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Laboratory evaluation of wood-based composites treated with alkaline copper quat against fungal and termite attacks

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ABSTRACT

Vacuum-impregnation with alkaline copper quat (ACQ) was applied as a post-treatment to five commercially-available wood-based composites (approximately 12-mm thick), including softwood plywood (SWP), hardwood plywood (HWP), medium density fiberboard (MDF), oriented strand board (OSB) and particleboard (PB). In general, ACQ-treated wood-based composites were not as resistant to biological attack as treated *Cryptomeria japonica* sapwood blocks, possibly due to the uneven distribution of preservative in the composites. Untreated and treated composites were tested for their resistance to two decay fungi (brown-rot fungus *Fomitopsis palustris* and white-rot fungus *Trametes versicolor*) and the subterranean termite *Coptotermes formosanus* by Japanese standardized laboratory test methods. Untreated MDF was the most resistant to both biological attacks, followed by PB, which was less resistant to *C. formosanus*. ACQ did not adequately protect SWP from *F. palustris* or termite, or OSB from *F. palustris* or *T. versicolor* even at the highest test retention of 5.2 kg/m^3, whereas the biological resistance of HWP was reasonably improved by ACQ. Since cut-end-coated composites treated at higher retentions of both ACQ and copper azole performed much better than uncoated materials, cut-ends were considered to provide decay fungi and termites with easy access or penetration. These findings support the importance of remedial treatment of processed building components at construction sites.

1. Introduction

When chromated copper arsenate (CCA) was introduced in Japan in 1963, it helped to assure the prolonged service life of various wood commodities, especially hem-fir sill plates (dodai) in Japanese houses. However, the disposal of CCA-treated wood waste became a serious environmental issue and the Japan Wood Preservers' Industry Association conducted a questionnaire survey. The survey results indicated that Japanese treatment plants could not meet the new strict criterion (tolerance limit) of arsenic (<0.1 mg/liter) in discharged water, which was revised as the Water Pollution Prevention Act in 1995.

Meanwhile, both copper azole (CA) and alkaline copper quat (ACQ) have been widely accepted as alternatives to CCA worldwide, since they are free of arsenic and chromium and are considered to be environmentally acceptable. In Japan, CCA alternatives were domestically standardized in 1995 (Japanese Industrial Standard JIS K 1570 1995), and the Japanese wood-preserving industry made a self-imposed decision to restrict or ban the use of CCA. Alternatives appeared in the marketplace in 1991, and have been gaining popularity since 1996. They now account for approximately 90% of the total amount of wood produced by pressure-impregnation with preservatives Ishida et al. (2004). CCA finally disappeared from the revised national standard JIS K 1570 (2004). The preservative performance of these alternatives is based on a system that forms water-insoluble biocidal copper precipitates in wood (Nagano et al. 1996a,b) or on a fixation mechanism that is related to ion exchange and the formation of ion pairs with cellulosic components (Butcher and Drysdale 1978; Preston et al., 1987). Although some wood-block tests have been carried out to examine the wood-protecting efficacy of copper-containing preservatives such as CA and ACQ under various laboratory conditions (Freeman and McIntyre 2008), there have been few experimental reports on the performance of composites treated with these preservatives.

In a previous study, CA was tested for its effectiveness at protecting treated composites at three retentions, respectively for the K1, K2 and K3 classes as designated by JAS (Japanese Agricultural Standard 2007). These classes are identical to use classes 1 (interior dry), 2 (interior damp) and 3 (exterior protected and unprotected from weather) of the ISO use class system (Suzuki 1995; Morris 1996; ISO 21887 2007). In addition, thickness

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swelling in vacuum impregnation and its recovery rates were also investigated.

The current study was conducted as part of serial investigations on alternative wood preservatives. The biological resistance of ACQ-treated composites was examined with specimens that matched those used in CA evaluations (Tascioglu and Tsunoda 2010) so that the results could be compared. Therefore, three test retentions were selected on the basis of JAS designations, the same as those with CA, to facilitate comparisons of the two preservatives while considering the gradient of active ingredients in composites treated with both preservatives. In addition, wood-based composites were treated with ACQ at 5.6 $kg/m^3$and with CA 2.0 kg/m^3, and tested against biological agents with and without the coating of cut-ends as well as with ACQ and CA at 2.6 and 1.0 kg/m^3, respectively, to discuss the gradients of active ingredients within the treated materials.

2. Materials and methods

2.1. Wood-based composites

Specimens (210 mm × 30 mm × thickness) were prepared from 5 different wood-based composites that are commercially available in Japan: softwood plywood (SWP), hardwood plywood (HWP), medium density fiberboard (MDF), oriented strand board (OSB) and particleboard (PB). The samples were prepared as described in detail in a previous article (Tascioglu and Tsunoda 2010). Since we could not obtain specimens of the same size for supplemental biological tests to discuss the effects of the gradient of active ingredients, specimens with dimensions of 100 x 100 mm × thickness were used.

