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THE EFFECT OF PROFILING ON THE CHECKING OF SOUTHERN PINE AND AMABILIS FIR DECKING BOARDS

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Summary

This study tests the hypothesis that the effectiveness of surface profiling at reducing the checking of decking boards exposed to weathering will vary between wood species. Southern pine and Amabilis fir decking boards were machined to produce three different types of profiles: flat, ribbed and rippled. Boards were exposed to accelerated weathering for 5 days and the number and sizes of checks in boards was measured. The ribbed profile reduced the total number, length and width of checks in Amabilis fir boards by 70.5, 43.5 and 78.5 percent, respectively. The ripple profile was slightly more effective than the ribbed profile at restricting checking in Southern pine, reducing the number, length and width of checks by 49.9, 26.7 and 49.9 percent, respectively. We conclude that surface profiling is more effective at reducing checking of Amabilis fir than it is at reducing the checking of Southern pine. The ribbed profile in particular is highly effective at reducing checking of Amabilis fir. Large, visually distinct checks, however, can develop in profiled samples when the grain is aligned at an angle to the grooves of the profiles. Therefore we conclude that the presence of spiral grain in wood or machining profiles at an angle to the grain can reduce the effectiveness of surface profiling at reducing the checking of decking boards.

1. Introduction

The checking of wooden decking boards has long been a source of dissatisfaction to consumers (Fowlie et al., 1990). This dissatisfaction is being exploited by manufacturers of plastic and plastic-wood decking who claim that their products do not check or split. These plastic decking boards have captured at least 15% of the total market for decking boards in North America at the expense of wooden decking boards (Markarian 2005). The loss of market share for wooden decking has led to interest in methods of reducing the checking of decking boards exposed to the weather. Checking of decking boards can be reduced by pressure-treating boards with preservatives that contain wax or oil (Zahora 1991, Evans et al., 2009), or by regularly applying a water-repellent stain to the decking boards when they are in service (Ross et al., 1992). An alternative approach to reducing the checking of decking boards is to machine the surface of boards to create a series of narrow V (ribbed) or U (rippled) shaped grooves. Decking boards with ribbed surface profiles are common in Europe and Australia, but we can’t find any published accounts from these regions on the effectiveness of profiling at reducing checking. Recent studies in Canada have demonstrated the effectiveness of surface profiling at reducing the surface checking of Alpine fir (*Abies lasiocarpa* (Hook.) Nutt.) and Amabilis fir (*A. amabilis* (Dougl.) Forbes) decking boards exposed to natural weathering (McFarling and Morris 2005, Morris and McFarling 2008, McFarling et al., 2009). Profiling also reduced the total length of checks in blue-stained lodgepole pine (*Pinus contorta* var *latifolia* Wats.) decking boards exposed to natural weathering, but it did not reduce the depth of checking, and ripple profiling did not reduce the width of checks (Morris and McFarling 2008). These studies suggest that the effectiveness of profiling at reducing the checking of wooden decking boards may vary between different wood species. In this study we test this hypothesis by comparing the checking of profiled Southern pine (*Pinus* sp.) and Amabilis fir decking boards with that of standard (flat) boards subjected to accelerated weathering. Southern pine is the most important wood used for decking in North America, and this is the first report on the effectiveness of profiling at reducing the checking of this species.

2. Methodology

Six Southern pine and a similar number of Amabilis fir decking boards measuring 2500 (length) x 140 (width) x 40 mm (thickness) were purchased from a retailer and donated by a lumber company, respectively. We attempted to obtain 'clear' boards that were free of knots. Knots were absent from all the Southern pine boards, but a few were present in some of the Amabilis fir boards. The Southern pine wood was faster grown and denser than the Amabilis fir wood, but the grain angles of the two species were similar (Table 1).

