Solid Color Deck Stains: *Trends, Substrates, and Formulation Study*

by Greg Monaghan
Rohm and Haas Company*

The changing decking market offers new products to consumers and new challenges to coatings manufacturers. The voluntary phase out of CCA-treated wood for residential applications at the end of 2003 opened up the decking market to new wood treatments as well as composite decking materials usually composed of wood fibers and recycled plastics. Solid color stains which are used to coat these substrates need good adhesion on weathered and unweathered composite substrates, abrasion resistance, stainblocking, and exterior durability. In addition, government regulations are forcing solid color stains to have lower VOC levels and many stains are now formulated from bases with high loadings of universal colorant. Background information on new decking substrates will be presented in this article along with data from an evaluation of acrylic binders in VOC-compliant solid color stain formulations for these substrates.

INTRODUCTION

Despite a slowing of new housing starts, growth in the use of decking materials is expected to remain strong. As existing decks reach the end of their useful lifespan, homeowners will be purchasing decking materials to repair or replace them. The use of wood plastic composites is expected to grow and new types of treated wood are now being sold to replace the chromated copper arsenate (CCA) decking. Formulating coatings which can be used on these wood plastic composite substrates, on weathered CCA decking, and on the new types of wood treatments can present significant challenges to the coatings manufacturer.

CCA AND NEW WOOD PRESERVATIVES

Chromated copper arsenate wood preservatives were withdrawn from the market for residential use in 2003. The remediation of existing CCA-treated

Presented at the 9th International Conference on Wood & Biofiber Plastic Composites, May 21-23, 2007, Madison, WI, sponsored by the USDA Forest Service Forest Products Laboratory and the Forest Products Society.
To be presented at the FSCT Advancement in Coatings Series, "Coating Wood and Wood Composites: Designing for Durability," July 23-25, 2007, in Seattle, WA.
*Charlotte Technical Center, 8901 Research Dr., Charlotte, NC 28262.

decks may present an opportunity to the coatings manufacturer as well as a challenge. Studies have found that coating the decks can significantly reduce leaching of chromium and arsenic from the CCA wood and solid color or semitransparent deck coatings may be used by homeowners who are concerned about CCA exposure.[1] A significant problem with reducing exposure in this way is that coating old, severely weathered CCA decks can lead to rapid cracking and flaking of many of the currently commercially available solid color deck stains. The current EPA coating recommendation to reduce possible exposure to the chemicals in CCA decks is to use semitransparent deck stains because the surface preparation to recoat a cracked or flaking deck coating (such as sanding or powerwashing) can increase exposure to arsenic.[2] Flexible solid color deck stains which can resist cracking on these weathered decks but which also are hard enough to resist dirt pick up and resist abrasion under foot traffic are needed. Since even the most flexible solid color stains will eventually fail on severely weathered decking, the importance of regular maintenance of solid color deck stains will need to be stressed.

Several types of CCA replacement wood treatments have been introduced. The most widely used replacements for CCA treatment are ACQ (alkaline copper quaternary compound), copper boron azole (CBA) and copper azole (CA-B) treatments. These new wood treatments have a somewhat different performance profile than the CCA treatment although these differences may be more apparent to the coatings chemist than a homeowner. The uncoated wood with the new wood treatments or treated wood with a semitransparent stain might be expected to be more UV sensitive than CCA-treated wood since the chromium in CCA is a free radical quencher and crosslinking agent for lignin.[3] The CCA replacements are also less resistant to mildew than CCA and mildewcides are sometimes incorporated into the new treatment formulations to prevent mildew growth as the boards are seasoned. Finally, higher use levels of the new treatments are required to give performance equal to the CCA treatment. The higher concentrations of copper can lead to more discoloration of coatings if the decking has not been adequately seasoned before being painted.

