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IMPROVING THE PERFORMANCE OF TRANSPARENT COATINGS

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Abstract

The objective of this project was to develop an economically, technically and environmentally viable transparent coating that will provide long-term weather protection without masking the natural colour and texture of wood. The project focused on: 1). preventing degradation of the underlying wood by light wavelengths penetrating transparent coatings; and 2). biocide combinations to extend duration of resistance to black stain fungi. The work done and the reports produced from this work are summarized in this report. Based on a critical review of the literature and the work done in this project over the past six years, the following recommendations can be made to optimize the performance of water-based transparent coatings on wood in exterior vertical applications. Use heartwood faces, round all corners, sand, even fresh wood, prime with an effective biocide combination and a visible light protection system, select a high performance coating virtually opaque to UV light with an optimum combination of water resistance and vapour permeability and with water-sheeting surface properties. Apply coating to a thickness of 60 microns. (2.4 mils)

1. Introduction

The project aimed to change the perception of wood products as high-maintenance building materials and to assist the industry in producing more value-added wood products. Wood used inside buildings is protected from weather and has a long service life, while wood outdoors, depending on application, deteriorates within a few years if it is not effectively protected against UV and moisture.

One of the reasons wood may not be chosen for outdoor decorative purposes is that it is regarded as a high-maintenance material. The decision was made to focus this project on high-end non-residential and recreational properties where wood is used not only for its structural properties but also for its natural look. Examples would include shopfronts, modern hybrid glulam/concrete/steel structures, including some Vancouver 2010 Olympic venues and housing, hotels, restaurants etc. at resorts such as Whistler BC. As the project proceeded, the opportunity was taken to work with the local developer of the best performing coating in field and lab tests, to re-focus this product towards the factory coating market. It was recognized that the best way to ensure reliable long-term coating performance is to apply it under factory controlled conditions.

This project initially focused on pre-treatments to prevent degradation of the underlying wood by light wavelengths penetrating transparent coatings. Not far into this project it was realized that equally important was the development of biocide combinations to extend duration of resistance to black stain fungi.

2. Methods

In general, Ponderosa pine sapwood and Douglas-fir heartwood were used as the test substrates. Both have been commonly used in millwork. Ponderosa pine sapwood holds coatings very well but is highly susceptible to the growth of black-stain, mold and decay fungi. Douglas fir heartwood has a wide differential between early wood and late wood density so it does not hold coatings quite as well but it is moderately resistant to black-stain, mold and decay.

The test methods were adopted and adapted from those of the USDA Forest Products laboratory with the assistance of Sam Williams and Peter Sotos. Basically, 2.4m lengths of nominal 1 x 6 inch board were divided into sections and each section was coated with a variant of the pre-treatment and coating system under test. Between three and five replicates were used for each experiment. The test boards were mounted at 45 degrees to the vertical facing south, normally at two test sites, one in Vancouver and the other at the Harrison Experimental Forest in Mississippi, courtesy of the USDA Forest Products Laboratory. Material was installed and inspected each year in May and November. Due to the timeframe of this project, new tests were designed without the benefit of long-term data from the previous tests. This necessitated testing a much wider range of permutations and combinations than would have been the case if the data from earlier tests could have been fully evaluated. As a result, some of the testing does not appear to follow a logical sequence when reviewed in retrospect.

An Atlas Weather-Ometer was also used for accelerated screening of UV resistance and a laboratory mold box test at a lower incubation temperature was also used for screening treatments to improve black-stain resistance.

3. Results and Discussion

The first step was to test commercial products reputed to be best in class. These results focussed attention on a water-based two-coat two-step polyurethane-based film-forming coating that had also shown excellent performance in earlier testing. An agreement was reached with the developer of this coating (Coating B) to use it as the vehicle for most of the further testing. A transparent water-based exterior urethane varnish, with considerably less UV screening capability (Coating A), was also used in most tests to generate faster results.

During the course of this project other coatings that came to the attention of FPInnovations staff were tested but none matched the performance of Coating B in laboratory and field tests The one that came closest in field and Weather-Ometer performance is a well known solvent based two-step film-forming coating. This product has almost the same light absorption spectrum as Coating B (see below).

The first field test in this project also evaluated a variety of surface preparation techniques to improve bonding. Sanding with 100 grit sandpaper doubled the projected life of Coating B but had no effect on the well known solvent-based two-step coating. This is likely because sanding reduces the acidity of wood surfaces caused by ageing, even in the absence of weathering, and the resins in water-based coatings are highly sensitive to surface acidity.

