USDA Forest Service
U.S. DEPARTMENT OF AGRICULTURE

Forest Products Laboratory | Research Paper FPL–RP–722 | December 2024

Effects of End Coatings on Defects During Air-Drying of Lumber

Scott Lyon
Collin Buntrock
Michael C. Wiemann
Scott Bowe

Abstract

End coatings are typically used to help prevent end checks on sawn lumber during the drying process. These drying defects can cause a loss of valuable lumber. This study was conducted to look at the effectiveness of three different types of end coatings. After 1 year of air-drying, boards with each of the three end coatings were compared with each other, and they were also compared with untreated control boards. Although all three end coatings were found to be effective in decreasing the amount and severity of drying defects compared with the untreated controls, there were no significant differences in effectiveness among the three types of treatments.

Keywords: air-drying, end coatings, drying stress, red oak, lumber

Conversion table

English unit	Conversion factor	SI unit
foot (ft)	3.048×10^{-1}	meter (m)
inch (in.)	2.54×10^{1}	millimeter (mm)

December 2024

Lyon, S.; Buntrock, C.; Wiemann, M.C.; Bowe, S. 2024. Effects of end coatings on defects during air-drying of lumber. Research Paper FPL-RP-722. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 4 p. https://doi.org/10.2737/FPL-RP-722

USDA Forest Service, Forest Products Laboratory
One Gifford Pinchot Drive, Madison, WI, USA 53726
(608) 231-9200
SM.FS.MailroomFPL@usda.gov

Effects of End Coatings on Defects During Air-Drying of Lumber

Scott Lyon, Forest Products Team Leader
Division of Forestry, Wisconsin Department of Natural Resources, Green Bay, Wisconsin, USA

Collin Buntrock, Wood Innovations Specialist
USDA Forest Service, State, Private, & Tribal Forestry, Cooperative Forestry, Rhinelander, Wisconsin, USA

Michael C. Wiemann, Botanist
USDA Forest Service, Forest Products Laboratory, Madison, Wisconsin, USA

Scott Bowe, Professor of Wood Products
Kemp Natural Resources Station, College of Agricultural and Life Sciences, University of Wisconsin-Madison, Woodruff, Wisconsin, USA

Introduction

For more than 100 years, the sawmill industry has applied end coating on logs and lumber to reduce drying defects (FPL 1919). Lumber dries from the surfaces in toward the center. Because the surface cells lose moisture first, they shrink sooner than the interior cells, causing drying stresses to develop, which may produce surface or end checks. Drying stresses occur first on the ends of lumber because ends dry at a faster rate and therefore shrink sooner than board faces. The stress typically begins when the lumber is first sawn and continues until about one-third of the moisture has evaporated. The surface and end checks may worsen later in drying, but all are created in this early stage. Drying rate depends on wood specific gravity, wood moisture content, temperature, relative humidity, and direction of moisture flow (Siau 1971). When wood moisture content is in equilibrium with the relative humidity and temperature of the surrounding air (referred to as equilibrium moisture content (EMC)), the wood ceases to gain or lose moisture and swelling and shrinking stops.

In general, diffusion (the movement of moisture) is 10 to 15 times faster along the grain than across the grain (Simpson 1991). Simply stated, wood dries much more quickly from the end grain than from the other board surfaces. It is this differential rate that results in serious drying defects such as end checking and splits. These defects can result in costly loss of usable wood. For example, a 4-in. end split or check on both ends of an 8-ft piece of lumber causes an 8% volume loss. If the volume loss is severe, it could potentially reduce the grade of the lumber. Applying end coatings to the ends of freshly sawn lumber helps to slow the drying from the ends of the boards and reduces checking and splitting (FPL 1999).

Historically, there were two classifications of coatings based on whether the coating needed to be heated for its application or not. Some of these coating applications included white lead, synthetic resin, wax, asphalt, pitch, paraffin, and paint (FPL 1919, 1959). Today's large-scale lumber manufacturers use a commercial emulsified wax product that is either brushed, rolled, or sprayed on the end grain to reduce drying degrade. This product is marketed as usable year-round with special formulations for cold and hot weather. Some smaller-scale producers have found exterior latex paint, roofing compound, or their own recipes useful to reduce drying degrade. To test the effectiveness of three different end-coating products, a small-scale air-drying study was conducted for one year in Antigo, Wisconsin. This study tested some of the products most commonly used by lumber manufacturers for end coating. The results of that study on the end grain drying defects of the sample lumber are given in this report.

