CCA Retention and its Effects on the Bonding Performance of Decommissioned Treated Wood: A Preliminary Study

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ABSTRACT

Chromated copper arsenate (CCA) continues to be widely used as a wood preservative for industrial uses in the U.S. Disposal of treated wood is a potential long-term environmental liability. Current practices for disposing of decommissioned preservative-treated wood include landfilling and incineration, which are increasingly impractical due to environmental impacts. To date, however, research has not yielded commercially successful methods of recycling spent treated wood. Novel approaches are needed for the recycling of large quantities of decommissioned treated wood products. Engineering quality decommissioned preservative-treated wood for value-added, structural, industrial products will extend the service life of treated wood and would be a practical solution to the current disposal problems of treated wood. However, the bonding of decommissioned preservative-treated wood with synthetic resins for engineered products has not been investigated adequately. The objectives of this preliminary study were to (1) investigate CCA retention across and along decommissioned utility poles, (2) evaluate the effects of two surface preparation methods on improving bonding strength between treated wood, and (3) evaluate the effect of CCA retention on bonding strength of decommissioned treated wood. Results showed that CCA retention decreased from the outside to the inside and from the top to the bottom of the decommissioned poles of this study. CCA interfered with the bonding of treated wood after treatment with both priming and incising.

Keywords: chromated copper arsenate, CCA, treated wood recycling, CCA retention, priming, incision, ground line, utility poles

INTRODUCTION

Wood in a humid environment is susceptible to biological attack and degradation (i.e., insects and fungi). Therefore, most wood products intended for exterior applications are treated with a chemical preservative. The preservative treatment may prolong the useful life of wood products in extreme environments by 20 to 40 times that of untreated wood, markedly reducing the need to harvest the forest. CCA is the most common waterborne preservative and has been widely used to treat lumber, utility poles, and crossarms since the late 1970's.

According to industrial statistics of the American Wood Preservers' Association (AWPA), the total production of preservative-treated wood was 514.3 million ft.^{3} in 1991 and 728 million ft.^{3} in 1997 (Micklewright 1998). The three major treated wood products in 1997 were lumber and timbers (98% treated with waterborne), crossties and bridge timbers (nearly 100% treated with creosote), and utility poles (15% with creosote, 36% with waterborne, 49% with oilborne). These products accounted for 86% of the total treated wood production in 1997. About 44% of southern pine lumber produced in 2000 was pressure-treated with some type of preservative. A study by Vlosky (2004) found that 26,564,911 lbs (dry oxide basis) of CCA were consumed by US treating plants in 2004, representing 40% of the total US waterborne preservative market.

Treated wood products that are placed in service will inevitably be decommissioned and removed from service. Over 2 million wood utility poles in the US, for example, are annually removed from service due to decay, termite attack, hurricane and storm, and/or mechanical damage (Cooper 1996, Bratkovich 2002). Traditional methods for disposing of decommissioned treated wood have been landfilling and incineration. It is estimated that about 5 million tons of spent preservative-treated wood are disposed of annually into landfills in the US (Falk 1997). In 2005, about 65% of decommissioned treated wood was landfilled (WRAP 2005). Treated-wood wastes accumulate in landfill sites. Preservatives leach out from these sites as rainwater infiltrates into these wastes (Jambeck et al. 2004), posing health and environmental concerns. Landfilling is also expected to become more costly and restricted due to the increased concentrations of chemicals such as arsenic that will accrue as additional quantities of treated wood are accepted into a landfill.

Burning of treated wood includes combustion and incineration. About 25% of decommissioned treated wood is combusted in the US (WRAP 2005). Burning of preservative-treated wood leads to the production of smoke and ash having high concentrations of preservative chemicals. Therefore, both landfilling and burning have environmental and liability implications.

Reusing decommissioned treated wood provides the opportunity to extend its useful service life and is often the most potential environmental option. Treated wood that was removed from service due to reconstruction or mechanical damage may retain most of its original mechanical strength and is a valuable resource for many value-added structural wood products. Current practices of simply reusing decommissioned treated wood include sawing the spent treated wood into products such as garden borders, posts, and fence components. However, this only recycles a small amount (10%) of all decommissioned treated wood (WRAP 2005). In addition, there are potential liability issues in the use of these wood products for residential purposes. Value added products resulting from recycling CCA-treated wood include particleboard and flakeboard (Davis 1993, Vick et al. 1996, Munson and Kamdem 1998, Mengeloglu and Gardner 2000, Li et al. 2004, Clausen et al. 2006), fiberboard (Felton and DeGroot 1996), waferboard (Boggio and Gertjejansen 1982), and wood-cement particle composites (Gong et al. 2004). Panels made from CCA-treated wood were phased out of interior and residential applications by the U.S. Environmental Protection Association (EPA) in 2004.

