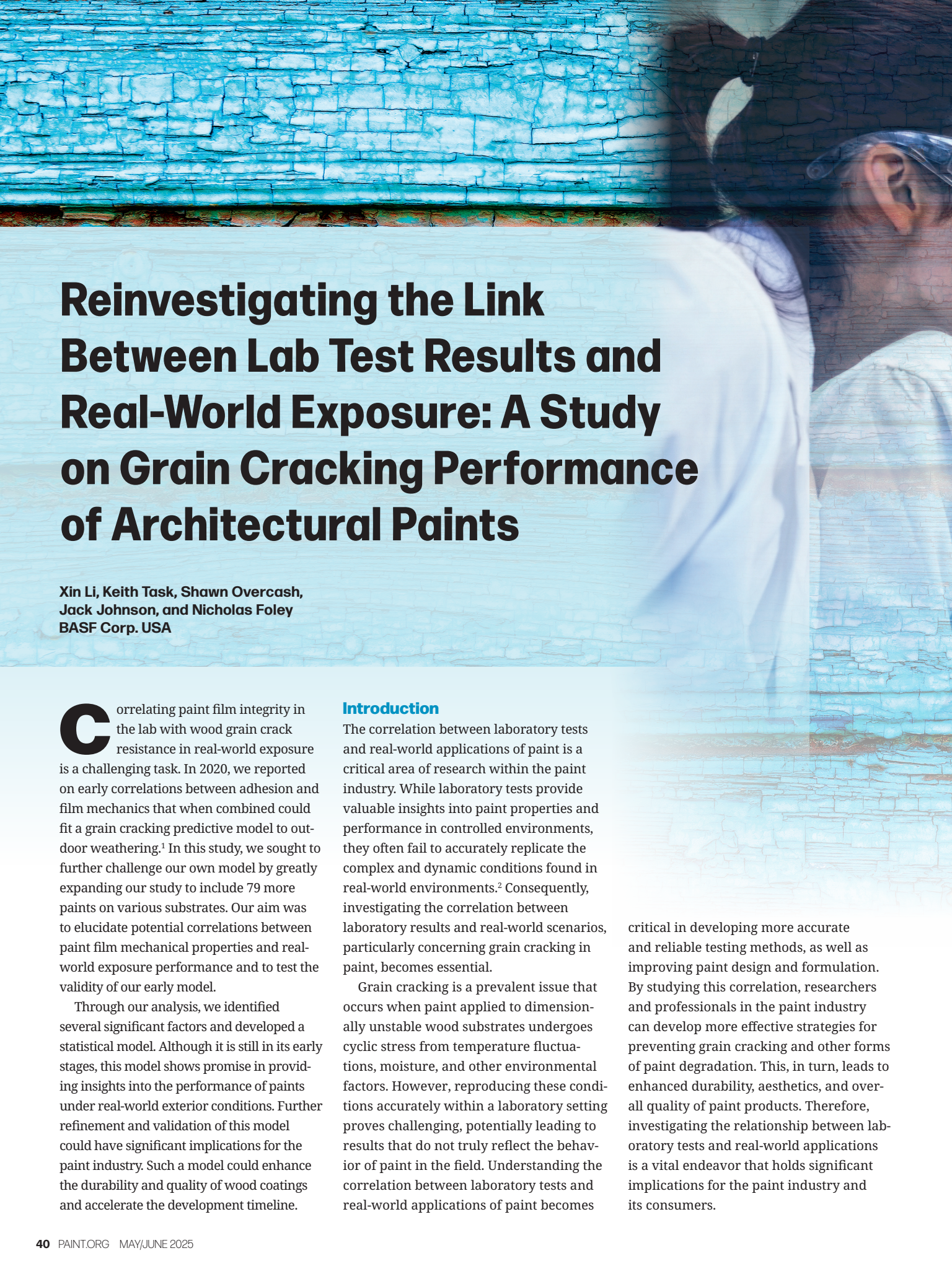




# Reinvestigating the Link Between Lab Test Results and Real-World Exposure: A Study on Grain Cracking Performance of Architectural Paints

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**C**orrelating paint film integrity in the lab with wood grain crack resistance in real-world exposure is a challenging task. In 2020, we reported on early correlations between adhesion and film mechanics that when combined could fit a grain cracking predictive model to outdoor weathering.<sup>1</sup> In this study, we sought to further challenge our own model by greatly expanding our study to include 79 more paints on various substrates. Our aim was to elucidate potential correlations between paint film mechanical properties and real-world exposure performance and to test the validity of our early model.

Through our analysis, we identified several significant factors and developed a statistical model. Although it is still in its early stages, this model shows promise in providing insights into the performance of paints under real-world exterior conditions. Further refinement and validation of this model could have significant implications for the paint industry. Such a model could enhance the durability and quality of wood coatings and accelerate the development timeline.