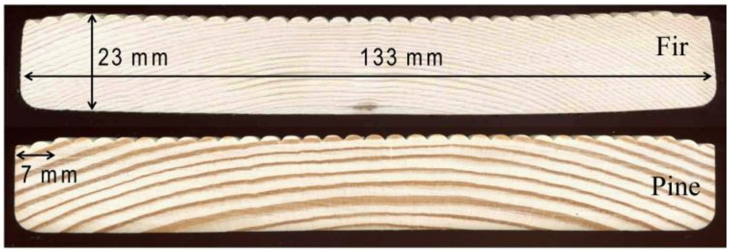
Table 1. Wood characteristics of Southern pine and Amabilis fir samples exposed to accelerated weathering

Board	Southern pine			Amabilis fir		
	Growth rings/cm	Density (kg/m^3)	Grain angle (˚)	Growth rings/cm	Density (kg/cm^3)	Grain angle (˚)
1	7.3	430	2.0*	8.0	375	2.0
2	7.0	523	2.2*	12.3	313	0.7
3	7.3	451	0.9	5.3	336	1.0
4	6.7	539	1.3	25.0	332	1.2
5	5.3	523	1.3	37.7	425	4.0*
6	6.7	457	1.2	13.3	360	1.5
Average	**6.7**	**487**	**1.5**	**16.9**	**357**	**1.7**

*Note the higher than average grain angles in these boards

All the boards were stacked horizontally and conditioned at 20 ± 1°C and 65 ± 5% relative humidity (r.h.) for 3 months. Each board was cross-cut to produce three samples of equal length. Samples from each board were allocated at random to the three different board profiles: flat, ribbed and rippled. Samples were machined using a rotary moulding machine and customized tooling to produce boards with these different surface profiles. Figure 1 shows cross-sections of Southern pine and Amabilis fir samples with ribbed and rippled profiles. The ribbed profile tapers-off towards the edge of the boards and the ripple profile does not completely extend to the edge of boards (Fig. 1). Both of these modifications to the profiles are designed to minimize edge damage to the boards caused by foot-traffic. Machining reduced the thickness of boards to 23 mm and their widths to 133 mm (Fig. 1). Board samples were cross-cut to produce samples which were 400 mm in length.

Ribbed



Rippled

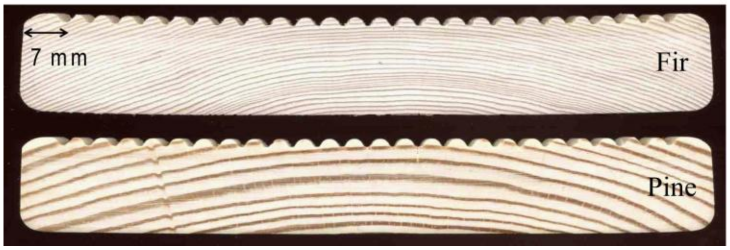


Figure 1. Cross-sectional dimensions of profiled Southern pine and Amabilis fir samples

Decking board samples measuring 4 x 4 cm were placed on the x-y stage of a chromatic confocal profilometer (Altisurf 500) and the surface topography of a small area (10 x 10 mm) was measured. The profilometer used a 3 mm probe, scan speed of 100 mm/sec, sampling frequency of 300 Hz, and resolutions in the x-y and z directions of 12 x 12 µm and 3000 µm to 92 nm, respectively. The software Papermap was used to produce two and three dimensional images of the profiled samples showing the dimensions of the ribs and ripples. The grooves were 1 mm deep in samples with a ribbed profile and 2 mm deep in samples with a rippled profile (Fig. 2). In-between the ridges the grooves tapered down to flat areas, which were 0.3 mm and 0.8 mm wide, in the ribbed and rippled samples, respectively (Fig. 2).