Technologies can be developed to economically and safely reuse the decommissioned preservative-treated wood for value-added exterior structural products. In structural design, quality decommissioned wood can be used as bending-stressed components on surfaces or shear stress components in the middle, depending on the strength of the wood. Structural members made from decommissioned treated wood can also be reinforced with untreated virgin wood and other materials, and/or also through the use of principles borrowed from engineering design and biomimicking technologies. Through reengineering and design, these engineered composites may have physical and mechanical properties comparable to those made from untreated virgin wood, thus, enabling them to be used in exterior structural environments. However, such technological development can not be found in the literature.

The reuse and reengineering of decommissioned treated wood can be problematic. Preservatives in the wood may interfere with the bonding of synthetic resins. Structural laminated composites are commonly consolidated using synthetic resins such as resorcinol phenol formaldehyde (RPF). Waterborne preservatives (mainly CCA) reduce the shear strength of plywood (Thompson 1962, Choong and Attarzedah 1970, Hutchinson et al. 1977), reduce bending and internal bonding of waferboard (Boggio and Gertjejansen 1982), and have negative impacts on thickness swelling and mechanical properties of particleboard and flakeboard (Munson and Kamdem 1998, Mengeloglu and Gardner 2000).

The bonding of decommissioned preservative-treated wood with synthetic resins for structural laminated composites has not been investigated adequately. In the pressure treatment of wood poles, for instance, the depth of preservative penetration specified by the AWPA is from 2.5 to 3.0 in, depending on the species (AWPA 2006). During fixation, storage, and transportation, preservatives may migrate to the deeper part of the poles. Consequently, the radial distribution of preservative could be extremely variable. Reduced retention may improve the bonding of wood adherents. However, the differential rate of retention across the lumber cut from treated wood such as utility poles could impact the mechanical properties of final composite products. Investigation of the effects of retention rates of preservatives (waterborne and oilborne) on the bonding of treated wood will be crucial to the reengineering of decommissioned preservative-treated wood.

The objectives of this preliminary study were to (1) determine CCA distribution across and along decommissioned utility poles, (2) investigate the effects of CCA on the bonding of decommissioned treated wood, and (3) evaluate two surface preparation methods (i.e., priming and incising) on the bonding strength of treated wood.

MATERIALS AND METHODS

Six decommissioned CCA-treated utility poles were obtained from local power companies. These poles were decommissioned in 2007 and had a life span from 7 to 13 years. Summary data obtained from the marks on the poles are listed in Table 1. Among these poles, Poles 3, 4, and 6 were complete poles when they were collected and had the same length as marked on the poles, while Poles 1, 2, and 5 were not complete poles. Sections were missing from these poles either at the top or at the bottom.

After the poles were brought to the Calhoun Research Station, metal attachments, wires, and nails were first removed. Then they were air-dried under an open shed for two months. Each pole was first divided into 98-in pole sections. Each section was sawn into lumber using a bandsaw. Each piece of lumber was planed to final thickness of ¾ in. After planning, lumber from the same section was stacked together in the same order as it was cut. Two stacks of lumber from each pole were randomly selected for this study. The remaining stacks of lumber were saved for a future study. Three 42-in. lumber sections were removed from each piece of lumber of the two selected stacks: two from one stack and one from the other. Similarly, the removed lumber was kept in stacks again in the same order as it was originally cut from the log sections. These three stacks of lumber (hereafter referred to as Sample-A, 42-in. long) were used for the bonding evaluation.

A small section (1 in. in length) (hereafter referred to as Sample-B) was removed from one end of each piece of lumber of Sample-A. Four to seven 1-in. block samples were consecutively removed from each of Sample-B. These blocks were 1 in. cubes and were used to measure the CCA retention from the outside to the center of each lumber sample of Sample-A. The blocks were dried in an oven at 212±5°F for 24 h and then ground into powder with a Wiley mill. An X-ray spectrometer was used to analyze CCA retention according to the American Wood Protection Association (AWPA) Standard A9-01 (AWPA 2006).

