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Performance Characterization of Coatings on Treated-Wood

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ABSTRACT

Coating performance is greatly influenced by the properties of the wood substrate. This study was focused on evaluating the performance of coatings on both preservative- and thermally-modified wood. A number of commercially formulated semi-transparent stains (Alkyd, Alkyd-Acrylic and PU) were applied on four different types of preservative treated and oil-heat-treated wood and their performances were evaluated in natural weathering exposure in Toronto, Canada. The results showed that the treatment enhanced the performance of the coatings. This enhancement occurred by reducing the water uptake by thermal treatment and preservative treatment with chromated copper arsenate (CCA). Even though wood treated with Cu amine-based preservatives had a higher water uptake than untreated wood, the erosion and color change of coating on Cu-amine treated wood was significantly lower than on untreated wood. There were some water-based formulations that had overall better performance than solvent-based coatings on thermally treated wood. Prog. Color Colorants Coat. 6(2013), 61-65. © Institute for Color Science and Technology.

1. Introduction

One of the key elements in green building construction is the use of sustainable construction materials like wood. Wood products are desirable materials because they generate low greenhouse gas and acidic emissions at all life cycle stages, they come from a renewable source and have low energy requirements for processing. However, as a biological material, wood is susceptible to decay and weathering. To protect it from decay caused by fungi and insects, addition of preservative chemicals or modification of wood is required. Preservative treated wood, though protected from decay for long periods [1], does not withstand weathering degradation. Thermally modified wood imparts water repellency, decay resistance and dimensional stability to wood [2-5], but treated-wood is still susceptible to grey discoloration caused by UV exposure [6]. The application of coatings improves treated wood aesthetic appeal, and in addition has the potential to reduce the effect of weathering factors (moisture and UV) [6, 7].

Coatings available in the market are generally recommended for a broad range of wood products. Coating manufacturers usually do not consider differences in wood surface properties and how greatly they affect performance of coatings. An example of this

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would be the extension of application of coatings that were designed for chromated copper arsenate (CCA) treated wood to Cu-amine preservative treated wood.

To formulate a durable coating, one must know chemical and morphological characteristics of the substrate it is to be applied to, especially in the case of a complex substrate like wood. Developing environmentally friendly coatings which are compatible with each group of wood products and have low volatile organic compound (VOC) is a major challenge for the coating industry. To reduce the footprint of coatings in the environment, the first step is to increase coatings service life by improving their compatibility with different treated wood products. The main focus of this paper is to compare performance of coating on heat-treated wood with their performance on preservative-treated wood while exposed to natural weathering.

2. Experimental

A set of flat-grained southern pine (various hard pine – *Pinus* species) wood samples were treated with three different types of preservatives: CCA-C (47.5% Cr_2O3, 18.5% CuO, and 34% As_2O_5), ACQ-C (66.7% copper oxide, 33.3% quat as alkyl dimethyl benzyl ammonium chloride), and CA-B (96.1% copper, 3.9% tebuconazole). All preservative treated-wood samples were pressure treated to above ground retention (AWPA, 2006), and the samples were allowed to fix for 1 week at 50°C and 95% relative humidity. Another set of radial-grained southern pine wood samples were heated to 200°C in a hot soybean oil bath with 10% wax for three hours and left in an oven at 100°C over night to gradually cool down. An extra set of samples was used as untreated (control) samples.

Nine commercially formulated stains were applied only on the top of untreated wood and heat-treated wood samples (34mm x 112mm x 135mm) and their end grains were sealed by applying a thick layer of water-based white color paint formulated for exterior siding. All stains were applied twice based on manufacturer recommendations, except coating number one which was recommended as only one coat application; however, the total wet film thicknesses of all coatings were kept equally at 0.127 mm (5 mils). Additionally, five other semitransparent stains were applied by brush on the top surface and end grain of preservative treated wood samples (20mm x 140mm x 280mm). After one week of air drying, samples were exposed to natural weathering. More details of the preservative treatment and fixation schedule can be found in Nejad and Cooper 2011 [8]. Performance characteristics of semitransparent deck stains were evaluated during natural weathering for untreated wood samples and for samples treated with preservative chemical over three years and heat-treated wood samples over six months of natural exposure (Figure 1).