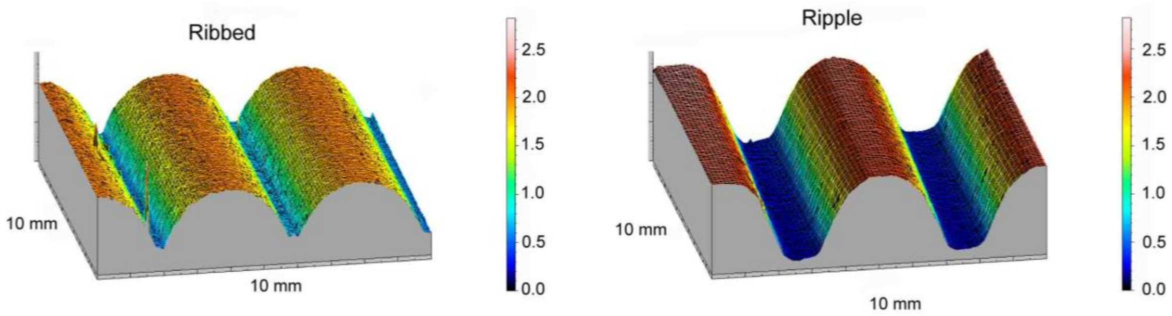


Figure 2. Surface topography of ribbed and rippled profiles in Amabilis fir

Southern pine and Amabilis fir samples with the same surface profile were exposed as a pair to accelerated weathering for a period of 5 days. Three pairs of samples with different profiles (flat, ribbed and rippled) obtained from one of the original Southern pine and Amabilis fir boards were weathered first before exposing another set of six samples (2 species x 3 profiles) in pairs to accelerated weathering. Samples were exposed to frequent wetting and drying at 62 ºC, and also UV light, in a device designed to accelerate the surface checking of decking boards (Ratu and Evans 2008). The weathering cycle was the same as described previously with the following modifications: 1. The amount of water sprayed on to the surface of each decking board sample every 30 minutes was increased from 12 mL to 18 mL; 2, After six hours of wetting and drying, samples were subjected to a 'wet cycle' during which each of the specimens were sprayed with 18 mL of water every 10 minutes for 1.5 h (at ambient temp). Five days of exposure to this weathering cycle produces the same level of checking of Southern pine samples as 20 weeks of outdoor exposure in the spring and summer in Vancouver, Canada (Ratu 2009). At the end of each weathering cycle, pairs of samples were removed from the weathering device and visible checks on the surface of samples were counted. The length and width of these checks were measured using a transparent Plexiglas ruler and an optical magnifying glass containing a calibrated graticule, respectively. Checking is expressed as the total number, length and width of checks in each sample. The average length and width of the 10 largest checks in each sample were also quantified.

A specimen 5 cm long in the longitudinal direction was sawn from the end of each decking board sample. These specimens were then resawn to produce 5 x 5 cm cubes. The basic wood density of these cubes was calculated using their oven dry weight (obtained by oven drying them at 105 °C overnight) and water-saturated volume (by Archimedean displacement). The grain angle of each board was measured on one of its unprofiled faces using a scribe and protractor.

Analysis of variance for a balanced hierarchical design was used to assess the effect of surface profile (flat, ribbed and rippled), wood species and the interaction of surface profile and wood species on checking. All statistical computation was performed using version 12 of the statistical program Genstat.

3. Results and Discussion

Surface profiling was very effective at reducing the total number and total width of checks that developed in Southern pine and Amabilis fir boards during accelerated weathering (Fig. 3), in accord with previous research on the effect of surface profiling on the checking of decking boards (McFarling and Morris 2005, Morris and McFarling 2008, McFarling et al., 2009). Accordingly, analysis of variance revealed a highly significant effect ($p<0.001$) of surface profile on total check number and width of checks in decking boards. The effect of surface profile on check length was not as strong ($p=0.054$) because the ribbed and rippled profiles had no significant effect on total check length in Southern pine, and Amabilis fir, respectively (Fig. 3b).