After Sample-B removal, the remaining Sample-A (41-in. long) was trimmed to remove a margin from one edge of the lumber. A 5-in. wide member was removed from each of the Sample-A and used as a member (ply) for the bonding test. Four pairs of neighboring plies were selected for this preliminary study from the stacks of Pole 1 and Pole 4 with two pairs from each pole. The rest plies in each stack were saved for the future study. For the selected plies, each pair of plies was evenly divided into three pairs of ply sections. The section pairs were then glued together with resorcinol phenol formaldehyde (RPF) resin (LT-5210) to form laminates. Prior to gluing, the glue surface of each ply was treated in one of three different ways: not treated (i.e., control), incised, or primed with a modifier (MO-654). Of the 2 pairs of plies from each pole, two section pairs were treated with priming, two with incising, and the other two as controls. In the modifier treatment, sample surfaces were brushed with the modifier at 11 g/ft.^{2}. For incised beams, sample surfaces were incised at 929 incisions/ft.^{2}. RPF resin and modifier MO 654 were obtained from Hexion Co. (Springfield, OR).

The RPF resin was uniformly applied onto one surface of each piece of the primed and untreated members made from decommissioned wood, and the primed and untreated members made from untreated virgin members at 43 g/ft.^{2}. For incised plies, 47 g/ft.^{2} RPF was applied. Laminates were kept under pressure for 24 h to cure the resin. After gluing, the laminates were conditioned to equilibrium moisture content (EMC) at 73 ± 4°F and 50 to 65 ± 5% relative humidity. After environmental conditioning, twelve 2-in. square samples were cut from each section pair for shear evaluation according to American Society for Testing and Materials (ASTM) D905 (ASTM 1996a).

RESULTS AND DISCUSSION

CCA Retention in Decommissioned Utility Poles

As expected, CCA retention decreased from the outside surfaces to the inside of the decommissioned poles. Fig. 1 shows CCA retention across Pole 1 at four locations. Fig. 2 shows average CCA retention along Poles 4 and 6 at 5 assay zones. Both Figures indicate that CCA retention decreased toward the center of each pole. The sapwood contained more CCA than the heartwood. This is necessary because the sapwood would be typically attacked first by insects and fungi in service. Fig. 1 also shows CCA retention increased from the outside to the inside of the pole at the top of the pole. This was rare for other poles of this study. Generally, CCA retention was more uniformly distributed at the top and under ground lines for most poles of this study.

Fig. 3 shows the balance of the three components of CCA across Poles 1 and 3. The balance of CrO_3 decreased and As_2O_5 and CuO increased from outside surfaces to the piths of the poles except for the bottom of Pole 3, in which only As_2O_5 increased. It suggests that CrO_3 had the lowest penetration capacity among the three components of CCA. One of the functions of CrO_3 is to help the fixation of As_2O_5 and CuO onto wood. Therefore, As_2O_5 and CuO were fixed to the wood more in the sapwood than in the heartwood because of the higher concentrations of CrO_3 in the sapwood. Problems may rise, however, when checks occur. CCA in heartwood and under the ground line might be leached out through the checks and water flows.

It was found that CCA retention varied along the decommissioned utility poles of this study. Fig. 4 shows CCA retention of Pole 4 at four assay zones. In the first assay zone, which was the 1-in. layer in the outside surface of the pole, CCA decreased from the top to the bottom (Fig. 4a). The top had the highest CCA retention and the bottom had the lowest. At deeper assay zones, CCA retention increased in the middle and decreased again to the bottom. The retention variation along the pole likely was due to the migration of CCA during service. CCA in the first assay zone was leached out to the surrounding ground by rain water. It has been reported that CCA was leached out from a simulated landfill (Jambeck et al. 2004). Inside the pole, some CCA at the top migrated along the pole to the lower portion and pyramided, resulting in increased CCA in the middle (Fig. 4c - 4d).

For recycling purposes, the varied CCA content across and along utility poles may affect the mechanical performance of the laminated products made from the decommissioned poles. Because of the interference of CCA on bonding, the glue-line shear stress varied across the laminates made from decommissioned wood and affected the mechanical properties of the members.

Surface Treatment Effects on Shear

Fig. 5 shows surface treatment effects on the bonding between treated wood. It was found that priming with the modifier MO-654 significantly increased the shear strength. Shear strength of the primed samples was comparable to the bonding shear of untreated virgin wood. The comparison between incision and the control was not statistically significant, indicating incising had no significant effect on improving the bonding performance. Variation existed in the shear collected from the incised samples of this study. Incising will be further investigated in our next study.

