AN ANALYSIS OF THE PHYSICAL PROPERTIES OF RECOVERED CCA-TREATED WOOD FROM RESIDENTIAL DECKS

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ABSTRACT

A large volume of CCA-treated wood removed from residential decks is disposed of in landfills every year, and better environmentally conscious alternatives are needed. Recycling CCA-treated wood from the decks could be a feasible alternative, but there is a lack of knowledge regarding the physical properties of the material. This research analyzed the chemical and mechanical properties of spent CCA-treated wood from residential decks to evaluate the material for reuse in other applications. Several of the joists and the decking of removed decks were found to be below the originally stated retention level. The joists had higher retention levels, and length of service was not a factor in level of chemical retention in the decking or joists. The spent decking had similar stiffness properties, but the bending strength was lower than recently treated material. As with the chemical properties, the mechanical properties were not affected by the amount of time the deck was in service. Overall, it was found that the preservative retention properties were lower than expected, the stiffness was equal to, and the strength was lower than, recently CCA-treated wood. This does not indicate that the material is unusable, but aids in determining suitable applications where recycled CCA-treated wood can be used.

Keywords: CCA, MOE, MOR, chemical retention, residential decks, recovery, reuse.

INTRODUCTION

Chromated Copper Arsenate (CCA) treated wood is the predominate material used for the construction of residential decks in the United States. According to the Southern Forest Products Association (SFPA) (1999), in 1997, 5 million cubic meters of CCA-treated wood were used in the construction, repair, and remodeling of residential decks. Research has shown that nearly 80% of all residential decks built in the United States used CCA-treated wood (Shook and Eastin 2001; Truini 1996). Further research has found that the average age of a deck being removed from service was 13 years by (Alderman 2001) and 9 years by McQueen and Stevens

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(1998). The investigators also determined that approximately 2.4 million cubic meters of CCA-treated wood from residential decks is currently being removed from service and disposed of primarily in landfills. The research also concluded that aesthetics of the deck, rather than its structural performance, was an extremely influential factor in the homeowner's decision to remove the deck. This leads to the question, can the service life of the CCA-treated wood be extended after deck removal? Therefore, to reuse the CCA-treated wood, the physical properties of the material must be comparable to that of recently preserved CCA-treated wood.

CCA-treated wood has retention levels ranging from a low of 0.004 g/cm^3 to a high of 0.04 g/cm^3 (Southern Pine Council 1999). Most residential decks use CCA-treated wood that has a retention level of 0.004 g/cm^3 or 0.006 g/cm^3 for above ground contact and 0.006 g/cm^3 exclusively if the wood will be in ground contact (Southern Pine Council 1999). A number of scientists have evaluated the amount of arsenic around and on the surface of structures composed of CCA-treated wood (Kluger 2001; Finch and Dainelle 1993; Ginsberg and Stilwell 2001; Hauserman 2001; Pianin 2002). The research showed that arsenic levels were high around and on the structures made of CCA-treated wood, but the retention level of the wood was not given. Extensive research has been performed on the disposal practices and the leaching of CCA-treated wood in landfills (Townsend and Solo-Gabriele 2002). Some of the research performed simulated the effect of spent CCA-treated wood in unlined landfills and concluded that in simulated environments the arsenic from spent CCA-treated wood does leach into the ground water. While this research has been useful in studying the potential hazards associated with the use and disposal of CCA-treated wood, little research has been performed to analyze the current retention levels of CCA-treated wood in residential decks. Research studying the retention level of spent CCA-treated wood from residential decks could aid in the extension of the useful life of the material.

There have been numerous studies performed on the mechanical properties of new CCA-treated wood (Winandy 1995; Winandy et al. 1985), but little research has been performed on the mechanical properties of CCA-treated wood that has been in-service for several years. Some mechanical tests have been performed on wood from deconstructed buildings (Falk et al. 1999). The research found that the deconstructed wood had similar stiffness properties of recently manufactured wood, but the strength properties were less than of the new wood. If CCA-treated wood is to be recycled from spent residential decks, then information is needed regarding the strength and stiffness of the removed material.

The objective of this work was to evaluate the chemical and mechanical properties of CCA-treated wood removed from service in residential decks. This research also compared the preservative retention and mechanical properties of CCA-treated material that had been in-service for several years to recently treated wood. This research will determine if the preservative retention and mechanical properties of recovered CCA-treated wood from residential decks are suitable for "second-life" products.

