Preservative treatment of ash wood from emerald ash borer (*Agrilus planipennis*) infested trees

Pascal Nzokou
Sedric M. Pankras*
D. Pascal Kamdem*

Abstract

Portions of Michigan, Ohio, Indiana, and Ontario have been infested by the emerald ash borer (EAB), an exotic pest believed to have been imported from Asia. The pest is reported to have killed 10 million to 15 million ash trees and continues to spread. Most of southern Michigan is under quarantine, and the movement of ash lumber, firewood, logs, and nursery stock is restricted. The eradication program also involves removing infested, dying, and non-infested trees within and around infestation areas. Logs removed are currently shipped to marshalling yards, chipped, and burned for energy. The present project investigates the preservative treatment of some of ash lumber as an alternative to burning. Results showed that ash sapwood can be treated at retentions suitable for aboveground utilization, and no reduction in mechanical properties was observed.

Michigan has been infested by the emerald ash borer (EAB), a destructive exotic pest of ash trees first found in southeastern Michigan in the summer of 2002 (Scarr et al. 2002). The EAB, identified as *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), is reported to have been imported into North America from Asia in packaging materials (Haack et al. 2002). The EAB larvae dig galleries under the bark and feed on the cambial line, creating S-shaped patterns that eventually cut the sap lines, causing die back in ash trees (Haack et al. 2002).

The pest poses a serious threat to Michigan's 700 million ash trees. According to the Michigan Department of Agriculture (MDA), the EAB has killed 10 million to 15 million ash trees in southeastern Michigan, causing massive environmental and economic damage to this region of the state (McCullough et al. 2004, Smitley and McCullough 2005). To limit the spread of the pest, the MDA put most of southeastern and central Michigan under quarantine and recommended the removal of all ash trees around infestation areas. Thus, large quantities of ash are being harvested in Michigan, but the harvested wood is only chipped and burned for energy, a very low value use. Therefore it has become necessary to develop value-added uses for some of the large quantities of ash wood going into the waste stream.

This article reports on the preservative treatment of ash lumber obtained from logs harvested in the eradication program. The objective was to characterize the treatability and the influence of the treatment on mechanical properties of ash wood.

Material and methods

Specimen preparation

An 8-foot-long log was randomly selected from an EAB disposal site in Whitmore Lake, MI. The log was processed on-site with a portable sawmill and converted into nominal 2- by 4-inch by 8-foot lumber (1.5 in [3.78 cm] by 3.5 in [8.82 cm] by 8 ft [241.92 cm]). Sapwood material was carefully separated from heartwood and pieces from each group labeled accordingly. Processed lumber was shipped to the Department of Forestry at Michigan State University where it was

The authors are, respectively, Assistant Professor, Research Assistant, and Professor, Dept. of Forestry, Michigan State Univ., East Lansing, MI (nzokoupa@msu.edu, pankrasm@msu.edu, kamdem@msu.edu). This research project was funded by the USDA through the Southeastern Michigan Resource and Development Council (SEMIRCD). The authors wish to acknowledge support from the Michigan DNR, and the Dept. of Forestry at Michigan State Univ. This paper was received for publication in May 2005. Article No. 10061.
*Forest Products Society Member.

Forest Prod. J. 56(10):69-72.

Table 1.—Chemical retention of preservative pressure treated ash wood (elemental copper for WBCuN and OBCuN, CuO for ACQ-C).[a]

		WBCuN[a]		OBCuN[b]	ACQ-C[c]	
		0.34%	0.61%	0.52%	0.38%	0.74%
		(kg/m^3 [pcf])				
Sapwood	End-sealed	0.81 [0.05]	1.14 [0.07]	1.68 [0.11]	1.63 [0.1]	3.27 [0.2]
	Unsealed	1.82 [0.11]	N/A	2.17 [0.14]	2.35 [0.15]	N/A
Heartwood	End-sealed	0.35 [0.02]	0.56 [0.04]	1.11 [0.07]	0.77 [0.05]	1.16 [0.07]
	Unsealed	1.39 [0.09]	N/A	1.38 [0.09]	1.78 [0.11]	N/A

[a]WBCuN = waterborne copper naphthenate; OBCuN = oilborne copper naphthenate; ACQ-C = alkaline copper quat type C.