## Introduction

The correlation between laboratory tests and real-world applications of paint is a critical area of research within the paint industry. While laboratory tests provide valuable insights into paint properties and performance in controlled environments, they often fail to accurately replicate the complex and dynamic conditions found in real-world environments.<sup>2</sup> Consequently, investigating the correlation between laboratory results and real-world scenarios, particularly concerning grain cracking in paint, becomes essential.

Grain cracking is a prevalent issue that occurs when paint applied to dimensionally unstable wood substrates undergoes cyclic stress from temperature fluctuations, moisture, and other environmental factors. However, reproducing these conditions accurately within a laboratory setting proves challenging, potentially leading to results that do not truly reflect the behavior of paint in the field. Understanding the correlation between laboratory tests and real-world applications of paint becomes

critical in developing more accurate and reliable testing methods, as well as improving paint design and formulation. By studying this correlation, researchers and professionals in the paint industry can develop more effective strategies for preventing grain cracking and other forms of paint degradation. This, in turn, leads to enhanced durability, aesthetics, and overall quality of paint products. Therefore, investigating the relationship between laboratory tests and real-world applications is a vital endeavor that holds significant implications for the paint industry and its consumers.





In our previous study, we focused on evaluating the mechanical performance of 18 different paints.<sup>1</sup> The aim was to establish correlations between the performance of these paints and their real-world exposure results. To achieve this, we employed multiple linear regression (MLR) models. During the course of our research, we discovered that the results obtained from various laboratory and accelerated test methods were significantly confounded. These results did not yield easily decipherable trends.

To overcome these challenges, we expanded our study to include additional parameters. Specifically, we measured the

tensile elongation at multiple conditions, adhesion to water-conditioned surfaces, and film hardness. By incorporating these factors, we were able to develop a predictive model that exhibited a high degree of accuracy. It is important to note, however, that this model is currently limited to the scope of a single commercial paint study.

To progress the development of high-performance exterior wood coatings, it is crucial to validate and expand on our findings. This entails conducting a similar study that encompasses a broader range of paints, covering a wider spectrum of mechanical performance. By doing so, we

can further investigate and identify correlations between mechanical properties and real-world exposure results. This expanded research will ultimately serve to enhance the predictive model and transform it into a valuable tool for the development of high-performance exterior wood coatings.

In this study, we examined 79 paints with different formulations, colors, sheens, and significant variations in mechanical performance. These paints were applied to various substrates and evaluated every six months to determine if we could establish a correlation between accelerated testing and long-term real-world exposure results.



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This comprehensive analysis aims to provide a more robust understanding of the correlation between laboratory tests and real-world applications of paint, ultimately contributing to the advancement of paint technology and the development of superior paint products.

## Experimental Setup

### Paints

In this study, the 79 paints used included 16 experimental waterborne acrylic architecture paints and 63 commercial waterborne architecture paints purchased from hardware or paint stores. The paints were selected to cover a wide range of formulations, pigment volume concentrations (PVC), mechanical properties, and historical exposure results based on our own in-field benchmarking results. **Table 1** provides information on the number of paints used in the study based on different sheens and bases. The sheens include semi-gloss, satin, and flat, while the bases include a white and deep (tinted with 12 oz per gallon black colorant) from each sheen.

### Real-world Exposure

For real-world application in the U.S. market, exterior paints are typically applied in 2 coats with a natural spread rate on fresh Southern Yellow Pine (SYP).<sup>3</sup> In this study, all paints were applied on 3/4-in. thick fresh SYP without primer, using 2 coats. A brush was used for application with natural spread rate, with a drying time of four hours between coats. A typical natural spread rate by brush application in our study was approximately 4 g for a 5.5 in. x 5.5 in. area for the first coat, and 2 g for the same area for the second coat. To prevent premature failure starting from the board edges, any remaining surface on the boards that was not covered by the experimental paints was coated with a premium exterior paint.

Typically, good quality exterior paints with 2 coats on fresh SYP do not show any grain cracking failure in the first two years or even longer. To assess early indications of failure, our lab evaluated only 1 coat on fresh SYP. Additionally, the study also tested the performance of 1 coat of paint on weathered Southern Yellow Pine (WSYP). It is known that acrylic paints tend to have weaker adhesion to weathered SYP. To create weathered SYP, uncoated boards were left outdoors for a minimum of three months.

Exposure to the elements causes the wood surface to crack and become uneven, making it easier for the paint applied later to crack as well.<sup>4</sup> At times, researchers have used the real-world exposure performance of 1 coat boards at earlier times to predict the potential extrapolative performance of paint under the standard 2 coats on fresh SYP condition at later time points. However, the correlation between the grain cracking performance with 2 coats on fresh SYP and with 1 coat SYP or WSYP is not clear. One goal of the study was to find out if there were strong correlations of the real-world performance under different application and substrate conditions.

In this study, all 79 paints were also applied with 1 coat on fresh SYP, and a randomly selected subset of 24 paints within the 79 paints was applied with 1 coat on WSYP. The aim was to investigate if the grain cracking results from 1 coat on fresh SYP or on WSYP could serve as good early indicators of failure for 2 coats on fresh SYP.

