The Use of Boron Rods as a Boron Source for Dual Treated Timber

Mark E. Mankowski
USDA Forest Service, Forest Products Laboratory
Starkville, Mississippi

Grant Kirker
Stan Lebow
USDA Forest Service Forest Products Laboratory
Madison, Wisconsin

James Renfroe
Wood Care Systems
Kirkland, Washington

Jeffrey J. Morrell
Oregon State University
Corvallis, Oregon

ABSTRACT

Fused borate rods were installed at equal distances along the length of unseasoned red or white oak bridge timbers. Moisture content and boron levels were examined at 15 and 30 weeks after rod installation at various points along the bridge timbers. Moisture contents for both red and white oak were greater than 60% at all time checks. Boron levels were highest near the point of borate rod placement, but high levels were also recorded 4 and 6 inches from the rod installation point. Boron levels transverse to the boron rod installation point were lower than in the longitudinal direction. Acceptable boron levels were recorded at points up to 6 inches away from the boron installation point after 30 weeks. Boron levels in the transverse direction remained lower than acceptable levels for dual treatment.

INTRODUCTION

Extending the service life of large bridge timbers and railroad cross-ties is of great importance as it is very costly and labor intensive to prematurely replace these materials (Edlund, et al. 1983; Amburgey and Sanders, 2009; Kitchens and Amburgey, 2015; , Kim and Lloyd, 2017). In recent years, traditional creosote treatment of these wood products has been aided by an initial treatment with soluble borate applied via dipping or pressure treatment. The diffusible boron penetrates through the wood and gives added internal protection after the timber or tie is over treated with creosote. This dual treatment has been shown to greatly extend the service life of the member especially in high biodeterioration hazard areas (Amburgey and Sanders, 2009; Kitchens and Amburgey, 2015). In 2012, the AWPA standardized dual creosote-borate treatments, specifying that borate pre-treatment retention must reach 0.17 PCF B_2O_3. The borate treated member is then over treated with the regular AWPA standard retention of creosote or copper naphthenate (AWPA, 2018).

As the dual treatment process has caught on in the wood treatment industry, some facilities that would like to perform this type of treatment cannot because of the initial cost to install a pressure cylinder or dipping system for the initial borate treatment. A possible alternative is internal treatment with borates using non-pressure applications similar to those used in remedial treatments of wood in service. One study reported substantial boron diffusion when borate was added to ports drilled into timbers prior to pressure-treatment with copper naphthenate (Lloyd, et al., 2015). A more concentrated form of boron used for some remedial borate treatments is the borate rod which can readily dissolve at wood moisture contents (MCs) above 30% (Smith and Williams, 1969; Morrell, et al., 1992; Morrell and Schneider, 1995; DeGroot, et al., 2000; Cabrera and Morrell, 2009). Borate rods are solid, fused borate containing 98% disodium octaborate tetrahydrate and have been shown to readily diffuse when used to remedially treat utility poles or timbers in service (Morrell and Schneider, 1995; DeGroot, et al., 2000). Highley and Ferge (1995) showed that fused borate rods diffused in treated timbers and that boron levels could be monitored using increment cores at various longitudinal and transverse points from the fused rod application point. Placing large boron rods in large bridge timbers and railroad ties at certain distances apart could be a passive form of dual treatment. Borate rods installed in green, high moisture content, timber before the creosote Boultonizing treatment would most likely continue to diffuse after creosote treatment and after the member reaches its installation point. If rods are placed at regularly spaced locations along the length of a large timber, boron should diffuse throughout the timber and potentially reach the specified AWPA level needed to prevent decay and insect attack.

The goal of this study was to examine a cost-effective method for dual treatment for smaller operations that cannot afford to install equipment for borate pressure treatment. Given that boron diffuses readily at MCs above 30%, the goal of this study was to evaluate the use of borate rods in green red and white-oak bridge timbers over a 18 month exposure period at a severe test site (Saucier, MS).

