International Biodeterioration & Biodegradation 85 (2013) 305–310

Contents lists available at ScienceDirect

International Biodeterioration & Biodegradation

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

Performance of oak, beech and spruce beams after more than 100 years in service

Nejc Thaler, Miha Humar*

University of Ljubljana, Biotechnical Faculty, Department of Wood Science and Technology, Jamnikarjeva 101, SI-1000 Ljubljana, Slovenia

ARTICLE INFO

Article history:
Received 13 August 2013
Received in revised form
23 August 2013
Accepted 27 August 2013
Available online 19 September 2013

Keywords:
Mechanical properties
Bending strength
Compressive strength
Durability
Wood beams
Water uptake

ABSTRACT

The aim of this study was to investigate differences in the mechanical and fungicidal properties of three different wood species (English oak (*Quercus* sp.), common beech (*Fagus sylvatica*) and Norway spruce (*Picea abies*)) that had been in indoor use for several decades, compared to control specimens of freshly cut timber. The collected material was cut into smaller samples prior to further analysis. Extractive content, mechanical, fungicidal and sorption properties were determined according to standard procedures. The obtained results showed that the mechanical properties of oak wood do not deteriorate over the investigated time frame. On the other hand, the resistance of oak wood against fungi decreases over time. The reason for this is yet to be confirmed; it may be due to degradation of secondary metabolites. Similar results have been reported for spruce wood. There were no statistically significant differences in the mechanical properties of old and new spruce wood. In contrast to oak wood, there were also no significant differences in fungicidal properties, bearing in mind that spruce wood has lower durability than oak wood. Aging of beech wood resulted in a considerable decrease in the tested mechanical properties but showed no significant differences in fungicidal properties. Old beech wood specimens were moderately deteriorated by insects and fungi, which was the reason for the loss of bending and compressive strength. Our results confirm that most of the relevant properties do not deteriorate with time and that wood can be reused for a variety of other applications even after decades in service.
© 2013 Elsevier Ltd. All rights reserved.

1. Introduction

Wood has a number of excellent properties as a building material; it has a high strength to weight ratio, it is a good thermal insulator, it can be shaped and connected to form larger structures and it is one of the most sustainable and environmentally friendly materials. However, if wood is not properly used, it has a number of weaknesses. One of the most obvious is susceptibility to degradation by fungi and insects. This has made many engineers and a significant part of the public sceptical about the use of wood. In Europe and in most temperate climates, fungi are the biggest threat to wooden constructions. Fungal degradation can be overcome (or at least hindered) by using naturally durable wood species (Råberg et al., 2005), by wood modification (Thybring, 2013) or by application of fungicidal preservatives (Freeman and Mcintyre, 2008). In conditions under which biodegradation is avoided however, the service life of wood can exceed one thousand years (Riksantikvaren, 1979). Indoor aging of wood is in general considerably slower than outdoor aging, as wood used in-door is not exposed to continuous wetting and UV degradation accompanied by biological degradation. Aging then becomes the major source of deterioration. During long-term use of wood, possible factors of aging could be the combined effect of thermal oxidation by oxygen that is partly dissolved in water and acid hydrolysis by bound water and acids contained in the wood (Matsuo et al., 2011). This results in cellulose degradation which might influence mechanical and sorption properties of wood (Kozlov and Kisternaya, 2013), and light induced free radicals cause color changes (Matsuo et al., 2011).

Resistance to various kinds of wood-degrading organisms is a natural attribute of wood, which is relevant to the expected service life of wood products. Service life depends on the wood species, extractive content, water exclusion efficacy, use conditions and a number of other factors (Highley, 1995; Brischke and Rapp, 2008). One of the questions related to the use of wood is how these properties vary over the course of the service life of wood products. For example, the fungicidal properties of English oak decrease with natural weathering (Brischke et al., 2013), predominantly due to the leaching of extractives. Although the natural durability of freshly cut timber has been fairly extensively studied, to the best of our knowledge there have not been many reports on the overall

* Corresponding author. Tel.: +386 1 320 36 38.
E-mail address: miha.humar@bf.uni-lj.si (M. Humar).

0964-8305/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.ibiod.2013.08.020

performance of wood materials after a certain period of use. Brischke et al. (2012) studied the correlation between conditions of oak bridges and the fungicidal properties of oak from these bridges. They reported that the fungicidal resistance of the wood in use clearly influences the appearance of bridges rather than poor detail and imperfect protection design. Studies of the mechanical properties of 200-year old English oak and Norway spruce from Poland and Switzerland showed that the modulus of elasticity of the 200-year old wood and the freshly cut reference wood remained within the same range (Kránitz et al., 2010). However, it must be stressed that there were no signs of biological deterioration. On the other hand, Yang et al. (2012) reported that the mechanical properties of *Populus cathayana* wood from ancient Tibetan buildings deteriorated significantly over time. The most important reason for the decrease was degradation caused by insects and fungi. The cited studies show that old wood is a suitable material for reuse and recycling if the wood is not degraded.

In most of the old structural timber, there are smaller or bigger cracks present. In general, the dimension of the cracks increases with the cross-section dimension. However it should be considered that formation of cracks is usually not regarded as an 'aging phenomenon', even though it will clearly affect several strength properties of wood. Cracks are predominately formed during drying and wetting of wood due to moisture gradients that result in dimensional chances and consequently in tensile stress (Oltean et al., 2007).