Due to the large variations in real-world exposure results, all experiments were conducted in duplicate, and the grain cracking ratings were calculated by averaging the results of the two duplicate experiments.

The test fence exposure setup involved placing the painted boards on a test fence located in Charlotte, NC, facing south at a 45° angle. The boards were checked every

six months by the same person using the ASTM D661 method. The grain cracking was rated on a scale from 0 to 10, where 10 represents no cracking and 0 indicates full cracking of the entire surface.

It is important to note that paints may exhibit other failure modes such as peeling, flaking, erosion, etc., and the rating process was subjective, which means some variation and error were expected in this study.

### Lab Test of Dry Paint Film

The tensile elongation test is a widely used method for assessing the brittleness and ductility of paint films. It provides valuable information about the mechanical properties of the specimens, including elastic modulus, strain and stress at break, and total energy required to break. However, contrary to the belief that higher strain at break at room temperature helps prevent cracking in exterior coatings, there is no direct correlation between tensile elongation and cracking, as discussed in our previous study.<sup>1</sup>

The objective of this study is to develop a model that combines mechanical tests under different conditions, as well as other physical tests, to predict real-world exposure grain cracking ratings. To achieve this, we expanded the range of mechanical measurements compared to our previous study, aiming to create a more comprehensive model.

### Tensile Elongation Test

Paint samples were prepared by applying paints on a Teflon board using a 20-mil four-side film applicator. The paints were then air-dried for seven days in a controlled temperature and humidity room (23 °C, 50%). Specimens were cut into a dog-bone shape with a gauge length of 1 in., oriented perpendicularly to the direction of film preparation. Tensile elongation tests were conducted with a Bluehill Instron at a speed of 1 in. per minute at room temperature. All reported data from the tensile testing was an average of at least three specimens.

Besides the standard tensile elongation test at room temperature, we also tested the tensile elongation of dry films under different lab accelerated weathering conditions to simulate real-world weathering conditions. In Charlotte, where the

**TABLE 1**  
Number of Paints Used in This Study

| Sheen/Base                                         | Semi-gloss | Satin | Flat |
|----------------------------------------------------|------------|-------|------|
| White                                              | 24         | 4     | 25   |
| Deep (tinted with 12 oz per gallon black colorant) | 11         | 4     | 11   |

study was conducted, substrate deformation can occur throughout the year, with temperatures ranging from  $-10^{\circ}\text{C}$  to  $35^{\circ}\text{C}$ . Therefore, we explored the tensile elongation performance of the specimens after different accelerated artificial weathering conditions and/or at different temperatures. The combination of results from tensile elongation tests under different accelerated weathering and temperature conditions may provide more insights into grain cracking in real-world scenarios.

For the tensile elongation test at low temperature, the specimens were prepared as described previously, but the tensile tests were conducted at two low temperatures:  $0^{\circ}\text{C}$  and  $-20^{\circ}\text{C}$ . The temperatures chosen were either close to or below the typical glass transition temperature of architecture paints (typically  $-10^{\circ}\text{C}$  to  $30^{\circ}\text{C}$ ).

For the tensile elongation test after accelerated weathering, two methods were used: QUV exposure and fog box exposure. QUV exposure simulates the effects of UV light from the sun, while fog box exposure simulates water damage. For the QUV exposure, the specimens were prepared as described in the experimental setup and then placed in a QUV chamber, manufactured by Q-Lab, under a UVA bulb with irradiance of  $0.89\text{ W/m}^2$  at  $60^{\circ}\text{C}$  for seven days. After the exposure, the specimens were tested using the same tensile elongation test procedure as described earlier.

Similarly, for the fog box exposure, an in-house, custom-built fog box was used. In the fog box, tap water mist was sprayed continuously from the top, and all specimens were laid horizontally on a piece of polyolefin substrate. The dry paint film specimens were placed in the fog box for seven days,