MATERIALS AND METHODS

For the study, timbers and borate rods were supplied by WoodCare Systems (Kirkland, WA). Five red oak (*Quercus rubra* L.) and 6 white oak (*Quercus alba* L.) timbers measuring 10in x 10in x 10ft (25.4cm x 25.4cm x 304.8 cm) were treated with borate rods. The rods measured 3 (7.63 cm) inches long and ¾" (1.9 cm) thick. Rods were placed in 5 inch (12.7 cm) deep ¾" (1.9 cm) holes spaced 13.25 inches (33.7 cm) apart along the length of green timbers. Number and spacing of rods was calculated to deliver 0.17 pcf B_2O_3. Bore holes were plugged and then the timbers were pressure treated with creosote. Timbers were shipped to the Harrison Experimental Forest (HEF) located in the Desoto National Forest in south Mississippi and installed in September 2018.

Holes were drilled in line with the center of three red oak and three white oak timbers. Rods were inserted into pre-drilled holes that were sealed with an inch long ¾" (1.9 cm) diameter plastic plug. The unseasoned ties were loaded into a treatment cylinder and an 18-22' Vacuum was pulled while filling the cylinder with hot creosote. The timbers were boiled in the cylinder for 12 hours after which the hot oil was drained and a pressure of 40 psi was built up in the wood. Hot oil was then pumped into the cylinder under pressure until the AWPA retention of 8.0 pcf for creosote was reached. The target retention was determined by dividing the total cubic feet of wood in the charge by the desired pounds of creosote per cubic foot. This was determined by a gauge measuring creosote volume. The pressure process was applied for another 12 hours. Once the desired gauge retention was achieved the pressure was stopped and a final vacuum of 18-22" was pulled to reduce the creosote on the surface. The vacuum was then stopped and the cylinder emptied. The freshly treated timbers were set on a drip pad for 24 hours or until no dripping was observed. The moisture in the interior of the timber would remain high during this process (80-100%) ensuring the initiation of boron diffusion after the creosote over treatment as rods dissolve at the fiber saturation point. The treated timbers were shipped to the Harrison Experimental Forest in Saucier, MS where they were placed in the field test. Timbers were placed directly on the ground approximately two feet apart with plugged rods holes facing upward.

Moisture content of the timbers was measured at 6 weeks by taking two 6 inch cores from each timber. Cores were placed in plastic drinking straws, with one end pre-stapled shut. The open end was then stapled shut in the field. The straws were placed in a plastic zip-lock bag, kept on ice, and transported to the FPL laboratory in Starkville, MS. The cores were removed from the straws, weighed and the dried at 60º C for 24 hours. This temperature was used as there was a concern that boron may be driven off at higher drying temperatures. The cores were conditioned in a desiccator for 5-10 minutes then re-weighed to obtain the dry weight.

After 11 weeks, the condition of the borate rods was monitored by removing the plugs of the rod holes for every other plug on the timbers and examining the rod condition using a flashlight. After 15 weeks, increment cores were taken in a cruciform pattern in three red oak and three white oak timbers starting at the second rod hole away from the end of the timber (Figure 1). This was repeated at the next rod hole from the end of the timber after 30 weeks (Figure 1). Sampling was conducted in a manner similar to that described by Highley and Ferge (1995) where cores were taken from longitudinal and tangential points in relation to the position of a boron treatment. Six inch (15.24 cm) long cores were taken with an 8 inch (20.3 cm) increment borer. Cores were taken longitudinally from the rod hole at 2, 4, 6" (5, 10, 15 cm) in each direction (Figure 2). The 6' (15 cm) distance cores were positions 1 and 2. The 4" (10 cm) distance cores were positions 5 and 6. The 2" (5 cm) distance cores were positions 9 and 10. Cores were also taken in the tangential direction from the edge of the rod hole. These cores were 1.5 inches (3.8 cm) (positions 3 and 4) and 3 inches (7.6 cm) (positions 7 and 8) from the rod hole (Figure 2). The bridge timbers were sampled at 15 and 30 weeks as shown in Figure 1. Sampling was conducted in a progression that was assumed to be moving from areas of low to high boron concentration. Cores 6 inches from the rod hole were taken first – i.e. positions 1 and 2. The outer 3 inch tangential cores (positions 3 and 4) were taken next and so forth. The cores were carefully pushed out of the increment borer into a plastic drinking straw, stapled closed, bagged and put on ice. The increment borer was cleaned with deionized water and blown out with canned air in between each sampling. Samples were transported to FPL, weighed, dried at 60º C for 24 hours and re-weighed to obtain moisture content.

