International Biodeterioration & Biodegradation 65 (2011) 547–552

Contents lists available at ScienceDirect

International Biodeterioration & Biodegradation

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

Comparison based on field tests of three low-environmental-impact wood treatments

Sabrina Palanti*, Elisabetta Feci, Anna Maria Torniai

CNR IVALSA, Istituto per la Valorizzazione del Legno e delle Specie Arboree, Via Madonna del Piano 10, 50019 Sesto Fiorentino (FI), Italy

ARTICLE INFO

Article history:
Received 12 August 2010
Received in revised form
10 December 2010
Accepted 14 December 2010
Available online 15 March 2011

Keywords:
Pinus pinea
Natural durability
Wood preservatives
Use classes

ABSTRACT

In order to promote the use of *Pinus pinea* L. wood within the Migliarino-San Rossore Nature Reserve (Pisa, central Italy), three low-environmental-impact wood treatments, supposed to enhance natural durability, were compared. Impregnations with an oil-based preservative and natural waxes and a wood thermal treatment were tested in the field in accordance with standards ENV 12037 and EN 252. The above-ground test revealed that: *P. pinea* sapwood is more durable than *Pinus sylvestris* sapwood; all the alternative treatments showed a low mean decay level; wax and oil treatments performed as well as the traditional copper-based preservative; the natural durability class of *P. pinea* will only be calculated upon the complete failure of all reference lap-joints. The main outcomes from the in-ground test were: All the tested treatments increased the durability of wood, and the protective effectiveness of alternative treatments was comparable to traditional copper-based ones, or even superior in the case of heated oil. Taking certain mechanical and aesthetic limitations into account, all the treatments were suitable for the promotion of the *P. pinea* wood commodity in use classes 3 and 4.

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1. Introduction

Conventional chemical wood protection is based on a broad spectrum of biocide formulations such as copper/organic biocides, copper-organometallics, and metal-free preservatives (Hughes, 2004), especially for use class 3 according to EN 335-1, 2006; several alkyl ammonium compounds, such as tertiary amine salts and quaternary ammonium compounds, are also conventionally used as wood preservatives (Pernak et al., 2004). There is growing interest within Europe in oils and water repellents for wood preservation both at the industrial and research level, and this interest is focused on the screening of different natural and synthetic oils (Sailer and Rapp, 2001; van Eckeveld et al., 2001; Palanti and Susco, 2004), and on the development process of wood preservation technology (Thevenon, 2001; Treu et al., 2001).

Over the past decade, wood modification techniques that allow for improved wood durability without the use of biocides, e.g., thermal treatments, oil treatments, and chemical modifications, have developed very rapidly. The interest in alternative wood treatments and processes is in accordance with new trends in European legislation on wood preservatives, which banned the compounds most toxic to human and animal health and those with a high environmental impact. In fact, in 2003 European legislation banned the use of the inorganic salt CCA type in any application where the treated wood may pose a risk to human and animal health (e.g., residential areas, parks, and gardens).

Within this legislative framework, it is important to promote the use of products with a low-environmental impact for use within a conservation area such as the Migliarino-San Rossore Nature Reserve, which is in Pisa, in central Italy. In this area, the wood species *Pinus pinea* L. forms typical coastal forests that are periodically subjected to thinning and pruning. The wood derived from this logging, not yet commercially exploited, could instead be used to produce wooden objects for use within the nature reserve, such as signs, playground equipment, and benches.

The final objectives of this work were therefore to determine the natural durability of *P. pinea* from Migliarino-San Rossore in different use classes and to determine the protective effectiveness of some alternative treatments to copper salts. The research is based on the comparison of three commercial wood treatments with low-environmental impact, utilised to improve the natural durability of *P. pinea* in above-ground conditions (use class 3) and in-ground contact (use class 4).

The comparison was performed using a heated-oil preservative, a wax-based preservative, and a thermal treatment.

The heated-oil treatment was based on a mixture of vegetable and mineral oils combined with the triazole fungicides propiconazole and tebuconazole. In a previous work, heated-oil-based

* Corresponding author. Tel.: +39 055 5225512; fax: +39 055 5225507.
E-mail address: palanti@ivalsa.cnr.it (S. Palanti).

0964-8305/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ibiod.2010.12.012

preservatives showed good water repellence, but the performance of triazoles in oil was not as good as in water-borne preservatives. In the end, a conclusion was reached that the EN 113, 1996 laboratory test was not appropriate to demonstrate the efficiency of oil-based preservatives (Palanti and Susco, 2004).

A wax treatment based on a mixture of natural wax impregnated into the wood at 183 °C was supplied by Tilo GmbH, an Austrian natural wood flooring company.

The Company NOW (also known as RETITECH, France) executed the thermal treatment using the retification process. This process consists of starting with previously dried wood, around 12% in moisture content, heated slowly up to 210–240 °C in a nitrogen atmosphere with less than 2% oxygen. Wood treated at 230–240 °C is more durable but it can lose up to 40% in modulus of rupture and it is more brittle (Vernois, 2001). Militz et al. (2004) reported strongly increased durability for the NOW thermal treatment on maritime pine and a small increase in durability in Scots pine treated with Tilo wax.

