4 | 15.2 | 57.2 | 2.7 | 10.7 |
| HAM      | NS           | 81.4                        | 3.6 | 21.0 | 76.8 | 5.3 | 32.6 | 75.0 | 5.9 | 31.4 | 74.4 | 6.2 | 30.7 | 74.2 | 6.3 | 28.8 | 64.5 | 7.6 | 30.5 | 68.7 | 5.3 | 18.9 |
|          | O            | 64.7                        | 6.2 | 22.1 | 62.8 | 7.2 | 29.4 | 62.5 | 6.8 | 27.4 | 63.3 | 6.5 | 26.7 | 62.3 | 5.8 | 24.1 | 41.3 | 5.7 | 17.3 | 51.1 | 2.6 | 13.8 |
|          | TM           | 47.3                        | 7.1 | 21.3 | 48.1 | 6.8 | 20.4 | 49.7 | 6.8 | 19.8 | 49.8 | 7.0 | 18.6 | 41.4 | 6.6 | 13.8 | 49.8 | 4.7 | 11.5 | 49.8 | 4.7 | 11.5 |
| SCV      | NS           | 80.7                        | 3.9 | 21.4 | 74.3 | 6.8 | 33.2 | 73.5 | 7.7 | 33.1 | 73.4 | 6.7 | 28.0 | 70.1 | 7.0 | 26.3 | 60.5 | 3.4 | 13.5 |      |     |      |
|          | O            | 63.3                        | 7.1 | 22.1 | 62.5 | 7.6 | 29.0 | 63.5 | 7.5 | 27.8 | 64.6 | 6.4 | 25.0 | 60.8 | 5.4 | 22.9 | 52.2 | 2.0 | 11.9 |      |     |      |
|          | TM           | 42.6                        | 8.5 | 17.9 | 47.0 | 7.1 | 19.6 | 49.7 | 7.6 | 20.2 | 51.9 | 6.6 | 18.5 | 52.0 | 6.7 | 17.4 | 49.6 | 2.3 | 10.3 |      |     |      |

After 12 weeks of exposure, the most prominent average difference appeared on Norway spruce wood ( $\Delta E = 20.3$ ), followed by English oak ( $\Delta E = 16.9$ ) and thermally modified spruce ( $\Delta E = 12.4$ ). The highest colour difference was determined at oak wood exposed in Ås ( $\Delta E = 29.1$ ) and the lowest at thermally modified spruce in Oslo ( $\Delta E = 7.7$ ). As already mentioned, fungal disfigurement could be one of the possible reasons for disfigurement. As there was considerable portion of the surface discoloured due moulding. However, there is not very tight correlation determined between fungal surface disfigurement and colour changes (Table 7, Table 8 and Table 9).

Table 8: Colour difference ( $\Delta E$ ) of Norway spruce (NS), English oak (O) and thermally modified spruce (TM) during exposure on different locations across Europe.