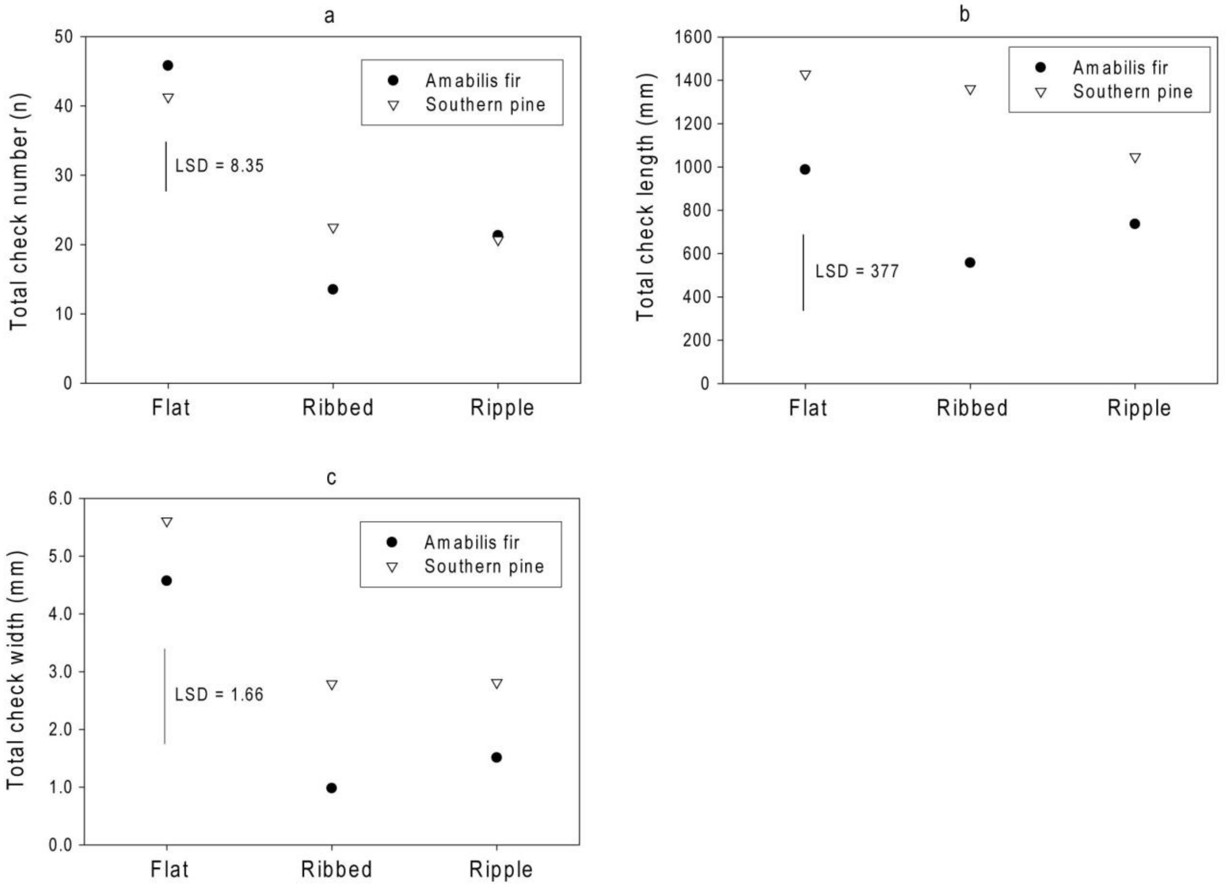


Figure 3. Total number and sizes of checks in Southern pine and Amabilis fir board samples with different profiles after accelerated weathering for 5 days: a, Total number of checks in samples; b, Total length of checks in samples; c, Total width of checks in samples. The error bar (LSD) represents the minimum difference between samples from the same species that is statistically significant

We also examined the effect of surface profile on the average length and width of the 10 largest checks in decking boards (Fig. 4), because larger checks influence the appearance and consumer perception of (flat) decking boards to a greater extent than smaller checks. Surface profile had a significant effect ($p=0.017$) on the average width of the ten largest checks that developed in boards because checks in ribbed Amabilis fir boards were much narrower than those in the other boards (Fig. 4b). The effect of surface profile on average check length was not as strong ($p=0.09$), but a consistent trend emerged for Southern pine and Amabilis fir boards with ribbed and rippled profiles. In these cases, and unexpectedly, the average lengths of the 10 longest checks in the profiled boards were greater than those that developed in boards with a flat profile (Fig. 4a).

