CWPA Proceedings, 2002, pp 112-121

REMEDIAL TREATMENT OF POLES USING COPPER-BORATE RODS

Ryan Smart and Wesley Wall
Genics Inc.
Edmonton, AB

Summary

Borates have provided many years of protection to wooden structures in both interior and exterior situations. The following paper reports the findings of a sampling of utility poles that had been commercially treated with copper-borate rods four years previously. The poles were primarily pentachlorophenol treated western red cedars which had been installed approximately 25 years ago. Three samples were taken from each pole and then divided the inner, middle, and outer zones. The moisture content of each zone was determined and was found to be above the level required for diffusion in almost every case. The average boron concentrations were found to be well above the levels required to prevent the colonization of decay fungi.

1. Introduction

The use of boron compounds as a stand alone wood preservative treatment was first identified in the 1930's. Boron is ecologically favourable due to its very low mammalian toxicity in comparison to other chemical wood preservatives. For this reason, boron has been successfully used since this time in many geographical areas. Recently, there has been a renewed interest in boron as a wood preservative in previously underutilized areas as a result of public pressure to find a more operator and 'environmentally friendly' yet cost effective preservative system (Barnes et al, 1980, Rainer, 1993).

Research on the ability of borates to control wood colonizing fungi has been extensively reported. The effectiveness of borates against wood destroying decay basidiomycetes has been demonstrated both in the laboratory and in service, and as yet, no wood decaying fungus has been reported to be tolerant to borates at normal preservative retentions (Dickinson & Murphy, 1989). A number of laboratory and field investigations involving wood poles have been carried out on a variety of wood species (Morrell et al., 1990; Morrell et al., 1992; Friis-Hansen, 1987; Peylo and Bechgaard, 2001; and Cartlidge et al. 1995) with promising results. Dickinson (1990) reports that the lifetime of creosoted softwood poles are often limited by internal rot, principally caused by *Lentinus lepideus*. The toxic threshold for this species is in the range of 1 kg/m^3 (Fahlstrom, 1964). Bechgaard et al. (1980) initially proposed 1.5 kg/m^3 as the minimum required boron concentration for impel rods in railway sleepers, but later revised this to 1 kg/m^3 for poles (Peylo & Bechgaard, 2001). New Zealand standards propose minimum retentions of 0.5 to 1 kg/m^3 BAE for borate treated wood (Cross, 1992). Therefore, it is safe to assume that a concentration of 1 kg/m^3 BAE should be effective for the prevention of fungal colonization in poles.

The one restriction that borates have had in timber preservation has been a result of their solubility. As a result, the depletion of borates can occur in ground contact situations. For this reason, borate treated wood was initially restricted to protected environments such as interior situations or painted external joinery. However, the concern about borate leaching is frequently overstated (Lloyd et al. 1999). Morris (2000) reported a significant extension of the service life of exterior wooden window framing when treated with borates. The study was conducted on painted L-joints which had been broken apart to break the protective paint film. After 10 years, only 12% of the test specimens showed signs of decay, while two-thirds of the untreated controls had failed. Findlay (1959) references a study reported by Blew (1949) where poles treated to about 16 kg/m^3 borax, lasted in the ground for approximately four times as long as the untreated controls. These studies show that even under exterior situations, boron can significantly extend the life of wooden structures.

The greatest asset of boron preservatives is their ability to be mobile within the treated wood (Lloyd, 1998). This allows boron compounds to be highly effective in remedial situations such as utility poles. When applied to the pole, they remain mobile and will continue to diffuse, thus providing one of the most effective wood preservative systems today. Probably the most significant advance in the use of borates for in-situ treatments has been the development of fused borate rods (Dickinson, 1990). This allows for the insertion of a highly concentrated borate in a form where the solubility can be controlled. This form of treatment relies on the principle of diffusion from application points in the groundline zone, where the wood is typically at ideal moisture contents (30 percent and higher) for decay. Diffusion takes place more slowly at marginal moisture contents of twenty to thirty percent (Edlund et al., 1983), and is very limited in wood that doesn’t reach a moisture content greater than 20 percent (Highley et al., 1996).

