International Biodeterioration & Biodegradation 86 (2014) 66–70

Contents lists available at SciVerse ScienceDirect

International Biodeterioration & Biodegradation

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

Absorption–desorption behaviour and dimensional stability of untreated, CC impregnated and pine oil treated glulam made of Scots pine and Norway spruce

Henrik Heräjärvi*, Veikko Möttönen, Maija Reinikkala, Reeta Stöd

Finnish Forest Research Institute, Eastern Regional Unit, P.O. Box 68, FIN-80101 Joensuu, Finland

ARTICLE INFO

Article history:
Received 1 April 2013
Received in revised form
14 June 2013
Accepted 26 June 2013
Available online 17 July 2013

Keywords:
Absorption
Desorption
Dimensional stability
Glulam
Impregnation
Pine oil
Water resistivity

ABSTRACT

In order to survive, the wood degrading microbes need a moisture content of wood exceeding the fibre saturation point, *i.e.*, 26%–32%, depending on the species. Maintaining wood moisture content below this level effectively prevents biodegradation. This can be achieved either by preventing wood's exposure to liquid water or increasing the hydrophobicity of wood by some impregnation or modification treatment. The objective of the study was to define the dimensional stability in changing environmental conditions, as well as the water absorption and desorption behaviour of untreated, copper-chromium impregnated and pine oil treated glulam. Scots pine was used for pressure impregnated and pine oil impregnated beams while the reference beams were made of Norway spruce, which is the most commonly used species for glulam production nowadays. The 6 inner lamellae of the glulam beams originated from small-sized logs, whereas the surface lamellae were made of larger logs. Beams with 44 × 200 mm cross cut dimensions were glued using melamine-urea-formaldehyde resin, and divided into three treatment groups. Treatment 1 was not impregnated (Norway spruce), treatment 2 (Scots pine) was impregnated with copper-chromium based preservative in commercial pressure impregnation process, and treatment 3 (Scots pine) was impregnated with pine oil using the process of Ekopine Ltd. After the treatments, 20 glulam specimens with dimensions of 44 × 200 × 170 mm (thickness–width–length) were produced from each treatment group. The cross-cut surfaces of the specimens were sealed using waterproof varnish to ensure that the water movement took place only through the side surfaces of the specimens. The air-dry specimens (MC 7.7–12.6%) were immersed into water for 6 weeks, during which period they were weighed repeatedly. After the immersion treatment, they were brought to a standard climate (65% RH, 20 °C temperature). Again, their mass was recorded until it did not change anymore. Then the same specimens were taken into a weather chamber where they were subjected to four 2-week-long test cycles with varying temperature and relative humidity, totalling 8 weeks of artificial weather exposure. Pine oil impregnated specimens resisted the water absorption significantly better than the untreated and pressure impregnated specimens. Due to the low initial MC after the absorption period, pine oil impregnated specimens also dried rapidly below 20% MC, while the drying of untreated and pressure impregnated glulam to the same level took 3–4 weeks in standard climate. The pine oil impregnated specimens had clearly better dimensional stability in the weather chamber, compared with the untreated and pressure impregnated specimens. Also the mass variation of pine oil impregnated specimens was significantly reduced in comparison to the other two treatment groups, indicating lower hygroscopicity for the pine oil treated specimens. To conclude, the pine oil impregnation of wood can be considered as an effective preservation method against moisture exposure. It appears to be a promising method to prevent biodegradation by maintaining the moisture content of wood below the level that enables mould and fungal growth.

1. Introduction

The need for an increase in the utilisation of small diameter logs in structural uses means higher demand for controlling and modifying the challenging wood properties such as high proportion

---

* Corresponding author. Tel.: +358 503913037.
E-mail address: henrik.herajarvi@metla.fi (H. Heräjärvi).

0964-8305/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.ibiod.2013.06.028

of juvenile wood and sapwood. In addition to the physical challenges, there are chemical ones, as well. Microbial degradation can occur only if wood has a moisture content exceeding 20% of its oven-dry weight (Cartwright and Findley, 1958). In case of aboveground structures such moisture level is relatively easy to maintain. However, there are only few commercial methods effectively resisting microbial and fungal degradation of wood in ground contact. These include coal-tar creosote and acetylation. Due to the environmental concerns or production cost challenges new methods are needed to protect wood from microbial or mould growth.

The most common method to preserve wood against microbial growth is pressure impregnation with copper (CuO) salt based additives. Finland alone produces more than 200,000 m^3 of pressure impregnated sawn timber annually (Production statistics…2012). Less toxic wood preservation methods are widely explored to satisfy the needs of the environmentally conscious consumers.