ACQ is composed of 66% copper compound and 33% of a quaternary ammonium compound, didecyldimethylammoniumchloride (DDAC).[4] Both the copper and the quaternary ammonium components are effective against wood destroying fungi and insects which ingest the wood. Insects which do not ingest the wood such as carpenter ants or borer beetles are not affected by ACQ treatment.[5] Although the copper in ACQ is broadly effective against most fungi, it is not effective against all types of fungi so it cannot be used as the sole preservative. The use of the DDAC as a cobiocide along with the copper gives ACQ-treated wood very good resistance to fungi. The most commonly used form of ACQ uses ethanolamine as the carrier solution (ACQ-D). Recent research indicates that the ACQ-D is relatively leach resistant because of chemical fixation reactions within the wood which occur rapidly—within hours—after treatment.[6] The fixation reaction for ACQ-D begins in part with the rapid formation of insoluble copper–amine–wood complexes and on aging gives insoluble copper compounds in the wood. ACQ-B is another form of the preservative which uses ammonia as the carrier instead of ethanolamine. Ammonia helps the ACQ-B to penetrate into more difficult-to-treat woods like Douglas Fir and the ACQ-B is used primarily on the West Coast where these species are more commonly used as building materials. ACQ-B does not undergo the same rapid fixation reactions as the ACQ-D and the wood needs to be kiln dried or seasoned adequately in outdoor exposure to be sure that the fixation has occurred.[7]

CBA or copper boron azole preservatives are typically composed of 49% copper, 49% boric acid and 2% of an organic triazole such as tebuconazole[8] or propiconazole. As in the ACQ, the copper in CBA is effective against most fungi and insects but needs an auxiliary fungicide. Boric acid is effective against insects and fungi but it is water soluble and is subject to leaching from the wood. Tecbuconazole is an effective fungicide and is leach-resistant in the wood but its effectiveness as an insecticide is still uncertain.[9] Propiconazole is also an effective fungicide but it is considered ineffective as an insecticide.[6] CBA treatment is now being generally supplanted by the recently approved Copper Azole treatment (CA-B) which does not have boron and has higher levels of copper and triazole. CA-B is 96% copper and uses 4% organic triazole as the co-biocide and is usually used in an ethanolamine carrier.[6,10]

Some special precautions are needed in constructing decks using lumber with these surface treatments. Wood treated with these preservatives can cause more corrosion than CCA-treated lumber,[11] so stainless steel or hot dipped galvanized fasteners are typically recommended. The treated woods should also not to be used in contact with aluminum and a ¼-in. space between treated boards and aluminum siding is usually recommended.

Both types of preservative can be made with added wax for water repellency. If the wood is treated with water repellent, the manufacturers recommend weathering for 30–60 days before applying an oil-based stain or weathering for six months before applying an aqueous stains. In our laboratory testing, we have found that most commercial water based solid color stains have good adhesion to unweathered wax-treated lum ber and that the six month weathering may not be necessary.

Freshly treated ACQ and CBA lumber is often a greenish brown color and will turn to a light tan color after exposure to sunlight. Both types of wood treatment can be painted or stained as long as the boards have a chance to weather and become seasoned. If they are painted or stained before the wood is seasoned, the preservatives may discolor latex paints or stains. Some laboratory screening was done to find latex stains which might block or prevent this discoloration but no effective stain blocking method was found. The best way found to avoid this discoloration is to allow the treated wood to weather for one month before painting or staining.

COMPOSITE DECKING

There are many types of wood plastic composite (WPC) decking now available. The composite boards are about two to three times as expensive as treated wood. ACQ-treated yellow pine is $6.97 for a 12-ft board while most composite decking starts at $19.00–$20.00 for a 12-ft board. For a finished deck surface, many of the less expensive wood plastic composites are similar in price to cedar decking or exotic hardwoods such as IPE.

