Technical Note

Effects of End Plates on Reducing Checking of Pentachlorophenol-Treated Douglas-Fir Crossarms

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Abstract

The effect of metal end plates on reducing checking of pentachlorophenol-treated Douglas-fir crossarms was evaluated over 13 wet–dry cycles. Check development was variable over the first three to four cycles, and then steadily increased for both plated and nonplated ends of arms; however, both the number of checks and the maximum width of the checks were significantly lower on plated ends. The results suggest that end plating reduces the potential for deep check development in crossarms that could lead to early failure.

Checking of wood is a natural phenomenon that occurs due to the development of uneven stresses during drying (US Department of Agriculture [USDA] 1999). In general, wood dried to below the fiber saturation point tends to shrink as the water bound to the cellulose microfibrils is removed (Panshin and de Zeeuw 1970). The degree of longitudinal shrinkage is minor in mature wood, tends to be greater in the tangential direction, and is the largest in the radial direction. Average tangential shrinkage in Coastal Douglas-fir is 7.6 percent, while radial shrinkage is only 4.8 percent (USDA 1999). Uneven shrinkage in the radial and tangential directions during drying leads to the development of internal stresses that can reach levels that exceed the strength of the wood in one or more directions. Typically, these stresses are relieved through the development of radial checks that tend to be closely aligned with the rays.

Checking is a normal response to wood drying. It usually has little effect on natural properties, although the checks can produce an unsightly surface appearance that renders the wood less useful for some decorative applications. Repeated wetting and drying of wood can exacerbate check size, leading to further reductions in value.

One nondecorative, structural application in which checks can lead to reduced properties is wood used as a crossarm on a utility pole. Crossarms are typically used with the longitudinal axis of the wood oriented perpendicularly to the pole and the wires suspended from insulators hung from the arms. While wood has long served as a reliable, economical crossarm material, repeated wetting and drying can lead to the development of deep, wide checks and eventually to splitting. Checks on the upper surface of the arm often penetrate beyond the depth of the original preservative treatment. Water collecting in these checks creates ideal conditions for fungal attack. Cracks that develop on the ends of the arm perpendicular to the ground can widen to the point that the insulator pins drop through the arm, resulting in costly line outages. This problem can be particularly severe in drier climates.

One possible solution for limiting checking and splitting on crossarms is to apply metal truss plates to the ends of the arms to restrain wood movement, thereby limit checking. This practice is common in the railway tie industry in which tie plates are applied to ties either at the start of seasoning or to ties that have split during seasoning (Conners 2008). Although the plates will fail in cases of extreme splitting, they have allowed producers to retain a much higher percentage of ties that are acceptable to railroads.

While these plates should provide similar protection to wood crossarms in terms of reduced checking, there are to date no studies evaluating their ability to restrain check development on these materials. The objective of this study was to compare checking of plated and nonplated Douglas-fir crossarms subjected to repeated wet–dry cycles.

Materials and Methods

Thirteen Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) crossarms (87.5 mm by 112.5 mm by 2.4 m long)

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were end plated on both ends with a galvanized nail plate (72 by 122 mm) with 42 teeth extending 12 mm into the wood (Fig. 1). No effort was made to select arms since the goal was to evaluate commercial materials. The arms were then cut in half to produce 26 1.2-m-long sections, each with a plated and a nonplated end. The arms were then pressure treated in a commercial treatment with pentachlorophenol in P9 Type A oil to a target retention of 4.8 kg/m to meet the American Wood Protection Association (AWPA) Standard U1 Section (AWPA 2010). The time between plating and cutting was less than 7 days to minimize the risk of check development prior to treatment.

The arms had few visible checks at the start of the study. As a result, checking data were only tallied once the wet–dry cycling had begun. One arm section was set aside and not subjected to wetting or drying. Since there is no specific standard method for moisture cycling on wood crossarms, the cycle was established to ensure that the arms reached moisture contents above the fiber saturation point (approximately 30%) and were then dried as aggressively as possible. The remaining 25 arms were first immersed in water for a minimum of 30 days. Preliminary weighing revealed that this immersion resulted in wood moisture contents above the fiber saturation point. The arms were removed from the water, and the number of checks and the width of the widest check were measured on each end. All checks on each cross section were counted, and then the widest check on each face was measured (to the nearest millimeter). The arms were then kiln dried to a target moisture content of 17 to 20 percent using a schedule with a large wet bulb–dry bulb depression (82.2°C dry bulb–65.6°C wet bulb) to maximize the development of drying stresses. Check width and number were again measured on both ends of each arm after drying. This process was repeated an additional 12 times over a 3-year period. Although the plate obscured some of the cross section, checks did extend across the plate and could be accurately measured, especially with an increased number of wet–dry cycles.