Table 2.—Penetration and percentage coverage of copper preservatives in ash pressure treated sapwood and heartwood.[a]

	Preservative	Max X	Min X	Max Y	Min Y	% Coverage	Observation
Sapwood	0.5% ACQ-C	9	5.5	7.5	2	0 to 25	Poor
	1% OBCuN	42	42	18	18	75 to 100	Full
	0.5% WBCuN	42	6.5	20	1.5	50 to 75	Good
	1% ACQ-C	42	42	18	18	75 to 100	Full
	1% WBCuN	42	7.5	12.5	5	50 to 75	Good
Heartwood	0.5% ACQ-C	1	1	1	1	0 to 25	Poor
	1% OBCuN	41	20	18	11	75 to 100	Full
	0.5% WBCuN	2.5	0	2	0	0 to 25	Poor
	1% ACQ-C	40	25	18	11	50 to 75	Good
	1% WBCuN	11	2	18	2	125 to 50	Average

[a]ACQ-C = alkaline copper quat type C; OBCuN = oilborne copper naphthenate; WBCuN = waterborne copper naphthenate; Max X = maximum distance of penetration in X axis; Min X = minimum distance of penetration in X axis; Max Y = maximum distance of penetration in Y axis; Min Y = minimum distance of penetration in Y axis.

air-dried in the wood shop with drying stickers inserted between each layer.

Defect-free specimens measuring 1.5 inches (3.78 cm) by 3.5 inches (8.82 cm) by 16 inches (40.32 cm) were prepared to measure the treatability of sapwood and heartwood, while specimens measuring 0.75 inch (1.89 cm) by 0.75 inch (1.89 cm) by 16 inches (40.32 cm) were prepared to test the influence of the treatment on the strength properties of sapwood and heartwood. The average density at 10 ± 2 percent moisture content was measured at 645 kg/m^3 for sapwood and 723 kg/m^3 for hardwood. Five specimens per treatment were prepared for the treatability and 12 samples per treatment for testing the mechanical properties. From each board, specimens were cut and allocated to each of the preservative-treated and the untreated group to allow comparison between treated and untreated samples from the same boards. Different boards were used for replication in each treatment. Samples for the treatability study were end sealed with a commercial elastomeric sealant, or maintained unsealed.

Treatment

Pressure treatment of blocks was accomplished using a modified full-cell process, with an initial vacuum of 85 kPa (25 in Hg) for 20 minutes followed by 1241 kPa (180 psi) pressure for 1 hour, and a final vacuum of 85 kPa (25 in Hg) for 20 minutes. A 7.4 percent stock solution of alkaline copper quat (ACQ-C) under the commercial name NW100 containing copper as elemental mixed with ethanolamine complexes from Osmose Inc. (Buffalo, NY) was diluted to 0.5 and 1 percent for the ACQ-C treatment. Waterborne copper naphthenate (WBCuN) solutions (0.5% and 1%) were prepared from a 4.9 percent solution of CuNap-5W from Merichem Company (Houston, TX). Oilborne copper naphthenate (OBCuN) solution (1%) was made from a 2 percent solution of Perm-E8 from ISK Biotech (Memphis, TN). The actual amount of copper was determined by atomic absorption spectroscopy (AAS) and the copper oxide used calculated according to American Wood-Preservers' (AWPA) Standard A2-02 (AWPA 2002).

Determination of chemical retention

Each specimen was weighed before and after treatment to determine preservative uptake. Retention was determined by using the volume of each sample, the weight gain after treatment, and the solution concentration.

AAS was also used to analyze chemical retention in the assay zone of the outer 15-mm-thick slices and inner 20-mm slice of treated samples according to AWPA Standard A7-97 (2002), Digestion Method #5 Perchloric. The copper retention was expressed as oxides, and then converted from a weight percent to kg of preservative per m^3 wood based on the measured density of the wood species.

Determination of the chemical penetration

After preservative treatment, specimens were air-dried for 14 days, then cut in half. The freshly cut surfaces were sprayed with 0.5 percent solution of chrome azurol-S (AWPA 2002). The chrome azurol-S induces a dark blue stain in areas with copper concentrations more than 25 ppm.

The percentage area stained was taken as an indicator of the copper penetration and was estimated according to the method described by Slahor et al. (1997), summarized as follows. Four depths of penetration were recorded: a Min(imum) X and a Max(imum) X measured in the width direction, and a Min(imum) Y and a Max(imum) Y measured in the thickness direction. Maximum measurements were limited to one-half the total distance for each dimension. A visual rating of the cross section penetrated was given: 0 = 0 to 25 percent, 1 = 25 to 50 percent, 2 = 50 to 75 percent, and 3 = 75 to 100 percent (Slahor et al. 1997).