There are usually several products with different finishes available from each composite decking manufacturer. Most of the boards are made with recycled plastic and wood flour or other fibers. Although most composite manufacturers market their products as being relatively maintenance free, there are several reasons why people may want to paint them. A homeowner who wants to match the color of the deck to the color of the trim of his house may paint new composite decking. Many composite boards also will have a significant color fade to gray upon exposure to UV light and may need to be repainted to restore the original color. Finally, wear patterns or staining of the weathered composite decking may make coating them desirable. The composite decking can be easily stained by grease or oils from barbecue grills. These stains are not easily removed and sanding them off is not usually recommended since it can remove the embossed wood grain. Different composite manufacturers have different recommendations for coating their products. Most recommend weathering the panels for two to three months before coating but a few manufacturers specifically recommend that their products not be coated at all.

Composite substrates are a more stable substrate than wood decking, and do not have the same tendency to cracking; however, they offer a few challenges for the coatings manufacturer. The trend towards using an embossed wood grain on the composite board may mean that a coating will need to be harder and more abrasion resistant in order to avoid both wear on the raised areas of the embossing and excessive dirt pickup in the low areas. Adhesion to the different plastics used in the composite boards can also be a significant problem, depending on the ratios of wood fiber and polymer used, as well as the use of release agents during board manufacture. The recycled feedstocks used in the boards can vary depending on the availability of the source materials, so there is a potential for significant substrate variation which could affect adhesion of the coatings. Another potential problem with many types of composite decks is tannin staining. The wood fibers used in some types can come from oak or other high tannin species, so there can be a significant discoloration of solid color stains. Finally, weathered composite boards may include chalk which can reduce the adhesion of deck coatings.

Although there are now deck coatings on the market designed specifically for composite decking, a deck coating can be sold more widely if it can be used for both composite and wood decks. To be used for both substrates, the solid color stain needs to have excellent crack resistance on weathered wood decks as well as good abrasion resistance and good dirt pick-up resistance on both new and weathered composite decking.

TESTING PROCEDURES

Wet adhesion tests are designed to measure paint's ability to retain its grip in the presence of bulk moisture (heavy rains, panel washing procedures, etc.). While grid tape, knife peel, and blistering resistance tests are commonly employed to evaluate wet adhesion, Rohm and Haas chemists also rely heavily on the so-called "force to peel," or "weighted pull," test for this purpose. Chemists find this method particularly appealing because it provides a quantitative measure of wet adhesion that is less subjective than crosshatch and knife peel tests. As in the case of other wet adhesion procedures, it is typically conducted on a variety of substrates including aged gloss alkyd and chalky oil, latex paints, and bare wood.

In the force to peel wet adhesion test, the investigator applies 2.5 g of a test paint to a 1½ in. x 6 in. section of the substrate with a 1 in. brush. As soon as this process is completed, the investigator centers a 1½ in. x 9 in. strip of cheesecloth directly over the coated section of the substrate so that 1½ in. of the strip extends beyond the upper and lower edges of the fresh paint. While embedding the cheesecloth in the first coat of paint, the investigator covers the cheesecloth with 7.5 additional grams of paint. The painted panel then is cured at a controlled temperature and humidity after which two parallel lines are inscribed through the cheesecloth and into the substrate (1/4 in. from each side border along the entire length of the strip). The two cut lines create a 1 in. strip in the cheesecloth. The panel is then placed in a fog box for 30 min or more depending on the severity of the test. When conditioning is complete, the board is removed from the fog box and attached to a ring stand with the painted side horizontal and tilted forward from the perpendicular. A weight hanger is then attached to the top edge of the cheesecloth with a paper clip or "S" hook. Next, the investigator begins adding weight to the hanger until the cheesecloth begins to peel at a rate of 10 to 20 mm per minute. The weight (grams) at which this degree of peeling occurs is recorded as the score for the paint.

Early water resistance is also an important property for solid color stains. Stains which have poor early water resistance may have color tracked from the deck into the house if the deck is subjected to foot traffic after an overnight dry when there is dew on the deck. Early wet color rub off was tested on drawdowns that were dried overnight and then rubbed with a wet paper towel for 30 strokes. Paints are rated on the amount of color transferred to the towel.

Tannin stain blocking was also evaluated by applying two coats with a four-hour dry time between coats, and then placing the wet panel in high humidity for 16 hr. In this severe test, the tannins are drawn into the wet topcoat and differences between solid color stains can be easily seen.