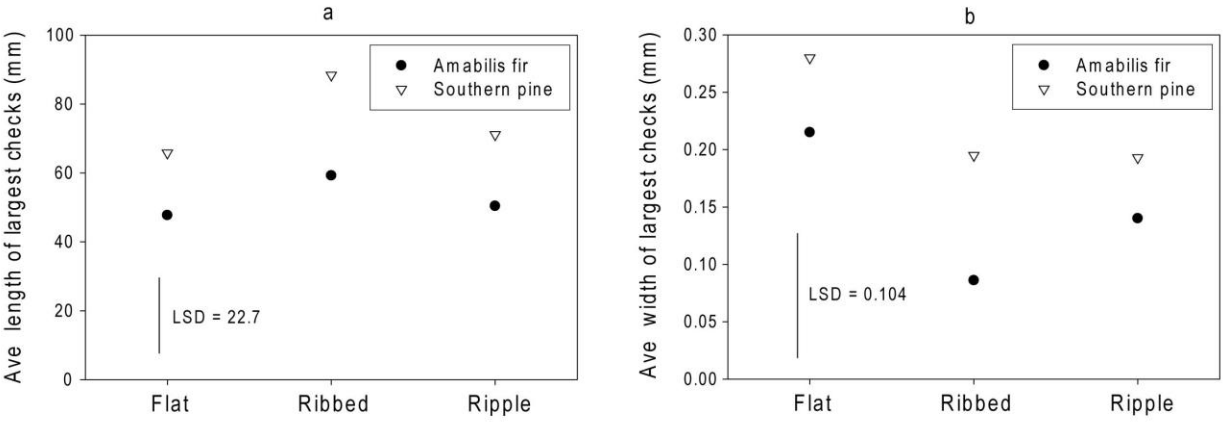


Figure 4. The average size of the 10 largest checks in Southern pine and Amabilis fir board samples with different profiles after accelerated weathering for 5 days: a, Average length of 10 largest checks in samples; b, Average width of 10 largest checks in samples

The number of checks that developed in the Southern pine and Amabilis fir boards averaged across all three profiles was similar and, accordingly, there was no significant effect ($p>0.05$) of species on check number. Checks in flat and profiled Amabilis fir boards were smaller than those that developed in comparable Southern pine boards, and this is reflected in the strong effect of species on total check length ($p=0.032$) and total check width ($p=0.011$). In comparison the effect of species on average length ($p=0.084$) and width ($p=0.056$) of the 10 largest checks in weathered boards was not as strong. The difference in checking between species was most pronounced for boards with a ribbed profile. Amabilis fir boards with this profile showed significantly ($p<0.05$) less checking (for all check parameters) than ribbed Southern pine boards. The checks in Amabilis fir boards with a rippled profile were also smaller than those in Southern pine boards, but the differences in check sizes in the two species were not statistically significant ($p>0.05$). Statistical analysis of the effect of surface profile on checking included observations for boards with a flat profile. The differences in the checking of profiled samples in the two species can also be compared by expressing checking of profiled samples as a ratio of checking in matched samples with flat profiles (Table 2).

Table 2. Total numbers and sizes of checks in profiled Southern pine and Amabilis fir samples expressed as a ratio of those that developed in matching unprofiled (flat) boards

Species	Ribbed profile			Ripple profile		
	Number	Length	Width	Number	Length	Width
Southern pine	0.545	0.952	0.497	0.501	0.733	0.501
Amabilis fir	0.295	0.564	0.214	0.465	0.746	0.330

These ratios are lower for Amabilis fir samples than for the Southern pine samples (except check length in rippled Southern pine samples) indicating that surface profiling is more effective at reducing checking in Amabilis fir than in Southern pine (Table 2). These ratios also confirm that the rippled profile is more effective than the ribbed profile at reducing checking in Southern pine than in Amabilis fir and vice versa.