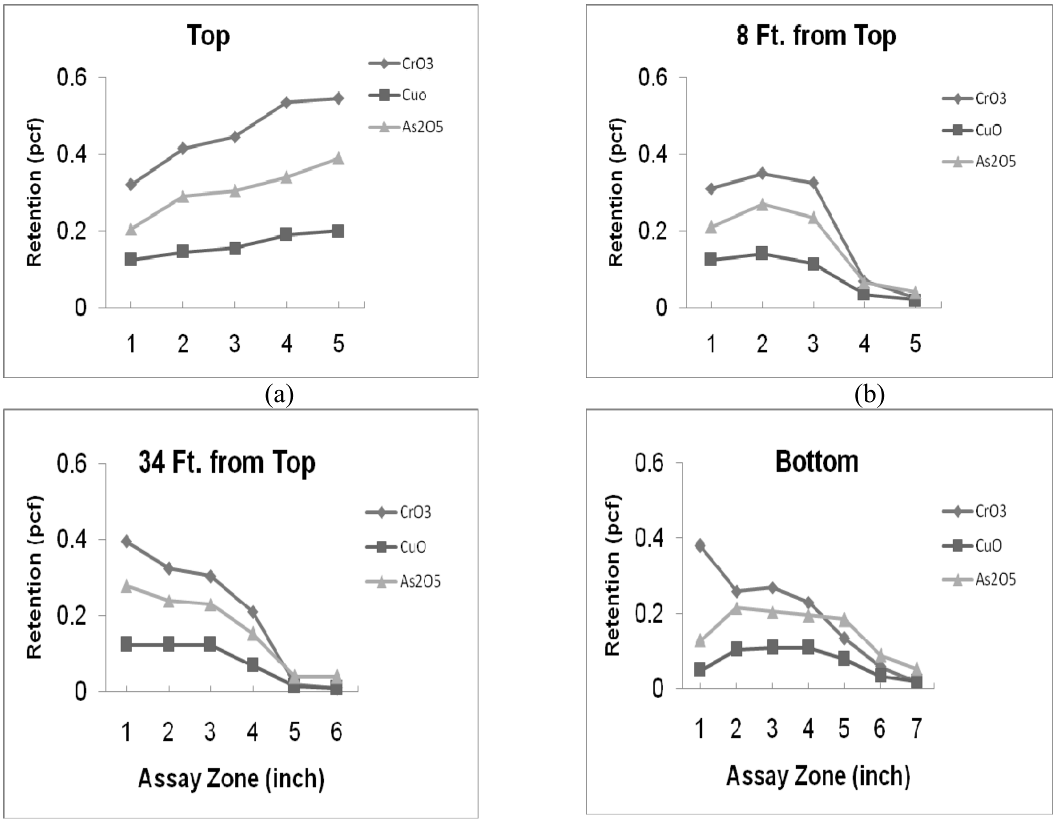
CCA Retention Effects on Shear

CCA retention in the lumber was correlated with the glue-line shear strength. As expected, the glue-line shear decreased with an increase of CCA retention (Fig. 6). This result confirmed the finding by previous investigators that CCA interferes with glue bonding (Boggio and Gertjejansen 1982, Davis 1993, Vick et al. 1996, Felton and DeGroot 1996, Munson and Kamdem 1998, Mengeloglu and Gardner 2000, Li et al. 2004, Clausen et al. 2006). It was also found that glue-line shear decreased as CCA retention increased of samples treated with priming and incising.

The average glue-line shear strength of samples treated with priming, incising, and no treatment all met the minimum requirement of shear strength for structural laminated products by the ASTM D 2559-92 (ASTM 1996b).