The need to recycle aged wood has increased greatly over recent years. The so-called cascade use of wood is one of the leading strategies in developed countries. One possible option is to use recovered wood as a source of energy. However, its application for furniture construction and interior design is preferable (Kránitz et al., 2010). For these purposes, the relevant properties of aged wood must be known. The aim of this study was to investigate and determine differences in mechanical, fungicidal and sorption properties of English oak (*Quercus* sp.), common beech (*Fagus sylvatica*) and Norway spruce (*Picea abies*) wood beams that had been in use for several decades.

2. Material and methods

2.1. Wood material

Wood was obtained from structural wooden beams that had been in indoor use for over 130 years (oak and beech wood in use from 1875 to 2012) and 220 years (spruce in use from 1790 to 2012). The English oak wood specimen had been part of a support beam in a corn-rack, the spruce wood beams had been used as support beams in an old farm kitchen with an open hearth and the beech wood specimen was a part of decking in an old wooden barn. The old oak sapwood had been attacked by insects but the heartwood was intact. Old beech wood samples had been severely attacked by the common furniture beetle (*Anobium punctatum*) and by accompanying white rot decay. Two different types of old spruce wood beams were used, one with average annual rings (1.81 mm) and one with extremely narrow annual tree rings (0.51 mm). Ring width of oak and beech was 3.20 mm and 1.56 mm, respectively. Density of oven dried wood was 370 kg/m^3 (spruce wood wide ring widths), 569 kg/m^3 (spruce wood narrow ring width), 572 kg/m^3 (beech) and 820 kg/m^3 (oak). For the purpose of this research only heartwood of respective wood species was used. Cross-section of oak beam was 200 mm × 180 mm, of spruce beam 120 mm × 250 mm and of beech 40 mm × 320 mm. There were some small cracks present, but they were avoided during machining. None of the materials were treated with biocides, surface coatings or adhesive. They were located in use class 1 or 2 applications thus they were not exposed to any kind of precipitation. They were hardly ever wet, perhaps only during heavy thunderstorms with heavy winds, once or twice per year.

For comparison, recent wood was used. All control material was provided from the same geographical location than the investigated old wood (central Slovenia). Wood was air dried for two years prior to analysis. For oak and spruce only hardwood was used. There were no signs of the biological decay, neither by fungi nor by insects. Quality of the wood met requirements of the standard EN 113 (CEN, 2006a). Properties of the control (recent) wood were similar to the old one. Spruce had average annual ring width of 2.36 mm, oak 3.58 mm, and beech 3.71 mm. Spruce wood had oven dry density of 380 kg/m^3, beech wood 590 kg/m^3 and oak wood 611 kg/m^3.

2.2. Decay test

The decay test was performed according to the modified EN 113 (CEN, 2006a) standard. Disposable Petri dishes ($\varnothing$ = 85 mm, h = 15 mm) containing 20 ml of 4% potato dextrose agar were inoculated with 5 different fungi: 3 white rot (*Hypoxylon fragiforme*, *Pleurotus ostreatus*, and *Trametes versicolor*) and 2 brown rot (*Gloeophyllum trabeum*, and *Antrodia vaillantii*). A plastic mesh was used to avoid direct contact between the samples and the medium. The assembled test dishes were then incubated at 25 °C and 80% relative humidity (RH) for 12 weeks.

Specimens with dimensions 25 mm × 25 mm × 8 mm were prepared and 9 replicates per fungus species were used for each type of wood (315 specimens in total). After incubation, fungal mycelium was removed from the samples, which were first weighed for moisture content. After 24 h of drying at 103 °C, mass loss was determined gravimetrically.

2.3. Evaluation of mechanical properties

Modulus of elasticity (MoE) and modulus of rupture (MoR – bending strength) were determined according to the EN 310 (CEN, 1993) procedure with a static three-point bending test on a Zwick Z005 universal testing machine (Zwick-Roell, 2012). In total, 147 test specimens (21 replicates for each wood species) with dimensions 65 mm × 25 mm × 5 mm were prepared and conditioned in a standard climate (RH = 65 ± 5%; T = 20) (20 ± 2 °C) until a constant mass of the specimens was achieved. The specimens were tested for MoE and MoR immediately after incubation in the standard climate.

Compressive strength was determined according to the ASTM D1037-99 (ASTM, 1999) standard on a Zwick Z100 universal testing machine (Zwick-Roell, 2005). In total, 105 test specimens (15 for each wood species) with dimensions 40 mm × 25 mm × 15 mm were prepared and incubated in a standard climate until a constant mass of the specimens was achieved. The specimens were tested for compressive strength immediately after incubation in the standard climate. After the test, the compressive strength (F_m) was calculated.

2.4. Evaluation of short term water uptake

Short term water uptake was measured according to a modified EN 1609 (CEN, 1997) procedure using a tensiometer device (Krüss, 2011). The size and number of specimens used was the same as for compression strength specimens (40 mm × 25 mm × 15 mm). The mass of partially immersed samples (1 mm) was recorded every 2 s for 200 s. The result was given as the mass of water uptake per area of immersed specimen (g mm^{-2}).

Download English Version:

https://daneshyari.com/en/article/6289314

Download Persian Version:

https://daneshyari.com/article/6289314

Daneshyari.com