DECK RESTORATION COATINGS

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Wood decks are popular home features that add outdoor living space but require regular maintenance to preserve aesthetics and functionality. Transparent, semi-transparent, and opaque wood stains help to protect wood from UV degradation, dirt accumulation, and weather-related discoloration when applied at recommended intervals, but these are not viable options for treating and coating wood deck substrates that have been poorly maintained to the point of becoming cracked and splintered. Targeting decks that fall within this segment, a unique and growing category of thick-film coatings has emerged based on the value proposition of restoring instead of replacing well-weathered decks. Within this space, scientists have identified key binder performance properties necessary for coating product differentiation and have further defined a screening protocol based on predictive lab tests that show correlation to real-world exterior performance. This protocol was used to screen a broad set of novel binder technologies for key performance properties, resulting in the development of two new binders designed to meet the specific needs of deck and concrete restoration coatings.

INTRODUCTION

For many homeowners, the thought of a wood deck brings happy memories of summertime barbeques and backyard get-togethers. Contemplating the rigors of regular deck maintenance, however, often triggers less-than-happy thoughts. Keeping a wood deck in optimal shape—or even simply useable shape—requires considerable diligence and effort. As a natural material, wood is highly susceptible to degradation brought on by exposure to the outdoor elements, including direct sunlight, rain, ice, and snow. For example, it is well known that exposure to ultraviolet (UV) light from the sun degrades the surface of wood.[1] Early stages of this wood degradation, combined with exposure to dirt and moisture, alter the appearance of the wood from its initial golden honey color (see *Figure* 1a) to a silvery gray (*Figure* 1b).

Despite the challenges associated with maintenance, wood decks remain a very popular home feature. According to the North American Deck and Railing Association, there are roughly 30 million wood decks in the United States, and that number is growing.[2] Commercial products ranging from clear wood protectors to semi-transparent stains

Figure 1a–c—Effects of outside exposure on wood aesthetics over time.

Table 1—Key Features of Commercial Deck and Concrete Restoration Coatings (per labels/literature)

Low VOC (<50 g/L)
Encapsulates splinters
Fills/hides cracks up to ¼ inch
Two full coats are required
Apply at low spread rates compared to typical wood stains or house paints

to solid-colored opaque stains are commonly used to help protect and to add to the visual appeal of aging wood decks. These products offer effective protection when re-applied at recommended intervals. Extending the cycle beyond the recommended timeframe, however, can leave the wood cracked, splintered, and—for all intents and purposes—unusable (see *Figure* 1c). Once this occurs, replacement of the deck is often the choice of the homeowner in order to regain useable outdoor space. In fact, a 2009 CINTRAFOR (Center for International Trade in Forest Products) survey of builders found that over 43% of deck construction projects were repair or replacement of decks, often driven by aesthetic issues rather than structural ones.[3,4]

Over the last few years, a unique coating segment has emerged that offers a different option for consumers with structurally sound but unattractive, very well-weathered wood decks. Referred to as deck and concrete restoration coatings (since the products are marketed for use on concrete patios as well as wood decks), products in this segment are applied in two very thick coats and claim the ability to help hide cracks and help encapsulate splinters in distressed wood. *Table* 1 shows a compilation of property claims and coating attributes that appear consistently on the labels and literature of commercial deck restoration products.

As demonstrated by anecdotal information and the introduction of multiple products within this segment, the value proposition for deck and concrete restoration coatings is resonating with both

Table 2—Laboratory Screening Protocol for Deck and Concrete Restoration Coatings

Region (A) and (B)—Adhesion (Wet and Dry)	ASTM Reference
Knife peel (1 and 7 day dry time)	D6677
Pull-off	D7234[a]
Region (C)	
Abrasive scrub resistance	D2486
Taber abrasion	D4060
Direct impact resistance	D2794
Accelerated dirt pick-up resistance	Dow Method
Spot stain resistance	D1308
Region (D)	
Mandrel bend flexibility	D522
Thermal cycling	D6944[a]

(a) method modified

the homeowner and the paint formulator alike. For the formulator, the sales volume potential of this type of product is great compared with traditional wood deck stains. For example, it would take two gallons of a standard deck stain for a two-coat application on an average-sized deck (350 ft^2 as reported in the 2009 CINTRAFOR survey[4]), versus five to seven gallons of a deck restoration coating at the commonly recommended coverage rate of 100–150 ft^2/gal *per coat*. This equals roughly three times the volume of a traditional stain, but compared to the alternative of full deck replacement, the value proposition for the homeowner is still highly attractive.