MATERIALS AND METHODS

The discarded CCA-treated wood from six residential decks was obtained. The service life of the deck components ranged from 13 to 27 years, with the mean service time being 17.7 years. The initial retention level of the chemicals in the removed deck material was obtained from the treating stamp or tag located on the lumber. All deck material, with one exception, was Southern Yellow Pine (SYP), which includes slash pine *(Pinus eliottii),* loblolly pine *(Pinus taeda),* shortleaf pine *(Pinus echinate),* pitch pine *(Pinus rigida),* and longleaf pine *(Pinus palustris).* One deck (Deck No. 5) had a Southern Pine Inspection Bureau (SPIB) grade stamp identifying the species as "Mixed Pine," which according to the SPIB indicates that some of the lumber could have been produced from Virginia pine *(Pinus virginiana)* or pond pine *(Pinus serotina),* along with SYP.

The majority of the decking was 2 × 6 dimension lumber, which is not uncommon because 5/4-in. radius edge decking (RED) did not become popular in this market until the mid 1980s, after many of these decks were constructed. Deck No. 1 was the only deck that contained RED and was the newest deck removed. Future decks removed from service will contain larger amounts of RED.

Chemical retention analysis

The American Wood Preservers Association (AWPA) Book of Standards (1984) was followed to obtain samples for chemical assay. The joists and decking of the six removed decks were tested along with recently treated 5/4 × 6 radius edge decking (RED) and 2 × 6 wood (new material was obtained from a local lumber supply center and had not been used in any application prior to the tests). In total, fourteen sample sets were tested, which included the six decking samples and six joists samples from each removed deck, and the two samples from the recently treated 2 × 6 and 5/4 × 6 lumber. An increment borer with a diameter of 0.48 cm was used to obtain the samples. The samples were obtained in a defect clear area of the board with no obvious amount of slope of grain. The sample was extracted from the edge and at least two feet from the end of the lumber. The core samples obtained were approximately 1.5 cm in length.

Ten cores were extracted from randomly selected boards in each sample set and were mailed in plastic bags to Chemical Specialists, Inc., located in Charlotte, NC, for the chemical assay tests. The samples were dried to approximately 0% moisture content, and then the wood was ground into a fine powder. The ground treated wood was then analyzed for Arsenic (As_2O_5), Copper (CuO), and hexavalent chromium (CrO_3) content using an Asoma X-ray fluorescence analyzer. Three replications were performed on each test to account for any errors during the test. There was enough material to perform two separate tests from each of the fourteen samples; therefore a total of 28 chemical assays were completed.

Mechanical strength analysis

Decking samples (2 × 6 and 5/4 RED) were collected from the six spent CCA-treated residential decks. Thirty random samples from the decking of each structure and recently purchased treated 2 × 6 and 5/4 × 6 radius edge decking (RED) were obtained resulting in 8 sample sets, each containing 30 samples. Recently treated SYP 2 × 6 and 5/4 RED were tested because existing data regarding the strength values of the CCA-treated wood were limited for comparison. Also, since no early data existed, an appropriate sample size to obtain normality could not be efficiently determined; therefore the Central Limit Theorem (Ott and Longnecker 2001) was followed, and a sample size of 30 from each set was acquired.

The 30 samples of decking (2 × 6 and RED) of the 8 sample sets were cut to a length of 76.2 cm and labeled, and conditioned approximately 60 days to reach equilibrium moisture content of 12%. Prior to testing, the width and thickness of each sample were recorded. A testline Mechanical Testing System (MTS) was used to test the strength properties, and a test span of 60.96 cm was selected to match the maximum joist spacing allowed for Southern Yellow Pine 5/4 RED (SPIB 1986). Pieces were tested in flatwise bending to simulate the performance of the decking material in-service (Fig. 1).

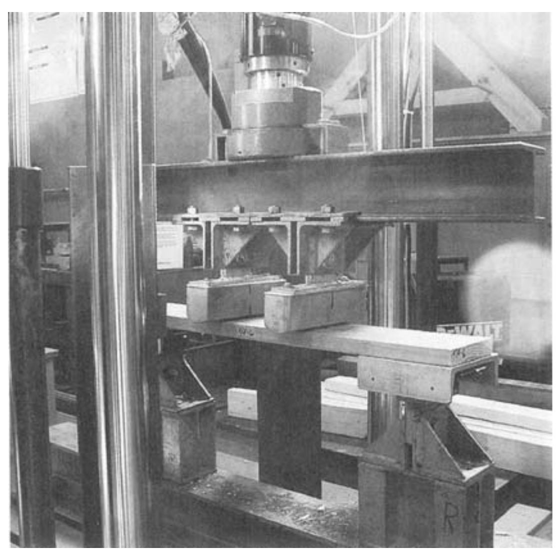

FIG. 1. MTS with test specimen loaded flat-wise in third point loading system.