Methods

Thirty No. 1 Common grade red oak (*Quercus* spp.) boards that were 8 ft 6 in. long were sawn the first week of July 2021 by a circular head saw and a horizontal band resaw to produce 1-in.-thick 8-ft-long boards ranging from 5 to 11 in. wide. Each board was freshly end-trimmed to remove any previous checking and splits, then cross-cut in half to produce 4-ft-long boards to be used for the study. One sample was discarded because of manufacturing defects, resulting in 59 boards included in the study. Three of these were used to monitor moisture content during the drying process. Of the remaining 56 boards, 42 were randomly selected to be end-coated on both ends (the treatments) and 14 were used as controls (left uncoated). The end coatings included an exterior latex paint, a commercial emulsified wax product, and a roofing compound. These were applied randomly to the ends of the boards. For effective application, each coating was applied thickly to the entire surface of each end and then any excess was scraped off (Fig. 1). Each end of each of the 42 boards was considered a treatment, making a total of 84 end-coating treatments. Each end of the 14 uncoated boards was considered a control, making a total of 28 uncoated controls. The treatments and controls are summarized in Table 1, with the color of the treatment (shown in Fig. 1) given in parentheses. The orange-colored coating on the ends of the three moisture content control boards is a commercial dry-kiln sample board sealer called B.O.S.S. (bright orange sample sealer) manufactured by UC Coatings (Buffalo, New York, USA). The boards were stacked with stickers placed at the absolute end to minimize warp and end checking. A plywood sheet "roof" was installed to keep off rain, snow, and direct sunlight. The roof overhang extended beyond the board ends limiting direct sunlight (Fig. 1). The lumber was then air-dried for 12 months near Antigo, Wisconsin, (45.1°N latitude), to an average moisture content of 11.8%. Comparable climate is found in Minneapolis, Minnesota (45.0°N latitude), for which EMC ranges from 11.7% in May to 14.9% in December. As a reference, small-scale lumber manufacturers often use the metric of one year per inch of lumber thickness to air-dry to an outside EMC. This estimate is an extrapolation from the drying calendar produced by the Forest Products Laboratory (Reitz 1972), which gives the amount of time needed to air-dry lumber to 20% moisture content in the upper Midwest based on the month in which drying is begun.

Table 1—Type, number, and color of board end treatments including untreated control board ends (Fig. 1 shows the board ends with the different-colored treatments)

Treatment	Number of board ends (color of treatment)
Exterior latex paint	27 (blue)
Emulsified wax	29 (white)
Roofing compound	28 (black)
Uncoated control	28 (no color added)

Results and Discussion

The roofing compound was the most difficult and messy to apply. The emulsified wax and latex paint both cleaned up easily with soap and water. At the end of the drying period, visual inspection was used to identify the extent of end checking or end splitting. Because this project compared different end coatings, a circular handsaw was used to trim off a thin wafer from the end of each sample to determine the underlying defects, if any, that were present but not visible through the end coating. When defects were found, another 1-in. strip of the board was removed, and if any were still present, an additional 1-in. strip was removed. Figure 2 shows two examples of end splits that formed as a result of air-drying. Table 2 gives the total number and approximate length of defects (checks or splits) found for each end-coating treatment.

Of the three different end-coating treatments, the roofing compound had three board ends with checks or splits that

Figure 1—Randomly selected end coatings of air-drying lumber. Orange end coloring marks the boards that were used to monitor moisture content (similar in use to kiln samples in a kiln charge). Boards with black-colored ends were treated with roofing compound, blue-colored ends were treated with latex paint, and white-colored ends were treated with emulsified wax. Boards with no color added are the uncoated controls.

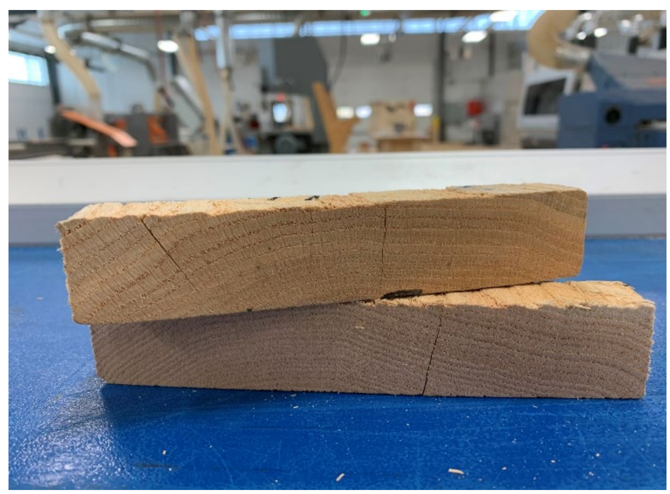

Figure 2—End splits resulting from rapid end drying. The splits are in the radial direction because the wood rays form planes of weakness.

