Journal of Building Engineering 13 (2017) 207–215

Contents lists available at ScienceDirect

Journal of Building Engineering

journal homepage: www.elsevier.com/locate/jobe

Moisture performance and durability of wooden façades and decking during six years of outdoor exposure

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ARTICLE INFO

Keywords:
Above-ground exposure
Cladding
Fungal decay
Moisture monitoring
Time of wetness

ABSTRACT

Wood is frequently used for claddings and decking where it is exposed to moisture and various biotic agents limiting its serviceability. In-situ moisture monitoring can help to determine the moisture-induced risk for decay and might therefore serve as faster alternative to traditional durability testing, which usually requires exposure for many years. This study aimed on determining the moisture-induced risk for decay of differently severe exposed wooden components, i.e. combined façade-decking elements and horizontal double layer set ups mimicking poorly designed terrace decks made from twelve different wood species and thermally modified wood.

The huge variation of moisture-induced risk for decay of timber used above ground became evident. Dosage as well as service life estimates differed in dependence of wood species, design detailing, and decay type to be expected. An exposure dose was utilized for alternative durability classification of timber in less severe exposure conditions such as for cladding applications and compared with common durability classification based on decay assessment. Differences in durability between the various wood species and materials became apparent in the horizontal double layer and met fairly well the expectations based on durability classification according to the European standard EN 350 and previous findings from above ground field tests.

Combined façade-decking elements were found to be useful for moisture content (*MC*) monitoring of wood in less severe exposure situations such as façades and freely ventilated decking, but not for correlation between moisture induced risk and fungal decay, since the latter occurred exclusively at water trapping contact faces. Nevertheless, the use of *MC* and temperature recordings combined with a dosimeter-based decay model might allow for an alternative time-saving way to estimate and classify wood durability.

1. Introduction

Wood is frequently used outdoors for applications in and above ground. To fulfill its functional performance is has to withstand a variety of abiotic and biotic loads such as wetting, discoloration, and decay by fungi and other micro-organisms. Today the majority of wood is used above ground where moisture conditions can vary a lot. Wooden decking and cladding is traditionally used for housing, but is also an element of modern architecture in many countries and regions around the world [2,11,12–14,22,23,37]. The preferential use of wood in buildings comes along with its positive image regarding ecological and environmental aspects [36,41]. As shown by numerous life cycle assessment studies wood can easily compete with other building materials with respect to impacts on the environment [e.g. 33]. Opposite of its environmental friendliness its serviceability over time is limited, because wood is susceptible to various decay organisms. Service life prediction and performance estimation of wood-based building products is therefore an important task for the timber industry and requested by national and international standardisation and approval bodies [25].

Standard tests for assessing the durability of wood and wood-based products in above ground exposures are rare; in particular for less severe exposures such as vertically exposed claddings (use class UC 2 and UC 3.1 according to EN 335 [18]) test protocols are lacking due to unacceptably long exposure periods needed till onset of decay can be observed [30]. Alternatively, in recent years wood moisture content

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http://dx.doi.org/10.1016/j.jobe.2017.08.004
Received 21 March 2017; Received in revised form 27 July 2017; Accepted 7 August 2017
Available online 10 August 2017

(*MC*) was monitored on decking and façades for quantifying the moisture-induced risk for fungal decay with respect to different parameters such as coatings, compass orientation, climate or ventilation [3,7,16,21,32,43]. Most often electrical conductivity measurements are used since they are inexpensive, easy to install, and allow measurements of local *MC* at a particular region of interest [27,29]. For more detailed studies, e.g. on the distribution of moisture within a wooden component or moisture mapping, more advanced techniques have been applied such as nuclear magnetic resonance (NMR) technology [15], 3-D X-ray computed tomography, and neutron radiography [28].

The overall aim of this study was to determine the moisture-induced decay risk of differently severe exposed wooden components in a quantitative manner. The focus was on façades and decking. For comparison a horizontal double layer was studied to examine the effect of water trapping in badly executed design details as occasionally occurring on terraces and cladding. Differences between wood species including permeable sapwood, more and less refractory heartwood as well as thermally modified wood should be investigated under the influence of different exposure conditions. Two different dose-response decay models should be applied to estimate the service lives of the various wooden components in dependence of the rot type expected to infest the wood first.

Finally, a field test set up was sought for the less severe exposure situations within UC 3 (EN 335 [18]; i.e. exterior above ground exposed to the weather, but with limited wetting conditions) such as a free ventilated decking, and within UC 2 (EN 335 [18]; i.e. Interior, or under cover, not exposed to the weather / Possibility of water condensation) such as a sheltered board-on-board cladding. Therefore, façade –decking elements were exposed and instrumented for continuous *MC* and temperature recording to quantify the moisture and temperature induced risk for decay. The latter is considered to be material-specific and might be utilized for durability classification of wood-based materials in acceptably long exposure times.