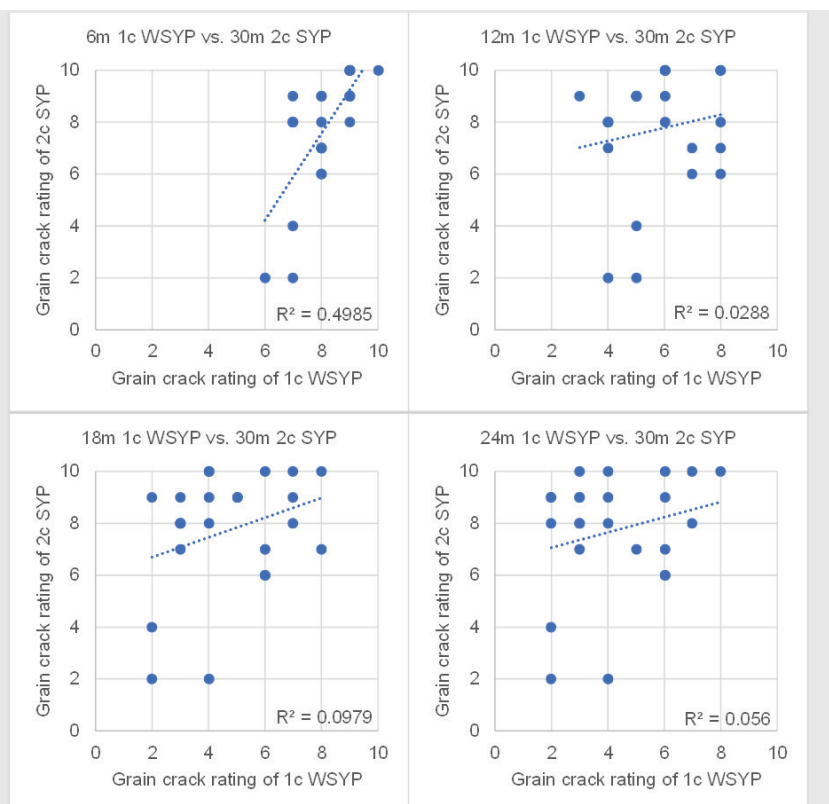
followed by one day of air-drying and testing using the same tensile elongation test setup at room temperature.

### Adhesion Test

In addition to the tensile elongation tests, adhesion tests were conducted before or after accelerated weathering to evaluate the adhesion of the paint films to the substrate using the method described in ASTM D3359 Test Method B. This is because weaker adhesion to substrates may be correlated to earlier cracking. For the adhesion test, paint was applied on fresh SYP using a 250 micron (10 mil) four-side film applicator. The specimens were then air-dried for seven days in a controlled temperature and humidity room before the adhesion test. We also tested adhesion after fog box exposure, by applying paints on SYP and drying for seven days, followed by fog box exposure for seven days. After the exposure, the specimens were air-dried for four hours and the adhesion was evaluated.

**FIGURE 1**

**Grain crack rating of 6th, 12th, 18th, and 24th month 1 coat on weathered Southern Yellow Pine (1c WSYP) vs 30th month 2 coats on fresh Southern Yellow Pine (2c SYP).**



## Results and Discussion

The main objective of this study was to determine whether laboratory tests or accelerated tests can be used to predict the grain cracking performance of 2 coats on fresh SYP. In this section, the correlation between the accelerated exposure test (1 coat on fresh SYP or on weathered SYP), laboratory tests, and the real-world performance of 2 coats on fresh SYP is explored.

### One Coat on Fresh SYP or WSYP and Their Correlation with 2 Coats on Fresh SYP

To assess whether early failure with 1 coat on WSYP can predict the grain cracking performance of 2 coats on SYP at the 30th month, we plotted the grain cracking ratings for the paints with 1 coat on WSYP at different time points against the ratings for 2 coats on SYP at the 30th month. This is illustrated in **Figure 1**. The time period of 30 months was chosen because 24 months represents the time when we began to observe 2 coats of some paints starting to show cracking. In **Figure 1**, we observed that only the 6th month exposure data with 1 coat on WSYP showed some weak correlation with the 30th month results for



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2 coats on SYP. However, as the exposure period for 1 coat on WSYP increased, the correlation with the 30th month 2 coats on SYP data quickly diminished. It remains unclear whether longer exposure of 2 coats on SYP will correlate better with 6th month or 12th month 1 coat on WSYP. Further data from longer exposure periods is necessary to establish the relationship between 1 coat on WSYP and 2 coats on SYP.

We also examined the correlation between 1 coat on SYP and 2 coats on SYP. **Figure 2** presents the grain cracking ratings for 1 coat on SYP at the 6th, 12th, 18th, and 24th month, respectively, compared to the grain cracking ratings for 2 coats on SYP at the 30th month. It is evident that the data for 1 coat on SYP, regardless of time, showed weak correlation with the 30th month results for 2 coats on SYP. These results suggest that the performance of 1 coat on SYP at earlier time points may not serve as a reliable indicator to predict the performance of 2 coats on SYP at later time points.

### Correlating Lab Testing with Real-world Grain Cracking Performance

As detailed below, the next focus of our study was on correlating laboratory testing with the 30th month grain cracking performance of 2 coats on fresh SYP.

**Figure 3** illustrates the correlation coefficient between each lab test result and the grain crack rating of 2 coats on SYP at the 30th month. It is evident that no single lab test method exhibits a strong linear correlation with the grain cracking rating, as all the absolute values of correlation coefficients are less than 0.4.