While borates have had a long record of effective wood preservation, it has been recognized that it is beneficial to formulate borates with co-biocides in order to increase their effectiveness (Amburgey, 1990). Vasishth performed experiments with several copper-borate complexes and found them to be very effective in protecting wood from a variety of microorganisms. Cartlidge (1997) reports that when copper and boron are present together, the mobility of both chemical species can be favourably altered by chemical interaction. The result is an increase in copper penetration and a slowing of the boron mobility thereby retarding the release of boron to the environment. Others have reported similar findings in either field or laboratory experiments, in that the combination of copper and boron substantially increase the penetration or preservative retention of copper (Kumar and Morrell, 1990; Vasishth et al 1990; Wall et al. 2002).

2. Methodology

Poles were randomly selected from an area in Alberta which had been inspected in 1998, four years prior to sampling. The poles had been installed over many decades, with the oldest being from 1968 and the newest in 1995. All poles were pentachlorophenol treated western red cedars with the exception of one lodgepole pine and one Douglas-fir pole. Groundline circumferences for the selected poles ranged from 96.5 cm to 198 cm (38 to 78 inches). These poles had all been internally treated with copper-boron rods by a commercial inspection company during the course of the utilities inspection and treatment process. The groundline installation method was used where three equidistant holes are drilled at the groundline, at an angle of 45 degrees to the vertical. Poles with circumferences over 39 inches received 3 copper-boron rods per hole, while those with circumferences less than 39 inches only received 2 rods per hole (only pole 230592).

In August of 2002, 17 of these poles were selected to be sampled for the presence of boron. A 0.2 inch increment borer was used to obtain three samples from each pole. Each sample was taken approximately six inches below groundline at a location between the rod installation holes. Full cores were taken from the surface right through to the pith. These cores were sectioned in the field into three equal zones corresponding to the inner, middle, and outer portions of the pole. The three sections were then composited for each pole to give one composite of each zone (inner, middle, outer) for each pole. Each composite was placed into a drinking straw and both ends were crimped and taped to prevent contamination and to preserve the moisture content of the core samples.

The core samples were shipped to PowerTech Labs for quantitative chemical analysis. The borings were weighed, oven dried at 105^{o}C, and then weighed again to determine the approximate moisture content of the core samples. The cores were then ground to 20 mesh using a Wiley mill. A 0.4 gram portion of each boring was digested with 10 ml of 0.5 N sulfuric acid for 30 minutes in an ultrasonic bath, filtered using a Whatman #41 paper and made up to 25 ml with distilled, deionized water prior to analysis by Inductively Coupled Plasma Emission Spectroscopy.

An additional inspection was carried out to determine if there was any reservoir of chemical remaining in the treatment holes. Nine plugs were drilled out to check for the presence of intact rods. Intact rods were located by pushing a steel rod very hard into the application hole and comparing the distance of penetration to what the expected drill hole depth should be.

3. Results and Discussion

The moisture contents of the sampled poles are shown in Table 2. Moisture contents were quite variable between poles and within poles even though all samples were taken from the same location on each pole. In this study, all poles were pentachlorophenol, and most were roughly about the same vintage with the exception of the five newer poles (Table 1). Even though there was considerable variation between samples, when the averages for each zone were considered, the moisture contents were more than twice as high in the exterior zone than in the inner and middle zones of the poles. This is to be expected, as sampling occurred below the groundline. In many situations, the soil is the source of the poles moisture. There is a mass flow of moisture into the pole from the ground, which is then wicked up the pole.

Rhatigan et al. (2002) reported findings of significant variation due to treatment, age, and even time of sampling (season). Older poles as well as butt-treated poles typically exhibit higher moisture contents. Seasonal variations occur as a result of changes in precipitation patterns, and can affect the migration of diffusible preservatives. A pole may be sufficiently wet for diffusion to occur throughout the entire cross-section for a short period of time. However, once the moisture ingress ceases, the pole slowly dries out, leaving scattered pockets of higher and lower moisture This would result in varying rates of diffusion.