2. Material and methods

2.1. Wood specimens and field test set up

Specimens made from 15 different wood-based materials as listed in Table 1 were submitted to the following four exposure variations (Fig. 1).

Table 1
Wood species and treatments used for exposure in field trials.

Material	Botanical name	Begin of exposure
Beech	*Fagus sylvatica* L.	01.12.2009
English oak	*Quercus robur* L.	01.12.2009
Black locust	*Robinia pseudoacacia* L.	01.12.2009
European ash	*Fraxinus excelsior* L.	16.04.2011
European ash OHT (oil-heat treated)	*Fraxinus excelsior* L.	16.04.2011
Norway spruce	*Picea abies* Karst.	01.12.2009
Norway spruce OHT (oil-heat treated)	*Picea abies* Karst.	16.04.2011
Scots pine	*Pinus sylvestris* L.	01.12.2009
Scots pine sapwood	*Pinus sylvestris* L.	01.12.2009
Larch	*Larix decidua* Mill.	01.12.2009
Larch sapwood	*Larix decidua* Mill.	01.12.2009
Douglas fir HD (high density)	*Pseudotsuga menziesii* Franco	25.08.2010
Douglas fir LD (low density)	*Pseudotsuga menziesii* Franco	01.12.2009
Douglas fir sapwood	*Pseudotsuga menziesii* Franco	01.12.2009
Western red cedar WRC	*Thuja plicata* Donn ex D. Don in Lambert	01.12.2009

Note: Unless otherwise indicated pure heartwood was tested.
Note: Specimens of Larch sapwood and Douglas fir sapwood contained heartwood portions, which were not considered for the measurements.

- South oriented, vertical cladding
  Boards (25 × 100 × 500 mm^3) were mounted vertically on a combined façade-decking element and carried out as board-on-board cladding. Three replicate specimens of the tested wood species were exposed as cover boards; connected base boards were made from untreated Norway spruce.
- North oriented, vertical cladding
  Boards (25 × 100 × 500 mm^3) were mounted vertically on a combined façade-decking element and carried out as board-on-board cladding. Three replicate specimens of the tested wood species were exposed as cover boards; connected base boards were made from untreated Norway spruce.
- Horizontal single layer (decking)
  Boards (n = 3 replicates; 25 × 100 × 500 mm^3) were exposed horizontally on two bearings of a combined façade-decking element.
- Horizontal double layer
  Specimens (n = 11 replicates; 500 × 50 × 25 mm^3) were exposed horizontally in double layers with the upper layer displaced laterally by 25 mm with respect to the lower layer. Supports were 25 cm above ground and made from aluminium L-profiles.

All test rigs were made from untreated Norway spruce (*Picea abies*) and exposed on the roof (18 m height) of the building of the Faculty of Architecture and Landscape Sciences in Hannover-Herrenhausen, Germany. Specimens from the same material were exposed on the same test rigs. Maximum number of tested materials per façade-deck test rig was three. For each type of exposure three replicate specimens were provided with electrodes for daily wood *MC* and temperature recordings during the first five years of exposure.

2.2. Moisture content and temperature recording

The measurement system applied in this study was described in detail by Brischke et al. [4] and can be summarized in brief as follows: electrodes of polyamide coated stainless steel cables were conductively glued in the specimens. The electrodes were connected to a small data logger (Materialfox Mini, Scanntronik Mugrauer GmbH, Zorneding, Germany) that recorded the electrical resistance of the wood. The data loggers were calibrated in a range between 12% and 50% *MC* and species-specific resistance characteristics were developed by Brischke et al. [4] and Brischke and Lampen [5]. Measurements above fiber saturation were increasingly inaccurate, but still indicated a tendency within the calibration range. Minimum and maximum temperatures were recorded daily using Thermofox Mini data logger (Scanntronik Mugrauer GmbH, Zorneding, Germany) and used to calculate the average daily temperature. Unless otherwise indicated, the measurement points were placed in the center of the specimens. Consequently, *MC* measurements were conducted at approximately 10–12 mm distance from the specimen surface. Measurements close to contact faces, e. g. supporting beams, were avoided.

2.3. Decay assessment

Fungal decay was assessed visually and with the help of a pick-test according to EN 252 [17]. Assessment intervals were between three and six months during the first two years and once per year afterwards. Therefore, a pointed knife was pricked into the wood and backed out again. Decay became evident through softening of the wood substance. Depth and distribution of decay was determined and recorded for rating the specimens according to the 5-step rating scheme according to EN 252 [17] as follows: 0 (sound), 1 (slight attack), 2 (moderate attack), 3 (severe attack), and 4 (failure). Failure was here defined either as 'break' of the specimen after a manual hit on the center of the specimen according to the procedure described in EN 252 [17] or if at least 50% of the cross section was decayed. In addition, the specimens were