A series of field and laboratory tests evaluated primers with various combinations of hindered amine light stabilizers (HALS), UV absorbers (UVA) and additives intended to dissipate the energy absorbed by UVA. In most of these tests the UVA Tinuvin 1130 (Ciba) was the only effective pre-treatment to absorb the wavelengths passing through coating B. No other additives provided additional benefit. A field test showed the HALS Lignostab (Ciba) had a beneficial effect in reducing early darkening of wood due to light exposure.

The original formulation of coating B contains a combination of organic UV protectants, plus transparent iron oxide and a proprietary inorganic UV blocker. In collaboration with the developer of Coating B, a series of formulations with increased levels of UV protection were put into test. Unfortunately these coatings failed to black staining fungi before showing any differences in weathering resistance and most modifications had negative effects on black stain resistance suggesting interference with the solidity of the coating.

A laboratory test to evaluate the absorption spectrum of coatings and UV protectants was developed using our UV/Visible spectrometer. This enables preliminary screening in a matter of minutes rather than months for a Weather-Ometer test and years for a field test. A comparison of the light absorption spectra of commercially available coatings showed that Coating B had the highest absorption in the violet part of the spectrum. Research in Japan has shown the high energy violet end of the visible spectrum can do considerable damage to wood over the long term.

A field test of a range of coating thicknesses showed a major improvement in resistance to black-stain increasing from two coats through five coats but no further. Measurement of coating thickness showed five coats had a thickness over 60 microns (2.4 mils).

A series of formulations of Coating B with alternative biocides applied to Ponderosa pine sapwood failed to black stain fungi within one year of field exposure. There were two patterns of attack and some biocides protected against one and other biocides protected against the other. A laboratory test confirmed the two different patterns were associated with two different fungi. IPBC was better able to control *Aureobasidum pullulans* and Propiconazole was better able to control *Epicoccum purpurascens*. A combination of IPBC and Propiconazole gave the best performance but was still unable to control one of the *Aureobasidium* strains. Clearly a three-biocide system was required and suitable candidates were selected based on the results of the earlier field test, taking into consideration the likelihood of being able to register these actives with Canada's Pest Management Regulatory Agency. A laboratory experiment showed higher loadings of IPBC and Propiconazole or combinations of IPBC and Propiconazole with Tebuconazole, Thiabendazole and Oxine copper were most effective.

A major field trial of three-biocides in the coating showed reduced efficacy of Coating B, possibly due to the additional formulating agents disrupting film integrity. There was no apparent pattern to the variation among the ratios of IPBC and Propiconazole or any benefit from the addition of Thiabendazole, Tebuconazole or Oxine Copper. Clearly the repeated lesson from all this work is to not reformulate Coating B but rather ensure that it is applied properly and improve its performance with a primer.

A combination of IPBC and Propiconazole pre-treatment gave good protection in a laboratory weathering and fungal exposure tset but failed to black stain, even with zinc oxide, in a field test. Clearly a three-biocide system was required and zinc oxide was not a useful candidate. In a major trial of three-biocide pre-treatments with or without the light protection system, pre-treatments containing the light protection system showed dramatic improvement in black stain resistance. This was likely due to reduction in lignin breakdown which releases carbon compounds the black stain fungi use as food. Earlier laboratory testing had shown no direct effect of the UV protectants on black stain fungi. The benefits from the light protection system were greater than any of the third biocides added. There was no apparent benefit to the addition of Thiabendazole, Tebuconazole or DDACarb. Further work is required on three-biocide systems but this should probably be done by preservative manufacturers since relationships among active ingredient manufacturers and preservative formulators tend to control which combinations of biocides can be commercially used.

Another difference between Coating B and other coatings, with higher gloss, was the rate of drying after rain and dew. Coating B caused sheeting of water and the thin film dried out within minutes after rain stopped. Most other coatings caused beading of water which took an hour or more to dry out due to the smaller surface area to volume ratio. Spores of black-stain fungi would have less time to germinate and form an adhering transpressorium before drying out on Coating B than if they were inside, or at the edge of, a water droplet on another coating.

The information developed in this project has already been used to help advise, through WoodWorks staff, engineers and architects specifying coatings for Olympic venues, Skytrain stations and other high-visibility non-residential uses of wood. It has also been used to develop web content for the www.durable-wood.com web site jointly run by FPInnovations – Forintek Division and the Canadian Wood Council.

4. Conclusions

Key findings from this work, literature reviews and discussions with experts in the field have enabled the development of requirements for maximizing the longevity of transparent coatings on wood.

- Use heartwood faces

- Round all corners
- Sand, even fresh wood
- Pre-treat with an effective biocide combination and a visible light protection system
- Selection of a coating
    - virtually opaque to UV light
    - with an optimum combination of water resistance and vapour permeability
    - with water-sheeting surface properties
- Coating application to a thickness of 60 microns. (2.4 mils)

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