Evaluation of the Performance of Composite Wood Decking Bonded with Phenol Resorcinol Formaldehyde and Polyurethane Adhesives after Accelerated Aging Tests

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Abstract

The feasibility of applying an innovative process to manufacture composite decking boards with quartersawn or starsawn southern pine lumber bonded with phenol resorcinol formaldehyde (PRF) and polyurethane (PU) adhesives was studied. It was feasible to make quatersawn-based composite decking panels with possible improved surface qualities. Accelerated aging tests showed that composite quartersawn decking samples were more resistant to aging than flatsawn decking samples in terms of shear strength, especially after exposure to 12 wet–dry aging cycles. Compared with the PRF adhesive, the PU adhesive resulted in greater initial dry shear strength but had lower shear strength after the accelerated aging test. Furthermore, the amount of wood failure increased for the PRF-bonded samples and decreased for the PU-bonded samples after accelerated aging tests. Compared with solid quartersawn decking boards, the quartersawn composite decking boards had the same modulus of rupture and modulus of elasticity.

In recent years, the forest products industry has lost a significant share (up to 32%) of the residential decking market, which has a total value of $6.5 billion annually (Freedonia 2014), to wood fiber–plastic composite products (Markarian 2005, Koenig 2010). According to Busta (2013), the demand for plastic and metal boards and rails is growing faster than that for solid wood, and if the situation does not change, wood will continue losing market share to plastic. The major reason for this shift from solid wood to other alternatives is the relatively poor weathering performance of wood (e.g., excessive checking, splitting, and warping; Fowlie et al. 1990, Green 2005). Treatment with water repellents can improve weathering of wood somewhat, but it fails to provide the long-term solution that is necessary to maintain customer satisfaction. Therefore, an improved wood decking product is needed to compete in the current market. Because plastic decking sells for approximately three times the price of wood decking, based on the economics alone there appears to be good market potential for an improved wood decking product that is intermediate in cost compared with plastic and solid wood. Consequently, the market should be able to accommodate some increase in the cost of an engineered composite wood decking product.

When exposed to an exterior environment, the surface of a solid wood panel is subject to alternate wetting and drying. Wood substrate beneath the exposed surface, however, likely dries slower than the wood on the surface. This

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disparity creates shrinkage stress at the surface layer due to the restraint of subsurface layers whose moisture content (MC) is different from that of surface layer, especially when the subsurface layer MC exceeds the fiber saturation point. This restraint will generate surface tension stresses of a magnitude depending on the degree of shrinkage strain established in the surface layer. Once the stresses exceed the tensile strength of the wood perpendicular to the grain, checks will develop (Schniewind 1963, Hoadley 2000).

Many researchers have conducted studies at ameliorating checking in wood by using kerfing (Graham and Estep 1966; Helsing and Graham 1976; Ruddick and Ross 1979; Ruddick 1981, 1988; Morrell 1990; Evans et al. 1997, 2000, 2003; Kurisaki 2004; Christy et al. 2005; Evans 2016); wax, oil, or water repellents (Fowlie et al. 1990, Zahora and Rector 1990, Zahora 1991, Ross et al. 1992, Evans et al. 2009); surface profiling (McFarling and Morris 2005, Morris and McFarling 2008, McFarling et al. 2009, Evans et al. 2010, Akhtari and Nicholas 2014, Cheng and Evans 2016); and incising (Evans 2016). The concepts of kerfing, profiling, and incising are directed at ameliorating the formation of shrinkage stresses, which will be quite high around the whole growth ring if no measures are taken to reduce its buildup. Using wax, oil, or water repellent is another way to reduce the buildup of shrinkage stress by modifying the hygroscopicity of wood so that the shrinkage will be less during MC changes. Because no crosslinking or bonding occurs between wax or oil with wood, any reduction of shrinkage stresses introduced by wax or oil will be temporary as the wood weathers.

Observations over the years and recent publications (Sandberg 1996, Sandberg and Soderstrom 2006) indicate that quartersawn lumber has considerably less checking and warping as well as better overall weathering characteristics than flatsawn wood. This is because the relative shrinking and swelling in wood is more dominant in the latewood than in the earlywood. Flatsawn wood contains large portions of continuous layers of latewood, whereas quartersawn wood consists of alternate layers of earlywood and latewood (Browne 1960). The Primwood Method, developed by Sandberg and Soderstrom (2006), has proven to be an economical method of producing quartersawn lumber by first star sawing the logs into a combination of quartersawn boards and triangular pieces, which are glued together with an adhesive to form billets. The billets are then sawn into radial-faced quartersawn composite boards for different applications.