DEVELOPING PREDICTIVE TESTS AND A SCREENING PROTOCOL

While real-world exposure performance is the ultimate litmus test for any exterior coating technology, accurate predictive testing in the lab can help to accelerate the development of new coatings categories. The development of a sound testing protocol for a two-coat, thick-film deck and concrete restoration coating began with consideration of the coated substrate and its intended real-world use. As shown in *Figure* 2, four key regions of focus were identified as follows: (a) the substrate-

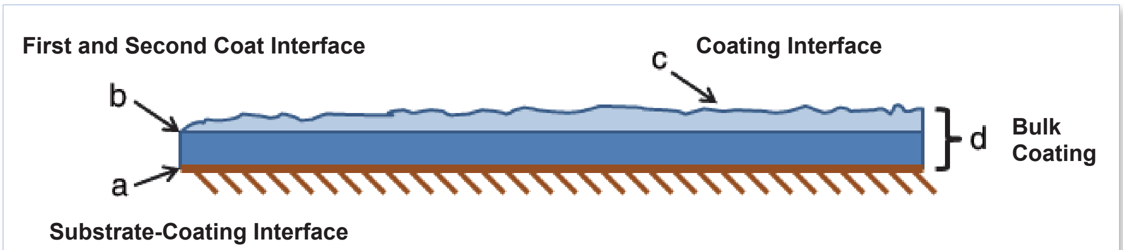

Figure 2—Illustration of key regions in two-coat thick-film deck and concrete restoration coating.

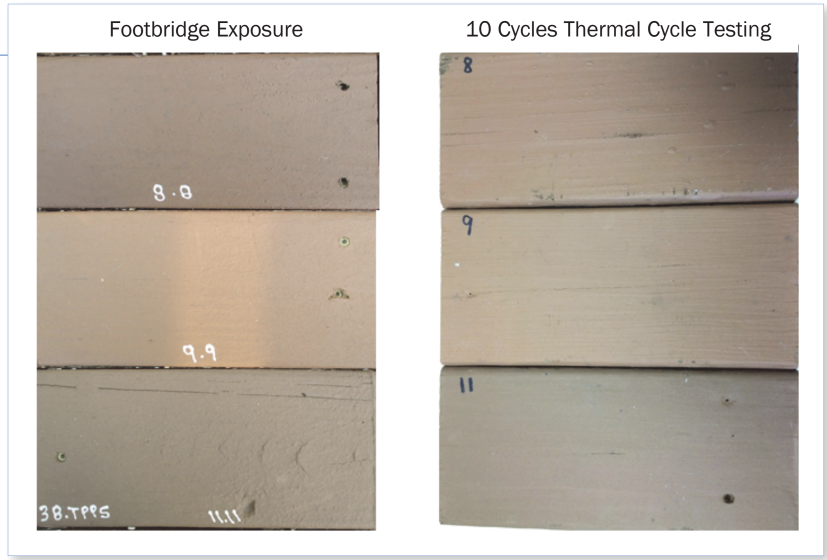

Figure 3a—Comparison of footbridge exterior exposure (left) vs thermal cycling testing (right) on cracking failure and blister development.