CONCLUSIONS

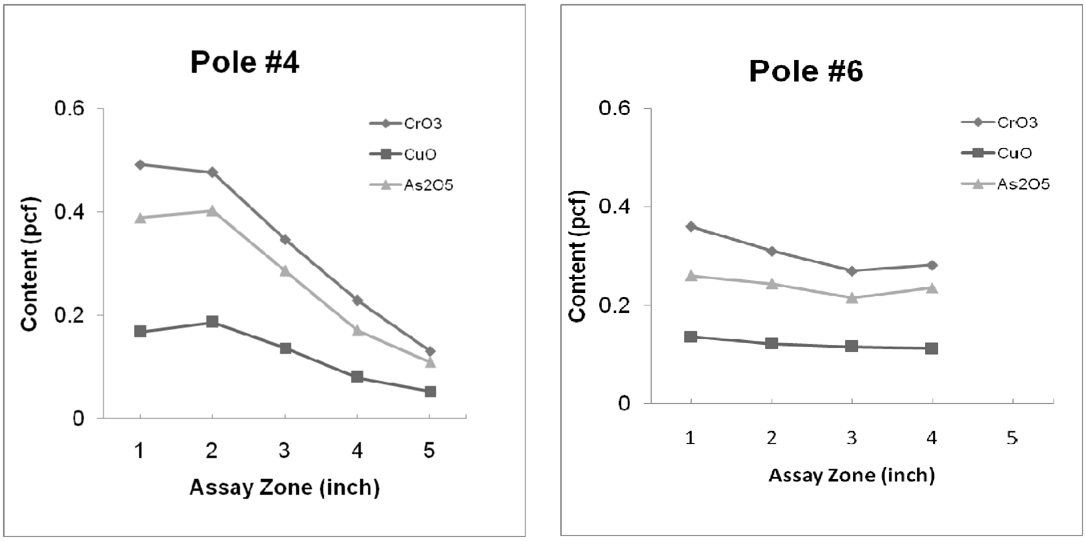
A preliminary study was conducted on CCA retention in decommissioned utility poles and its effects on bonding between treated wood. CCA retention decreased from outside surfaces to the inside and from the top to the bottom of decommissioned poles. Priming of treated wood lumber cut from decommissioned utility poles with a modifier increased the bonding strength. However, CCA reduced the glue-line shear strength of the lumber treated with priming and incising. The average glue-line shear strength of samples treated with priming, incising, and no treatment all met the minimum requirement of shear strength for structural laminated products by the ASTM D 2559-92 (ASTM 1996b).



(a) (b)

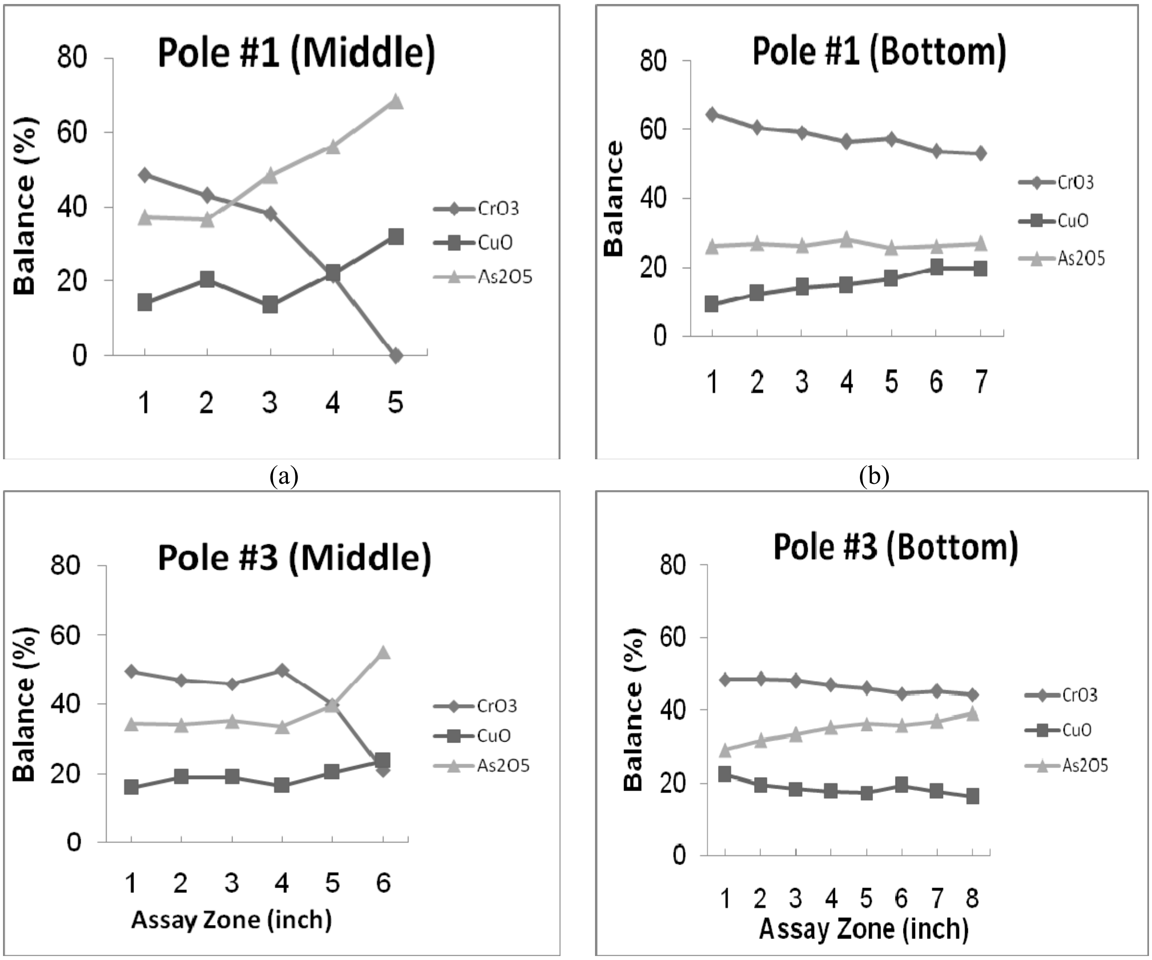
(c) (d)

Fig 1. CCA retention across Pole 3 at four locations along the pole.