The objectives of this study were (1) to examine the feasibility of using southern pine to make quartersawn composite lumber, (2) to evaluate the properties of both quartersawn and flatsawn deck boards obtained from the composite lumber, and (3) to determine whether phenol resorcinol formaldehyde (PRF) or polyurethane (PU) is a better adhesive for bonding the wood billet components.

Materials and Methods

Green southern pine logs were converted into triangle billets, to lumber, and then to composite boards (Fig. 1) for evaluating the performance of flatsawn (Fig. 1F, left) and quartersawn (Fig. 1F, right) decking board samples, which were glued together with PRF and PU adhesives. The samples were evaluated for bonding strength, wood failure, and aging characteristics after being subjected to 12-cycle accelerated aging tests. Details are described in the following sections.

The decking boards used in this study were manufactured from five green loblolly pine (*Pinus tadea*) logs measuring 249 cm in length and approximately 30 to 36 cm in diameter. To obtain wood triangle billets, a hexagon pattern was marked on the butt of each log (Fig. 1A) to illustrate the cutting pattern. Each log was positioned on a hexagon jig and the outer surface cut longitudinally into a hexagon (Fig. 1B). Then, the log was cut in half longitudinally. The half-hexagon slab (Fig. 1C) was placed in a triangle jig, and a 249-cm-long, triangular section was cut. The remaining portion of the original half-hexagon slab was then cut in half, which yielded two triangular sections. The process was repeated for the other half-hexagon, resulting in six triangular sections from each log (Fig. 1D).

Southern pine lumber is typically dried with a high-temperature schedule (Boone et al. 1993). However, we selected a low-temperature drying schedule to minimize warping and the moisture gradient in the wood. The triangular sections were stacked, stickered, and placed in a dry kiln with a dry-bulb temperature of 71°C and a wet-bulb temperature of 60°C over a 4-day time period. Following kiln drying, the wood sections were equalized at room temperature for 3 months, after which 30 of the 249-cm-long triangular sections were cut into 112-cm lengths with a band saw to remove splits, cracks, and other defects in the wood. During the process, any deformed triangular sections were discarded.

Adhesive application

The triangular sections were machined on each gluing face with a jointer to create uniform and fresh gluing surfaces for proper adhesion. Two types of commercial adhesive, PRF and PU, were used in the experiment. Details on the two adhesives are listed in Tables 1 and 2.

For the PRF application, the adhesive and hardener were mixed at the ratio of six parts PRF adhesive to one part hardener. Then, the adhesive was mixed for 5 minutes on an industrial adhesive blender before application with a roll coater to both sides of the wood, using an application rate of 200 g/m^2 on each surface. The PU adhesive was a ready-to-use liquid, which was also applied to both surfaces with a roll coater at an application rate of 200 g/m^2 to each surface. For each adhesive, six wood triangular sections were used to produce three adhesive-laminated quartersawn billets. For comparison purposes, three flatsawn billets bonded with PRF adhesive were also made. So, in total, three quartersawn billets and three flatsawn billets were made for PRF adhesive and three quatersawn billets for PU adhesive. The total operation time after adhesive mixing to clamping was less than 30 minutes at room temperature for both adhesives.

Clamping

A clamp was made specifically for gluing the triangular sections together. The clamp consisted of a steel I-beam with four hollow steel arms that supported the ends of the triangular sections. The four arms pivoted at the base of the clamp and locked into place at the top with a pin. Ten threaded rods were used to clamp down a maximum of three billets during gluing. As each piece was glued, it was placed in the clamp and oriented so that the grain of the wood

