Figure 2. Bridge timbers dual treated with boron rods and creosote then placed at the Harrison Experimental Forest in Saucier, Miss., in 2018.

Photo Credit: Mark E. Mankowski

DOUBLE DUTY

Boron rods as a simple, low capital alternative for dual treatment of ties and timbers

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The Forest Products Laboratory (FPL), part of the USDA, in Madison, Wis., along with its new satellite laboratory in Starkville, Miss., have been involved in the examination and testing of wood preservative systems to improve durability of railroad ties and other wood products for the last 110 years. In keeping with the spirit of a pragmatic approach to research, FPL continues to devote a significant portion of its efforts toward applied research in wood preservation, often in collaboration with industry and university partners. In September of 2018, the FPL Starkville group partnered with Wood Care Systems, Kirkland, Wash., to establish a test to examine diffusion of boron from boron rods placed in green, high-moisture content, red and white oak timbers and ties. Premature replacement of crossties and bridge timbers is extremely costly and labor intensive, making options for service life extension highly attractive.

In recent years, traditional creosote treatment of timbers and ties has been enhanced by an initial treatment with soluble borate applied via dipping or pressure treatment. The diffusible boron penetrates through the wood to provide 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 wood especially in high biodeterioration hazard areas. In 2012, the AWPA standardized dual creosote-borate treatments, specifying that borate pre-treatment retention must reach 0.30 lb per cubic foot boric acid equivalent (PCF BAE). The borate-treated member is then over-treated with the regular AWPA standard retention of creosote or copper naphthenate.

While 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. Other research reported substantial boron diffusion when borate was added to ports drilled into timbers prior to pressure treatment with copper naphthenate. A more concentrated form of boron used for some remedial borate treatments is the borate rod, which can readily dissolve at wood moisture contents above 30 percent. Borate rods are solid, fused 98 percent disodium octaborate tetrahydrate (DOT) and have

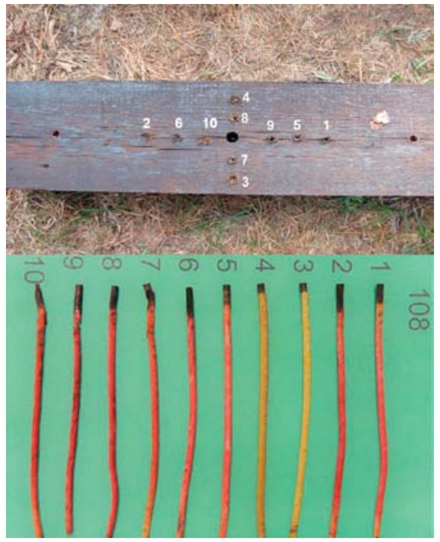

Figure 3. Sampling pattern (top) and corresponding increment cores stained with boron indicator (bottom). A reddish color indicates the presence of boron.

been shown to readily diffuse when used to remedially treat utility poles or timbers in service. Once fused, borate rods diffuse in treated timbers, boron levels can be monitored using chemical indicators sprayed on increment cores removed at various longitudinal and transverse points from the fused rod application point. Placing a sufficient quantity of boron rods in large bridge timbers and railroad ties at certain distances apart could provide a passive form of dual treatment, but this approach had not been previously studied. 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 is installed. Boultonizing will lower moisture in the outer 1-2 in. of a larger wood member allowing for adequate creosote penetration, but still leaving high moisture in the interior of the wood for increased boron diffusion. Placing rods at specific locations along the length of a large timber should result in boron diffusion throughout the timber and potentially reach the specified AWPA level of 0.30 BAE.

The overall objective of the project was to examine a cost-effective method for dual treatment for smaller operations that cannot afford to install equipment for borate pressure treatment. The goal of this initial study was to evaluate boron diffusion from borate rods in green, red and white oak bridge timbers over an 18-month exposure period at a severe test site.