The samples were tested in a third-point loading system for two main reasons. The first reason was to reduce the effect of span-to-depth ratio on the ratio of apparent to true modulus of elasticity (MOE) (Bodig and Jayne 1982). Second, the middle third load, where the majority of the failures occur, will have maximum force equally distributed and no shear force present.

The testing method followed was ASTM designation: D 198-99, Standard Test Methods of Static Tests of Lumber in Structural Sizes (ASTM 2000a). If possible, the largest defect of the test samples was intentionally placed in the middle third of the load span to create the most conservative MOE and MOR values possible. Load-deflection data were obtained from LabTech Control software, which then exported the data into Microsoft Excel, and the MOE and modulus of rupture (MOR) were calculated for each piece. The equations used to calculate MOE and MOR are as follows:

$$MOR = (P*L)/(b*h^2) \quad (1)$$

Where: P = Maximum load on beam (N)
L = Span of beam (m)
b = Width of beam (m)
h = Depth of beam (m)

$$MOE = [(P'/\Delta)*L^3]/(4.7*b*h^3) \quad (2)$$

Where: P'/Δ = Slope of load deflection curve under proportional limit (N/m)
L = Span of beam (m)
b = Width of beam (m)
h = Depth of beam (m)

The moisture content of the samples was determined, after mechanical testing, by acquiring the oven-dry weight according to ASTM Designation: D 4442-92 (ASTM 200b). This method has historically been more accurate than using **a** hand held moisture meter when determining moisture content of wood treated with waterborne chemicals. The moisture content of the samples was found to vary from 10% to 14%. Therefore, to insure that differing moisture contents were not a factor in comparing mechanical properties, ASTM designation: D 1990-00, Moisture Adjustment Procedure For Development of Characteristic Values For Mechanical Properties of Lumber (ASTM 2000c), was used to adjust all properties of the test data to a 15% moisture content. Also, the density of the samples in each set was assumed to be a normal representation of Southern Yellow Pine, and therefore the specific gravity of the samples was not determined.

Differences in the average MOE and MOR values between spent decking material and recently treated material were evaluated. The mechanical properties of the spent 2 × 6 decking material was compared to the recently treated 2 × 6 material, and the spent 5/4 × 6 RED decking material was compared to recently treated 5/4 × 6 RED material.

The distribution of each sample set was checked for normality, by performing the Shapiro-Wilk test of normality at an alpha level of 0.10, where:

- Null hypothesis was: data were normal
- Alternative hypothesis was: data were not normally distributed.

An independent t-test for equality of means was performed to determine if differences existed between MOR and MOE values of the deck from spent 5/4 × 6 RED and recently treated 5/4 × 6 decking, at an alpha level of 0.05, where:

- Null hypothesis was: property of new decking = property of spent decking
- Alternative hypothesis was: property of new decking ≠ property of spent decking

Analysis of Variance (ANOVA) was performed to see if differences existed between the MOR and MOE values of the five remaining sample sets of 2 × 6 decking material, at an alpha level of 0.05, where:

- Null hypothesis was: the mean mechanical property distributions are equal
- Alternative hypothesis was: the distributions were not equal

If differences in MOE and MOR values were determined to exist, then a Tukey Highly Significant Difference (HSD) multiple comparison test was performed to determine what set of spent 2 × 6 decking material had mechanical properties that were significantly different from the recently treated 2 × 6 decking, at an alpha level of 0.05.

TABLE 1. *Minimum retention of individual chemical components in CCA type C treated lumber required by AWPA.*

	Minimum retention levels (g/cm^3) of individual chemical components		
Total minimum retention (g/cm^3)	Copper (CuO)	Chromium (CrO_3)	Arsenic (AsO_5)
0.004	0.00067	0.0017	0.0012
0.006	0.00107	0.00274	0.00195

RESULTS AND DISCUSSION

Chemical retention analysis

The minimum retention of chemicals (g/cm^3) for the individual components, according to the AWPA Book of Standards (1984), is located in Table 1. This information was used to compare the recently treated CCA wood with the spent CCA-treated wood from the six discarded residential decks. As previously stated, 28 chemical assays were performed, two for each sample set. The data from the chemical assays displayed are the average of the two tests performed on the samples.