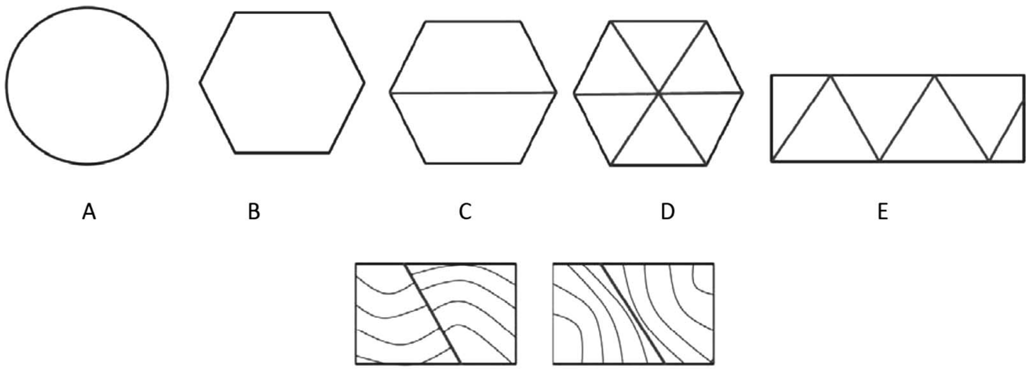

Figure 1.—Conversion of a log into decking board.

would produce quartersawn or flatsawn boards when the billets were cut. After all the pieces were assembled in the clamp, a 2 by 4-inch section of oak panel was placed on the top of the billets to prevent the clamping bar from crushing the pine lumber below. Five clamping bars were placed on each billet and tightened with a pneumatic air gun of 100 to 120 foot-pound force. The billets were tightened again within 15 minutes after the first clamping and left in the clamp for more than 24 hours to ensure that the adhesives had properly cured.

Re-sawing

After the 24-hour clamping, the billets were removed from the clamp and prepared for planing and re-sawing. The billets were planed until the excessive adhesive was removed from the sides of the billets. The billets were then re-sawn into quartersawn and flatsawn boards of 12.7 by 3 by 61 cm (width by thickness by length) and then planed into 2.54-cm-thick boards on a planer. A total of nine flatsawn and nine quartersawn boards were prepared for PRF adhesive and nine quartersawn boards for PU adhesive.

Accelerated aging test

To determine the difference between PRF and PU adhesive in the bonding of decking boards, the composite deck boards (2.54 by 12.7 by 61 cm) were subjected to 12 wet–dry cycles of accelerated aging and tested for delamination in accordance with ASTM D2559 (ASTM International 2012b). To further reveal the difference in compression shear strength between PRF and PU adhesives in accordance with ASTM D2559, the decking boards were cut into 1-inch-thick blocks, which were then divided into groups of three end-matched samples with bond line areas of 7.42 cm^2 (1.15 $in.^2$) designated for (1) no aging (control), (2) 12 wet–dry cycles of accelerated aging, and (3) 12 wet–freeze–dry cycles of accelerated aging. The accelerated aging tests were conducted in a stainless steel weathering cabinet equipped with a water spray and a temperature-controlled, forced-air heating system. The water spray nozzles were evenly spaced and delivered 6 to 8 liters/min of dechlorinated water to the top surface of the specimens. The wet–dry cycle used consisted of 12 hours of water spray, which brought the MC of the samples to above 30 percent. Following this, the samples were dried at 60°C to 70°C for 24 hours, which reduced the board MC to around 10 percent. A total of 12 wet–dry cycles were applied to the samples.

Aging with wet–freeze–dry cycles was similar to that with the wet–dry cycles. In this test, after 12 hours of water spray, the wet samples with MC greater than 30 percent were transferred to a freezer cabinet set at –18°C for 24 hours. Following this, the samples were again transferred to the weathering cabinet, and the forced-air heating that was set at 60°C to 70°C was activated, which dried the boards to a MC in the range of 10 percent. A total of 12 wet–freeze–dry cycles were applied to the samples.

Surface quality

After aging with 12 wet–dry cycles, three pieces of the quartersawn deck boards and three pieces of the flatsawn decking boards bonded with PRF adhesive were visually examined for delamination. The total number and the length of checks on both the top and bottom sides of the boards were recorded. So, in total, six sides were measured.

Table 1.—Phenol resorcinol formaldehyde (PRF) adhesive formula and physical properties.

PRF (Cascophen LT-75C)	100 parts
Hardener (Cascoset FM-282)	15–17 parts
Operational time at room temperature (21°C)	2-1/2 h
Gel time at 105°C	6.03 min
Viscosity	6,280 cPs
Clamp time	9 h

Table 2.—Polyurethane adhesive formula composition and physical properties.