Figure 1: Coated-heat-treated and coated-untreated wood samples exposed to natural weathering before (left) and after six months (right)

The parameters measured were water permeability, color change, general appearance ranking and checking of the wood. The color change of samples was measured using a Konica Minolta Spectrophotometer (CM-2002) with the CIE L*a*b* color system in SCE (specular component excluded) mode. The color change (ΔE) was determined according to the following equation as outlined in ASTM D2244:

$$\Delta E_{ab} = (\Delta L^2 + \Delta a^2 + \Delta b^2)^{1/2} \quad (1)$$

The color changes of samples were measured after 1, 2, 3 and every three months thereafter. Coatings also were characterized for solid content, viscosity, and density. Viscosities were measured at 20°C using Brookfield dial reading viscometer with either spindle #1 at 20 rpm or spindle #2 at 20 rpm for higher viscosity coatings. Solids contents were determined based on ASTM D2369 test method in which 2 mL of each coating was placed on an aluminum pan and heated in an oven at 110°C for 60 min. Specific gravities of coatings were measured by hydrometer (G & W Instruments) at 20°C.

3. Results and discussion

All measured coating properties that were used for application on heat-treated wood are presented in Table 1. Details of the measured properties of coatings applied on preservative-treated wood can be found in Nejad and Cooper 2011 [9].

Among preservative treated woods, coatings had the best appearance ratings on CCA-treated wood with least coating surface erosion and fungal growth. Cu-amine treated wood had on average 50% higher water uptake than CCA-treated wood [8]. Thermally modified wood had on average about %40 lower water uptakes than untreated wood whether coated or uncoated as shown in Figure 2. This significant reduction in water permeability of wood after heat-treatment makes the heat-treated wood a great candidate for exterior structures such as fences and decks. During the six-month period of natural weathering, the maximum moisture contents of the two alkyd-solvent-based coatings (number 1 and 2) were lower than the other water-based coatings. Similar to preservative-treated wood, the effect of heat-treatment was higher than the effect of coatings in reducing water uptake from wood during natural weathering.

Although, thermally modified wood seemed to turn to grey almost at the same rate as untreated wood (in less than six months), the measured ΔE color changes of heat-treated wood were significantly lower than for untreated wood. Also, the results of the two-way ANOVA showed that not only the effect of coating and treatment were significant, but there was also significant interaction effect between coating and treatment at 95% confidence interval.

Table 1: Description of coatings and their measured properties.

ID	Resin	Base	Density (g/cm^3)	Solid Content (Wt%)	Viscosity (cps)
1	Alkyd	solvent	0.87	43	73
2	Alkyd	solvent	0.96	66	1004
3	Alkyd	water	1.01	33	882
4	Acrylic	water	1.02	10	21
5*	Alkyd	water	1.01	11	213
6	Alkyd-Acrylic	water	1.04	24	24
7**	Alkyd-Acrylic	water	1.04	27	23
8	Acrylic	water	1.05	22	352
9	Acrylic	water	1.03	24	59

*All coatings were semi-transparent except coating number 5 which was transparent stain.

**Coating number 7 is modified version of coating number 6 with addition of 1% adhesion promoter.

As an example of this interaction effect, it can be seen in Figure 3 that coatings number 3 and 4 both had significantly lower color change on heat-treated wood compared to their color change on untreated wood samples.