Resistance to household stains was tested by applying the test chemical to the paint, allowing it to sit for one hour, then removing excess and cleaning the stained areas with 200 cycles using a 1% Tide solution. The Delta E was then taken between the stained, cleaned area and was compared to unstained areas.

To estimate abrasion resistance of the stains in the laboratory, Taber abrasion tests were run for two coats of the solid color stains on plywood substrate. In this test the panels were run for 600 cycles using a CS-17 abrading wheel and 500 g weights. Weight loss for the panels was reported, and lower numbers indicate better abrasion resistance. These numbers were taken as an indicator of abrasion resistance but the two-year footbridge exposures of these solid color stains on composite decking substrates were used for the final analysis of abrasion resistance.

TEST RESULTS

An experimental 100 VOC solid color stain neutral base formulation was prepared. This stain had a PVC of 26.3% and a volume solids of 28.4%. It was thickened with Acrysol RM-2020NPR and Natrosol 250 HBR and contained 20 lb of zinc oxide. These neutral bases were tinted with 11 oz/gal of universal colorants to a cedar color. Several binders were evaluated including a conventional exterior acrylic and a new ambient temperature crosslinking acrylic which has excellent grain crack resistance and good adhesion to a variety of substrates. Six commercial solid color stain controls ranging from 100 to 250 VOC were also tested. The commercial controls were also neutral bases and were tinted with the same levels of universal colorants as the experimental paints.

On unweathered treated wood, all solid color stains had good adhesion. On three-month weathered treated wood, however, there was a significant difference in the adhesion (see *Table* 1). The ambient temperature crosslinking acrylic had very good adhesion and was equal to the best of the commercial controls. The effect of the binder chemistry can be seen by comparing the conventional acrylic to the ambient temperature crosslinking acrylic in the same formulation. The stain based on the conventional acrylic polymer had lower wet adhesion to the weathered treated wood than the stain based on the ambient temperature crosslinking acrylic polymer.

On composite decking, the adhesion was different than on treated wood. The weathered composite decking was the easiest to adhere to and most stains performed well, but adhesion on the unweathered composite decking was much more difficult (see *Table* 2). The ambient temperature crosslinking acrylic had very

Table 1—Adhesion to Weathered Treated Wood

Deep Base Solid Color Stain—11 oz Colorant	Water-based Commercial Controls (6)	Acrylic Ambient Crosslinking Polymer	Conventional Acrylic Polymer
VOC	100–250	<100	<100
Wet Adhesion by Force to Peel Method (grams to failure)			
CCA	N/A	N/A	N/A
CBA	850 ± 400	1050	850
ACQ with wax	850 ± 600	1250	850
ACQ	1000 ± 600	1350	750

Table 2—Adhesion to Unweathered Composites

Deep Base Solid Color Stain—11 oz Colorant	Water-based Commercial Controls (6)	Acrylic Ambient Crosslinking Polymer	Conventional Acrylic Polymer
VOC	100–250	<100	<100
Wet Adhesion by Force to Peel Method (grams to failure)			
Composite #1	350 ± 100	950	450
Composite #2	350 ± 100	750	350
Composite #3	450 ± 100	850	450
Composite #4	550 ± 100	850	750