Dried cores were sprayed with curcumin indicator, allowed to dry for five minutes then sprayed with salicylic acid indicator to observe boron penetration (AWPA, 2018). The cores were then sectioned into inner 3 inch (7.6 cm) and outer 3 inch (7.6 cm) sections that were ground in a Wiley mill (manufacturer, location). Ground inner and outer samples were sent to Oregon State University where they were processed and analyzed for boron via the Azomethine-H method as described in AWPA Standard A65 (AWPA, 2018).

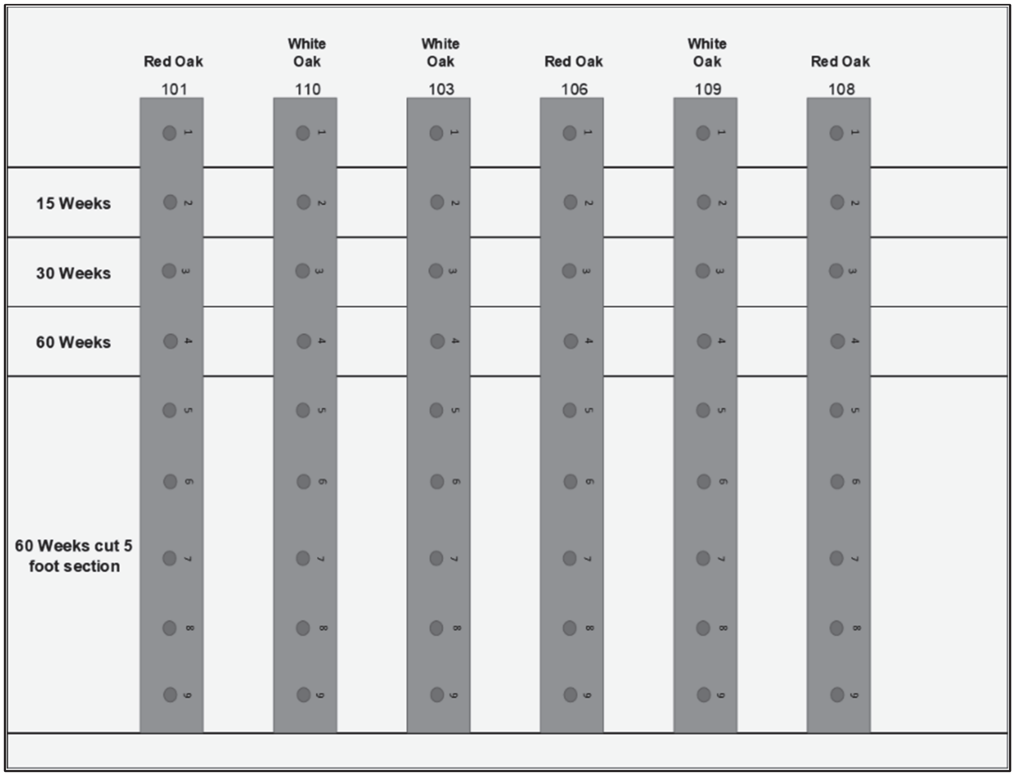

Figure 1. Field placement and sampling time scheme for borate rod and creosote treated bridge timbers placed in the field in Saucier, MS. The 60 week sampling and sectioning is not included in this report.

Figure 2. Longitudinal and tangential point sampling pattern around a hole that received a borate rod.

RESULTS AND DISCUSSION

Rod condition at 11 weeks

Rod holes were either filled with water and we could not detect the presence of a rod or they were empty indicating the borate rods had completely dissolved 11 weeks after application.

Moisture Content

Figure 3 shows the average moisture content for red and white oak timbers at 6, 15 and 30 weeks. Red and white oak had mean moisture contents of 71.0% and 62.8%, respectively, six weeks after treatment. After 15 weeks, the moisture contents for red and white oak were 63.5% and 66.7%, respectively. After 30 weeks the moisture contents were 59.7% and 62.9% for red and white oak, respectively. Elevated moisture levels for all periods sampled indicate that conditions were suitable for boron diffusion. It is unknown whether the rods dissolved at all during the creosote Boultonizing process; however, diffusion should have begun almost immediately since moisture contents of the timbers were above 60 % in both species. Many rod holes inspected 11 weeks after treatment contained water that most likely aided in boron diffusion.