Polymethylene polyphenyl isocyanate	25.12%
4,4′-Diphenylmethane diisocyanate	20.09%
Methylene diisocyanate	12.56%
Flash point	199°C
Density	1.13 g/cm^3
Operational time at room temperature (21°C)	30 min
Clamp time	6 h

Table 3.—Southern pine decking board sample characteristics.[a]

MC before gluing (%) ($n = 46$)	MC in testing (%) ($n = 6$)	Growth rings/in. ($n = 20$)	Density (g/cm^3) ($n = 6$)	Flatsawn grain angle (PRF) (°) ($n = 8$)[b]	Quartersawn grain angle (PU) (°) ($n = 13$)[c]	Quartersawn grain angle (PRF) (°) ($n = 9$)
10.6 (0.93)	11.8 (2.7)	8.3 (2.6)	0.47 (0.06)	9.4 (7.2)	74.4 (8.1)	75.6 (7.4)

[a] Numbers in parentheses represent the sample standard deviation.
[b] Boards bonded with phenol resorcinol formaldehyde (PRF) adhesive.
[c] Boards bonded with polyurethane (PU) adhesive.

MC and density

Before gluing, the MC of each board was tested with a pin-type moisture meter (Delmhorst Instructment Co.). Representative sapwood samples were obtained from the boards and used to determine rings per inch and specific gravity or density.

Block shear strength test

The MC of the samples used for block shear strength was determined with six samples. The samples were placed in an oven set at 103°C for 24 hours to determine the ovendry weight of the wood samples. The MC of the samples was determined with the following formula:

$$\text{MC (\%)} = (\text{Weight}_{\text{initial}} - \text{Weight}_{\text{dried}})/\text{Weight}_{\text{dried}} \times 100$$

where $\text{Weight}_{\text{initial}}$ is the weight when the samples were tested for dry block shear strength and the $\text{Weight}_{\text{dried}}$ is the weight after oven-drying.

The block shear test was conducted with 1-inch-thick blocks cut from quartersawn and flatsawn boards bonded with PRF and PU adhesives. Both aging and non-aging samples were tested, using at least seven replicates for each set. The test was performed in accordance with ASTM D2559 for shear strength and wood failure of the bond line and with the deformation speed of 12.7 mm/min (0.5 in./min).

Bending test

Edge-matched, unweathered quartersawn composite decking boards bonded with PRF adhesive and solid quartersawn lumber decking board samples were tested for modulus of elasticity (MOE) and modulus of rupture (MOR) in accordance with ASTM D1037 (ASTM International 2012a) using a 51-cm (20-in.) span on an Instron testing machine with six replicates. The samples were loaded in a three-point bending setup at a loading rate of 12.7 mm/min (0.5 in./min) until mechanical failure.

Microscopic observation

The bond lines of wood samples bonded with PRF and PU adhesives after accelerated aging with 12 wet–dry cycles and after 12 wet–freeze–dry cycles were examined microscopically to determine the impact of aging on the glue-line quality. Samples from both quartersawn and flatsawn boards were included. Confocal laser scanning microscopy was used, and images were acquired using a Carl Zeiss Axiovert 200 M Inverted Research microscope. The samples were illuminated with the 405-nm Diode 30-MW and 633-nm HeNe 5-MW laser lines.

Statistical analysis

Means and standard deviations of the tested data obtained were calculated. Duncan's multiple range tests with SAS 9.3 (SAS Institute Inc.) were used to determine the differences in different treatments.

Results and Discussion

General information

The general characteristics and properties for the decking boards used in this study are shown in Table 3. As can be seen from these data, the grain angles for the two types of boards deviate somewhat from true flatsawn and quatersawn material.

Surface quality after accelerated aging

After 12 wet–dry cycles of accelerated aging, no obvious delamination was observed in the bond line of either the flatsawn or quartersawn composite samples, indicating good bonding quality. Data on the comparative checking characteristics are listed in Table 4.

Statistical analysis showed that the flatsawn samples had more checks than the quartersawn samples (Table 4), a difference that was significant at $\alpha = 0.05$. It also showed that the flatsawn samples had longer checks than the quartersawn samples, but this was not significant at $\alpha = 0.05$. When checks developed in quartersawn samples, they sometimes were quite deep and long.

Block shear strength

After being subjected to 12-cycle aging tests, some of the test blocks were delaminated or had very low shear strength, which showed that using a 1-inch-thick block can help to reveal defects in the bond line after aging. The MCs of samples for shear strength tests are listed in Table 5. The shear strength of the controls (non-aging), PRF-bonded, and

Table 4.—A comparison of surface quality of flatsawn and quartersawn boards.[a]

	No. of checks	Check length (cm)
Flatsawn lumber	3.5 (1.4)	6.5 (3.3)
Quartersawn lumber	1.7 (1.0)	4.9 (3.2)

[a] Numbers in parentheses denote the sample standard deviation. Data obtained were based on the average of six readings.