Table 3—Stain Blocking and Stain Resistance of Solid Color Stains

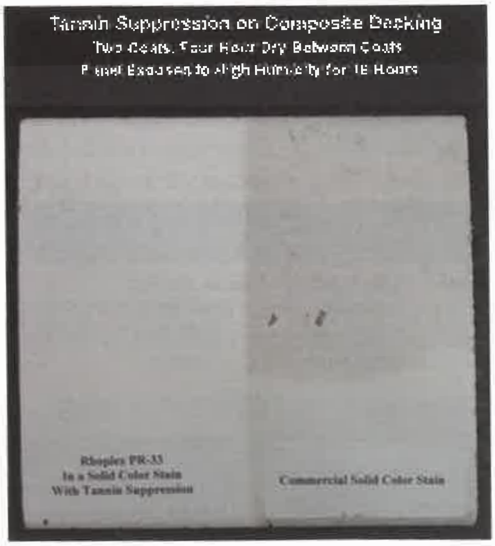
Solid Color Stain—Pastel Base	Water-based Commercial Controls (4)	Acrylic Ambient Crosslinking Polymer	Conventional Acrylic Polymer
Tannin (Redwood) 1–10, 10 Best	3–4	8	3
Tannin (Cedar) 1–10, 10 Best	3–4	8	3
Stain Removal (tea) ΔE	14–21	1.0	14
Stain Removal (grape juice) ΔE	5.7–8.0	1.2	7.9

good adhesion to the unweathered composites and was better than the commercial controls or the conventional acrylic polymer. Pastel base formulations of the commercial stains were slightly better for adhesion than the neutral bases but were still not as good as the solid color stain based on the ambient temperature crosslinking acrylic polymer.

New 100 VOC stain blocking formulations have also been developed to block tannin stains in pastel bases (see *Table* 3). These formulations are based on HEUR thickeners and hydrophobic dispersants to maximize the tannin stain resistance. Zinc oxide is used to help tie up tannins in the first coat and keep it from migrating into the topcoat. The ambient temperature crosslinking acrylic polymer had excellent tannin stain blocking in two coats while the commercial solid color stains and the stain based on the conventional acrylic polymer were poor for this property (see *Figure* 1).

In neutral bases, the tannin suppression is less than in the pastel bases because of the surfactants in the colorants, but testing has shown that even in the neutral bases most of the tannins are blocked in a stain based on the ambient temperature crosslinking acrylic. On severely bleeding boards which do bleed into the neutral bases, a third coat of the solid color stain based on the ambient temperature crosslinking acrylic was effective at blocking the tannin.

Figure 1—Tannin suppression on composite decking.



Resistance to common hydrophilic food stains is also an important property for decks. The tight film formed by the ambient temperature crosslinking polymer gave a deck stain which was very resistant to food stains and was significantly better than the commercial controls. The contribution of the polymer chemistry can again be seen in the difference in the stain resistance between the conventional acrylic and the ambient temperature crosslinking acrylic in the same formulation.

Even in a neutral base formulation with 11 oz of universal colorant, the stain based on the ambient temperature crosslinking acrylic had very good early water resistance as tested by the wet color rub off method (see *Table* 4). Lab testing of the Taber abrasion resistance was also promising with the ambient temperature crosslinking acrylic having very low levels of weight loss compared to the controls or the conventional acrylic polymer.

Although lab testing of the adhesion and abrasion resistance is an indicator of performance, the best test of the solid color stains is to actually have them exposed to foot traffic on exterior exposure. These stains have now been exposed on footbridges for 2.5 years at the Rohm and Haas Exposure Testing fence. They were applied to several different types of weathered composite decking as well as weathered treated wood. Some of the commercial controls are beginning to fail by cracking and flaking on the weathered wood but the solid color stain based on the ambient temperature acrylic polymer is showing very good durability with no cracking or flaking on weathered wood and very good dirt pick-up resistance. We are not finding any significant abrasion or film removal on high areas of the embossed composite substrates for any of the stains but this may be because composite decking in this footbridge exposure was preweathered for three months before coating. This might have been predicted from the lab results since most solid color stains had good adhesion to weathered composite decking.

Table 4—Water and Abrasion Resistance of Solid Color Stains

Deep Base Solid Color Stain—11 oz	Water-based Commercial Controls	Acrylic Ambient Crosslinking Polymer	Conventional Acrylic Polymer
Wet color rub off—Cedar 1 coat 30 cycles by hand	Very Poor-Excellent	Very Good	Very Good
Taber Abrasion 400 cycles	.0644 ± .0494	.0291	.0418

CONCLUSION

New substrates for decks present coatings formulators with new challenges. In addition to the traditional performance requirements for solid color decking stains, coatings designed for the new substrates must have excellent adhesion to unweathered composite decking and treated woods. The coatings are also expected to perform as well as interior floor paints with good stain resistance, grease resistance, and be easy to clean up. They should be flexible enough to have good crack resistance on weathered wood decking but also be hard enough that they resist dirt and abrasion on composite decking.