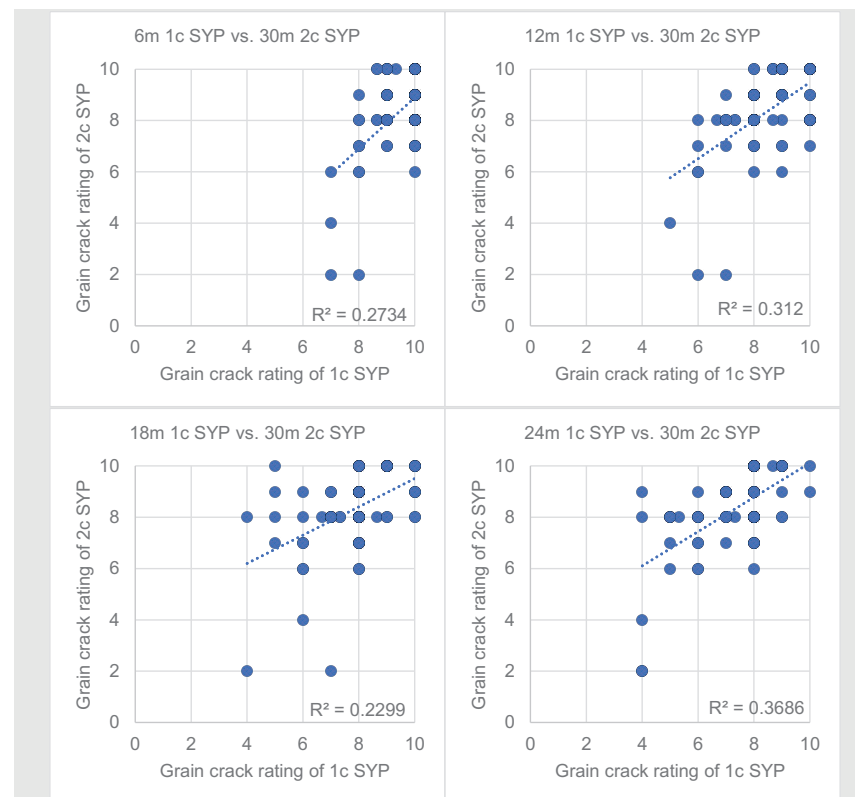
In our previous study, we concluded that while no individual test method can accurately predict grain cracking performance in the real world, it is possible that a combination of different test methods could yield improved correlations. Hence, in this study, we aimed to develop a mathematical model for the grain cracking results of 2 coats on SYP.

### Multiple Linear Regression Approach

To explore this concept, we initially performed linear regression analysis (estimating linear main effects only), with 30th month grain cracking being the response variable,

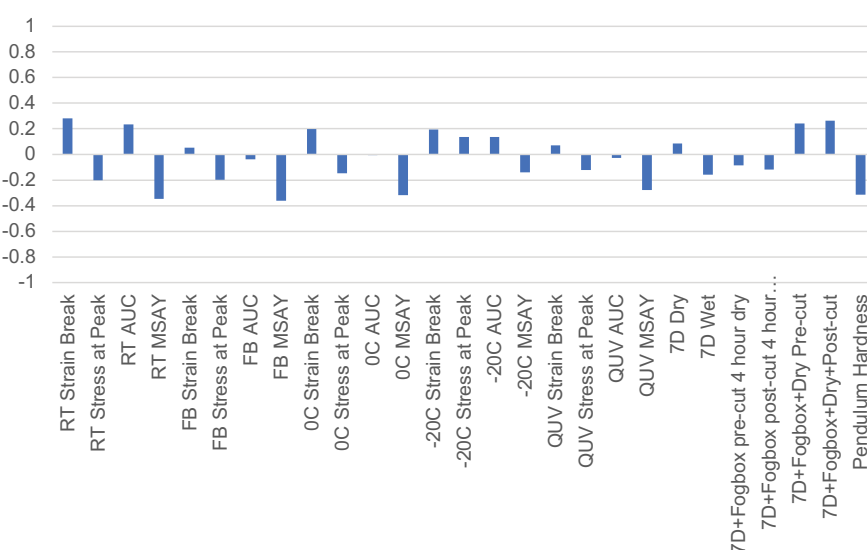
**FIGURE 2**

Grain crack rating of 6th, 12th, 18th, and 24th month 1 coat on fresh Southern Yellow Pine (1c SYP) vs 30th month 2 coats on fresh Southern Yellow Pine (2c SYP).



**FIGURE 3**

Correlation coefficient between each lab's test results and 30th month 2 coats on SYP. RT: Room temperature. FB: fog box. AUC: Area under the (stress-strain) curve, represents the total energy to break the film. MSAY: initial slope of the stress-strain curve, represents the Young's modulus of the film. 7D wet / 7D dry: wet/dry adhesion test without fog box. 7D + fog box: adhesion after sample exposed in fog box.





