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Properties of particleboard made from recycled CCA-treated wood

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Abstract

Recovery of chromated copper arsenate (CCA)-treated wood for reuse has been the focus of several international research groups due to the imminent disposal problem created when large quantities of CCA-treated wood ultimately come out of service. Bioleaching with *Bacillus licheniformis* CC01 and oxalic acid extraction are two methods known to remove significant quantities of metals from CCA-treated wood. Remediated particulate CCA-treated southern pine was reassembled into particleboard (PB) using 10% urea-formaldehyde resin. Particleboard panels were evaluated for internal bond (IB), modulus of elasticity (MOE), modulus of rupture (MOR), thickness swell (TS) and water absorption compared to particleboard manufactured from virgin southern pine and CCA-treated southern pine. Particleboard panels prepared from the remediated chips showed an average 28% reduction in IB and a 13% reduction in MOR compared to values for PB prepared with virgin chips under the pressing parameters used in this study, though individual IB values for all specimens were above the ANSI standard for medium density particleboard. An 8% increase in MOE in the remediated chip PB compared to the virgin chip PB may indicate densification of the fiber surface as a result of the acid extraction step of the remediation process. Thickness swell and water absorption after 24-hour submersion also increased in PB prepared from remediated chips (15% and 14%, respectively). We conclude that pressing parameter optimization could alleviate decreases in MOR and IB seen in PB made from remediated chips, and that the effects of acid extraction on MOR and IB properties should be further evaluated.

Key words: bioremediation, chromated copper arsenate (CCA), recycling, particleboard

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Introduction

In the United States, there is increasing concern about the disposal problem that the estimated 60 billion board feet of chromated copper arsenate (CCA)-treated wood, which has been placed in service since the early 1970's is going to create as it nears the end of it's expected service life (Cooper 1993; Micklewright 1994). Novel approaches to remediate, recycle or reuse this material are needed. One approach, which utilizes a combination of acid extraction and bioremediation (bioleaching), substantially reduces the amounts of copper, chromium and arsenic remaining in the wood following the remedation process (Clausen, in press; Clausen and Smith 1998; Cole & Clausen 1997; Crawford and Clausen 1999).

The remediation method of Clausen and coworkers exposes chipped CCA-treated wood to an oxalic acid extraction step followed by incubation of the extracted chips in a bacterial culture. It has been shown that the combination of acid extraction and bacterial exposure releases 70 to 100% of copper, chromium and arsenic from CCA-treated wood after 11 days. The properties of particleboard prepared from remediated chips were unknown.

The objective of this study was to press remediated chipped material into particleboard (PB) and evaluate the properties of the particle panels compared to virgin chipped southern pine PB and CCA-treated chipped southern pine PB.

Materials and methods

Remediation of CCA-treated wood

Two kg of chipped CCA-treated wood (hammermilled to 6-16 mesh) was remediated to remove the copper, chromium and arsenic as follows (Clausen, in press):

1) Eighteen hour exposure to 18 L of 0.8 percent oxalic acid (Sigma Chemicals, St. Louis, MO) at 25^{o}C in 18 liter polypropylene carboys.
2) Oxalic acid was siphoned off and eighteen liters nutrient broth (Difco, Detroit, MI) prepared according to manufacturers directions were added and inoculated with 500 ml of an 18 h culture of *Bacillus licheniformis* CC01 (Cole and Clausen 1997).
3) Carboys were incubated at 28^{o}C, 100 rpm for 10 days.
4) Spent medium was siphoned off, remediated chips were collected on cheesecloth covered screens and oven dried at 60^{o}C.

Two sets of controls consisted of either untreated virgin southern pine or southern pine treated with CCA-type C to a retention of 6.4 kg/m^3 (0.4 pcf) hammermilled to 6-16 mesh chip size.

Atomic Absorption Analysis

Remediated and CCA-treated chips were analyzed for copper, chromium and arsenic content by atomic absorption spectroscopy according to AWPA A11-93 (AWPA 1995).

Panel fabrication (Youngquist 1999)

Two 406 x 406 x 63 mm panels (16-inch square by 0.25" thick), with an approximate specific gravity of 0.80, were formed. Eight hundred ninety-nine grams of each of three chip types, (virgin southern pine, remediated southern pine or CCA-treated southern pine) were blended with 10% urea formaldehyde (UF) resin (Southeastern Adhesives' 9-2035, Lenoir, NC). The UF resin was applied in a rotating drum blender using an atomizing Binks spray gun. Panels were formed by hot-pressing for 5 min to an internal temperature of 121^{o}C. Panels were trimmed to 356mm square and cut into specimens for testing as diagramed in Figure 1. Specimens were conditioned for 2 weeks at 65% relative humidity (RH) and 20^{o}C prior to testing.