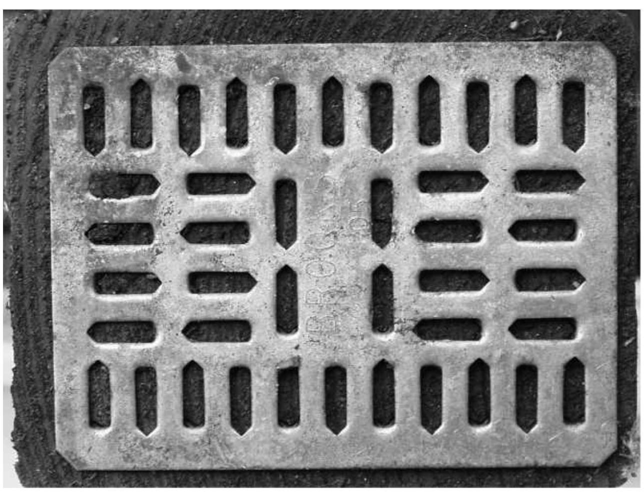

Figure 1.—Example of an end plate on a Douglas-fir crossarm.

Check frequency and width between plated and nonplated ends as measures of check severity were subjected to paired t tests ($\alpha = 0.05$) after 6 and 13 cycles.

Results and Discussion

The arm not subjected to the wetting and drying cycles had few checks on either end prior to testing. Check number and width on the arms subjected to wetting and drying tended to vary most widely between the wetting and drying cycles at the end of the wetting period (Table 1). Some of this variation can be attributed to closing of checks as the wood moisture content rose, but it also likely reflects the ability of the plate to restrain wood movement once a check has opened. Thus, check width at the end of the wet cycle was sometimes lower on the nonplated ends of the arm because the wood was able to move to a greater extent than on the plated end. While the wet-phase data show closing of checks with wetting, the data on dry arms are more useful from a utility perspective because they show the extent of change in checking that could eventually lead to splitting and subsequent arm failure. As a result, this discussion will primarily focus on data collected following the drying cycles.

The number of checks per arm was four times higher on nonplated ends than plated ends after one wet–dry cycle. The degree of difference declined slightly after the second cycle and then actually reversed after the fourth and fifth cycles.

Table 1.—Effect of an end plate on checking of Douglas-fir crossarms as determined by frequency of checks and width of the widest check over 13 wet–dry cycles.[a]

	No. of checks/arm				Widest check/arm (mm)			
	Wet cycle		Dry cycle		Wet cycle		Dry cycle	
Wet–dry cycle	(−) plate	(+) plate	(−) plate	(+) plate	(−) plate	(+) plate	(−) plate	(+) plate
1	2.31 (1.95)	0.34 (0.69)	0.46 (1.84)	0.12 (0.33)	0.13 (0.31)	0.14 (0.36)	0.06 (0.20)	0.08 (0.23)
2	0.19 (0.63)	0.08 (0.27)	1.08 (1.16)	0.42 (0.64)	0.03 (0.09)	0.08 (0.27)	0.54 (0.41)	0.40 (0.61)
3	0	0.08 (0.27)	0.23 (0.51)	0.16 (0.37)	0	0.08 (0.27)	0.16 (0.34)	0.17 (0.40)
4	0.08 (0.27)	0.08 (0.27)	0.52 (0.71)	0.96 (1.10)	0.03 (0.13)	0.10 (0.35)	0.30 (0.43)	0.49 (0.41)
5	0.03 (0.14)	0.08 (0.27)	0.56 (0.67)	0.80 (0.91)	0.03 (0.14)	0.12 (0.44)	0.41 (0.67)	0.50 (0.71)
6	1.92 (1.58)	0.32 (0.56)	2.00 (1.22)	0.36 (0.57)	0.38 (0.27)	0.12 (0.25)	1.16 (0.68)	0.38 (0.62)
7	1.40 (1.63)	0.52 (1.05)	2.24 (1.33)	2.00 (1.38)	0.23 (0.24)	0.16 (0.34)	1.52 (0.81)	1.15 (0.66)
8	0.96 (0.93)	0.12 (0.44)	2.44 (0.82)	1.44 (0.96)	0.62 (0.60)	0.09 (0.30)	2.32 (1.28)	1.26 (0.66)
9	0.92 (0.76)	0.52 (0.71)	2.96 (1.43)	1.52 (1.47)	0.66 (0.66)	0.30 90.40)	2.52 (1.11)	2.12 (0.71)
10	1.52 (1.47)	0.80 (1.12)	3.84 (1.11)	2.20 (1.23)	0.86 (0.87)	0.30 (0.40)	2.28 (1.04)	1.56 (0.67)
11	0.84 (0.69)	0.40 (0.50)	3.40 (0.91)	2.32 (1.11)	0.69 (0.60)	0.31 (0.43)	2.70 (1.29)	1.93 (0.74)
12	3.16 (2.53)	1.40 (1.47)	3.60 (1.12)	2.36 (1.19)	1.11 (0.62)	0.62 (0.43)	2.41 (1.31)	1.58 (0.54)
13	1.24 (0.88)	0.60 (0.89)	3.48 (1.05)	2.80 (1.19)	0.90 (0.66)	0.33 (0.45)	2.81 (1.58)	2.06 (0.63)