**FIGURE 4**

Initial investigation of correlation between lab test results and real-world grain cracking rating after the 30th month by using linear regression (A). Linear model after eliminating some of the highly correlated variables as well as some other variables which became non-significant (B).

|                            |          |
|----------------------------|----------|
| RSquare                    | 0.814384 |
| RSquare Adj                | 0.808584 |
| Root Mean Square Error     | 1.195372 |
| Mean of Response           | 6.741758 |
| Observations (or Sum Wgts) | 364      |

| Term                               | Estimate  | Std Error | DFDen | t Ratio | Prob> t |
|------------------------------------|-----------|-----------|-------|---------|---------|
| Intercept                          | 2.5307831 | 0.706856  | 329.4 | 3.58    | 0.0004* |
| RT Strain Break(8.21466,1804.46)   | 3.5827305 | 0.800668  | 324.3 | 4.47    | <.0001* |
| RT Stress at Peak(43.2038,911.797) | 0.7504205 | 0.197166  | 320.9 | 3.81    | 0.0002* |
| RT AUC(0.01079,195.365)            | -3.314416 | 0.766547  | 314.5 | -4.32   | <.0001* |
| FB Strain Break(2.72823,367.282)   | -0.900555 | 0.245782  | 329.8 | -3.66   | 0.0003* |
| OC AUC(0.00066,122.228)            | -0.457661 | 0.237346  | 319   | -1.93   | 0.0547  |
| -20C Strain Break(1.33655,42.4202) | 3.3515962 | 0.754744  | 327.6 | 4.44    | <.0001* |
| -20C AUC(0.00041,0.10125)          | -4.102738 | 0.800935  | 322.4 | -5.12   | <.0001* |
| 7D+Fogbox+Dry Pre-cut              | 0.2937167 | 0.071621  | 325   | 4.10    | <.0001* |
| Pendulum Hardness                  | -0.140829 | 0.026033  | 317.4 | -5.41   | <.0001* |
| Substrate[3/4 SYP]                 | 1.700175  | 0.315967  | 45.76 | 5.38    | <.0001* |
| No. of coats[2-1]                  | 1.7306492 | 0.417491  | 46.38 | 4.15    | 0.0001* |

**A**

|                            |          |
|----------------------------|----------|
| RSquare                    | 0.787718 |
| RSquare Adj                | 0.78415  |
| Root Mean Square Error     | 1.267806 |
| Mean of Response           | 6.741758 |
| Observations (or Sum Wgts) | 364      |

| Term                               | Estimate  | Std Error | DFDen | t Ratio | Prob> t |
|------------------------------------|-----------|-----------|-------|---------|---------|
| Intercept                          | 3.9299007 | 0.538279  | 228.4 | 7.30    | <.0001* |
| RT Stress at Peak(43.2038,911.797) | 0.6454549 | 0.199837  | 334.7 | 3.23    | 0.0014* |
| -20C AUC(0.00041,0.10125)          | -0.620305 | 0.232044  | 324.1 | -2.67   | 0.0079* |
| 7D+Fogbox+Dry Pre-cut              | 0.4610995 | 0.06631   | 322.8 | 6.95    | <.0001* |
| Pendulum Hardness                  | -0.162309 | 0.023901  | 317.8 | -6.79   | <.0001* |
| Substrate[3/4 SYP]                 | 1.7014713 | 0.323372  | 45.58 | 5.26    | <.0001* |
| No. of coats[2-1]                  | 1.7274595 | 0.427932  | 46.48 | 4.04    | 0.0002* |

**B**

the lab test results, the substrate (fresh or weathered SYP), and number of coats being the explanatory variables, and the board being a random effect, thereby investigating any potential correlations between lab data and real-world results. In the linear model, the grain crack rating was considered as a continuous response rather than a discrete one. **Figure 4A** presents the properties that have a significant ( $p < 0.05$ ) impact on the grain cracking rating according to the model and estimated coefficients. The R-squared value of approximately 0.8144 and the adjusted R-squared value of about 0.8086 suggests that ~80% of the variability in the data can be explained by the model. Furthermore, an F-test was done on the model, analyzing the ratio of the variability explained by the model to that not explained by the model (error), which indicated a significant relationship between lab test data and real-world performance ( $p < 0.05$ ). The close proximity of the adjusted R-squared and R-squared values suggests that the significance of some factors (lab test results) is genuine, and that we are not overfitting with non-significant terms. As certain lab test data may be confounded, we eliminated highly correlated variables, and non-significant variables which arose in the process, to create a more concise model, as depicted in **Figure 4B**.

### Logistic Regression

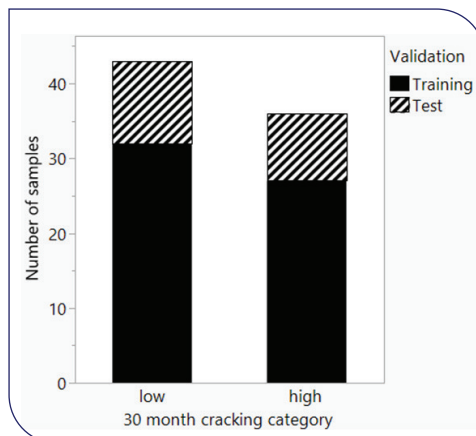
Following the preliminary study using the linear regression method, we confirmed the significance of some factors (lab test results). In this section, instead of treating the cracking rating as a continuous variable, we adopted a more realistic approach by categorizing it. We simplified the problem by bundling crack ratings, considering ratings of 9 and 10 as “high” and ratings of 8 and below as “low.” This approach transformed the problem into a two-class classification problem, which we analyzed using the logistic regression method. Further modifications to the approach revolved around the data being used: ratings were averaged over boards, and only the grain crack rating at 30th month of 2-coat fresh SYP samples was used.