Table 5.—Moisture content (%) of samples for shear strength tests.[a]

Sample conditioning	PRF adhesive quartersawn	PRF adhesive flatsawn	PU adhesive quartersawn
Non-aging	10.93 (3.79)	10.54 (9.56)	10.98 (2.21)
12 Wet–dry cycles	10.38 (5.37)	10.45 (4.79)	9.93 (3.51)
12 Wet–freeze–dry cycles	10.16 (3.07)	10.44 (4.35)	10.33 (3.51)

[a] $n = 6$. Numbers in parentheses represent the sample coefficient of variation. PRF = phenol resorcinol formaldehyde; PU = polyurethane.

Table 6.—Shear strength (psi) for quartersawn and flatsawn samples bonded with polyurethane (PU) and phenol resorcinol formaldehyde (PRF) adhesives.[a]

Sample conditioning	PRF adhesive quartersawn		PRF adhesive flatsawn		PU adhesive quartersawn	
	Mean (CV)	No.	Mean (CV)	No.	Mean (CV)	No.
Non-aging	1,362 (0.24)	23	1,727 (0.22)	10	1,521 (0.24)	25
12 Wet–dry cycles	1,226 (0.25)	23	1,148 (0.22)	7	940 (0.25)	19
12 Wet–freeze–dry cycles	1,077 (0.30)	18	1,099 (0.23)	8	940 (0.40)	18

[a] CV = coefficient of variation. 1 psi = 6.895 kPa.

PU-bonded samples after being subjected to aging with 12 wet–dry and 12 wet–freeze–dry cycles, respectively, are listed in Table 6.

The data in Table 5 show a trend of MC decrease after the 12-cycle aging treatment, especially for the PRF-bonded samples. Generally, the MCs of all the samples were statistically the same, except for the PU-bonded quartersawn samples after aging with 12 wet–dry cycles. The reason for this is unknown.

From the data in Table 6, it is apparent that for the non-aging samples, the flatsawn samples bonded with the PRF adhesive have a statistically greater shear strength ($\alpha = 0.05$) than the PRF-bonded quartersawn boards. Furthermore, in comparing the shear strength of the quartersawn boards, those bonded with the PU adhesive have 12 percent higher values, which agrees with normal observation. However, this is not statistically significant at $\alpha = 0.05$. The data in Table 6 also show that subjecting the samples to aging with wet–dry cycles and wet–freeze–dry cycles resulted in decreased shear strength of all samples.

For the quartersawn samples bonded with PU adhesive and the flatsawn boards bonded with PRF adhesive, statistically significant ($\alpha = 0.05$) reductions in shear strength of 38 and 34 percent, respectively, were apparent as a result of the test samples being subjected to the 12 wet–dry cycles of accelerated aging. A lower, statistically nonsignificant reduction in shear strength of 10 percent after accelerated aging was observed for the quartersawn samples bonded with PRF adhesive. These results show that for the same quartersawn samples, PRF adhesive tended to be more resistant to 12 cycles of wet–dry aging than the PU adhesive; when bonded with the sample PRF adhesive, quartersawn samples tended to be more resistant to 12 cycles of wet–dry aging than flatsawn samples.

With the exception of the quartersawn samples bonded with PU adhesive, exposing the test boards to the wet–freeze–dry aging resulted in greater, although not statistically significant, shear strength loss. Because the difference in these two types of aging tests was a freezing component, this suggests that freezing temperature may have a greater impact on PRF than on PU adhesives, which is in agreement with previous studies by Wang et al. (2015, 2016). This may be attributed to the fact that PRF adhesive has the sodium hydroxide catalyst, which is hydrophilic and makes the PRF bond line susceptible to freezing temperature, because water could be absorbed in the PRF adhesive. The water in the PRF adhesive may expand when frozen, which damages the PRF adhesive glue line.