Mechanical properties

The bending strength of a specimen subset was determined according to American Society for Testing and Materials Method D-143 Standard Method for the Determination of the Mechanical Properties of Clear Lumber (ASTM 2000). Specimens measuring 1 inch (2.52 cm) by 1 inch (2.52 cm) by 16 inches (40.32 cm) were prepared and treated as described and were stored in the wood shop to allow evaporation of the solvent and then placed in the conditioning room at 20°C (68°F) and 65 percent relative humidity to achieve an approximate equilibrium moisture content of 10 ± 2 percent. Twelve samples from each treatment were loaded to three-point bending on an Instron Universal Tester Model 4206. The span was 346 mm (14 in), and the span-to-depth ratio was 14:1. The crosshead speed was set at 1.25 mm/min.

Statistical analysis

Mechanical property data were analyzed for significant differences between the means using the one-way analysis of variance procedure in SigmaStat version 2.0 for Windows (SPSS Inc. 1997). Tukey's multiple comparisons test (95% confidence) was employed to determine differences between untreated samples and the various treatments.

Results and discussion

The chemical retention of pressure-treated ash heartwood and sapwood are summarized in **Table 1**. Unsealed sapwood retentions were 1.82 kg/m^3 for WBCuN (0.34% solution), 2.17 kg/m^3 for OBCuN (0.52% solution), and 2.35kg/m^3 for ACQ-C (0.38% solution). End-sealed sapwood retentions were 0.81 to 1.14 kg/m^3 for WBCuN, 1.68 kg/m^3 for OBCuN, and 1.63 to 3.27 kg/m^3 for ACQ-C. Unsealed heartwood specimens retentions were similar for all three chemical treatments: 1.39 kg/m^3 for WBCuN, 1.38 kg/m^3 for OBCuN, and 1.78 kg/m^3 for ACQ-C. The retentions were more variable for heartwood end-sealed specimens, measured at 0.35 to 0.56 kg/m^3 for WBCuN, 1.11 kg/m^3 for OBCuN, and 0.77 to 1.16 kg/m^3 for ACQ-C.

Overall, the retentions obtained for unsealed sapwood specimens for all three chemicals met the AWPA standards recommendations for use categories one, two, and three (UC1, UC2, UC3) for the treatment of wood and wood-based materials for interior construction not in contact with the ground (UC1); not in contact with the ground but may be subject to dampness (UC2); and exterior applications, coated or uncoated and not in contact with the ground (UC3A,UC3B). However, since the samples treated were only 16 inches long, it would be expected that when full-length lumber specimens are treated, the retention would be more related to the retentions for end-sealed samples. In that case, the end-sealed heartwood specimens treated with the two waterborne systems did not meet AWPA recommendations for UC3A and UC3B. The only system that had retention levels meeting UC4 (wood and wood-based materials used in contact with the ground) specifications was OBCuN. Although these AWPA recommendations are aimed at the treatment of softwoods, our results suggests that ash sapwood and heartwood lumber could be successfully treated and used for aboveground applications such as furniture, millwork, interior beams, flooring, and sill plates. Our findings also suggest that for aboveground applications where products are exposed to weather such as trim, decks, siding, and railing (UC3A, UC3B, UC4), oilborne copper naphthenate is more appropriate than waterborne formulations. These treatments will create a more valuable use of ash wood compared to chipping and burning as is currently the case in the EAB eradication program.

The chemical penetration and coverage, except for one case, was generally good (50% to 75% penetration) or full (100% penetration) for sapwood (**Table 2**). Penetration was more variable for the heartwood samples, with the best result obtained with OBCuN (100% penetration).

Table 3.—Chemical retention of oilborne copper naphthenate treated ash wood.

	Solution strength	Chemical retention (elemental copper)
	------(%)------	------(kg/m^3 [pcf])------
Pressure treatment	1.05	5.4 [0.34]
	0.70	4.0 [0.25]
	0.35	1.8 [0.11]
	0.18	0.8 [0.05]
Dip treatment	1	0.8 [0.05]
	0.70	0.5 [0.03]
	0.35	0.2 [0.01]
	0.18	0.1 [0.007]

Table 4.—Mechanical properties of preservative treated ash heartwood and sapwood.[a]