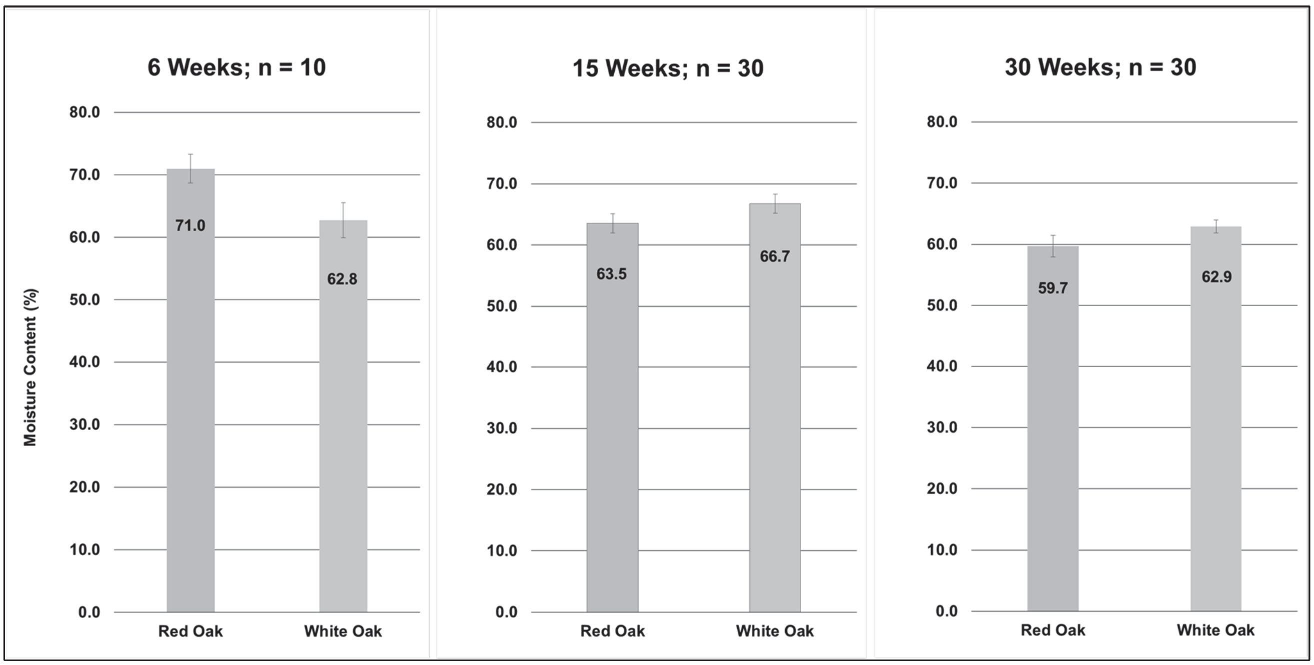

Figure 3. Average moisture contents of red oak and white oak bridge timbers as measured on increment core at 6, 15 and 30 weeks after treatment with borate rods and creosote. Timbers were treated green with high initial moisture content.

Boron Indicator

Boron was well distributed at the longitudinal position, particularly positions near the rod hole. The inner core sections were generally stained darker suggesting higher boron levels in the inner part of the timber at longitudinal sample points. We observed very little staining in cores removed from the tangential positions suggesting reduced boron movement. This was particularly true for positions 3 and 4 (3 inches (7.6 cm)) from the bore hole. It was noted that some staining was darker in the outer longitudinal positions (1 and 2) compared to the mid-way positions (5 and 6). This may have been from overlapping boron fronts from the adjacent rods in the timber.