These results for the checking of decking boards accord with some of the visual observations of the appearance of boards. The very narrow checks in the ribbed Amabilis fir boards formed at the base of the V-shaped grooves and could only be seen when viewed close-up. Hence, they did not affect the appearance of the decking boards. However, visible checks developed in the knots that were present in some of the ribbed Amabilis fir boards (Fig. 5a). In one ribbed Amabilis fir sample from board 5 a large visually distinct diagonal check developed that crossed 2 ribs (Fig 5b). The same type of visually distinct diagonal check developed in the matching rippled and unprofiled Amabilis samples and appeared to be due to the presence of higher grain angles in these samples (Table 1). A visually distinct check also developed at the top of one of the ridges in a rippled Amabilis fir sample from board 6 (Fig. 5c). No such checks developed in the ridges of the rippled Southern pine samples and the checks that developed in these samples were always formed at the base of the grooves (Fig 5d).

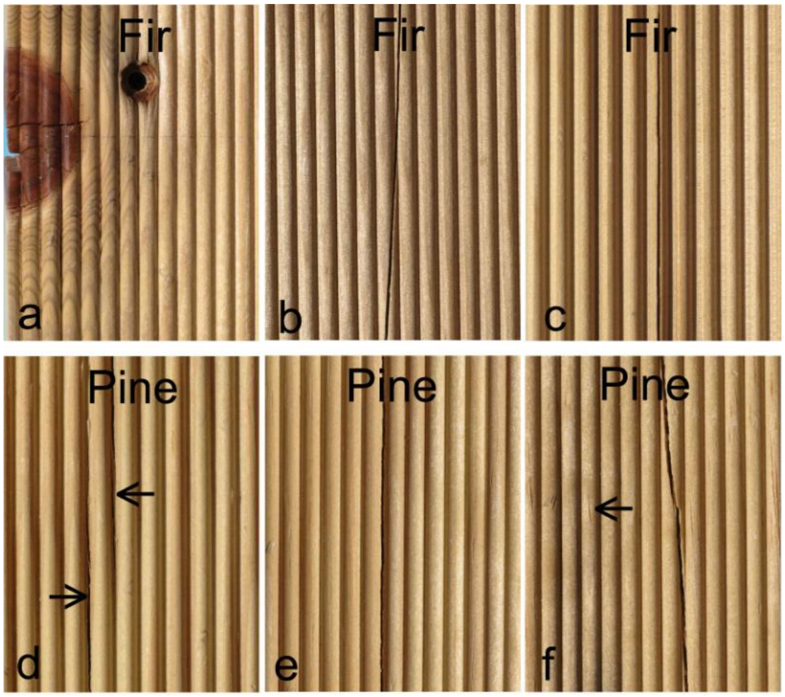


Figure 5. Appearance of profiled Southern pine and Amabilis fir samples after accelerated weathering for 5 days: a, Ribbed Amabilis fir sample with a visually distinct check in a knot, note that checks in the grooves below the knot are difficult to see; b, Ribbed Amabilis fir sample with a visible diagonal check crossing the ribs, note that the same type of check was found in the matching boards with flat and rippled profiles (not shown); c, Rippled Amabilis fir sample with a visually distinct check on top of one of the ridges; d, Rippled Southern pine sample showing small checks within the grooves (arrowed); e, Ribbed Southern pine sample showing a visually distinct check (separation) between ribs; f, Ribbed Southern pine sample showing a visually