| Location | Wood species | Weeks of exposure |      |      |      |      |      |
|----------|--------------|-------------------|------|------|------|------|------|
|          |              | 1                 | 2    | 3    | 4    | 8    | 12   |
| ULJ      | NS           | 17.2              | 9.6  | 10.7 | 10.6 | 12.9 | 18.9 |
|          | O            | 29.9              | 8.1  | 5.9  | 6.2  | 11.3 | 17.0 |
|          | TM           | 12.3              | 20.1 | 20.6 | 19.8 | 10.4 | 10.4 |
| SIL      | NS           | 16.9              | 22.9 | 11.1 | 11.1 | 11.0 | 11.0 |
|          | O            | 2.5               | 3.0  | 13.6 | 14.2 | 15.3 | 15.3 |
|          | TM           | 17.5              | 7.2  | 5.2  | 3.4  | 11.1 | 11.1 |
| HAN      | NS           | 13.5              | 13.7 | 14.8 | 13.6 | 15.3 | 18.6 |
|          | O            | 4.9               | 3.3  | 3.3  | 1.8  | 8.6  | 12.2 |
|          | TM           | 4.4               | 3.9  | 8.1  | 9.9  | 13.9 | 14.8 |
| DTI      | NS           |                   |      |      |      |      | 24.5 |
|          | O            |                   |      |      |      |      | 24.3 |
|          | TM           |                   |      |      |      |      | 13.1 |
| BOR      | NS           | 15.2              | 17.2 | 30.5 | 27.6 |      | 27.6 |
|          | O            | 9.9               | 11.7 | 34.0 | 22.6 |      | 22.6 |
|          | TM           | 9.0               | 9.8  | 19.2 | 12.1 |      | 12.1 |
| OSQ      | NS           |                   | 11.6 | 12.9 | 11.9 |      | 21.7 |
|          | O            |                   | 3.7  | 3.1  | 1.2  |      | 13.8 |
|          | TM           |                   | 8.2  | 8.7  | 9.9  |      | 10.6 |
| AS       | NS           | 9.7               | 9.2  | 7.3  | 7.1  | 9.2  | 26.4 |
|          | O            | 4.6               | 4.6  | 5.0  | 5.7  | 7.8  | 29.1 |
|          | TM           | 7.2               | 10.0 | 11.8 | 12.8 | 15.6 | 11.9 |
| HFA      | NS           |                   |      | 6.1  | 11.0 | 24.0 | 23.7 |
|          | O            |                   |      | 3.0  | 4.6  | 14.2 | 20.1 |
|          | TM           |                   |      | 7.5  | 10.8 | 10.0 | 11.6 |
| BIE      | NS           | 11.6              | 13.1 | 13.5 | 15.3 | 23.8 | 26.7 |
|          | O            | 4.3               | 5.6  | 4.5  | 3.7  | 14.4 | 19.3 |
|          | TM           | 5.4               | 7.6  | 8.5  | 9.4  | 12.0 | 13.3 |
| OSL      | NS           | 9.6               | 11.9 | 12.0 | 10.3 | 18.7 | 15.2 |
|          | O            | 17.1              | 5.2  | 2.6  | 2.1  | 15.9 | 9.5  |
|          | TM           | 20.2              | 5.9  | 5.7  | 8.1  | 6.1  | 7.7  |
| BNG      | NS           | 10.7              | 11.0 | 13.3 | 7.4  | 15.9 | 10.2 |
|          | O            | 8.0               | 7.1  | 2.8  | 4.8  | 12.9 | 6.1  |
|          | TM           | 5.3               | 8.8  | 6.8  | 12.3 | 6.4  | 18.7 |
| ITA      | NS           | 13.5              | 16.2 | 19.4 | 14.3 | 14.8 | 22.9 |
|          | O            | 4.1               | 6.7  | 4.3  | 1.1  | 6.7  | 18.7 |
|          | TM           | 5.9               | 5.5  | 8.9  | 9.8  | 12.8 | 8.5  |
| NTE      | NS           | 9.7               | 14.8 | 16.7 | 12.9 | 12.5 | 16.4 |
|          | O            | 9.1               | 8.8  | 18.6 | 6.0  | 6.2  | 12.2 |
|          | TM           | 2.2               | 6.3  | 3.0  | 7.6  | 12.0 | 17.3 |
| HAM      | NS           | 12.6              | 12.4 | 12.3 | 10.9 | 19.7 | 13.0 |
|          | O            | 7.7               | 5.8  | 4.8  | 3.1  | 23.9 | 16.3 |
|          | TM           | 1.2               | 2.8  | 3.7  | 9.6  | 10.3 | 10.3 |
| SCV      | NS           | 13.8              | 14.2 | 10.2 | 12.1 | 21.7 |      |
|          | O            | 7.0               | 5.7  | 3.3  | 3.1  | 15.9 |      |
|          | TM           | 4.9               | 7.5  | 9.5  | 9.6  | 12.1 |      |

### 3.4 Surface disfigurement

Aesthetic perception of wood considerably influences the service life of the wood (Gobakken and Høibø 2011, Grüll et al. 2011, Englund 2013, Brischke and Kaudewitz 2015). Wooden furniture used outside is frequently replaced due to the change of its visual appearance. One of the most important factors contributing to the visual appearance is fungal disfigurement caused by staining and moulding fungi.