The copper, chromium, and arsenic retention levels of the decking and joists of the six decks removed and the recently treated 5/4 × 6 and 2 × 6 lumber are illustrated in Fig. 2. Figure 2 represents the ratio of the current chemical retention levels obtained from the X-ray fluorescence analyzer to that of the minimum required, by AWPA (1984), for each individual chemical component of CCA. As shown in Fig. 2, each preservative retention level for the recently treated 2 × 6 samples were above the minimum requirements, except the 5/4 × 6, which was slightly below the requirement. The preservative retention levels for the joists and decking of Deck No. 4 along with the joists of Decks No. 1 and No. 3 were above the required minimum levels set by the AWPA. Both the joists and decking for Deck No. 5 were well below the minimum standards for recently treated wood for all chemical components, but Deck No. 5 was grade-stamped "mixed pine" by the SPIB. Therefore, other species, such as Virginia or pond pine, could have an effect on the treatability and thus the retention levels. The retention levels for the three chemical components of the decking were lower than the joists of Deck No. 1, as shown in Fig. 2. Overall, only one of the joists and decking from the six decks tested retained, (or originally contained), the required minimum level of arsenic, copper, and hexava-

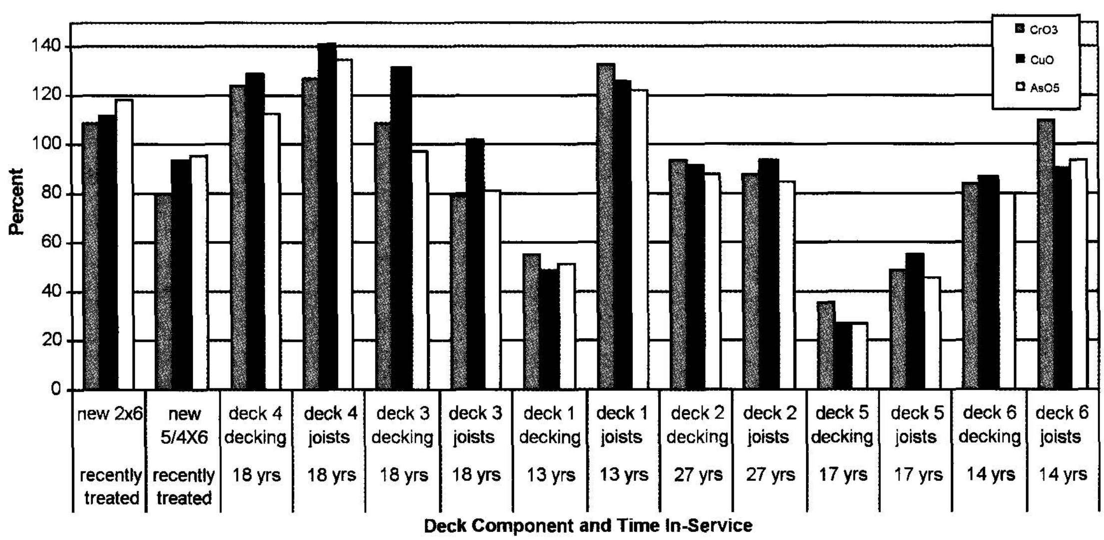

FIG. 2. Ratio of the current chemical retention level to the level indicated by the AWPA stamp or tag located on the test specimens.

lent chromium. There seems to be no relationship of the age of the deck, to the retention of chemicals in the decks. Deck No. 2 was in-service the longest (27 years) and had similar or better chemical retention compared to the other decks removed.

Nine of the 12 retention levels from the samples taken from the decking and joists of the residential decks were lower than the minimum standard required for recently treated wood, as shown in Fig. 3. The chemical assay samples from the joist and decking from Deck No. 4 were above the minimum standards required by AWPA, as shown in Fig. 3. Other than Deck No. 4, the decking samples used for chemical assay from Deck No. 1 were the only samples above the minimum retention in g/cm^3. Deck No. 5 had the lowest retention levels, and as stated previously, the low results could be a result of pressure treating mixed pine species; with southern pine species; treating both species at the same time might have altered the original retention in the wood. The decking of Deck No. 1 was also low compared to the stamped level it was treated to. It is plausible that the decking was not originally treated to 0.006 g/cm^3, but rather to 0.004 g/cm^3 and mistakenly stamped to be 0.006 g/cm^3.