The logistic regression model fits a logistic curve to the data using the variables to predict the probability of falling into a given category. Based on the probability, a “class” could be assigned, either “high” (crack rating of 9 or 10) or “low” (crack rating less than or equal to 8). During model development, our main concern was overfitting, where the model fits the data well but struggles to predict new results. To test the predictive accuracy of the developed model, we did not use all

data points for model building. Instead, 75% of the data points were used to train the model, while the remaining 25% were used to test the model’s prediction accuracy. Stratification<sup>5</sup> was employed when creating this train/test split. Stratification aims to maintain this split for each level of a categorical factor. Therefore, in our data, the target would be ~25% of the “low rating” samples allocated to the test set and ~25% of the “high rating” samples allocated to the test set as well. **Figure 5** illustrates the distribution of data for the training and test datasets.

**FIGURE 5**

Data set distribution of the data used for model training and data used for testing the model.





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The logistic regression model demonstrated promising results on both the training and testing datasets. **Figure 6** presents the confusion matrix<sup>6</sup> of this logistic regression model. For classification problems, the confusion matrix is an important way of assessing the accuracy of the model. For each class in the data set, the matrix records the proportion of that class being correctly predicted and incorrectly predicted. The data being properly predicted falls on the diagonal, with the incorrect predictions falling on the off-diagonal. By analyzing the confusion matrix, not only can one tell the accuracy of the model, but which classes were difficult to predict. For the testing dataset, which was used to validate the model's predictivity, the confusion matrix revealed that out of the 20 test paints, the model correctly predicted 9 out of 9 high-rated paints and 8 out of 11 low-rated paints. The model misclassified 3 paints with low ratings as having high ratings. When combining the training and validation data, the logistic regression model achieved an overall prediction accuracy of over 80%. This was considered significant and meaningful in real-world evaluation. It is important to note that there may be other factors not measured or considered in this study, and further fine-tuning and training of the model could lead to better predictions.

In this logistic regression model, the following factors were identified as significant factors for the grain cracking rating (with the below rating behavior corresponding to an increase of the factor value):

- The larger the strain at break after dry film exposure in the fog box, the more likely is a high cracking rating.
- The larger the total area of the stress-strain curve in tensile test after dry film exposure in the fog box, the more likely is a low cracking rating.
- The larger the peak stress in the tensile test at 0 °C, the more likely is a low cracking rating.
- The larger the strain at break in the tensile test at -20 °C, the more likely is a high cracking rating.
- The larger the strain at break in the tensile test at 0 °C, the more likely is a high cracking rating.

**FIGURE 6**  
Confusion matrix for the logistic regression model.

| Training |           |     | Validation |           |     |
|----------|-----------|-----|------------|-----------|-----|
| Actual   | Predicted |     | Actual     | Predicted |     |
| 30 month | Count     |     | 30 month   | Count     |     |
| cat      | high      | low | cat        | high      | low |
| high     | 27        | 0   | high       | 9         | 0   |
| low      | 0         | 32  | low        | 3         | 8   |

| Actual   | Predicted |       | Actual   | Predicted |       |
|----------|-----------|-------|----------|-----------|-------|
| 30 month | Rate      |       | 30 month | Rate      |       |
| cat      | high      | low   | cat      | high      | low   |
| high     | 1.000     | 0.000 | high     | 1.000     | 0.000 |
| low      | 0.000     | 1.000 | low      | 0.273     | 0.727 |

- The larger the initial slope of stress-strain curve in tensile test at -20 °C, the more likely is a high cracking rating.
- The larger the total area of the stress-strain curve in tensile test at -20 °C, the more likely is a low cracking rating.

In this model, we found that:

Strain Break: Higher strain at break under various test conditions tended to lead to a higher grain cracking resistance rating. This observation aligns with how paint manufacturers historically use paint film flexibility as a guide for exterior paint development.

The area under the stress-strain curve (AUC), which measures the energy required to break a film (film toughness), showed an inverse correlation with the grain cracking resistance rating. However, since some mechanical test results were highly correlated with other factors in this study, it is not meaningful to isolate the impact of a single factor and discuss its influence. The AUC was highly correlated with the strain at break, as the AUC represents the integral of the strain vs stress curve. Therefore, it is important to investigate the model as a whole rather than focus on factors that are confounded with other factors.