2.2. Preservative

The preservative used in this study was ACQ in JIS K 1570 (Japanese Industrial Standard 2004) supplied by Koshii Preserving Co. Ltd. (Japan). Treatment solutions were prepared in the same manner as for CA (Tascioglu and Tsunoda 2010). The target retentions were selected according to the requirements for lumber described in the Japanese Agricultural Standard (2007), and were 0.65, 1.30 2.60 and 5.20 kg/m^3 as ACQ, respectively, in the 5 composites. The two higher target retentions, 2.60 and 5.20 kg/m^3 were also used in supplemental tests. All solutions had pH values of around 9.6. CA was used to prepare composite samples treated at 1.0 and 2.0 kg/m^3.

2.3. Treatment

Vacuum-soak impregnation was used in the current study. A pre-dry vacuum level of 6 kPa was used with all of the composite types, and the subsequent soaking periods were adjusted according to the composite type to attain target retentions based on treatability (porosity, density, and raw material). The weight-gain method was used to calculate preservative retention in the treated specimens. Treatment methods and the subsequent handling of specimens were exactly the same as with CA (Tascioglu and Tsunoda 2010).

2.4. Determination of thickness swelling and equilibrium recovery rates

Thickness was measured at three points marked at equal intervals (5.25 cm) on each specimen surface with a digital micrometer before and after treatment to determine the swelling percentage. In addition, percent equilibrium recovery rates were determined after approximately 8 weeks of re-conditioning. The details have been provided previously in Tascioglu and Tsunoda (2010). The obtained data were statistically analyzed with an analysis of variance (ANOVA) test at a confidence level of $p > 0.99$.

2.5. Biological tests

Decay and termite tests were conducted according to JIS K 1571 (Japanese Industrial Standard 2004) with a minor modification of the specimen size: 28 mm × 20 mm × thickness for decay tests and 20 mm × 13 mm × thickness for termite tests. Only unweathered specimens were used in the current study. The specimen size was 20 mm × 20 mm × thickness for the supplemental decay and termite tests. Since the details can be obtained from the standard and a previous publication (Tascioglu and Tsunoda 2010), the test methods are only briefly mentioned here. Decay tests were conducted with all of the treated and untreated specimens.

Weight measurement: All individual specimens were weighed before and after the decay test, following oven-drying at 60 ± 2 °C for 48 h. The specimens were aseptically exposed to a monoculture of either *Trametes versicolor* (L.Fr.) Pilat or *Fomitopsis palustris* (Berk. et Curt.) Gilb. & Ryv. After 12 weeks of incubation at 26 ± 2 °C and >70% RH in the dark, the specimens were re-weighed to determine percent mass losses. Composite specimens that were treated with ACQ at 2.60 and 5.20 kg/m^3 and with CA at 1.0 and 2.0 kg/m^3 were cut-end-coated with epoxy resin and included in the decay test using a copper-tolerant fungus, *F. palustris*, in addition to uncoated samples.

In the termite tests, the highest retention (2.6 kg/m^3) of ACQ was tested first. When this was effective, it was considered to be worthwhile to test specimens with lower retentions to avoid the excessive sacrifice of termites. Since this retention did not perform well, specimens at a target retention of 5.2 kg/m^3 were additionally prepared and tested with or without cut-end-coatings. Other specimens were treated with CA at a target retention of 2.0 kg/m^3 and included in the termite test in the same manner as ACQ-treated samples. The termite bioassay was conducted as described previously (Tascioglu and Tsunoda 2010). The results from the biological tests were compared to untreated and water-treated composites by an ANOVA test at a confidence level of $p > 0.99$ (MYSTAT, 2009).

2.6. Reference biological test using sapwood blocks of *Cryptomeria japonica*

Reference tests were carried out with untreated and vacuum-soak impregnated sapwood specimens of *C. japonica* measuring 20 (T) × 20 (R) × 10 (L) mm at the same target retentions (0.65, 1.30 and 2.60 kg ACQ/m^3) according to JIS K 1571 (Japanese Industrial Standard, 2004) to monitor the decay capacity of test fungi and termite vigor. Both weathered and unweathered specimens were tested.

3. Results and discussion

3.1. Thickness swelling

Smith and Wu (2005) reviewed chemical treatments of wood-based composites and stated that there are principally three methods that are applicable to the protection of wood-based composites (pretreatment of wood, in-manufacturing treatment and post-treatment of finished composites), and that pressure treatment with waterborne preservatives is impractical for composites such as OSB and PB, primarily due to undesirable swelling, strength reduction and the potential occurrence of