Wood failure

Wood failure at the bond line of non-aging (control), PRF-bonded, and PU-bonded samples after being subjected to aging with 12 wet–dry cycles and 12 wet–freeze–dry cycles, respectively, is listed in Table 7. For the non-aging control samples, the flatsawn samples bonded with the PRF adhesive had greater wood failure than the PRF-bonded quartersawn samples, but this was not statistically significant ($\alpha = 0.05$). In comparing the wood failure of the quartersawn samples, those bonded with the PU adhesive had 28 percent (statistically significant, $\alpha = 0.05$) lower values. This agrees with the normal observations that PU adhesive resulted in low wood failure. The data in Table 7 also show that subjecting the samples to aging with wet–dry cycles and wet–freeze–dry cycles resulted in increased wood failure in PRF-bonded samples but decreased wood failure in PU-bonded samples.

As aging progressed, the fact that both shear strength (Table 6) and wood failure decreased in the bond line of PU-bonded quartersawn samples indicates one thing: PU adhesive failure occurred. Under the same situation, the fact that shear strength decreased and wood failure increased in the bond line of PRF-bonded quartersawn samples indicates that the PRF resin was durable but the wood was not.

For the samples bonded with PRF adhesive, increases in wood failure of 11 percent (from 84% to 93%) and 14 percent (from 88% to 100%), respectively, were apparent for quartersawn and flatsawn samples as a result of the test samples being subjected to aging with 12 wet–dry cycles. However, these were not statistically significant.

Table 7.—Wood failure (%) of different samples.[a]

Sample conditioning	PRF adhesive quartersawn		PRF adhesive flatsawn		PU adhesive quartersawn	
	Mean (CV)	No.	Mean (CV)	No.	Mean (CV)	No.
Non-aging	84 (0.25)	23	88 (0.24)	10	61 (0.70)	25
12 Wet–dry cycles	93 (0.15)	23	100 (0)	7	60 (0.71)	19
12 Wet–freeze–dry cycles	96 (0.14)	18	100 (0)	8	48 (0.89)	18

[a] PRF = phenol resorcinol formaldehyde; PU = polyurethane; CV = coefficient of variation.

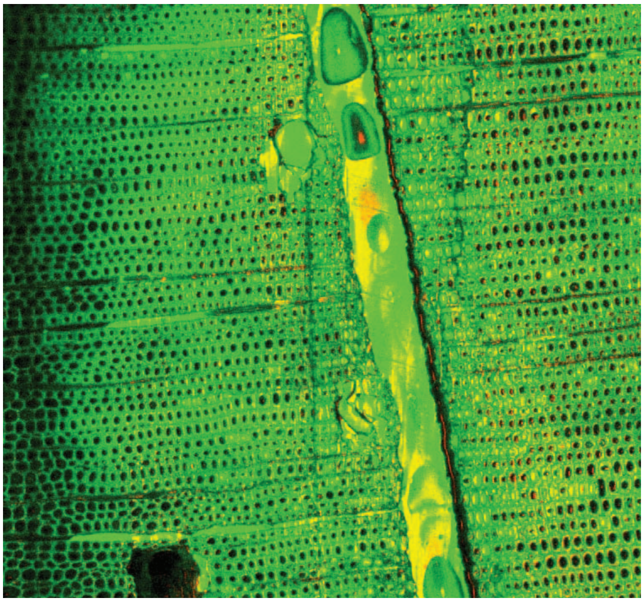

Figure 2.—After 12 cycles of wet–dry aging, separation occurred between the polyurethane adhesive and wood.

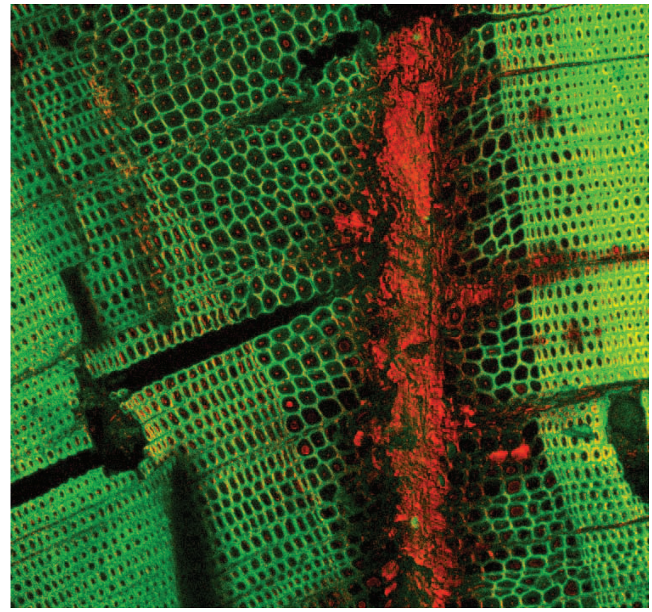

Figure 3.—After 12 cycles of wet–freeze–dry aging, the interface between the phenol resorcinol formaldehyde adhesive and wood was broken, and the damage from freezing temperature to the wood was more obvious.