Table 9. Fungal surface disfigurement on the Norway spruce (NS), English oak (O) and thermally modified Norway spruce (TM) on different locations across Europe. Rating scheme is resolved from Table 3.

| Location                                             | Weeks of exposure | Wood species |   |    |
|------------------------------------------------------|-------------------|--------------|---|----|
|                                                      |                   | NS           | O | TM |
| <b>Fungal disfigurement rating on the upper side</b> |                   |              |   |    |
| ULJ                                                  | 4                 | 2            | 1 | 0  |
|                                                      | 8                 | 3            | 3 | 0  |
|                                                      | 12                | 3            | 3 | 0  |
| SIL                                                  | 4                 | 1            | 0 | 0  |
|                                                      | 8                 | 3            | 2 | 0  |
|                                                      | 12                | 3            | 2 | 0  |
| HAN                                                  | 4                 | 0            | 1 | 0  |
|                                                      | 8                 | 1            | 1 | 0  |
|                                                      | 12                | 2            | 1 | 0  |
| DTI                                                  | 4                 | 0            | 0 | 0  |
|                                                      | 8                 | 1            | 0 | 0  |
|                                                      | 12                | 2            | 1 | 0  |
| BOR                                                  | 4                 | 2            | 1 | 0  |
|                                                      | 8                 | 1            | 0 | 0  |
|                                                      | 12                |              |   |    |
| OSQ                                                  | 4                 | 2            | 1 | 0  |
|                                                      | 8                 |              |   |    |
|                                                      | 12                | 3            | 3 | 1  |
| MUN                                                  | 4                 | 2            | 2 | 1  |
|                                                      | 8                 | 3            | 3 | 2  |
|                                                      | 12                |              |   |    |
| ÅS                                                   | 4                 | 1            | 1 | 1  |
|                                                      | 8                 | 1            | 2 | 1  |
|                                                      | 12                | 2            | 2 | 2  |
| HFA                                                  | 4                 | 1            | 2 | 0  |
|                                                      | 8                 | 3            | 3 | 0  |
|                                                      | 12                | 3            | 3 | 0  |
| BIE                                                  | 4                 | 3            | 1 | 1  |
|                                                      | 8                 | 3            | 1 | 2  |
|                                                      | 12                | 3            | 2 | 2  |
| OSL                                                  | 4                 | 1            | 1 | 0  |
|                                                      | 8                 | 1            | 2 | 1  |
|                                                      | 12                | 2            | 2 | 1  |
| BNG                                                  | 4                 | 1            | 1 | 0  |
|                                                      | 8                 | 1            | 2 | 0  |
|                                                      | 12                | 2            | 2 | 0  |
| ITA                                                  | 4                 | 1            | 1 | 0  |
|                                                      | 8                 | 1            | 1 | 0  |
|                                                      | 12                | 1            | 1 | 0  |
| HAM                                                  | 4                 | 1            | 2 | 0  |
|                                                      | 8                 | 3            | 3 | 0  |
|                                                      | 12                | 3            | 3 | 0  |
| SCV                                                  | 4                 | 0            | 1 | 2  |
|                                                      | 8                 | 0            | 1 | 2  |
|                                                      | 12                | 0            | 1 | 2  |

Similarly as reported for colour changes, the most prominent disfigurement appeared on Norway spruce (1.8), followed by oak (1.6). It seemed that thermally modified spruce was either least susceptible for fungal disfigurement (0.4) or the fungal disfigurement was the least visible on the dark surface. In the respective period, the most prominent staining appeared in Stockholm (OSQ, 2.3) and Biel (BIE, 2.3). In contrast, only little disfigurement was determined in Florence (ITA, 0.7), Hannover (HAN, 1.0) and Taastrup DTI, 1.0).

### **3.5 Cracks**

Formation of cracks strongly depends on moisture oscillation (*e.g.* Sandberg 1999, Sandberg and Söderström 2006). However, cracks become more apparent in dry conditions, therefore we expect that cracks will become more visible in dry periods of the year. However, cracks are important from the aesthetic point of view, but the cracks on the other hand plays key role in the moisture and consequent fungal performance (Meierhofer and Sell 1979, Austigard *et al.* 2014, Brischke and Melcher 2015). Cracks are trap for water and fungal spores and may therefore serve as starting points for fungal degradation.