The recently treated 2 × 6 samples had a chemical retention that was above the required limit, but the 5/4 × 6 samples were 20% below required minimum standards. The average retention of the eight chemical assay samples from the removed decks that were reported to be pressure treated at a minimum of 0.006 g/cm^3 was 0.0045 g/cm^3, approximately 30% below the retention level required after pressure treatment. The average of the four chemical assay samples tested that was originally pressure-treated at a minimum chemical retention of 0.004 g/cm^3 was found to be exactly equal.

The service time of the decks in this sample did not affect the retention level. As seen in Fig. 3, there appears to be no correlation between amount of time in service and retention levels lower than the minimum required. Other factors, such as lower then required retentions during the pressure treatment process and deck location and service conditions while the decks were in-service, could have been larger influences on the retention of preservative treating chemicals.

From chemical analysis, the samples from the joists had, on average, a higher chemical retention compared to the samples from the decking of the six removed residential decks. The average retention of the chemical assay samples from the decking was 0.0042 g/cm^3, and was 0.0048 g/cm^3 from the joist samples. As seen in Fig. 4, the joists chemical assay samples, on average,

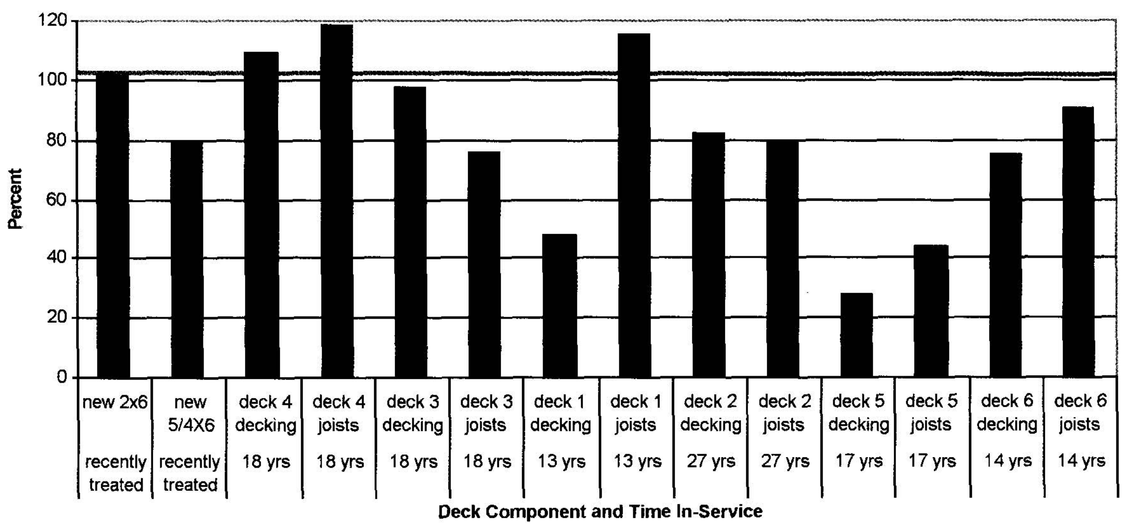

FIG. 3. Ratio of actual chemical retention to required minimum chemical retention by AWPA of chemical assay samples.

were approximately 15% below the minimum required chemical retention after preservative treatment. The decking samples, on average, were approximately 30% below the minimum required chemical retention after preservative treatment. Lack of physical and environmental exposure of the joists compared to the decking could be factors affecting the difference in preservative chemical retention.

Mechanical properties analysis

Table 2 displays the average and standard deviation from the mechanical strength tests of the decking samples from recently treated material and spent decking. The significance level for the Shapiro-Wilk normality tests, the t-tests for the 5/4 × 6 decking material, and multiple comparison tests for the 2 × 6 decking are also shown in Table 2.