Further exposing the samples to aging with the wet–freeze–dry cycles resulted in greater, although not statistically significant, wood failure of quartersawn samples bonded with PRF adhesive. Wood failure of flatsawn samples bonded with PRF adhesive was unchanged, although this also was not statistically significant. This trend indicates that the bond line of quartersawn samples was more resistant to the aging test than that of flatsawn samples.

Therefore, the information above illustrates the different patterns between PRF- and PU- bonded wood samples in terms of wood failure: PU adhesive may result in more cohesion or adhesive-adherend failure, whereas PRF adhesive results in more adherend failure or wood failure. The bond line of PRF adhesive was more durable than that of PU adhesive, and the bond lines of PRF-bonded quartersawn samples were more durable than those of flatsawn samples.

Figure 2 shows that after aging with 12 wet–dry cycles, a crack developed between the PU adhesive and wood. In contrast, Figure 3 shows that after aging with 12 wet–freeze–dry cycles, cracks developed but were mainly in the wood structure of PRF-bonded samples.

MOE and MOR test

Based on data in Table 8, the MCs of quartersawn composite and quartersawn solid wood lumber samples were similar. The density or specific gravity of quartersawn composite lumber samples is a bit greater than that of quartersawn solid wood lumber samples, which might be due to the PRF adhesive in the quartersawn composite lumber samples, but the difference is not statistically significant. MOE and MOR results (Table 8) show that compared with solid quartersawn lumber controls, the quartersawn composite lumber samples had low MOR but high MOE values, but again, these are not statistically significant. Compared with clean loblolly pine, based on the data from the Forest Products Laboratory (2010), both the quartersawn solid wood decking and quartersawn composite lumber had low MOR and MOE, showing that when applying quartersawn lumber in a decking application, the bending strength might be an issue. Because we only had six samples, to reach a conclusive statement, further research is needed.

Table 8.—Modulus of rupture (MOR) and modulus of elasticity (MOE) of different samples.[a]

	Mean (CV)		
	Quartersawn composite lumber	Quartersawn lumber	Clear control[b]
MOR (MPa)	82.2 (22.7)	87.9 (18.8)	88.2
MOE (GPa)	9.9 (28.2)	9.6 (28.4)	12.3
MC (%)	11.22 (7.1)	11.21 (5.9)	12
Specific gravity	0.49 (12.2)	0.48 (11.0)	0.51

[a] $n = 6$. CV = coefficient of variation; MC = moisture content.
[b] Data from Forest Products Laboratory (2010).

Conclusions

The feasibility of applying an innovative process to manufacture composite decking panels with quartersawn or starsawn southern pine lumber bonded with PRF or PU adhesive was studied. Results show that it is feasible to make quatersawn-based composite decking panels with possible improved surface qualities. Accelerated aging test data show that when bonded with PRF adhesive, composite quartersawn decking samples are more resistant to aging than flatsawn decking samples in terms of shear strength, especially after exposure to 12 wet–dry cycles of aging. Compared with the PRF adhesive, use of the PU adhesive resulted in greater initial dry shear strength but lower shear strength after an accelerated aging test. Furthermore, the amount of wood failure increased for the PRF-bonded wood and decreased for the PU-bonded wood after accelerated aging tests. Compared with solid quartersawn decking boards, the quartersawn composite decking boards had low MOR and high MOE, but these differences are not statistical significant.

Although it is possible to use the Primewood method to make quartersawn composite decking boards, the decking board property variation brought by different factors, such as radial and tangential face glue, heartwood and sapwood, clamping pressure, and different adhesives used, need further study and minimization. To make sure the bond line can help increase the MOE of quartersawn composite decking boards, end-matched quartersawn lumber should be used to make the composite board for the tests. Data in this study indicate that the difference in PRF and PU adhesives is revealed by 12-cycle aging tests. The data also suggest that the PU adhesive recipe or formula should be modified to have both high dry strength and high wood failure. Quartersawn composite decking might have a lower bending strength than flatsawn decking, which needs to be addressed in future studies.

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