Mechanical performance after water exposure and at low temperature has stronger influence than the mechanical performance of the fresh dry paint film tested at room temperature. The finding may provide insights for researchers to

design more durable paints in real-world exposure tests.

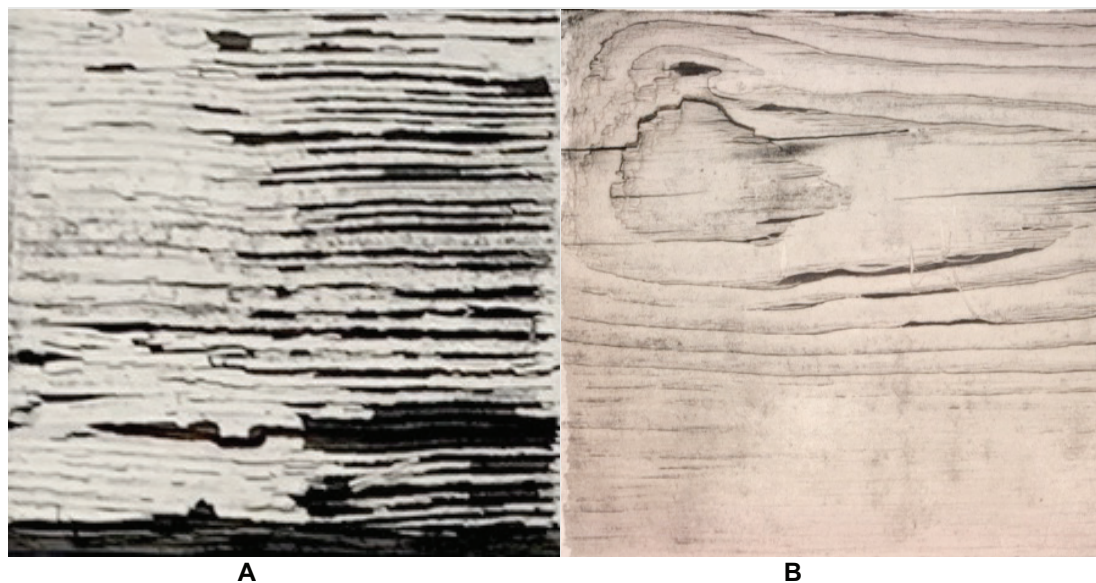
In our previous work<sup>1</sup> with a smaller set of paints, we conducted a similar study and built a model based on four years of exposure data with 2 coats on fresh SYP. In that study, we found that adhesion to SYP impacted grain cracking resistance. However, in the model discussed in this article, adhesion was not identified as a significant factor. Several possible explanations account for the difference between these two models. In this article's study, we significantly expanded the sample size and included other factors such as initial slope of the stress-strain curve and energy required to break the film (AUC). Furthermore, the previous study was based on four years of exposure data, while the current, ongoing study only used 30 months of exposure data.

**Figure 7A** depicts an example of paint from the previous study. It is evident that the paint not only exhibited grain cracking failure but also flaking and peeling off failure. Decoupling different failure modes during visual inspection was challenging. In the previous study, we believed that flaking and peeling off failure were related to adhesion on the substrates, which was confirmed by the model developed in that study. In the current study, since all boards were only exposed for 30 months and most paints had not yet developed flaking and peeling off failure as shown, for example, in **Figure 7B**,



## FIGURE 7

One example of paints with flaking/peeling failure in our previous study (A) and one example of paints in the current study that showed grain cracking but that has not yet developed significant peeling/flaking failure (B).



adhesion was not identified as a significant factor in this model. It is likely that the grain cracking model is exposure-time and weather-history dependent. Currently, this model is only valid for 30th month exposure results in Charlotte, NC. The significance of factors may change if exposure time, location, or weather history differs. Nevertheless, it is valuable to continue developing such a model as it demonstrates the concept that real-world exposure performance can be predicted through lab testing.

## Conclusion

In this article, we expanded upon our previous study<sup>1</sup> by increasing the sample pool size and incorporating additional mechanical and accelerated tests as input factors to investigate the correlation between lab tests and the real-world performance of architectural exterior paints in resisting grain cracking. Our findings indicate that a thinner coating (1 coat) or a reduction in adhesion between paints and substrates, achieved by using weathered Southern Yellow Pine (WSYP) as the substrate, shows a weak correlation with the standard 2 coats on fresh Southern Yellow Pine

(SYP) when exposed for up to 30 months in Charlotte, NC. Therefore, we suggest that testing on WSYP may not be a reliable early indicator for other substrates like SYP.

Linear and logistic regression approaches were used to analyze the correlation between mechanical tests of dry paint film under various conditions and real-world grain cracking performance. While no single test was found to correlate well with real-world results, we were able to form a predictive model with reasonable accuracy and predictivity by combining multiple factors. In comparison to our previous study, we believe that this model will be dependent on the location and exposure time. Therefore, a more comprehensive study will be necessary to develop a better model that covers different time points. ❖

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