The Shapiro-Wilk normality test was performed and concluded that all the MOE data from the 2 × 6 decking samples sets were normally distributed at an alpha level of 0.10. Figure 5 represents the average MOE of each sample set, with error bars representing a range of twice the standard deviation. This type of error bar was used because it represents 95% of the cases from the mean of a normal distribution (SPSS 2001). Analysis of Variance indicated that there are significant differences between the sample sets. Therefore, Tukey's HSD multiple comparison was performed and found that the MOE data from Deck Nos. 2,3,4, and 5 were statistically equal to the recently treated 2 × 6 samples. The MOE data from Deck No. 6 were found to be statistically greater than the recently treated 2 × 6 material. An independent t-test was performed to compare the data from the recently treated 5/4 × 6 samples to 5/4 × 6 decking of Deck No. 1, and the samples were found to be statistically equal at an alpha level of 0.05, as shown in Fig. 5.

The Shapiro-Wilk test for normality was performed on each data set, and the hypothesis of normal distribution of data was not rejected for the recently treated samples and Deck Nos. 4, 5, and 6, as shown in Table 2. Originally, the hypothesis was rejected for Deck Nos. 2 and 3 at an alpha level of 0.10. The test statistic of Deck Nos. 2 and 3 were 0.088 and 0.098, respectively. SPSS statistical analysis indicated that the data from Deck No. 2 had three statistical outliers; therefore, those outliers were disregarded from the data set. After those outliers were disre-

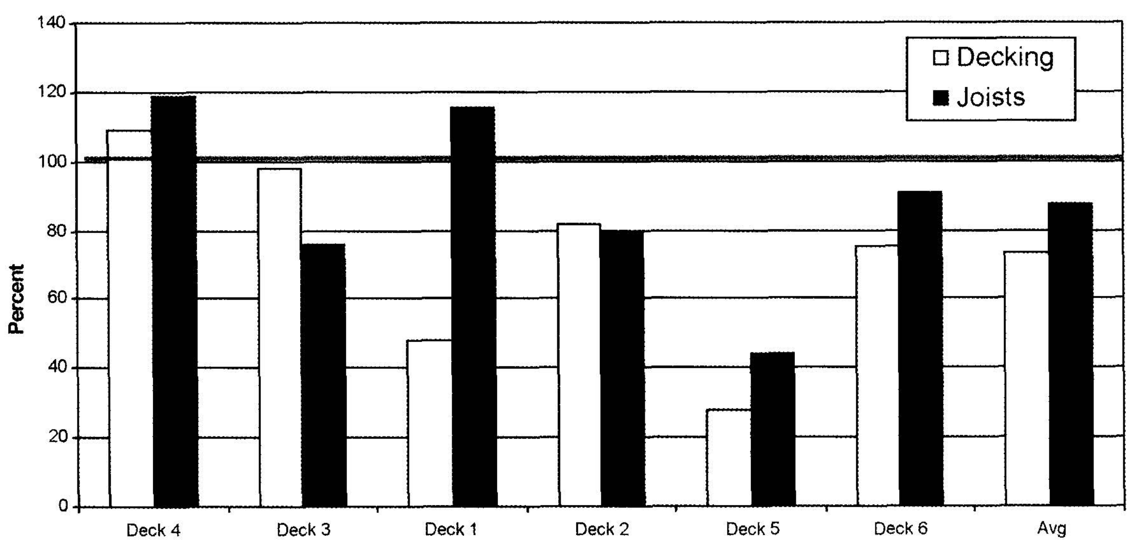

FIG. 4. Comparison of the ratio of current retention levels to that required at treatment of the recovered decking and joists of the discarded decks.