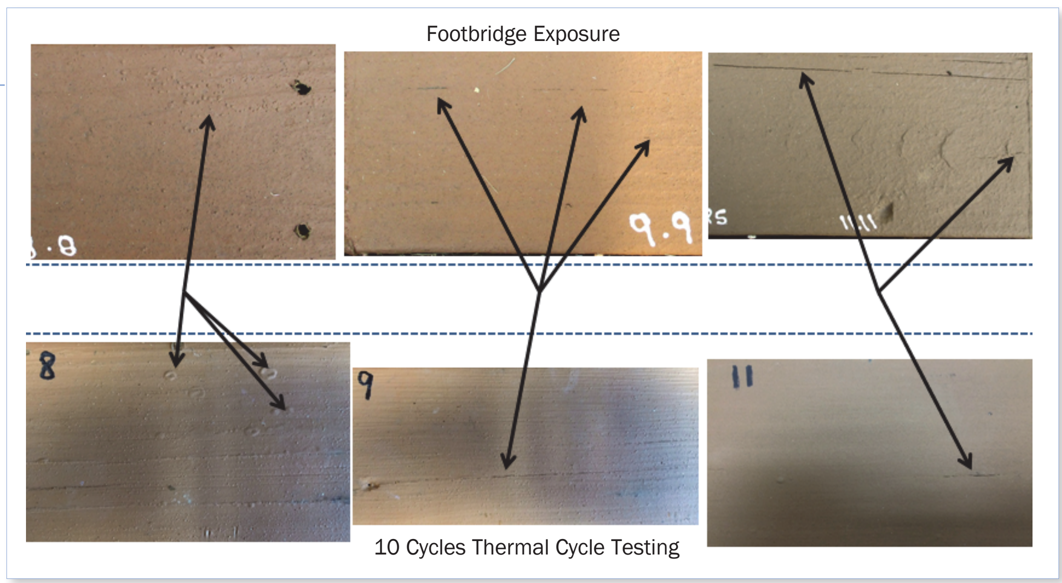

Figure 3b—Comparison of footbridge exterior exposure (top) vs thermal cycling testing (bottom) on cracking failure and blister development.

coating interface, (b) the interface between the first and second coats, (c) the top surface of the coating film, and (d) the bulk of the coating film. In regions (a) and (b), adhesion is the most critical parameter, as poor adhesion of the first coat of the restoration coating to either the substrate or to itself as the final topcoat would yield severe failure on the deck or patio. Region (c), the top surface of the coating, is the area that will receive punishment from abrasive damage, staining from dirt and spills, and abuse from the impact of dropped items such as bottles or barbeque utensils. Finally, region (d), the bulk of the coating film, must have the inherent mobility to move and flex along with the substrate. For concrete, this is a bit more inconsequential, as there are relatively small dimensional changes to consider, but wood boards will expand and contract readily with weather changes.

Table 2 provides an overview of the testing protocol used in screening new binder technologies and formulation approaches, based upon consideration of the four key regions from *Figure* 2. All coatings tested were brush- or roller-applied unless the test specifics precluded this. In cases where drawdowns were required, appropriately low spread rates were approximated, with a 20-mil wet film thickness drawdown representing one coat.

Where logical, ASTM methodology was followed. In some cases, however, appropriate modifications were made, such as extending the pull-off adhesion test method, technically defined for coated concrete substrates, to coated wood boards. The thermal cycling test method was also modified slightly from either of the methodologies described in ASTM D6944 and was conducted as follows: one cycle was defined as four hours in a

Table 3—Properties of EXP-113 and EXP-317 Binders for Deck and Concrete Restoration Coatings

Property	EXP-113 Typical Values	EXP-317 Typical Values
Appearance	Milky white liquid	Milky white liquid
Solids, weight	53.5%	60.5%
pH	8.5–9.0	8.7–9.0
Density	8.9 lb/gal	8.8 lb/gal
Minimum Film Formation Temperature	0°C	0°C
Viscosity (Brookfield, #3/30rpm)	500 cP	800 cP
APEO-free*	Yes	Yes

*Manufactured without the use of APEO surfactant. (These properties are typical but do not constitute specifications.)

50°C oven, four hours under fog box condition, and finally, 16 hours in a freezer (–20°C). The idea behind this cyclic test method is to stress the coating (bulk and interface) by running a coated wood section through multiple cycles of relatively rapid expansion (water adsorption and freezing) and contraction (drying). The ultimate goal is to provide an accelerated test method that is predictive of failures that would be observed upon exterior exposure as the wood deck cycles through real-world weather patterns.