distinct diagonal check crossing a rib, note that the resin canals, which are an indicator of grain angle, are aligned at an angle to the ribs (arrowed)
Checks also mainly formed at the base of the grooves in the ribbed Southern pine samples, but some of these checks were large and visually distinct (Fig. 5e). In addition, ribbed Southern pine samples from boards 1 and 2 each developed a check that crossed a rib. Both of these samples had higher grain angles than the other samples (Table 1). Fig. 5f shows a diagonal check crossing a rib of a Southern pine sample from board 1. The presence of spiral grain in this sample can be observed by comparing the alignment of the ribs with marks created by resin canals which run diagonally across the ribs (arrowed in Fig. 5f). The rippled Southern pine boards developed smaller checks and their visual appearance was better than those of the ribbed Southern pine boards, which, as mentioned above, sometimes developed quite large checks or separations between ribs (Fig. 5e). Smaller checks, however, were easier to see between the ridges of rippled Southern pine boards than between the ridges of ribbed Southern pine boards.

In the introduction to this note we hypothesized that the effectiveness of profiling at reducing the checking of wooden decking boards might vary between wood species. Our results supported this hypothesis because profiling, particularly the ribbed profile, was more effective at reducing checking of Amabilis fir than it was at reducing checking of Southern pine. This study was not designed to obtain information on how profiling reduces checking, but some of our findings provide insights into the mechanisms responsible for the reductions in checking of profiled specimens. Checks develop in restrained flat decking boards exposed to wetting and drying because differential shrinkage between surface and sub-surface layers leads to the development of surface tensile stresses (Schniewind 1963). Such stresses will be concentrated at surface discontinuities such as rays and resin canals and if these local stresses exceed the tensile strength of the wood then checks will occur. Localized stress concentrations and checking of materials subjected to tensile stresses can be reduced by machining grooves into their surface (Bhandari 2001). Surface profiling may have had a similar effect in the boards tested here. In addition, the grooves and ridges in profiled boards would reduce surface moisture gradients in boards because they allow water to more easily penetrate surface layers and provide a larger surface area for drying. Hence, the overall surface stresses that cause checking in decking boards are probably lower in profiled decking boards compared to flat sawn decking boards, which may also explain why checking of profiled boards was lower than that of flat boards. Nevertheless, stresses would still develop in profiled boards. It has been observed that checks in materials that contain stress relief grooves and are subjected to repeated stresses (as was the case here) develop cracks at the base of the grooves (Ghosh and Srivastava 2006). The same tendency was observed here and the checks that developed at the base of the grooves tended to follow the angle of the grain. The checks propagated in length rather than becoming wider because profiling had a greater effect at reducing check width than check length. Furthermore, the largest checks in profiled boards tended to be longer than those that developed in flat boards. However, even these long checks were difficult to see because they were very narrow, occurred at the base of grooves and were aligned with the orientation of the grooves. Observations in support of this explanation are the increased visibility of the wide checks that developed in some ribbed Southern pine samples and the fact that checks became very noticeable when they crossed the ridges of profiled samples.

These noticeable diagonal checks only developed in samples whose profiles were aligned at an angle that was 2° or greater to the grain.

4. Conclusions

Surface profiling was effective at reducing checking in both Amabilis fir and Southern pine decking board samples exposed to accelerated weathering, but it had a greater effect at reducing checking in Amabilis fir than in Southern pine. The ribbed profile was much more effective than the ripple profile at reducing checking of Amabilis fir. In contrast, Southern pine boards with a ripple profile checked less than matched samples with a ribbed profile. Therefore we conclude that the effectiveness of surface profiling at reducing checking of decking boards manufactured from different species depends on the type of profile machined into wood surfaces. Checks developed at the base of grooves, and appeared to be constrained from becoming wider to a greater extent than becoming longer because profiling had a greater effect at reducing check width than check length. Therefore we conclude that the beneficial effect of profiling on the appearance of boards arises because checks are much narrower than those on flat decking boards and are located at the base of the grooves where they are difficult to see. Checks that ran across ribs or ripples, however, were very easy to see. Such checks were observed in some of the profiled samples whose grooves were aligned at an angle to the grain. Therefore we conclude that the presence of spiral grain in wood or machining profiles at an angle to the grain can reduce the effectiveness of surface profiling at reducing the checking of decking boards exposed to weathering.

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6. Literature

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