Pine oil (or "crude tall oil") impregnation, either alone or combined with some other modification such as heat treatment, has been considered as an alternative for pressure impregnation (*e.g.*, Cartwright and Findley, 1958; Banks, 1973; Sailer et al. 1998, 2000; Paajanen et al. 1999; Van Eckeveld, 2001; Van Eckeveld et al. 2001; Paajanen and Ritschkoff, 2002; Koski, 2008; Temiz et al. 2008). Impregnating small diameter timber with pine oil is expected to reduce the wood technological problems such as dimensional stability and poor durability related to, *e.g.*, juvenile wood. Pine oil impregnation not only reduces the capillary water uptake of wood but also increases the hydrophobicity of wood surface (Koski, 2008). There are challenges limiting the possibility to use pine oil as a wood preservative on an industrial scale. The first one is the large quantity of oil needed to preserve wood. The high retention level increase the material costs on the one hand, and make the products quite heavy, on the other hand. Being a by-product of kraft pulping process, however, crude tall oil is available in large quantities wherever kraft pulp industries exist. Wood preservation is only one of the potential end uses for pine oil that can be further refined into biofuels, for instance. The second challenge is the leaching of oil from the wood. This is due to the high retention levels of oil especially in the surface layers of wood. Deeper inside wood, the lack of oxygen prevents polymerisation of the oil, causing leaching and uneven surface quality for the treated products (Koski, 2008).

When used as a wood preservative, pine oil has some restrictions related to wood machining. According to the experience of the industry representatives, oil penetrates into wood at its best via recently sawn or peeled surfaces, whereas planed surfaces are challenging to impregnate. The time period between surface machining and impregnation also has an influence on the permeability of wood, which is familiar from the glue joint behaviour. Since the temperature in the pine oil impregnation process is relatively high (approximately 130 °C, Tarvainen et al., 2001) and wood is dried down close to zero per cent moisture content, certain wood anatomical and chemical changes are most likely derived from the impregnation treatment. These changes have not been comprehensively studied, so far. As a result of pine oil impregnation, the equilibrium moisture content of wood is reduced down to the level of 5–8 per cent in standard climate (RH: 65%, T: 20 °C).

Finland produced approximately 330,000 m^3 of glulam beams in 2011. The raw material for glulam is mainly Norway spruce (*Picea abies*) but some Scots pine (*Pinus sylvestris*) is used, as well (Glulam Handbook, 2009). There is a growing interest to use small diameter logs also in glulam production. The main driver for this interest is the price of the logs: small diameter logs typically cost only 50–60 per cent of the price of conventional saw logs. Small log volume means not only demands of increased efficiency for material handling in logistics and manufacturing processes, but also challenging wood properties such as high volumetric proportion of knots, juvenile wood, and sapwood. Due to these facts, products made of small diameter logs are prone to twist and check, have poorer durability against weather, and often have poorer mechanical performance than products made of larger logs (*e.g.*, Bodig and Jayne, 1982; Zobel & van Buijtenen, 1989; Ranta-Maunus, 1999; Boren and Barnard, 2000; Heräjärvi et al., 2000; Boren, 2001; Wall et al. 2005; Stöd and Kilpeläinen, 2006; Stöd et al. 2006).

The objective of this article is to analyse the dimensional stability and water absorption–desorption behaviour of untreated, pressure impregnated and pine oil impregnated glulam in changing environmental conditions. Beams made of Norway spruce, the most commonly used glulam species, are compared with beams made of Scots pine and impregnated using copper-chromium and pine oil preservatives.

2. Material and methods

A total of 144 glulam beams were made of Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abies* Karst.), the wood material originating from South-Eastern Finland. The lamellae used in the beams had dimensions of 25 × 44 mm. The inner lamellae of the beams were sawn from small-sized saw logs (top diameter 100–150 mm), whereas the surface lamellae originated from conventional sized saw logs (top diameter > 150 mm). Each beam had six inner lamellae plus the surfaces, *i.e.*, eight lamellae altogether. Beams with 44 × 200 × 2000 mm nominal dimensions were manufactured in an industrial glulam production line, using Melamine-urea-formaldehyde resin as an adhesive.

Next, the material was divided into three sub-samples according to their treatment groups:

- Sub-sample 1 (Scots pine beams), was taken to commercial pressure impregnation chamber to be impregnated with ordinary copper based preservative,
- Sub-sample 2 (Scots pine beams), was taken to pine oil impregnation that was carried out by company Ekopine Ltd.,
- Sub-sample 3 (Norway spruce beams, a reference group) was stored indoors until further measurements.

After the impregnation treatments, 20 specimens were sawn from a random sample of the beams in each three treatment group, thus obtaining 60 specimens with 44 × 200 × 170 mm (thickness-width-length) dimensions for the water absorption and weather chamber tests (Fig. 1). The cross-cut surfaces of all specimens were sealed applying several layers of waterproof varnish. By this, we wanted to ensure that all water and vapour movement took place via the four side surfaces of the specimens irrespectively from the treatment group. Unlike the cross-cut surfaces, side surfaces were fully impregnated by copper salt or pine oil. After varnishing, the specimens were stored in a standard climate room with air temperature of 20 °C and relative humidity of 65%, until they reached a constant mass, *i.e.*, their equilibrium moisture content.

Conditioned specimens (MC 7.7–12.6%) were immersed into water in 11th of April, 2011 for six weeks. During that time their mass was regularly recorded. After each weighing, the specimens were immediately returned back to the water. After the 6-week immersion period, the specimens were removed from the water for the last time, weighed, and brought to a standard climate room. Again, their mass was repeatedly recorded until the equilibrium moisture content was reached. Measurements were terminated slightly before the equilibrium moisture content was reached. The specimens were weighed the last time in 2nd of November 2011, 147 days after initiating the water absorption-desorption test.