Figures 3a and 3b show a good correlation between the thermal cycle testing protocol (pictures were taken following 10 cycles) and the actual exterior exposure performance after roughly 10 months outside in Spring House, PA. Two key modes of failure are noted in the three coatings shown in *Figure* 3. Coating 8 has notable blister development within 10 thermal cycles, and blistering is also noted in the exterior exposure board. Coatings 9 and 11, on the other hand, demonstrate cracking failures along the grain direction in both the thermal cycling and exterior exposure images.

LAB TESTING AND RESULTS

With a testing protocol defined that provides comparative differentiation, a broad set of novel binder technologies was tested in a high-build, 43% PVC screening formulation. Design variables explored across the polymer technologies included glass transition temperature, polymer hydrophobicity, use of ambient crosslinking monomers, single mode versus bimodal particle size polymers, and functionality to accelerate the drying of thick films.

Across the numerous binders that were analyzed, two stood out as having an overall remarkable balance across key properties. These two binders, referred to as EXP-113 and EXP-317, are both 100% acrylic polymers for optimal exterior durability. Additionally, both are free of added APEO surfactants, and with minimum film forming temperature (MFFT) values approximately 0°C, may be formulated to <50 g/L VOC without the use of "low-VOC" plasticizing coalescents. *Table* 3 provides an overview of the binder properties of these two leading technologies. Demonstrating the excellent balance of properties seen with EXP-113 and EXP-317, *Figure* 4 shows their performance in a high-build, 43% PVC formulation compared to a set of commercial deck and concrete restoration coating products. Relative to the commercial products, both binders yielded very much enhanced resistance to cracking in lab studies while still maintaining as good as or better abrasion and dirt pick-up resistance.

EXPOSURE TESTING AND RESULTS

EXP-113 and EXP-317 binders both showed good property balances in the screening formulation relative to commercially available products that were included in the lab study (*Figure* 4). While this is a positive indicator that these formulations will perform well in the real world, the true determinant of this is how the coatings perform outside under the influence of the elements and weather cycles. To effectively establish this exterior durability data, coatings formulated with EXP-113 and EXP-317 binders were put on exposure at the Dow Exposure Station in Spring House, PA. They were part of exterior exposure studies that also include other experimental binder systems in our screening formulation, new deck restoration formulation approaches, and commercially available deck and concrete restoration coatings.

Images of EXP-113 and EXP-317 binder formulations on exposure since October 2013 are shown in *Figure* 5a. Two commercial deck restoration products from the same exposure series are also shown. Each of the two commercial products was tinted in two separate ways. In one case, the product was tinted at the point of purchase with the manufacturers' recommended colorant package for a "cedar-like" color. In the other case, the commercial product base coating was purchased free