As seen in Table 2, the average moisture contents of every pole is greater than 20 percent. In only a few sampling zones was the moisture content ever found to be below 20 percent, and in these cases, it was only marginally so. Morrell et al. (1990) have shown that diffusion of boron starts at moisture levels above 20 percent. Rapid diffusion of boron from the point of treatment occurs if the moisture content is greater than 25 to 30 percent (Edlund et al., 1989). Even under reduced moisture conditions, boron utilizes the natural moisture in the wood to diffuse away from the point of application, especially if the moisture content is greater than 15 percent (Schoeman et al., 1998). Therefore, based on the findings of the above, some level of diffusion would be expected to have occurred from the point of treatment in every pole in this study.

Boron concentrations are reported in Table 3. They were also variable and a distinct gradient from the center of the pole to the outer surface was not observed in many of the poles. However, a comparison of the averages for each zone reveals that the boron concentration was over four times greater in the inner portion of the pole in comparison to the outer portion. This agrees with the findings of Peylo and Bechgaard (2001) and Cartlidge et al (1995) who report that the highest concentrations of boron are in the heartwood regions of a pole. It would be expected that this concentration gradient from the inside to the outside of the pole would exist. The primary directions of diffusion would be downward and outward. This would create a lower concentration near the surface as the boron is slowly lost to the environment and becomes a background micronutrient in the soil. In addition, there is a greater volume of wood in the outer zone than in the inner zone. The fact that an average of 4.6 kg/m^3 BAE was found in the outer zone is very important as it shows that significant radial diffusion has occurred. The sampling points were located between the rods, so if radial diffusion had not occurred, these levels of boron would not have been detected in the outer zones.

While it is widely recognized that boron diffusion is greater in wood with a higher moisture content, this was not always evidenced in the analyzed BAE of each pole. This agrees with the findings of Highley et al. (1996). This phenomenon might be explained by the wide variation of moisture contents within a pole. Although the moisture content at the sampling point was sufficient for rapid diffusion, this does not signify that this same level of moisture exists at the point where the rod was inserted. This moisture variation can result in significantly different rates of diffusion, leading to different concentrations of boron in different areas of the pole. However, over time, these concentration gradients will tend to equilibrate. In addition, the lack of boron movement at low moisture contents is not a disadvantage since the boron will not be depleted until the moisture conditions favourable for fungal attack exist (Cartlidge et al. 1995).

The threshold value of 1 kg/m^3 BAE has been proposed for protection against fungal decay. A look at the boron concentrations in Table 3 shows that this level has not been achieved in all regions of every pole. However, as diffusion continues to occur, these levels will continue to equilibrate. The averages for each pole show that there is more than enough boron throughout the entire cross-section to achieve the threshold levels required. The actual average concentration (as an average of all three zones) for all the poles is 10.87 kg/m^3, which is far in excess of the 1 kg/m^3 which is necessary to prevent fungal colonization. In fact, the highest average concentration of boron in a single pole was found to be 42.91 kg/m^3. The lowest concentration found was 2.23 kg/m^3 BAE. As this was not a destructive sampling, it is difficult to determine at this time whether the lower concentrations are indicative of the early or late stages of diffusion. The presence of poles with concentrations of an order of magnitude higher would seem to suggest that the poles having zones with lower levels will continue to experience in influx of boron from areas of higher concentration. Then, as the diffusion process continues, the preservative levels will begin to decline as the boron slowly migrates down and out of the pole. However, the rate of leaching declines over time as the retention becomes too low to continue to drive the diffusion process (Lloyd, 1999).

In order to determine if there was any remaining copper-boron rod which could serve as a reservoir of preservative, nine plugs were drilled out to check for the presence of intact rods. Three of the nine holes contained partial rods, and four holes contained small green particles which stuck to the sampling rod. This indicates that the rods in these holes were in the final stages of dissolution and would only provide a limited reservoir of boron. Similar dissolution times have been reported for boron rods (Peylo & Bechgaard, 2001 and Henningsson et al., 1989). The absence of complete rods indicates that over the past four years, the moisture contents of all these poles have been sufficiently high enough to allow for dissolution to occur. As a result, the boron would have been able to diffuse away from the treatment holes to set up a chemical barrier to decay.