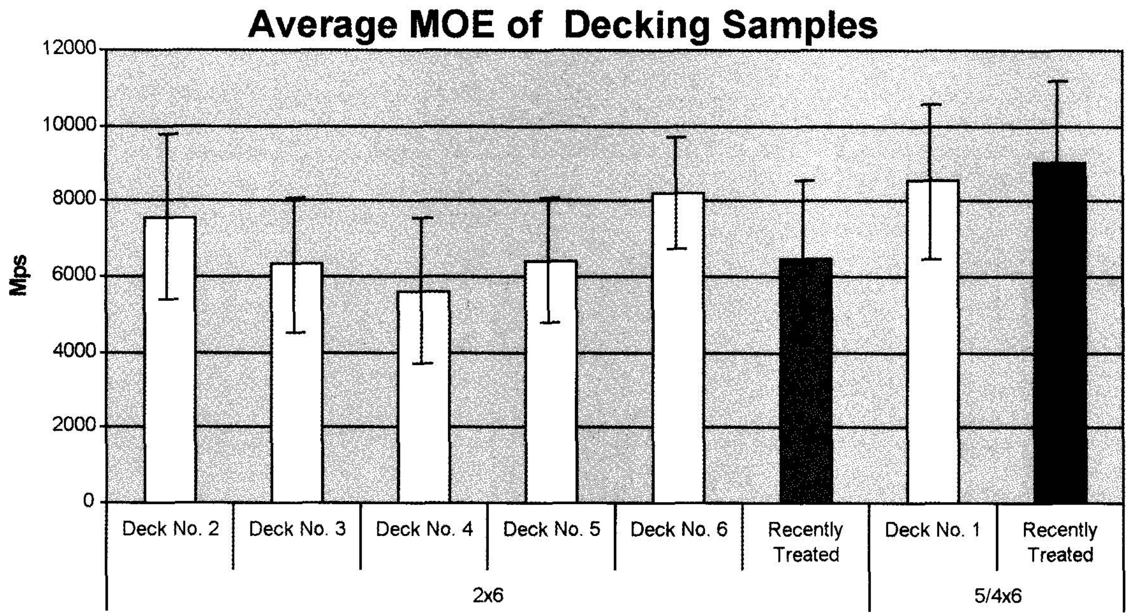

FIG. 5. Mean and range of the MOE data from the removed decking and recently treated samples.

garded, the data were again tested for normality. The new test statistic was 0.265; therefore the null hypothesis of normality was not rejected.

Figure 6 displays the mean MOR from each set and the distribution of the values from the mean. Analysis of Variance was conducted on the six sets and concluded that statistical differences exist between the MOR values at an alpha level of 0.05. Tukey's HSD multiple comparison test was performed, and the MOR values from

TABLE 2. *MOR and MOE data and statistical significance of mechanical property tests.*

5/4 RED Decking Samples									
	MOE Test Data				MOR Test Data				
	Mean (MPa)	Standard deviation (MPa)	Significance level from normality test	Significance level from t-test		Standard mean (MPa)	Significance deviation (MPa)	Significance level from normality Test	Significance level from t-test
deck 1	8537.64	2065.53	0.24	0.394*	deck 1	40.70	11.73	0.51	0.00
new 5/4×6	9009.06	2188.59	0.32		new 5/4×6	54.31	12.92	0.24	

2×6 Decking Samples									
	MOE Test Data				MOR Test Data				
	Mean (MPa)	Standard deviation (MPa)	Significance level from normality test	Significance level from Tukey's HSD		Mean (MPa)	Standard deviation (MPa)	Significance level from normality test	Significance level from Tukey's HSD
deck 2	7561.47	2193.22	0.14	0.229*	deck 2	39.13	11.05	0.27	0.80*
deck 3	6322.77	1774.17	0.44	0.999*	deck 3	33.69	10.89	0.10	0.02
deck 4	5608.40	1919.13	0.46	0.448*	deck 4	25.39	9.35	0.33	0
deck 5	6432.15	1661.30	0.37	1*	deck 5	31.66	8.84	0.15	0
deck 6	8223.08	1458.29	0.58	0.005**	deck 6	39.73	10.25	0.69	0.90*
new 2×6	6489.23	2064.43	0.47		new 2×6	42.54	15.32	0.76	

* represents samples that were statistically equal, at an alpha level of 0.05, to recently CCA-treated material of the same dimensions.
** deck # 6 was statistically greater than recently treated material.