(a) (b)

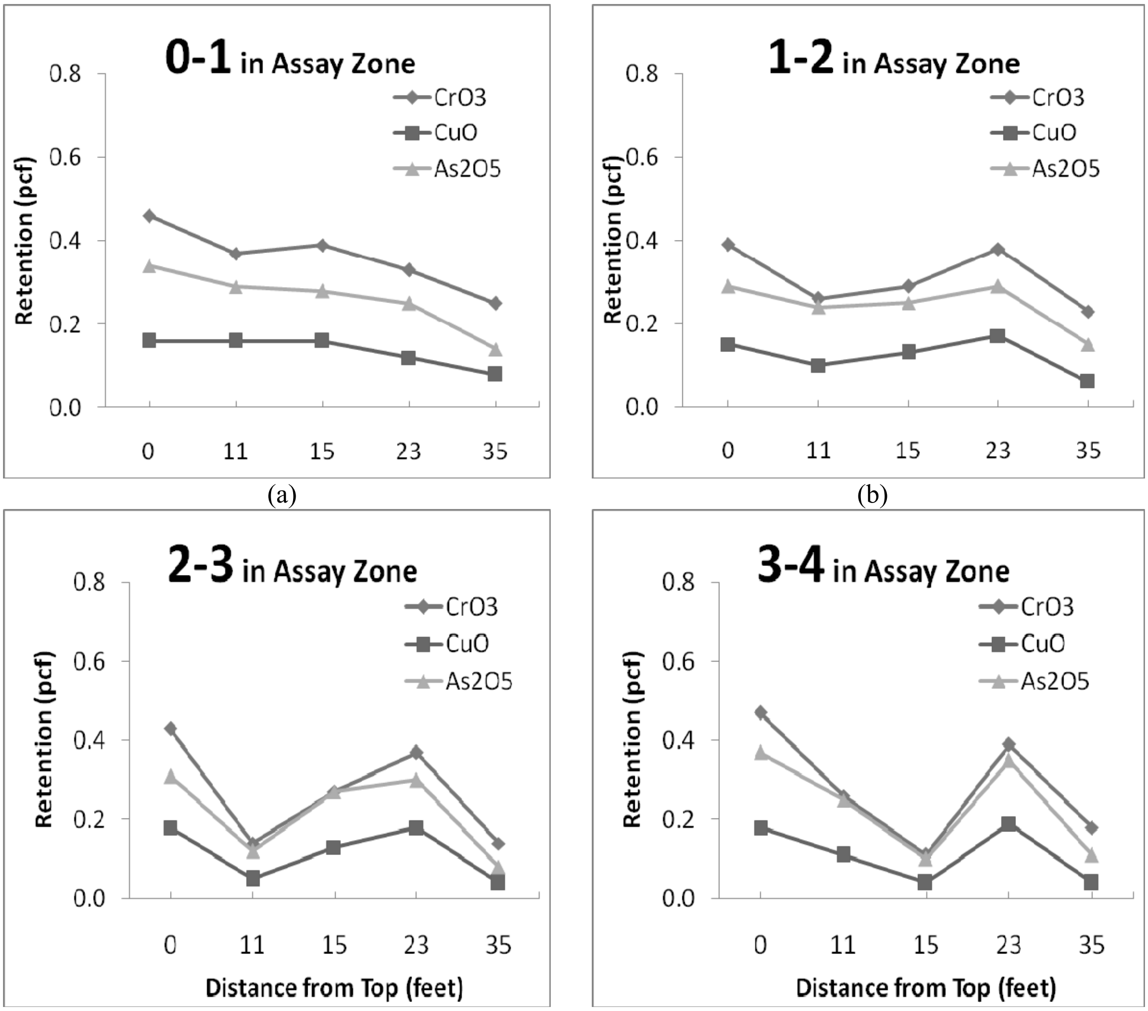
Fig. 2. Average CCA retention along Poles 4 and 6 at 5 assay zones.