Boron Analysis - Red Oak

Analytical results for boron levels in the core samples at the 15 and 30 week sampling times are shown in Figure 4. The boron levels from all inner and outer cores (n=60) are shown at the far left part of the chart. The dotted line between 0.15 and 0.2 pcf B_2O_3 is the AWPA standardized level of B_2O_3 (0.17 pcf) required for dual treated timbers. We also compared boron levels for the inner and outer sections of the cores, all longitudinal or tangential samples and the average of samples taken at each sampling point away from the rod hole (Figure 2). The average boron level in all cores met the AWPA standardized level at 30 weeks. However, boron levels were higher in the inner core and longitudinal sampling points compared to the outer core sections and tangential sampling points. These results agree with previous studies showing that boron generally diffused faster longitudinally versus tangentially (Highley and Ferge, 1995; DeGroot, et al. 2000).

Boron Analysis - White Oak

Analytical results for boron levels in the core samples at the 15 and 30 week sampling times are shown in Figure 5. The dotted line between 0.15 and 0.2 pcf B_2O_3 is the AWPA standardized level of B_2O_3 (0.17 pcf) required for dual treated timbers. The boron levels from all inner and outer cores (n=60) are shown at the far left part of the chart. Results were similar to red oak except less boron diffused tangentially after 30 weeks in white oak compared to red oak. The extent of longitudinal boron diffusion in white oak in this study was greater than that reported in previous studies (Morrell, et al. 1992; Highley and Ferge, 1995), perhaps because of the higher moisture contents observed in this study. It is also possible that the elevated temperatures used during pressure-treatment aided boron diffusion as suggested by Lloyd, et al, 2015.

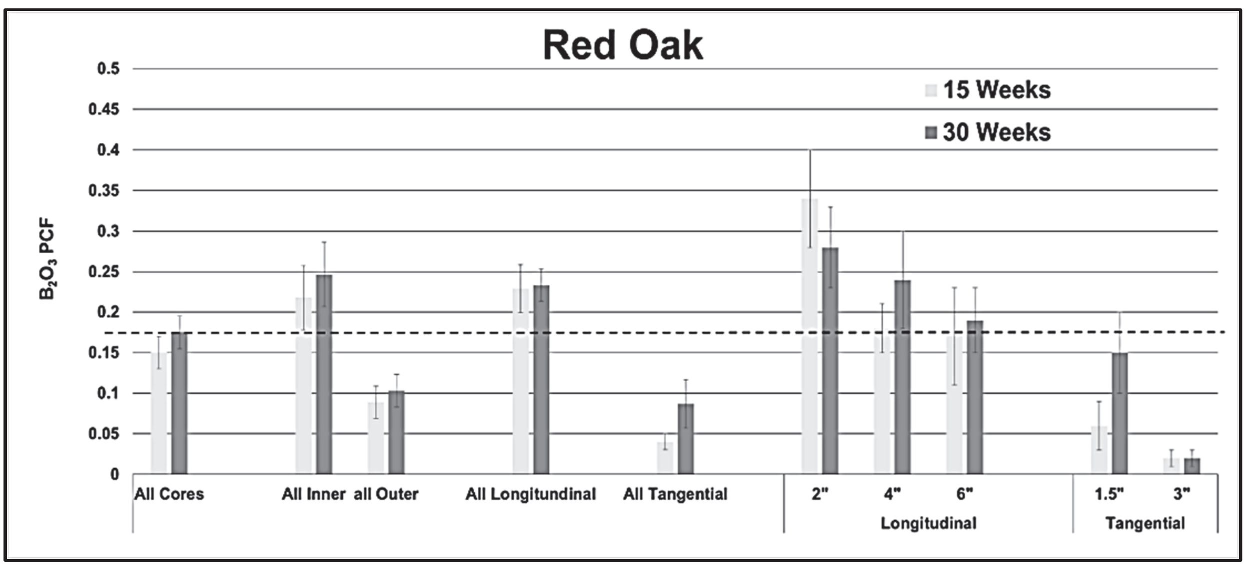

Figure 4. Boron (pcf B_2O_3) levels in increment cores taken at various points away from borate rods inserted in red oak bridge timbers that were then treated with creosote and sampled after 15 and 30 weeks. The horizontal dotted line signifies the AWPA specified treatment level for dual treatment with boron (0.17 pcf as B_2O_3).