		Heartwood	Sapwood
WBCuN[a]	Retention (%)	1.82 (0.11)	1.39 (0.09)
	MOR (× 1,000 psi)	14.6 (4.4)	13.7 (1.2)
	MOE (million psi)	1.4 (0.2)	1.5 (0.08)
OBCuN[b]	Retention (%)	2.17 (0.14)	1.38 (0.09)
	MOR (× 1,000 psi)	16.3 (2.4)	13.5 (1.4)
	MOE (million psi)	1.5 (0.2)	1.3 (0.1)
ACQ-C	Retention (%)	1.78 (0.11)	2.35 (0.15)
	MOR (× 1,000 psi)	14.0 (3.5)	15.2 (1.4)
	MOE (million psi)	1.4 (0.2)	1.5 (0.08)
Untreated	MOR (× 1,000 psi)	14.9 (2.4)	13.3 (3.4)
	MOE (million psi)	1.3 (0.1)	1.2 (0.07)

[a]WBCuN = waterborne copper naphthenate; OBCuN = oilborne copper naphthenate; ACQ-C = alkaline copper quat type C.
[b]Values in parentheses are standard deviations

A follow-up study using several OBCuN concentrations and both pressure and dip treatments was conducted. Results summarized in **Table 3** show that pressure treatments with 0.7 and 1.05 percent solutions resulted in retentions above 4.0 kg/m^3, which is acceptable for several aboveground and ground contact applications. This result suggests that ash lumber can also be pressure treated for ground contact applications such as farm posts and fences. The dip treatment generated much lower retentions, varying from 0.8 kg/m^3 to 0.1 kg/m^3. Such retention levels are well below that required for any exterior application.

The influence of the pressure treatment on the strength and stiffness properties is summarized in **Table 4**, which shows that the modulus of rupture (MOR) and modulus of elasticity (MOE) were not negatively affected by the chemical treatments.

Conclusions

The oilborne and waterborne preservative treatability of ash lumber obtained from the EAB eradication program in southern Michigan was investigated in order to evaluate for the potential for using ash as treated lumber. Results showed that treatment of sapwood with WBCuN, OBCuN, and ACQ-C can generate chemical retentions acceptable for aboveground applications. A subsequent test with higher concentrations of

OBCuN also showed that, using a pressure treatment process, treating solutions of 0.7 and 1.05 percent Cu in OBCuN can generate retentions above 4.0 kg/m^3, which are suitable for several ground contact applications. The retention of dip-treated specimens was very low and not suitable for any application.

The treatment process did not negatively affect the mechanical properties, suggesting that ash maintained its structural integrity after the treatment.

Results show that it is technically feasible to develop value-added treated wood products from ash wood currently going into the waste stream from the EAB eradication program. However, there are several challenges such as current practices in the preservative treatment industry to address before large quantities of ash wood start entering chemical treatments. In addition, the performance of the treatments against biological deterrents needs to be fully assessed before it can be considered effective. Treated specimens are currently exposed in our test site in Gainesville, Florida, and will be evaluated over time for susceptibility to decay and termite damage, and results will be reported in a later publication.

Literature cited

American Society for Testing Materials (ASTM). 2000. Standard test methods on wood. D 143-96. Annual Book of ASTM Standards. Vol. 04.10. ASTM, West Conshohocken, PA. 676 pp.

American Wood-Preservers' Association (AWPA). 2002. Standard A2-98; A7-93; AWPA book of standards. AWPA, Selma, AL. 463 pp.

Haack, R.A., E. Jendek, H. Liu, K.R. Marchant, T.R. Petrice, T.M. Poland, and H. Ye. 2002. The emerald ash borer: A new exotic pest in North America. Newsletter of the Michigan Entomological Soc. 47(3and4): 1-5.

McCullough, D.G., D. Cappaert, T. Poland, and D.R. Smitley. 2004. Control of emerald ash borer adults and larvae with insecticides. Michigan State Univ. Agri. Expt. Sta., East Lansing, MI. 8 pp.

Scarr, T.A., D. McCullough, and G.M. Howse. 2002. Emerald ash borer. Forest Alert—3. Ontario Ministry of Natural Resources, Michigan Dept. of Agriculture, and Ontario Ministry of Natural Resources, Ontario, Canada. 4 pp.

Slahor, J.J., C.C. Hassler, R.C. DeGroot, and D.J. Gardner. 1997. Preservative treatment evaluation with CCA and ACQ-B of four Appalachian wood species for use in timber transportation structures. Forest Prod. J. 47(9):33-42.

Smitley, D. and D. McCullough. 2005. How homeowners can protect ash trees from the emerald ash borer in southeastern Michigan. Internet Resources: www.emeraldasgborer.info. 5 pp.

SPSS, Inc. 1997. SigmaStat Statistical Software, Version 2.0 for Windows. SPSS Sci., Chicago, IL.