(a) (b)

(c) (d)

Fig. 3. The balance of the three components of CCA in Poles 1 and 3.



(a) (b)

(c) (d)

Fig. 4. CCA retention along Pole 4.

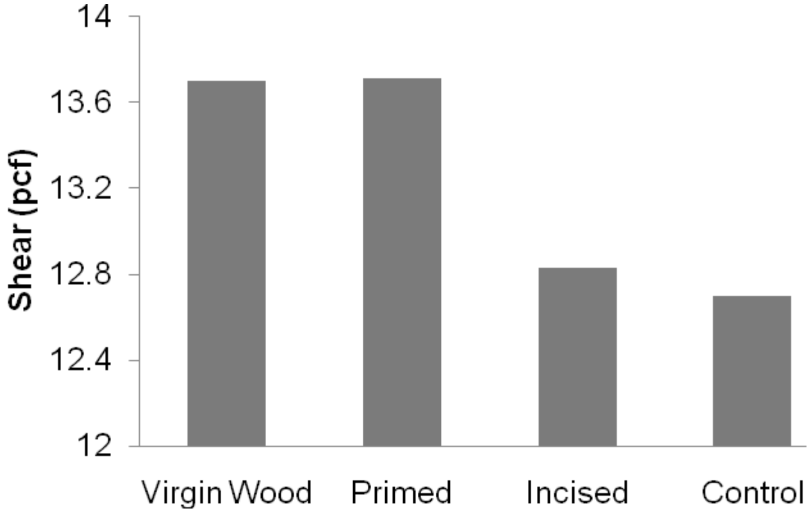


Fig. 5. Surface treatment effects on the bonding shear of laminates made from decommissioned CCA-treated utility poles.

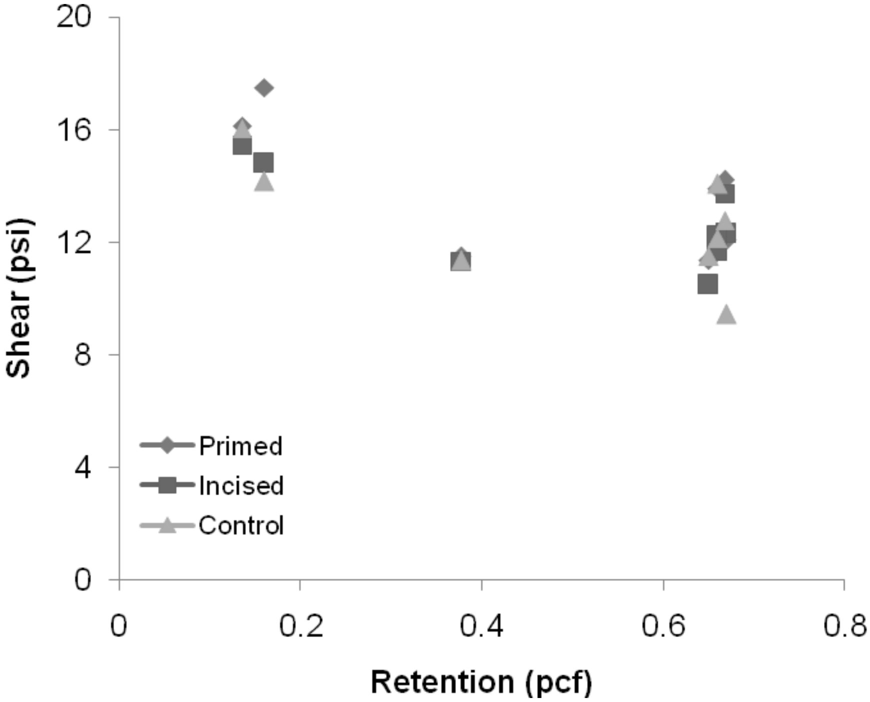


Fig. 6. Effects of CCA retention on the bonding shear strength of laminates made from decommissioned CCA-treated utility poles.

Table 1. Summary data of the CCA-treated decommissioned utility poles of this study.

Pole #	Class	Ori. Length (ft.)[1]	Act. Length (ft.)[2]	Missing Sections	Year Marked	Ser. Ended[3]
1	3	45	37	Bottom	1995	2007
2	3	45	7.6	Top	1995	2007
3	3	50	50	---	2000	2007
4	5	30	30	---	2000	2007
5	5	45	22	Top	1999	2007
6	5	35	35	---	1999	2007

[1] Original length.
[2] Actual length.
[3] Service period ended.