Materials and methods

For the study, timbers and borate rods were supplied by Wood Care Systems. Five red oak (Quercus rubra L.) and six white oak (Quercus alba L.) timbers measuring 10 in. x 10 in. x 10 ft were treated with borate rods. The rods measured 3 in. long and ¾ in. in diameter. Rods were placed in 5-in.-deep 13/16-in.-diam. holes spaced 13.3 in. apart along the length of green timbers (Figure 2). The rod size, quantity and placement were based on the amount of boron needed to effectively deliver a protective amount of chemical to the entire timber. Bore holes were plugged and then the timbers were pressure-treated with creosote at Appalachian Timber Services in Sutton, W.Va.

For this treatment, holes were drilled in line with the center of the three red oak and three white oak timbers. Rods were inserted into pre-drilled holes that were sealed with a 1-in.-long 7/8-in.-diam. plastic plug. The unseasoned ties were loaded into a treatment cylinder and an 18- to 22-in. vacuum was pulled while filling the cylinder with hot creosote. The timbers were boiled in creosote (Boultonizing) for 12 hours to condition the wood and remove some moisture after which the hot creosote was drained and an initial pressure of 40 psi (gauge) was applied. Hot creosote was then introduced into the cylinder and pressure was raised and held until the AWPA retention of 8 pcf for creosote was reached. The target uptake (determined by a gauge measuring creosote volume) was calculated by dividing the total cubic feet of wood in the charge by the desired pounds of creosote per cubic foot as determined by a gauge measuring creosote volume. Once the desired gauge retention was achieved, the pressure was released, the solution was drained and a final vacuum of 18 to 22 in. was pulled to relieve internal pressure and reduce the risk of bleeding. 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 percent) 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 the Desoto National Forest in Saucier, Miss., where they were placed in the field test in September 2018. Timbers were placed directly on the ground approximately 2 ft apart with the plugged rod holes facing upward (Figure 2).

Moisture content of the timbers was measured starting at six weeks after treatment by taking two 6-in. 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 after collection. The straws were placed in a plastic zip-lock bag, kept on ice, and transported to the FPL laboratory. The cores were removed from the straws, weighed and dried at 60°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 five to 10 minutes then re-weighed to obtain the dry weight. Differences between initial and final weights were used to calculate moisture content.

After 11 weeks, the condition of the borate rods was monitored by removing the plugs from 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 3). This was repeated at the next rod hole from the end of the timber after 30 weeks and then the next rod holes at 50 and 80 weeks. Sampling was conducted by taking increment cores from longitudinal and tangential points in relation to the position of the boron treatment. Six-in.-long cores were taken with an 8-in. increment borer. Cores were taken longitudinally from the rod hole at 2 in., 4 in., and 6 in. in each direction (Figure 3, top). The 6-in. distance cores were positions 1 and 2. The 4-in. distance cores were positions 5 and 6. The 2-in. distance cores were positions 9 and 10. Cores also were taken in the tangential direction from the edge of the rod hole. These cores were 1.5 in. (positions 3 and 4) and 3 in. (positions 7 and 8) from the rod hole (Figure 3, top). The bridge timbers were sampled for moisture content at 6, 15, 30, 50, and 80 weeks and for boron content at 15, 30, and 50 weeks (Figure 3). Sampling was conducted in a progression that was assumed to be moving from areas of low to high boron concentration to minimize possible cross contamination of samples. Cores 6 in. from the rod hole were taken first—i.e., positions 1 and 2. The outer 3-in. 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 between each sampling. Samples were transported to FPL, weighed, dried at 60°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 (Figure 3, bottom). The cores were then sectioned into inner 3-in. and outer 3-in. sections that were ground in a Wiley mill. 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.

Results

Rod condition at 11 weeks: Rod holes were either filled with water that prevented examination of the rods or they were empty, indicating the borate rods had completely dissolved 11 weeks after application.