Commercial copper-salt wood preservatives were used as reference.

Efficacy above ground was determined in accordance with the ENV 12037, 1996 lap-joint test, which consists of two overlapping parts held together mechanically and placed horizontally at 1.2 m above ground. Efficacy in-ground contact was determined in accordance with EN 252, 1989, the stakes test. The same year in which the European Committee for Standardisation issued standard ENV 12037, an EU project got underway to evaluate the method (Grinda et al., 2001). The observation of thousands of lap-joints revealed that decay starts later than in-ground test stakes (Bergman et al., 2008). Because of this, the final revision of the standard, the current CEN TS 12037, 2003, states that if the median rating for joint surfaces of untreated control replicates is less than 3.0 after five years, the test should be continued until a minimum value of 3.0 is achieved.

2. Materials and methods

2.1. Wood species

P. pinea L. from Migliarino-San Rossore Nature Reserve and *Pinus sylvestris* L. as reference, were used in this research.

Wood samples were taken from different wood species and had different characteristics:

P. sylvestris sapwood (S) – control
P. pinea heartwood (H)
P. pinea sapwood (S)
P. pinea glue-lam (mixture sapwood–heartwood) (GL)

2.2. Treatments

As reference preservatives, two different commercial copper salts were used: TANALITH E (Arch Timber, England), and IMPRALIT KDS (Rutgers Organics, Germany), with retention, respectively, for use classes 3 and 4.

2.2.1. Heated oil

A mixture of mineral and vegetable oils containing 0.15% propiconazole and 0.15% tebuconazole heated at 80 °C were introduced into the wood with the following impregnation cycle: 0.51 bar vacuum for 25 min, atmospheric pressure for 20 min and 0.85 bar final vacuum for 20 min. The final retentions are reported in Table 1.

Table 1
Heated-oil treatments. Mean retentions and tests effectuated. S = sapwood, H = heartwood, GL = glue-lam. *P. pinea* sapwood was treated in two different times. U.d.: unavailable data.

Wood species and replicates	Test	Average retention (Kg/m^3) and standard deviation
P. pinea S ($n = 13$)	Stakes EN 252	127.0 (34.65)
P. sylvestris S ($n = 14$)	Stakes EN 252	50.0 (16.06)
P. pinea H ($n = 13$)	Stakes EN 252	44.7 (24.63)
P. pinea GL ($n = 10$)	Lap-joint ENV 12037	115.4 (52.23)
P. pinea S ($n = 4$)	Lap-joint ENV 12037	71.56 (21.24)
P. pinea S ($n = 10$)	Lap-joint ENV 12037	60.00 (U.d.)

2.2.2. Wax

An industrial treatment based on natural wax impregnated at a high temperature of 183 °C was conducted by Tilo GmbH, an Austrian company, as described in Table 2.

2.2.3. Thermal treatment

The thermal treatment was performed by the French company NOW SA, which uses the retification process at 230 °C. The wood species treated, the number of replicates, and the tests performed are shown in Table 3.

2.3. Field tests

2.3.1. Above-ground performance test

The above-ground performance test was performed in accordance with standard ENV 12037, 1996.

The dimensions of the horizontal lap-joints were $(28 \pm 1) \times (85 \pm 1) \times (180 \pm 1)$ mm^3 and the close-fitting part in the middle was 60 mm long. The horizontal lap-joints were exposed on an aluminium rack located 1.2 m above-ground level. From 5 to 15 replicates per treatment and *P. pinea* wood type (glue-lam/sapwood) were conditioned before being sent to different treatment plants. Ten untreated replicates of *P. pinea*, divided into 5 sapwood and 5 glue-lam, and 15 replicates of *P. sylvestris* (5 sapwood and 10 glue-lam), were used as controls. As reference, 15 replicates each of *P. pinea* sapwood and glue-lam were treated with TANALITH E retention for class 3. The extent of fungal attack on the external surfaces and in the joint area was rated according to a rating system using the values 0–4 (0 is sound; 1 denotes slight attack; 2, moderate attack; 3, severe attack; and 4, failure) and compared to a reference. Five evaluations were conducted, every 13 months on average.

2.3.2. In-ground contact performance test

The in-ground performance test was carried out in accordance with EN 252, 1989. The test lasts a minimum of 5 years or until the stakes fail.

Stakes, dimensions $(500 \pm 1) \times (50 \pm 3) \times (25 \pm 0.3)$ mm^3, taken from the heartwood and sapwood of *P. pinea* wood and *P. sylvestris* sapwood, were cut and conditioned before being sent to different treatment plants. The stakes were placed vertically in the soil, leaving half the length exposed.

Table 2
TILO treatment, retentions and tests effectuated. * The average value was calculated on 4 samples, the symbol – means data not available.

Wood species and replicates	Test	Average retention (Kg/m^3) and standard deviation*
P. pinea S ($n = 13$)	Stakes EN 252	–
P. sylvestris S ($n = 13$)	Stakes EN 252	–
P. pinea H ($n = 13$)	Stakes EN 252	392.95 (10.79)
P. pinea GL ($n = 13$)	Lap-joint ENV 12037	258.98 (4.87)
P. pinea S ($n = 13$)	Lap-joint ENV 12037	199.08 (10.83)

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