Table 2—Number and length of drying defects on board ends after 1 year of air-drying

Treatment	Number of ends with no defects	Number of ends with defects	Number of ends with defects categorized by length of defect		
			<1 in. long	1–2 in. long	>2 in. long
Exterior latex paint	25	2	1	1	0
Emulsified wax	23	6	4	2	0
Roofing compound	19	9	4	2	3
Uncoated	1	27	6	12	9

were greater than 2 in. long and a total of nine boards with defects. This was more than either of the other treatments. Because the roofing compound was black in color, it may have absorbed additional heat, causing faster drying and more defects. In addition, because roofing compound is oil-based, it may not have fully adhered to the wet end grain of the freshly sawn boards. However, most of the sample boards treated with roofing compound still showed no defects.

The exterior latex paint treatment resulted in the least number of defects. One board end had end checks that were less than 1 in. long, and one had end checks between 1 and 2 in. long, but none had end checks greater than 2 in. Also, the latex paint coating was easy to apply to the ends of the boards. The emulsified wax, which was also easy to apply, did well, with only six samples with end defects. In four board ends, they were less than 1 in. long, and in two, they were between 1 and 2 in. long.

Table 2 shows that all end coatings reduced the number of end defects when compared with the uncoated controls. However, an analysis of variance (ANOVA) (Table 3) indicated that the type of end coating did not seem to matter a great deal even though the number of defects ranged from only two for the latex paint to nine for the roofing compound. The ANOVA showed no significant differences among the treatments in terms of overall presence of a defect or in terms of degree of defect severity. A p-value greater than 0.05 means that there was no statistically significant difference between treatments. This was the case for all end-coating treatments when compared with each other. A p-value less than 0.05 shows statistically significant difference between the treatments. This was the case for all end-coating treatments when compared with the uncoated controls.

Table 3—Analysis of variance by number of defects and severity of defects (Tukey multiple comparisons of means 95% family-wise confidence level)

Coating comparison	p-value, number of defects	p-value, severity of defects
Roofing compound and latex paint	0.054	0.716
Uncoated and latex paint	0.000	0.000
Emulsified wax and latex paint	0.505	0.988
Uncoated and roofing compound	0.000	0.005
Emulsified wax and roofing compound	0.619	0.879
Emulsified wax and uncoated	0.000	0.000

Conclusions and Further Considerations

This study showed that end-coating treatments were effective in reducing the amount and severity of defects caused by air-drying of lumber for 12 months compared with board ends that were not treated. However, the three types of treatments considered in this study did not significantly differ in effectiveness when compared with each other.

When determining which end coating works best for a production operation, it is important to consider how much product is needed. If large volumes are needed, ease of application should be considered. Another consideration is whether the coating is to be applied only in warmer weather or if there is a need to apply during cold weather. And, if the drying schedule requires additional drying in a kiln, the coating needs to be able to handle high temperatures and steam.

Acknowledgments

The authors thank Barbara Hogan of the Forest Products Laboratory for her careful review of this report and for the many corrections, revisions, and additions that she made to bring it to its final form. Northcentral Technical College in Antigo, Wisconsin, gave us the use of their vacuum and conventional steam kilns. Bill Smith of SUNY ESF in Syracuse, New York, and Omar Espinoza of the University of Minnesota gave valuable technical reviews that greatly improved the manuscript.

Literature Cited

FPL. 1919. Coatings that prevent end checking. Technical Note D-8. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 1 p. https://research.fs.usda.gov/treesearch/32251

FPL. 1959. Coatings that prevent end checks. Technical Note 186. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 4 p. https://research.fs.usda.gov/treesearch/32370

FPL. 1999. Air drying of lumber. General Technical Report. FPL-GTR-117. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 62 p. https://doi.org/10.2737/FPL-GTR-117

Reitz, R.C. 1972. News and views of this kiln-drying business: a calendar for air-drying lumber in the upper Midwest. Research Note FPL-RN-0224. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 3 p. https://research.fs.usda.gov/treesearch/5874

Siau, J.F. 1971. Flow in wood. Syracuse Wood Science Series, I. Syracuse, NY: Syracuse University Press. 131 p.

Simpson, W.T. 1991. Dry kiln operator's manual. Agric. Handb. 188. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 274 p. https://research.fs.usda.gov/treesearch/7164