Solid color stains based on new ambient temperature crosslinking technology can be formulated to offer a very good balance of properties which are superior to most commercial latex solid color stains. Stains based on the ambient temperature crosslinking polymers can be formulated to work well on both weathered treated wood and composite decking.

These ambient temperature crosslinking stains can be formulated into neutral bases with excellent water resistance and abrasion resistance, and which offer much better tannin and household stain resistance than conventional acrylic polymers. The ambient temperature crosslinking polymers also have better adhesion to unweathered composite decking than conventional acrylic polymers and excellent crack resistance on weathered wood. Long-term exposure tests of these ambient cure crosslinking polymers have shown that they also have excellent exterior durability under foot traffic

ACKNOWLEDGEMENT

The author would like to express his appreciation to Ms. Shelly Fox and Ms. Martha Wittek, not only for the sample preparation and applications testing, but also for their significant contributions to the project design and the interpretation of the results. CT

References

(1) Lebow S., "Coatings Minimize Leaching from Treated Wood." USDA Forest Products Laboratory, Nov. 2001, June 2007, www.fpl.fs.fed.us/...ngs-minimize-leaching-from-treated-wood.pdf.

(2) "Studies Provide Public with Updated Information on CCA-Treated Playground and Decks," U.S. Environmental Protection Agency. May 2005, June 2007, http://yosemite.epa.gov/opa/admpress.nsf/d9bf8d9315e942578525701c005e573c/eabcba60dbba6cfe8525702e0059bd15!OpenDocument.

(3) Williams, R.S. and Feist, W.C., "Durability of Coatings on Wood Treated with Chromium Salts," *Proc. of the Polymeric Materials Science and Engineering Division*, Vol. 68, Spring Meeting, American Chemical Society, Washington, D.C., 216-217, 1993.

(4) "Chromated Copper Arsenate (CCA): ACQ—An Alternative to CCA," U.S. Environmental Protection Agency, 2006. June 2007, http://www.epa.gov/oppad001/reregistration/cca/acq.htm.

(5) Chemical Specialties Inc., Preserve Fact Sheet. www.treated-wood.com/products/preserve/faq.html, 2001.

(6) Humar, M., Zlindra, D., and Pohleven, F., "Fixation of Copper-Ethanolamine Wood Preservatives to Norway Spruce Sawdust," *Acta Chim. Slov.*, 54, 134-139 (2007)

(7) Lebow, S. and Tippie, M., "Guide for Minimizing the Effect of Preservative-Treated Woods on Sensitive Environments," Forest Products Laboratory, USDA Forest Service, Feb. 2001, 28 p., June 2007, www.fpl.fs.fed.us/documnts/fplgtr/fplgtr122.pdf.

(8) "Chromated copper arsenate (CCA): Copper Azole --An Alternative to CCA," US Environmental Protection Agency, 2006, June 2007, http://www.epa.gov/oppad001/reregistration/cca/copperazole.htm.

(9) Ibach, Rebecca E., "Wood Preservatives," In: *Wood Handbook: Wood as a Engineering Material*, Forest Products Laboratory, USDA Forest Service. 28 p., March 1999, www.fpl.fs.fed.us/documnts/fplgtr/fplgtr113/fplgtr113.htm.

(10) Lebow, S., "What's in that Pressure-Treated Wood?," USDA Forest Service, Forest Products Laboratory, July 2007, 3 p., www.fpl.fs.fed.us/documnts/techline/whats-in-that-pressure-treated-wood.pdf.

(11) Cushman, T., "New Wood Treatments, May be More Corrosive," *J. Light Construction*, Sept, 2004.