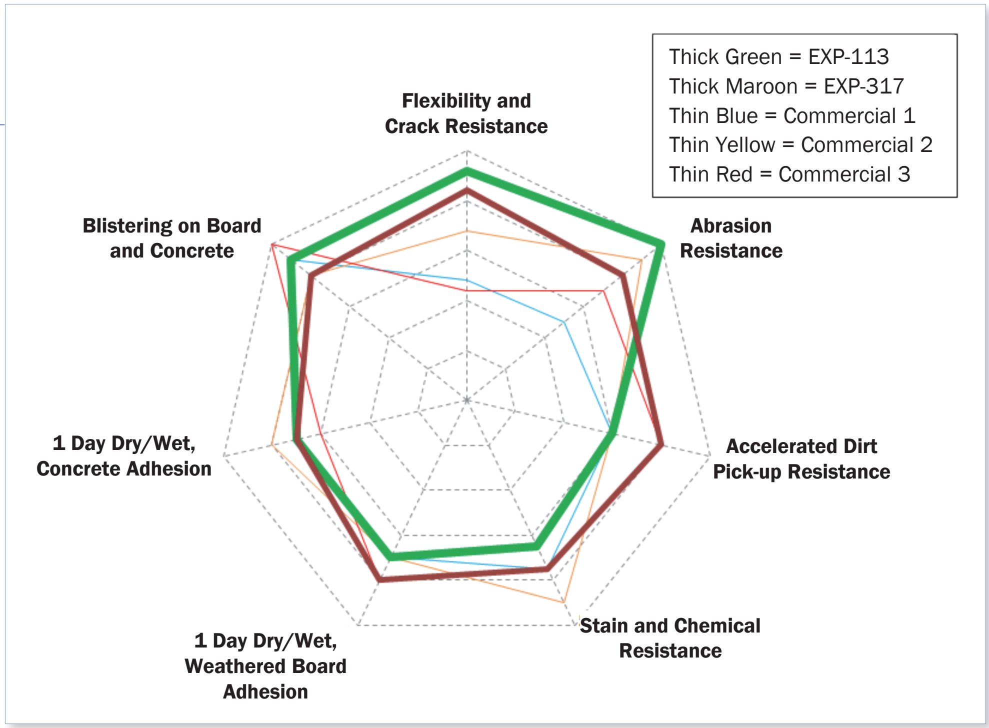

Figure 4—Performance property balance comparison of coatings formulated with new binder technologies vs commercial deck and concrete restoration coating products.

of any colorant, then the same colorant package that was used to tint the coatings made with EXP-113 and EXP-317 was dosed.

Two coats of each formulation were roller-applied at constant coat weight (equivalent to the recommended spread rate for these products) over well-weathered pine deck boards, similar in condition to that seen in *Figure* 1c. Initial images of these coated boards are shown in *Figure* 5a. The coated deck boards were subsequently exposed in a horizontal-up direction in Spring House, PA. *Figure* 5b shows images of the coatings following roughly 9.4 months of exposure. Note that during this time, extreme winter weather conditions often referred to as the "2013–2014 Polar Vortex" occurred at the Spring House site.

Both EXP-113 and EXP-317 are seen to be performing very well in this exposure study thus far, while the commercial products are already showing notable signs of cracking. It is interesting to note that in the EXP-113 image in *Figure* 5b, there is a crack from the neighboring coating (circled, upper right of the image in *Figure* 5b) that only advances slightly into the EXP-113 coating. The crack is stopped from progressing further through the EXP-113 film.

As one would anticipate, most cracking is seen along the grain lines of the wood, since this is where much of the dimensional movement would be exaggerated and where stresses transferred into the film would be magnified as the board cycles through seasonal weathering. However, there are secondary cracks observable in the Commercial #1 images of *Figure* 5b that run off-line to the wood grain. To explore deeper and provide more evidence that the movement of the wood is a main contributing factor to the observed cracking, *Figure* 6 shows images of the same set of six coatings, exposed at the same time and in the same location as those shown in *Figure* 5a, but coated over a more dimensionally stable composite decking substrate. No cracking is seen at the same 9.4-month time point for any of the coatings, strongly suggesting the cracking observed in the commercial samples in *Figure* 5b was produced as a result of the wood movement.

The exposure results from *Figures* 5a, 5b, and 6 imply that the Commercial #1 and Commercial #2 coatings have less flexibility to be able to move as the substrate moves and thus adsorb and dissipate the transferred stresses. With this direct observation from the exterior exposure, we refer back to *Figure* 4, where it was seen in laboratory property analysis that EXP-113 and EXP-317 had notably better flexibility and crack resistance than Commercial #1 and Commercial #2. (Note: all data shown in *Figure* 4 for the commercial coatings was for the lab-tinted samples.) Looking further into the lab data, the cracking from the exposure results shown in *Figure* 5 does seem to correlate specifically with the results of the Mandrel bend flexibility test. This is shown in *Table* 4, where a Mandrel bend result is given at each of three distinct temperature conditions. One would expect that the flexibility needed to pass the Mandrel bend test,