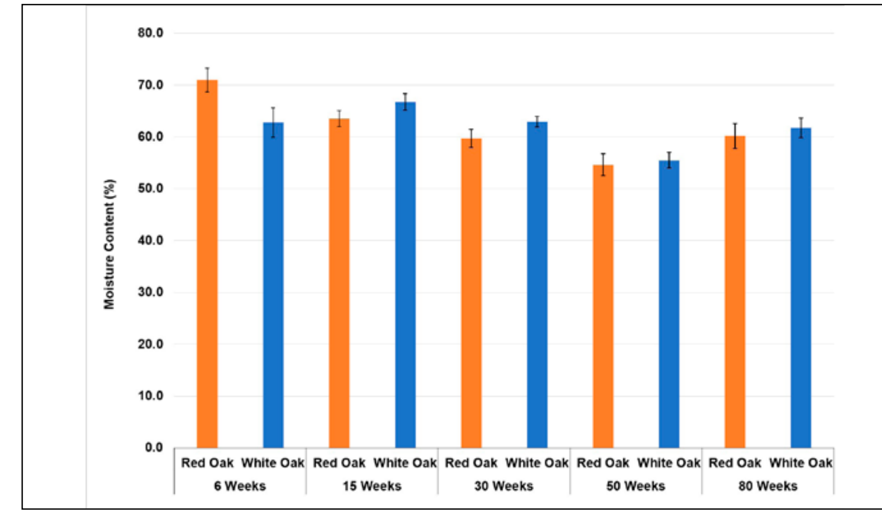

Figure 4. Average moisture contents of red oak and white oak bridge timbers as measured on increment cores removed 6, 15, 30, 50, and 80 weeks after treatment with borate rods and creosote. Timbers were treated green with high initial moisture content.

Moisture content: Figure 4 shows the average moisture content for red and white oak timbers at 6, 15, 30, 50, and 80 weeks. Red and white oak had mean moisture contents greater than 50 percent at all sampling times for the duration of the test. Moisture contents were lower at 50 weeks, most likely because this sampling point

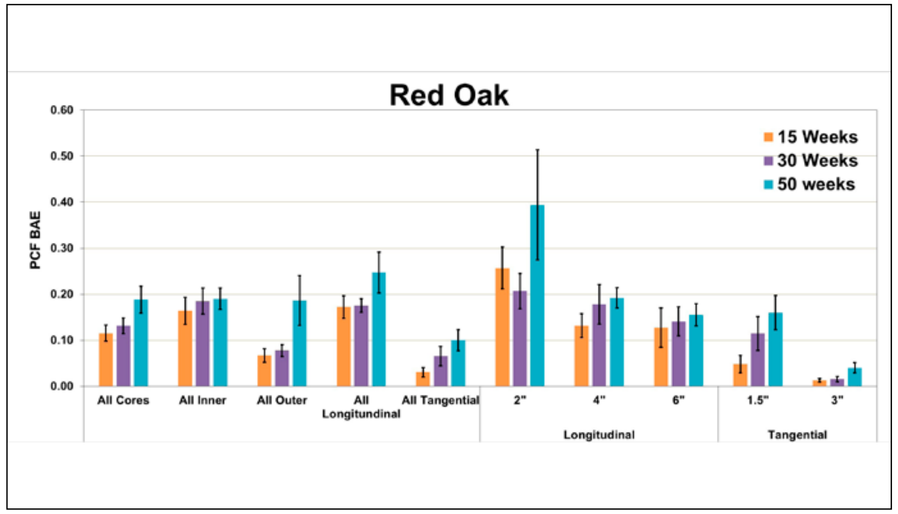

Figure 5. Boron (PCF-BAE) levels in increment cores taken at various points away from borate rods inserted in green red oak bridge timbers that were then treated with creosote and sampled after 15, 30, and 50 weeks.

was September 2019 when ambient conditions at the field site were hot and dry. Moisture contents increased again at the 80-week point (March 2020) reflecting cooler and wetter weather conditions at sampling. Elevated moisture levels for all periods sampled indicated that conditions were suitable for boron diffusion (wood moisture 30 percent or higher). It is unknown whether the rods dissolved at all during the creosote treatment process; however, diffusion should have begun almost immediately since moisture contents of the timbers were above 60 percent in both species. Many rod holes inspected 11 weeks after treatment contained water that most likely aided in boron diffusion.

Boron Indicator: Boron was well distributed longitudinally away from the treatment sites, particularly in 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. Very little staining in cores removed from the tangential positions was observed, suggesting reduced boron movement. This was particularly true for positions 3 and 4 (3 in.) from the bore hole. It was noted that some staining was darker in the outer longitudinal positions (1 and 2) compared to the midway positions (5 and 6). This may have been from overlapping boron diffusion from the adjacent rods in the timber (Figure 3).