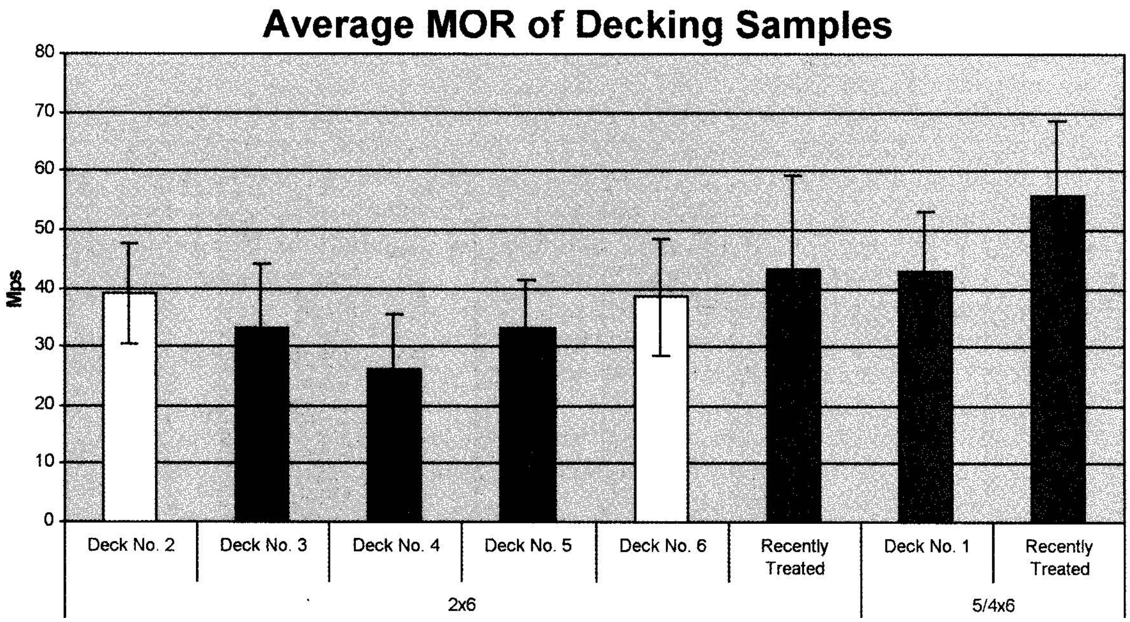

FIG. 6. Mean and range of the MOR data from the removed decking and recently treated sample sets.

Deck Nos. 6 and 2 were statistically equal to the recently treated 2 × 6 decking material. The multiple comparison test also found that the samples from Deck Nos. 3, 4, and 5 had statistically lower MOR values than the recently treated 2 × 6 decking. An independent t-test of the 5/4 × 6 decking of Deck No. 1 and the recently treated 5/4 × 6 decking concluded that the MOR values were not statistically equal at an alpha level of 0.05, as shown in Fig. 6.

CONCLUSIONS

Chemical tetention levels

Most of the chemical assay samples from the decking and joists resulted in lower than anticipated values. It should be noted that the low chemical retention of the assay samples does not mean that the treated wood in not reusable. Most of the samples used for chemical assay were above 0.004 g/cm^3, which is the minimum required for above-ground contact applications for CCA-treated wood. The majority of residential decks today are treated to a level of 0.006 g/cm^3. Therefore, much of the CCA-treated wood coming out of service in residential decks will at least have a chemical retention level equal to or greater than 0.004 g/cm^3, and can be used in applications where above-ground contact is required. From the results, the recovered decking and joists that indicated they were originally treated to 0.006 g/cm^3 contained proportionally lower current retention levels than the less densely treated material (0.004 g/cm^3). The results cannot verify that the material was treated to lower retention level originally or that material treated at a higher retention level of CCA will have a tendency to leach a higher volume of chemical during its time in service.

The objective of the chemical analysis of the deck components was to determine the feasibility of reusing spent CCA-treated wood from residential decks, not the exposure of the CCA chemicals to the environment. Conclusions cannot be drawn from the data that any preservative chemicals have leached because the initial retention levels were not known.

Mechanical property tests

Although this information is from only six removed decks and two sets of new material, the analysis indicated that there is potential reuse of removed CCA-treated SYP decking from residential decks. The stiffness of the decking material was found to be statistically equal to that of recently treated wood; however, the bending strength of the removed decking was lower, overall, than the recently treated wood. A valid theory for this phenomenon is that physical and climatic degradation resulting in splits or checks and/or nail holes could have induced flaws that recently treated wood does not contain, and therefore, crack propagation could occur in several more locations on the samples of spent decking and cause the lower bending strength of the recovered decking compared to the recently CCA-treated samples.

Age was seen as a non-factor for lower mechanical strength properties. Deck No. 2 was the oldest deck in-service at 27 years and had the same bending strength and stiffness as recently treated material. Conversely, Deck No. 4, which was in-service for 18 years, had MOE values statistically equal to recently treated samples, but MOR values statistically less than the recently treated specimens.

The mechanical property tests concluded that the recovered CCA-treated wood could be reused in many applications. The MOE properties are similar to that of recently treated wood, but the strength properties are lower, indicating that this material can be used in applications where bending strength is not as important as elasticity. Products where light loads are applied and released, such as outdoor furniture, decking components such as railings, decking and stairs, and pallets, could use spent CCA-treated wood as successfully as recently treated material.

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