International Biodeterioration & Biodegradation 86 (2014) 210–217

Contents lists available at ScienceDirect

International Biodeterioration & Biodegradation

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

Accelerated above-ground decay testing in Australia and New Zealand

Laurie J. Cookson [a,*], David Page [b], Tripti Singh [b]

[a] School of Biological Sciences, Monash University, Clayton, VIC 3800, Australia
[b] Scion, Private Bag 3020, Rotorua, New Zealand

ARTICLE INFO

Article history:
Received 14 August 2013
Received in revised form
2 September 2013
Accepted 2 September 2013
Available online 12 November 2013

Keywords:
Above-ground decay
Field testing
CCA
Azoles
Innisfail
Accelerated field simulator

ABSTRACT

The aim of this research into above-ground (H3) fungal field testing was to find a method that would shorten the time required for evaluating new preservatives and protection systems. A trial was installed at two sites in Australia and one in New Zealand, as well as in two indoor accelerated field simulators. One-quarter H3 retentions were installed, including CCA as positive controls, as first results suitable for preservative registration occur when these reach 70% soundness. Twelve test methods were examined, some established and others developed for the project. In two methods, feeder blocks pre-inoculated with laboratory-raised fungi were placed next to test specimens in an effort to accelerate decay. The treatments examined were CCA, alkaline copper high quat (AChQ), azoles, kerosene, TBTN, and water. Untreated *Corymbia maculata* heartwood was included for natural durability. Inspection was annual for 4 yr. The fastest tests were those that held moisture for longer periods in test specimens and were the "rot box" at Innisfail, followed by the ground proximity, deck-on-ground, and "embedded" tests at this high-rainfall location. The most reliable tests giving expected relative order of failure were those allowing diversity of fungi rather than those that became dominated by a few, and included those placed close to the ground or with increased volume of untreated wood substrate in frames. Reliability was also influenced by duration of the trial. Pre-inoculation with *Gloeophyllum abietinum* gave more representative results than pre-inoculation with *Oligoporus placenta*.

1. Introduction

The wood preservation and timber durability market is going through a period of rapid change, where new preservatives and protection systems need to be brought onto the market quickly. While laboratory tests and screening can be completed in a relatively short time (usually within six months), field tests are also needed to prove preservative efficacy because timber is often used in structural applications where reliable long-term performance is crucial. The designs for in-ground (H4) testing are well established, involving stakes or posts partially buried vertically in soil (e.g., Beesley, 1978), or horizontally under soil in fire-prone areas (Lenz et al., 1992). A variation for H4 decay testing is the accelerated field simulator (AFS), which is a humid heated room containing troughs of soil in which the stakes can be placed for exposure to a higher decay hazard (Deppe and Gersonde, 1977; Johnson et al., 1982; Bruce et al., 1991; Cookson et al., 2000).

There is much greater variety in outdoor above-ground (H3) decay testing (Fougerousse, 1976; De Groot, 1992; Carey and Orsler, 1995; Zahora, 2002; Meyer et al., 2013; Zahora et al., 2013), with three designs listed in the Australasian Wood Preservation Committee's (AWPC) protocols for preservative evaluation in Australia and New Zealand (decking, L-joint, and flat panel tests) (AWPC, 2007). According to the AWPC, the H3 decay field test should include a reference (commercial) preservative at its H3 approved retention, along with the half and quarter H3 retentions. Comparison with the candidate preservative can be made when the quarter retention of the H3 reference preservative, such as CCA, has significant biodeterioration (less than 70% mean soundness). To shorten field test duration, high-hazard test sites are usually selected. In Australia, the highest hazard for above-ground decay occurs in the wet tropics of Queensland, where, for example, Innisfail experiences an average rainfall of some 3.6 m/yr. Nevertheless, H3 decay trials are the slowest of the test procedures listed in the AWPC protocols, and even at Innisfail it can be 6–7 yr before the necessary level of decay will occur in the quarter retention of the reference preservative. Such a long testing duration can stifle innovation, and lessens commercial interest in the development of the H3 market.

One of the main issues to be aware of in H3 decay testing is the wide range of exposures that can occur within that hazard class.

* Corresponding author. 5 Parkside Court, Warrandyte, VIC 3113, Australia. Tel.: +61 3 98444292.
E-mail addresses: laurie.cookson@monash.edu, laurie@ljcookson.com (L. J. Cookson).

0964-8305/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.ibiod.2013.09.021

The extremes are probably best illustrated by considering window joinery and decking. Window joinery and millwork is usually painted and joints are detailed to shed water, while decking is usually exposed and unpainted. The effect is most pronounced with preservatives based on tributyl-tin (TBT), which have given good service life to window joinery, but not when exposed in decking trials (Cookson and Hedley, 2005). The TBT undergoes chemical debutylation in wood (Jermer et al., 1983; Archer and Meder, 1987), and some surface degradation from ultraviolet radiation (Blunden and Chapman, 1982).

Another difference is that basidiomycete fungi have greater relative importance in H3 than in H4 exposure (Preston et al., 2000). H4 in-ground and cooling tower timbers are often significantly affected by soft-rot fungi as well. Many basidiomycetes respond well to laboratory culturing and cause rapid mass loss. Therefore, the soil-block decay test is useful for giving some information on the comparative performance of H3 preservatives, and can act as a screen to exclude some of the weaker preservative candidates from further testing. However, care is needed when interpreting laboratory decay tests, and these tests are not a substitute for field testing. For one thing, the soil-block test does not include natural weathering or UV exposure. Also, as pure mycelial cultures are mostly used, some fungi can decay treated timber more readily than when they are in a natural environment and in competition with other fungi (Dawsonandoh and Morrell, 1991). Therefore, copper-based preservatives often perform worse against copper-tolerant fungi in laboratory bioassays than in the field due to competition, or the need for inoculation to occur from spores that are more copper-sensitive (Choi et al., 2002). Nevertheless, there is the potential to artificially accelerate decay in the field and in simulated indoor tests by including inoculation with laboratory grown basidiomycetes (Fougerousse, 1980; Hedley et al., 2002; Morris et al., 2009).