[a] Numbers in parentheses represent one standard deviation around the mean of 25 crossarms.

Check numbers were consistently higher on the nonplated end of the arms from the sixth cycle onward, although frequency increased for both plated and nonplated ends over these cycles. The number of checks was significantly higher on nonplated ends of the arms at 6 and 13 wet–dry cycles ($P = 0.0119$, 1.37×10^{-6}, respectively). The reasons for the consistent increase in checking severity is unclear, but may reflect the gradual increase in micro-checking that eventually became visible to the naked eye.

Check width also tended to vary over the first three wet–dry cycles. In some cases, plated ends had slightly larger check widths than did the nonplated ends. Check width increased more or less steadily over the first 10 wet–dry cycles for both plated and nonplated ends of the arms; however, the check widths were significantly lower on the plated ends after 6 and 13 wet–dry cycles ($P = 0.0004$, 0.018, respectively). It is important to note that check width did increase with wet–dry cycle for both plated and nonplated ends, but the effect was more pronounced on the nonplated ends of the crossarms (Figs. 2 and 3). Maximum check width on plated arms was 73 percent that of the nonplated arms after the 13th wet–dry cycle, illustrating the benefits of end plating for reducing check development associated with cyclic moisture exposure.

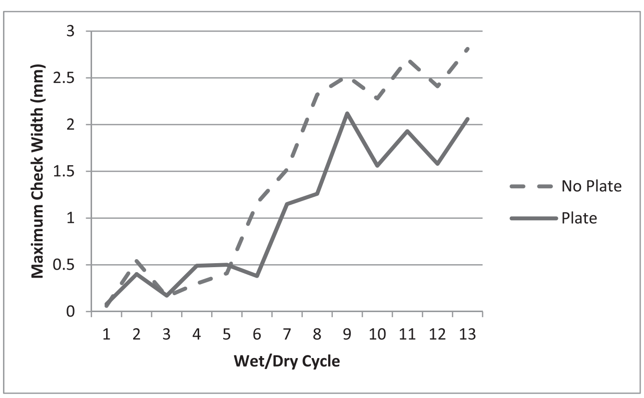

Figure 2.—Maximum check width on the ends of Douglas-fir crossarms with and without end plates over 13 wet–dry cycles as measured at the end of each dry cycle.

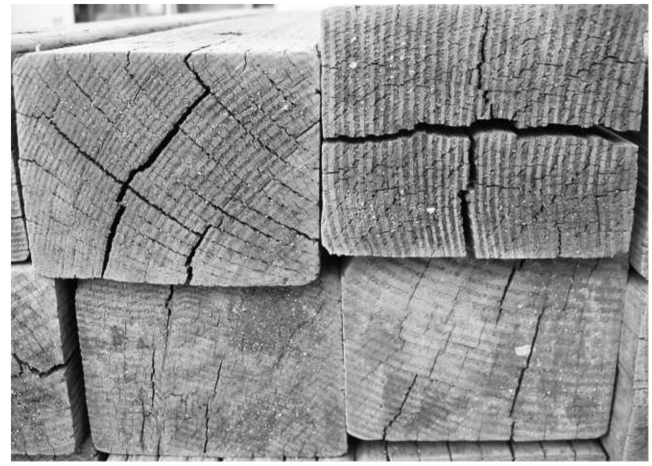

Figure 3.—Examples of checking on the nonplated ends of four arms after 13 wet–dry cycles showing the wide range in degree of checking observed.

Conclusions

End plating produced significant reductions in both the number and size of checks developing on the ends of Douglas-fir crossarms subjected to repeated wet–dry cycles. The results indicate that end plating may be an effective means for limiting the risk of splitting on crossarms in service.

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