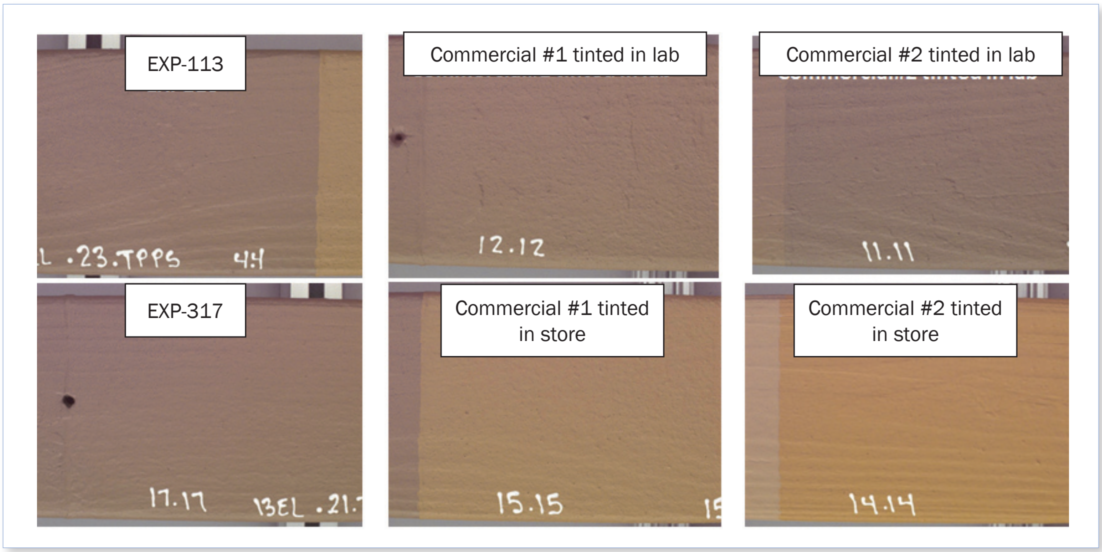

Figure 5a—Coating images prior to exposure (October 2013).

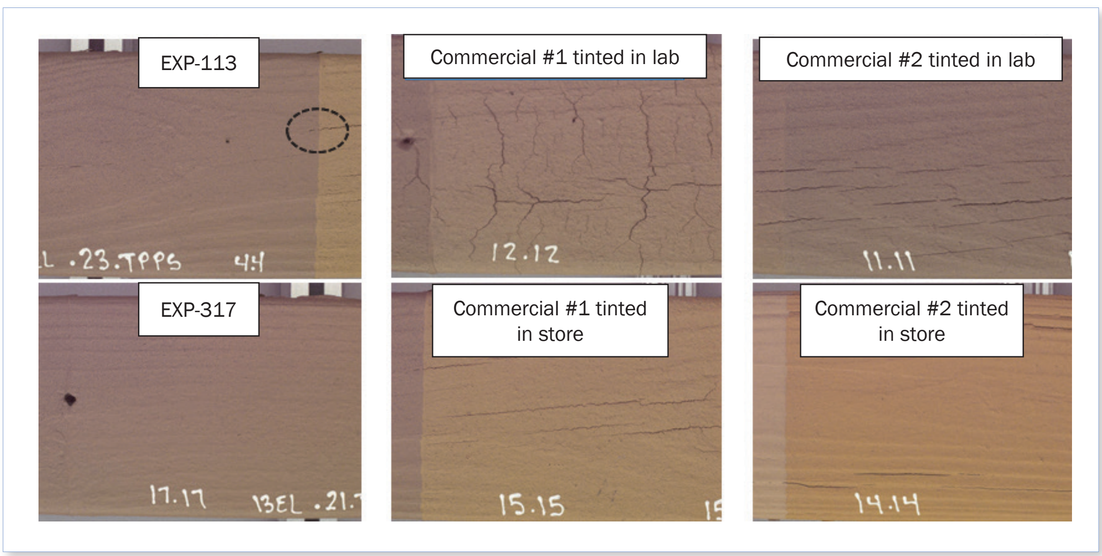

Figure 5b—Coating images after 9.4 months of exposure (August 2014).