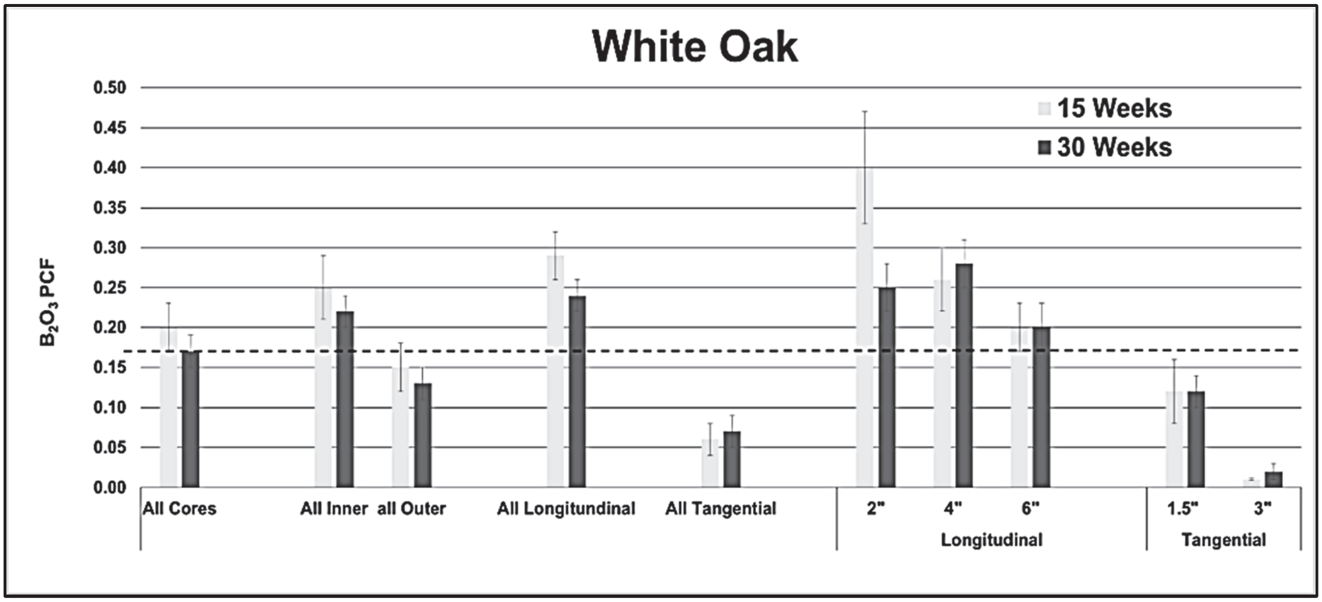

Figure 5. Boron (pcf B_2O_3) levels in increment cores taken at various points away from borate rods inserted in white oak bridge timbers that were then treated with creosote and sample after 15 and 30 weeks. The horizontal dotted line signifies the AWPA specified treatment level for dual treatment with boron (0.17 pcf as B_2O_3).

CONCLUSIONS

The relatively fast, non-destructive, cruciform sampling pattern was useful for determining qualitative and quantitative boron diffusion. This pattern ensured limited destruction of the entire timbers creating an opportunity for more assessments over time. Passive dual treatment with fused borate rods resulted in the required boron loadings in large timbers of two hardwood species, but levels were lower in the outer and tangential locations away from where rod was placed. Substantial longitudinal diffusion was even observed for white oak, which suggests that treatment of low permeability hardwoods may be possible. The moisture content of both red and white oak timbers remained well above the 30% wood moisture content needed for sufficient boron diffusion for the first 30 weeks after treatment. As the fused boron rods dissolved, boron moved more longitudinally vs tangentially, which was expected given the higher longitudinal permeability of these species.

The lack of boron in the outer, tangentially direction from the boron rods is of concern given that the rods appear to have completely dissolved rod installation patterns and dosages may need to be modified to achieve more uniform boron diffusion. It must also be noted that the sampling points represent only a small fraction of the volume of these large timbers and further sampling is planned.

ACKNOWLEDGEMENTS

The authors would like to acknowledge Craig Bell of the FPL for assisting with the experimental setup and Matt Konkler from OSU for analytical boron analysis.

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