4. Conclusions

The results show that the copper-borate rods have almost totally dissolved after four years in poles and that the boron is diffusing throughout the wood. The moisture contents within most areas of the poles are adequate for rapid diffusion to occur. The concentrations of boron found at the sampling points after four years confirm that significant diffusion has occurred. The high concentrations of boron remaining in the groundline zone of these poles suggests that they will be protected from fungal decay for years to come.

5. Literature

Amburgey, T.L. 1990. The need for co-biocides when treating wood with borates. P 51-51 in Proceedings First International Conference on Wood Preservation with Diffusible Preservatives. M Hamel and D. Robertson (eds.) Forest Products Research Society, Madison WI.

Barnes, H.M. Ambergey, T.L., Williams, L.H., and Morrell, J.J. 1989. Borates as Wood Preserving Compounds; The Status of Research in the United States. The Int. Res. Group on Wood Pres. Doc. No. IRG/WP/3542.

Bechgaard, C., Lennart, B., and Jermer, J. 1980. Remedial treatment of creosoted railway sleepers of redwood by application of boric acid. The Int. Res. Group on Wood Pres. Doc. No. IRG/WP/3134.

Cartlidge, D.M., Ashby, G.R., and Wylie, I. 1995. Groundline treatment of poles using boron rods. P 133-149 in Proceedings Canadian Wood Preservation Association.

Cartlidge, D.M. 1997. Evaluation of Cobra™ wood preservative rods. PowerTech Labs Inc. Report, Project 6325-44-02. Unpublished.

Cross, D. 1992. The benefits to New Zealand of boron salt treatment of Pinus radiata. The Int. Res. Group on Wood Pres. Doc. No. IRG/WP/3692.

Dickinson, D.J. and Murphy, R.J. 1989. British Wood Preservers Association Annual Convention, Paper 6.

Dickinson, D.J. 1990. Remedial treatment: in-situ treatments and treatments of historic structures. P 87-90 in Proceedings First International Conference on Wood Preservation with Diffusible Preservatives. M Hamel and D. Robertson (eds.) Forest Products Research Society, Madison WI.

Edlund, M.L., Henningsson, B., Kaarik, A., and Dicker, P.E. 1989. A chemical and mycological evaluation of fused borate rods and a borate/glycol solution for remedial treatment of window joinery. The Int. Res. Group on Wood Pres. Doc. No. IRG/WP/3225.

Findlay, W.P.K. 1959. Boron compounds for the preservation of timber against fungi and insects. 6th Wood Prot. Cong., July., Germ Wood Res. Assn.

Friis-Hansen, H. 1987. A suggestion for the improvement of the chemical protection of wooden poles. The Int. Res. Group on Wood Pres.

Highley, T.L., Green III, F., and Finney, W.F. 1996. Distribution of boron from fused borate rods in douglas-fir transmission poles. The Int. Res. Group on Wood Pres. Doc. No. IRG/WP/96-30112.

Kumar, S. and Morrell, J.J. 1990. Treatment of western softwoods with boron-amended inorganic preservatives. For. Prod. J. 40 (3): 25-29.

Lloyd, J.D. 1998. Borates and their biological applications. The Int. Res. Group on Wood Pres. Maastricht, Netherlands.

Lloyd, J.D., Schoeman, M.W., and Stanley, R. 1999. Remedial timber treatment with borates. 3rd International Conference on Urban Pests. Prague.

Morris, P.I. 2000. Ten year performance of L-joints made from borate diffusion treated wood. The Int. Res. Group on Wood Pres.

Morrell, J.J., Sexton, C.M., and Preston, A.F. 1990. Effect of moisture content of douglas-fir heartwood on longitudinal diffusion of boron from fused borate rods. For. Prod. J. 40 (4):37-40.