This research compared a range of H3 decay test methods likely to cause accelerated decay over 4 yr of exposure. The most likely way of accelerating decay is by maintaining dampness in test samples for longer periods. This may be achieved by increasing the proportion of water-trapping surfaces surrounding the test specimens. Another method for retaining moisture can be by painting and sealing several faces of the test specimens, although a problem here is that the choice of coating becomes a variable, and the effect of UV and weathering is reduced. Test units could be sprayed with water (Van Acker and Stevens, 2003), although at some test sites this is impractical. Above-ground test specimens in the AFS can be watered regularly, and could be placed outside over the summer to obtain a proportion of natural weathering (Cookson, 2010). As mentioned, acceleration could also be achieved by inoculating the test system with known wood-decay fungi, rather than simply waiting for natural incursions. While searching for accelerated decay rates, test designs should also give a representative relative order of failure to the treatments in the test, so that results have greater relevance to other test sites and designs. Therefore, the relative order of failure of seven timber types in each test design and location was also compared in this study.

2. Materials and methods

This trial was installed at five locations, three field sites and two indoor field simulation sites (Accelerated Field Simulators or AFSs), which were Innisfail (Australia, wet tropics, 3600 mm mean annual rainfall), Rotorua (New Zealand, cool temperate, 1400 mm mean annual rainfall), Clayton near Melbourne (Australia, cool temperate, 700 mm mean annual rainfall), AFS at Clayton, and AFS at Rotorua. In Clayton, AFS specimens were placed in layers within large empty troughs and the layers were rotated after each annual inspection. Incubation conditions were 28 °C and 85% relative humidity. In Rotorua, AFS frames holding specimens were placed on racks, and conditions were 25 °C and 95% relative humidity, while in another room for in-ground stakes conditions were 27 °C and 85% RH. Specimens in the AFSs were watered periodically so that test specimens in most test designs were damp but not waterlogged. Each year the exposures in the AFSs for the above-ground trials (not the in-ground stakes) were alternated between 9 mo exposure in the AFS, followed by 3 mo outdoor field exposure during summer.

The main timber substrate used was *Pinus radiata* sapwood, with a mean air dry density of 472 kg m^{-3}. Untreated *Corymbia maculata* heartwood (spotted gum) from Queensland was included in the trial as an example of naturally durable timber, and had a mean air dry density of 1080 kg m^{-3}. Clothes pegs made in China (*Pinus massoniana*) were included in one aspect of the trial.

The timbers and treatments examined were: untreated heartwood of *C. maculata* (class 2 in-ground natural durability), water-treated *P. radiata* sapwood, and *P. radiata* sapwood treated with high flash kerosene (HFK, 25.3% m/m) or quarter-H3 retentions of CCA (Tanalith O, 0.085% TAE), AChQ (alkaline copper high quat, 0.048% m/m Cu and 0.232% m/m DDAC), azole LOSP [light organic solvent preservative, 0.014% m/m azoles (tebuconazole and propiconazole 1:1)] and TBTN (tributyl-tin naphthenate, 0.042% m/m tin). Note that 0.04% m/m tin is a quarter of the H3 requirement in Australia, but half the H3.1 requirement in New Zealand.

The LOSP treatment cycle for azoles, TBTN, and HFK was an initial vacuum of −55 kPa (−80 kPa for HFK) for 5 min, introduction of preservative while maintaining vacuum (usually taking 10 min), release of vacuum and drain treatment solution, followed by a final vacuum of −90 kPa for 30 min. The mean LOSP uptake was 60 kg m^{-3} (75 L m^{-3}), and the mean HFK uptake was 115 kg m^{-3}. The water-based treatments (tap water, CCA, and AChQ) were applied using an initial vacuum of −95 kPa for 30 min, 1 h at 1400 kPa, and no final vacuum. Specimens were removed from the treatment solution and lightly surface blotted before weighing. Mean solution uptakes were 650 kg m^{-3}.

Further chemical composition details can be found in Cookson and Carr (2009) and Cookson et al. (2012). Some 5110 timber *P. radiata* specimens were treated, from which the required 2300 *P. radiata* test specimens were selected. The water-borne preservative treated test specimens chosen for exposure had retentions mostly within 10% of the nominal retentions. Greater variety of uptake was obtained with the LOSP and HFK treatments (due to reduced solution uptakes rather than “saturation” treatments), so that retentions within 15–20% of the nominal retentions were accepted for exposure. There were ten replicate test specimens of each timber and treatment at each site and for each exposure method.

Test specimen dimensions, which varied according to the exposure method employed, were:

- Flat panel test, 75 × 25 × 200 mm long (70 mm wide for *C. maculata*)
- Deck-on-ground, 75 × 25 × 300 mm long (70 mm wide for *C. maculata*)
- Raised deck, about 1 m above ground, 75 × 25 × 300 mm long (70 mm wide for *C. maculata*)
- Embedded test, 35 × 35 × 200 mm long
- Embedded test, 35 × 35 × 200 mm long; exposed surfaces painted
- Embedded test pre-inoculated, 35 × 35 × 200 mm long
- Rot box, 75 × 25 × 200 mm long (70 mm wide for *C. maculata*)
- Rot box pre-inoculated, 75 × 25 × 200 mm long (70 mm wide for *C. maculata*)
- Ground proximity test, 75 × 25 × 200 mm long (70 mm wide for *C. maculata*)