Boron analysis red oak: Figure 5 shows the analytical results for boron levels in the core samples at the 15-, 30-, and 50-week sampling times. The boron levels from all inner and outer cores (n = 60) are shown at the far left part of the chart. The research team 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 5). The average boron level in all cores increased over the sampling period indicating boron diffusion. 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.

Boron analysis white oak: Figure 6 shows the analytical results for boron levels in the core samples at the 15-, 30-, and

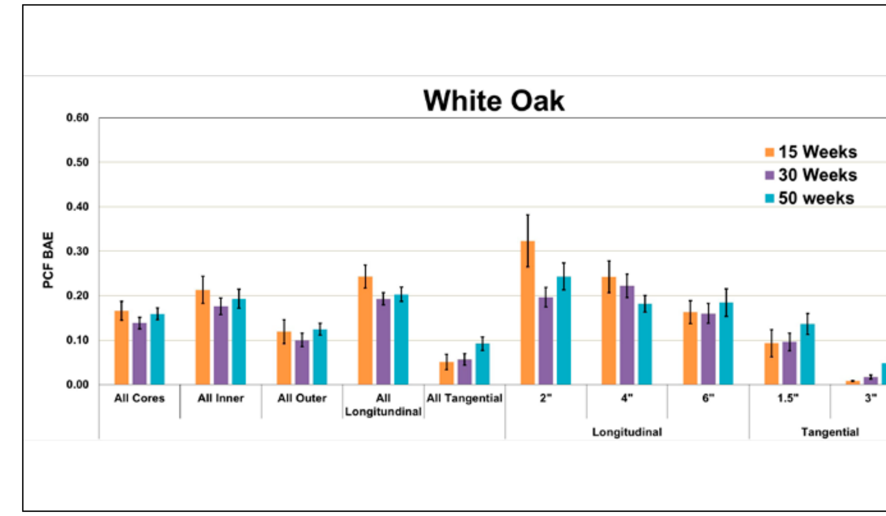

Figure 6. Boron (PCF-BAE) levels in increment cores taken at various points away from borate rods inserted in green white oak bridge timbers that were then treated with creosote and sampled after 15, 30, and 50 weeks.

50-week sampling times. 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, perhaps because of the higher moisture contents observed in this study. It also is possible that the elevated temperatures used during pressure-treatment aided boron diffusion.

Sampling and staining of cross sections cut from the small mining timbers treated similarly to the bridge timbers and exposed for 50 weeks at the test site also showed that boron levels were elevated longitudinally from the treatment sites but tangential movement was still limited. The boron (red) levels appeared to be highest around the initial rod placement spot, but penetration also was observed 2 in., 4 in. and 6 in. away.

Pre-treatment of red and white oak bridge timbers with boron rods resulted in effective levels of boron near the point of application, but treatment patterns may need to be altered to produce complete protection across the timbers. The sampling points discussed here represent only a small fraction of the volume of these large timbers and further sampling is planned 1.5 to 2.5 years after installation. The research team also has crossties treated and sampled in the same fashion as described here. The FPL Starkville is currently beginning the cross-sectioning of the ties and timbers to visually examine boron diffusion at 1.5 and two years after treatment. The team expects to find much more even distribution of boron in the future as moisture contents remain high and diffusion continues.

Conclusions

The relatively fast, non-destructive, cruciform sampling pattern was useful for determining qualitative and quantitative boron distribution in the timbers. This pattern ensured limited destruction of the entire timbers creating an opportunity for repeated 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 rods were 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 percent wood moisture content needed for boron diffusion for the total exposure time. 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, tangential direction from the boron rods is of concern given that the rods appear to have completely dissolved, but it is important to note that boron should continue to diffuse through the timbers to become more evenly distributed over time as long as the moisture content remains above 30 percent. Rod-installation patterns and dosages may need to be modified to achieve more uniform boron diffusion. It also must be noted that the sampling points represented only a small fraction of the volume of these large timbers and further sampling is planned. RT&S

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