Morrell, J.J., Sexton, C.M. and Archer, K. 1992. Diffusion of boron from fused borate rods through selected woods. For. Prod. J. 42 (7/8):41-44.

Peylo, A. and Bechgaard, C.G. 2001. Lifetime of Impel in poles – maintenance cycles for utility poles. The Int. Res. Group on Wood Pres. Doc. No. IRG/WP 01-30258.

Rainer, J.B. 1993. Borates as wood preservatives – an environmental, health and safety perspective. Proc. Wood. Pres. 2nd Int. Sym. Cannes, France. IRG/WP/93-50001, 60-71.

Schoeman, M.W., Lloyd, J.D. and Manning, M.J. 1998. Movement of borates in a range of timber species at various moisture contents. The Int. Res. Group on Wood Pres. Maastricht, Netherlands.

Vasishth, P., Vasishth, R.C. and Nicholas, D.D. 1990. The effect of boron addition on copper-wood equilibrium. P 35-38 in Proceedings First International Conference on Wood Preservation with Diffusible Preservatives. M Hamel and D. Robertson (eds.) Forest Products Research Society, Madison WI.

Wall, W.J., Smart, R.S. and Goodman, J. 2002. Copper/Boron mobility in pine and cedar. In Proceedings American Wood Preservers Association.

Tables

Table 1. Basic information for the sampled poles.

Pole #	Circumference (in)	Species	Year
230568	59	WC	1978
230569	59	WC	1974
230570	49	WC	1977
230571	55	WC	1974
230572	78	WC	1969
230574	56	WC	1978
230576	42	DF	1974
230577	51	WC	1977
230578	49	WC	1977
230581	55	WC	1974
230582	59	WC	1974
230592	38	WC	1968
230593	48	WC	1995
230595	43	WC	1995
230596	41	WC	1990
230597	50	WC	1990
230598	42	LP	1989
Averages	**51.41**		

WC = Western Red Cedar LP = Lodegepole Pine

DF = Douglas-fir

Table 2. Moisture Contents of the sampled poles.

Pole #	Outer MC	Mid MC	Inner MC	Average MC
230568	164.6	26.1	27.7	72.80
230569	76.1	20.5	52.5	49.70
230570	63.3	24.1	27.9	38.43
230571	73.4	23.2	44.4	47
230572	123.6	45	30.9	66.50
230574	68.3	22.7	24.7	38.57
230576	65.4	44.6	58.3	56.10
230577	86	22.8	23.6	44.13
230578	74.9	19.1	32.6	42.20
230581	82.2	17	26	41.73
230582	82.4	25	25.7	44.37
230592	26.3	19.9	21.8	22.67
230593	46.9	62.4	27.1	45.47
230595	38.5	28.7	55.3	40.83
230596	66.8	31.6	24.4	40.93
230597	61.6	31.8	24.8	39.40
230598	72.2	70.9	112	85.03
Averages	**74.85**	**31.49**	**37.63**	**47.99**

MC= Moisture Content **MC values are in %**

Table 3. Boron Concentrations of sampled poles.

Pole #	Outer B	Mid B	Inner B	Average B
230568	0.89	0.49	14.38	5.25
230569	7.19	1.23	3.92	4.11
230570	0.53	2.75	15.85	6.38
230571	0.95	2.96	18.89	7.60
230572	37.39	63.06	28.29	42.91
230574	0.38	0.93	5.38	2.23
230576	1.78	18.39	38.28	19.48
230577	0.25	0.25	7.85	2.78
230578	8.17	1.06	1.06	3.43
230581	0.41	0.41	13.28	4.70
230582	12.38	0.23	6.33	6.31
230592	2.52	10.03	10.38	7.64
230593	0.83	7.42	11.02	6.42
230595	1.16	2.42	66.66	23.41
230596	1.63	6.21	12.59	6.81
230597	0.58	5.68	23.10	9.79
230598	1.74	16.52	58.52	25.59
Averages	**4.63**	**8.24**	**19.75**	**10.87**

B = Boron Concentration **B values are in kg/m3 BAE**