Table 10. Total crack length, number of cracks and mean crack width on Norway spruce (NS), English oak (O) and thermally modified Norway spruce (TM) at different locations across Europe after 3 months of exposure.

| Location | Value              | Wood species |      |       |
|----------|--------------------|--------------|------|-------|
|          |                    | NS           | O    | TM    |
| ULJ      | Total crack length | 0            | 0    | 0     |
|          | # cracks           | 0            | 0    | 0     |
|          | Mean crack width   | 1.5          | 2.3  | 0.8   |
| SIL      | Total crack length | 11.7         | 25.0 | 3.0   |
|          | # cracks           | 3.0          | 5.7  | 1.3   |
|          | Mean crack width   | 1.5          | 2.3  | 0.8   |
| HAN      | Total crack length | 0            | 0    | 0     |
|          | # cracks           | 0            | 0    | 0     |
|          | Mean crack width   | 0            | 0    | 0     |
| DTI      | Total crack length | 0            | 0    | 0     |
|          | # cracks           | 0            | 0    | 0     |
|          | Mean crack width   | 0            | 0    | 0     |
| BOR      | Total crack length | 0            | 0    | 0     |
|          | # cracks           | 0            | 0    | 0     |
|          | Mean crack width   | 0            | 0    | 0     |
| OSQ      | Total crack length | 11.7         | 25.0 | 3.0   |
|          | # cracks           | 3.0          | 5.7  | 1.3   |
|          | Mean crack width   | 1.5          | 2.3  | 0.8   |
| ÅS       | Total crack length | 0            | 0    | 0     |
|          | # cracks           | 0            | 0    | 0     |
|          | Mean crack width   | 0            | 0    | 0     |
| HFA      | Total crack length | 11.7         | 25.0 | 3.0   |
|          | # cracks           | 3.0          | 5.7  | 1.3   |
|          | Mean crack width   | 1.5          | 2.3  | 0.8   |
| BIE      | Total crack length | 0            | 0    | 163.1 |
|          | # cracks           | 0            | 0    | 1.7   |
|          | Mean crack width   | 0            | 0    | 0.1   |
| OSL      | Total crack length | 11.7         | 25.0 | 3.0   |
|          | # cracks           | 3.0          | 5.7  | 1.3   |
|          | Mean crack width   | 1.5          | 2.3  | 0.8   |
| BNG      | Total crack length | 0            | 2.3  | 0     |
|          | # cracks           | 0            | 0.7  | 0     |
|          | Mean crack width   | 0            | 0.1  | 0     |
| ITA      | Total crack length | 19.9         | 0    | 0     |
|          | # cracks           | 1.6          | 0    | 1.0   |
|          | Mean crack width   | 4.2          | 0    | 0     |
| NTE      | Total crack length | 0            | 12.3 | 0     |
|          | # cracks           | 0            | 1.0  | 0     |
|          | Mean crack width   | 0            | 0.1  | 0.3   |
| HAM      | Total crack length | 0.3          | 5.5  | 1.7   |
|          | # cracks           | 0.3          | 4.3  | 1.3   |
|          | Mean crack width   | 0.2          | 0.1  | 0.1   |
| SCV      | Total crack length | 12           | 25   | 3     |
|          | # cracks           | 1.3          | 1    | 1     |
|          | Mean crack width   | 1.0          | 2.3  | 0.8   |

Monitoring of cracks is rather challenging. Cracks are predominately visible, when wood is dry. This might explain, why for instance no cracks were reported from Hannover, Taastrup, Borås and Ås. In most of the locations, the highest number of cracks was reported for thermally modified wood; however these cracks were rather small. We believe that there will be more cracks formed after the summer with longer dry periods.

### 3.5 Moisture content

MC monitoring results are expected not before 6 months of exposure and will be reported later on.

## 4. CONCLUSIONS

In the frame of the COST FP 1303 Cooperative Performance Test 28 institutions and industry partners teamed up to generate performance data of wood and wood-based materials under consideration of environmental factors such as organisms, solar radiation, and other climate parameters. During the remaining running time of the action and beyond it is expected to collect data from in total 28 test locations for reported wood species and for the wood species of national importance. Data shall be used to further establish relationships between the various examined performance criteria and geographical and climate related parameter.

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