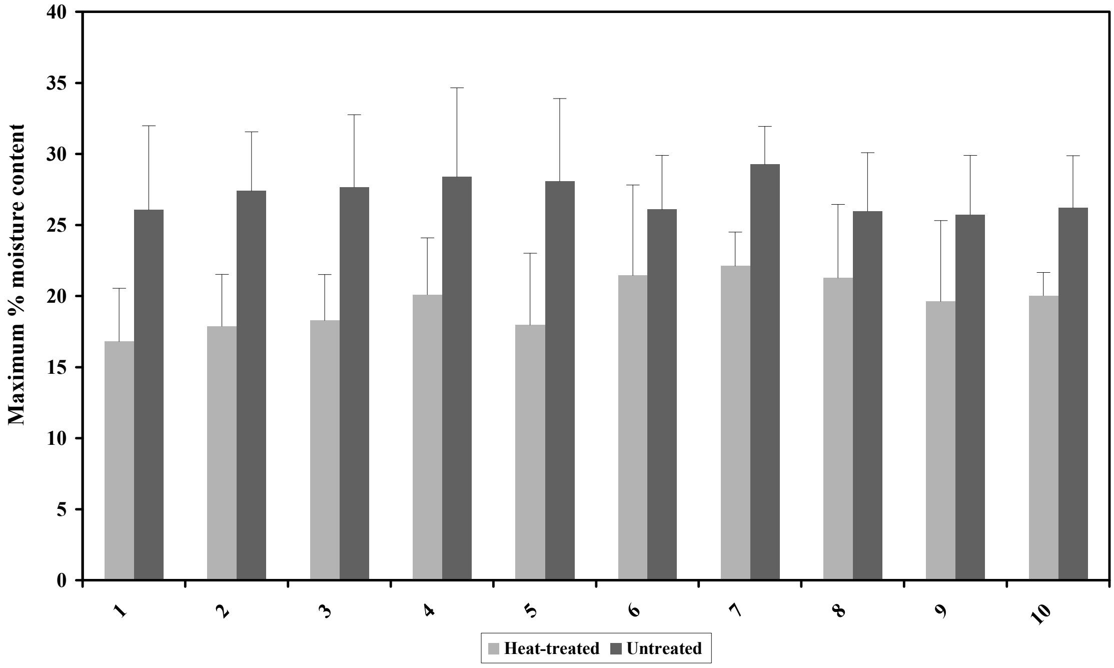

Figure 2: Maximum moisture content of coated and uncoated of untreated and heat-treated wood samples (average of five replicates).

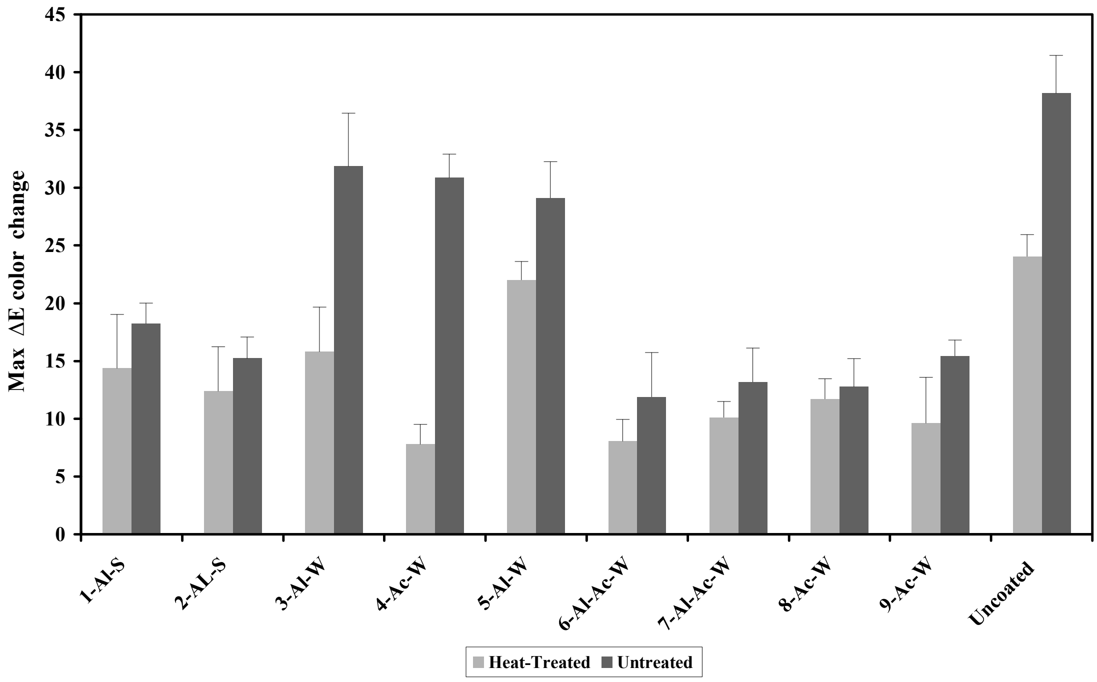

Figure 3: Maximum ΔE color change of coated and uncoated of untreated and heat-treated wood samples after six months of natural weathering (average of five replicates).

Transparent coatings are generally not recommended for exterior applications [10], and our results showed the same thing on oil-heat-treated wood samples. Coating number 5 which was a transparent formulation had the highest color change and ranked the same as untreated wood samples both on heat-treated and untreated wood samples. Among other coatings used on heat-treated wood study, up to this point, coating number 6 which is an alkyd-acrylic water-based coating performed the best. Overall, coating had better performance on both preservative and heat-treated wood than untreated wood such that lower color change, less erosion, and lower water-uptake (but only on CCA and heat-treated wood) were obtained.

4. Conclusions

When formulating a coating for exterior application on preservative or heat-treated wood structures, the surface properties of treated wood should be considered to achieve better compatibility and higher performance. For instance:

1. Coatings for application on Cu-amine treated wood should have higher water repellency than previously formulated coatings that were designed for application on CCA-treated wood.
2. Heat-treated wood has excellent water repellency and dimensional stability; therefore, when formulating a coating for application on heat-treated wood, the main focus should be on improving its adhesion and UV-stability.

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