REFERENCES

1. American Society for Testing and Materials (ASTM). 1996a. Standard test method for strength properties of adhesive bonds in shear by compression loading, ASTM Designation: D 905-94. Annual Book of ASTM Standards, 15.06, ASTM, Philadelphia, Pa. pp. 21-24.
2. American Society for Testing and Materials (ASTM). 1996b. Standard specification for structural laminated wood products for use under exterior (wet use) exposure conditions, ASTM Designation: D 2559-92. Annual Book of ASTM Standards, 15.06, ASTM, Philadelphia, Pa. pp. 154-158.
3. American Wood Protection Association (AWPA). 2006. Annual book of standards. American Wood-Preservers' Association, Birmingham, AL. 456 pp.
4. Boggio, K. and R. Gertjejansen. 1982. Influence of ACA and CCA waterborne preservatives on the properties of aspen waferboard. Forest Prod. J. 32(3):22-26.
5. Bratkovich, S. M. 2002. Markets for recycled treated wood products. In: Proc. Enhancing the Durability of Lumber and Engineered Wood Products. Forest Products Society. Madison, WI. pp. 37-40.
6. Choong, E.T. and A. Attarzedah. 1970. Gluability of non-pressure treated southern pine veneer. Louisiana State Univ. Wood Utilization Notes. Agri. Expt. Sta. Release No. 18.
7. Clausen, C.A., J.H. Muehl, and A.M. Krzysik. 2006. Properties of structural panels fabricated from bioremediated CCA-treated wood: Pilot scale. Forest Prod. J. 56(3):32-35.
8. Cooper, P. A. 1996. Management of used poles removed from service. In: Proc. 2nd Southern Pole Conference. Sponsored by Forest Products Lab, Forestry & Wildlife Research Center, Mississippi State University in associated with Southern Pressure Treaters Association, Forest Products Society and Society of Wood Science & Technology, pp.102-112.
9. Davis, G. 1993. Investigation of alternative markets for recycled wood. RFP 92R-40-SW, Metropolitan Serv. District, Solid Waste Dept. Portland, OR.
10. Falk, B. 1997. Wood recycling: Opportunities for the wood waste resource. Forest Prod. J. 47 (6): 17-22.
11. Felton, C. and R.C. DeGroot. 1996. Fiberboard: an option for recycling wood treated with waterborne preservatives. In Proc. The Use of Recycled Wood and Paper in Building Applications. Madison, Wisconsin, Sep. 1996.
12. Gong, A., D.P. Kamdem, and R. Harichandran. 2004. Compression tests on wood-cement particle composites made of CCA treated wood removed from service. In Environmental Impacts of Preservative-Treated Wood Conference. Feb. 8-11, Orlando, FL.

13. Hutchinson, C.I., S.L. Choong, and J.M. McLaughling. 1977. Bonding of radiate pine veneers treated with CCA preservatives by the momentary immersion method. New Zealand J. of Forestry Sci. 7(1):113-122.
14. Jambeck, J.R., T. Townsend, and H. Solo-Gabriele. 2004. Leachate quality from simulated landfills containing CCA-treated wood. In: Environmental Impacts of Preservative-Treated Wood Conference. Feb. 8-11, 2004. Orlando, FL.
15. Li, W., T.F. Shupe, and C.Y. Hse. 2004. Physical and mechanical properties of flakeboard from recycled CCA-treated wood. Forest Prod. J. 54(2):89-94.
16. Mengeloglu, F. and D.J. Gardner. 2000. Recycled CCA-treated lumber in flakeboards: Evaluation of adhesives and flakes. Forest Prod. J. 50(2): 41-45.
17. Micklewright, J. T. 1998. Wood Preservation Statistics - 1997. Prepared for the American Wood-Preservers' Association (AWPA), Granbury, TX.
18. Munson, J.M. and D.P. Kamdem. 1998. Reconstituted particleboards from CCA-treated red pine utility poles. Forest Prod. J. 48(3): 55-62.
19. Thompson, W.S. 1962. Effect of preservative salts on the gluing of treated sweetgum veneer. Forest Prod. J. 12(9):431-436.
20. Vick, C.B., R.L. Geimer, and J.E. Wood Jr. 1996. Flakeboards from recycled CCA-treated southern pine lumber. Forest Prod. J. 46(11/12):89-91.
21. Vlosky, R.P. 2004. An overview of the U.S. preservative wood treating industry: 2004. Southern Pine Council. Kenner, La. 71 p.
22. WRAP. 2005. Options and risk assessment for treated wood waste. Summary Report. Published by TRADA Technology Ltd. for WRAP. ISBN 1 900510 46 4. 21 p.