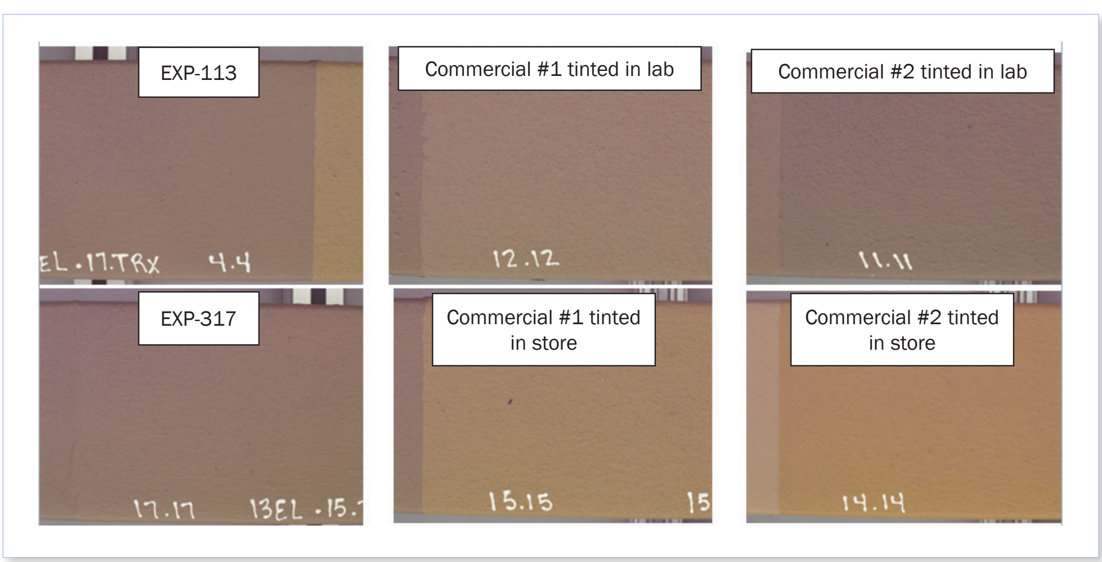

Figure 6—Coating images after 9.4 months of exposure (August 2014).

Table 4—Results of Mandrel Bend Testing Correlated with Exterior Exposure Crack Resistance

		Mandrel Bend Flexibility - Temperature Study					
	Severity of Cracking	77°F		45°F		32°F	
	Exposure Panels (ref *Figure* 5)	1/2" rod	1/8" rod	1/2" rod	1/8" rod	1/2" rod	1/8" rod
EXP-113	Minimal	PASS	PASS	PASS	PASS	PASS	FAIL
EXP-317	None	PASS	PASS	PASS	PASS	FAIL	FAIL
Commercial #1 - Lab tint	Extremely severe	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL
Commercial #1 - Store tint	Very severe	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL
Commercial #2 - Lab tint	Very severe	PASS	PASS	FAIL	FAIL	FAIL	FAIL
Commercial #2 - Store tint	Severe	PASS	PASS	FAIL	FAIL	FAIL	FAIL

even at the larger diameter rod, would be greater than what would be needed to accommodate the wood movement, but it may be that the lab test provides a differentiating indicator for crack resistance on exterior exposure.

CONCLUSIONS

According to a 2007 study by the National Association of Home Builders & Bank of America Home Equity, wooden decks have an average life expectancy of about 20 years under "ideal conditions."[5] The goal of the relatively new and rapidly growing deck and concrete restoration coating market segment is to add years onto the usable life of these wood decks as they become worn, weathered, and otherwise unusable. To deliver on this concept, these high-build coatings must be able to withstand the harsh natural elements and sometimes even harsher human insult coming down from above, while still having the capability to withstand the weather-driven movement of the substrate itself and maintain an aesthetically pleasing look and feel through many years of use. All-acrylic binder technologies such as EXP-113 and EXP-317 polymers designed around the specific needs of these specialty coatings will help further the growth of this consumer market by continuing to drive improvements in performance over real-world deck and patio applications. CT

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