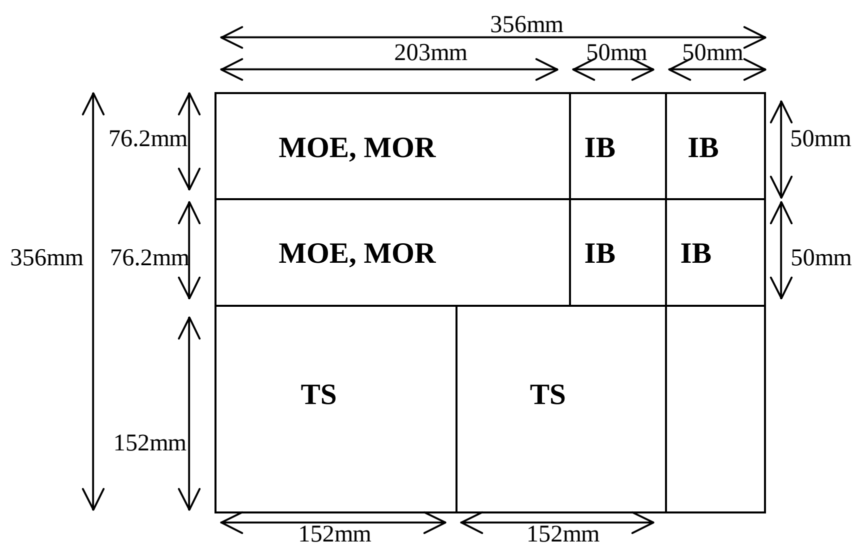

Figure 1. Cutting diagram of PB specimens for testing according to ASTM D 1037-96a. MOE=modulus of elasticity, MOR=modulus of rupture, IB=internal bond, TS=thickness swell. Figure 1 is not drawn to scale.

Static bending

Conditioned samples, 76.2 x 203 mm (3 x 8 inch), two from each of two panels per particle type were tested for MOE and MOR per ASTM standard D 1037-96a. Moisture content and specific gravity were also calculated for these specimens.

Internal bond

Tensile strength perpendicular to the surface was determined for four 50 x 50 mm (2 x 2 inch) square conditioned specimens per panel or 8 specimens per fiber type according to ASTM standard D 1037-96a. A continuous load of 10 mm/min was applied throughout the test.

Thickness swelling and water absorption

Conditioned specimens, 152 x 152 mm (6 x 6 inch) (2 per panel; 4 per fiber treatment) were evaluated for 24 hour water absorption and thickness swelling according to ASTM standard D 1037-96a. Water absorbed from the increase in weight during submersion and thickness swelling as a percentage of the conditioned thickness was calculated.

Results and Discussion

Remediated chips analyzed by atomic absorption analysis showed that the dual remediation process of acid extraction and bacterial culture reduced residual copper, chromium and arsenic in CCA-treated chips by 70%, 81% and 100%, respectively (Table 1).

Table 1. Atomic absorption analysis of CCA-treated and remediated chipped southern pine for copper, chromium, and arsenic content.

Chip type	**Copper** (mg/g)	**Chromium** (mg/g)	**Arsenic** (mg/g)
CCA	2.5	4.06	2.15
Remediated	0.75	0.77	0

Physical properties of the panels and results of the MOE, MOR, moisture content, internal bond, and specific gravity are shown in Table 2. The modulus of elasticity for particleboard (PB) made with remediated chips showed an 8% increase compared to PB made from virgin chips and a 38% decrease compared to PB made with CCA-treated chips. Increased MOE values combined with a decrease in MOR and IB for remediated chip PB could be the result of densifying the chip surfaces because the oxalic acid extraction step of the remediation process may have caused embrittling of the fiber. The modulus of rupture for remediated chip PB showed a 13% decrease compared to virgin chip PB, and a 14% decrease compared to CCA-treated chip PB as well as a high standard deviation between remediated PB specimens.

Table 2. Test results for southern yellow pine particleboard bonded with UF resin by chip type.

Chip type	**Thickness** mm	**MOE**[a] N/mm^2	**MOR**[b] N/mm^2	**MC**[c] %	**IB**[d] N/mm^2	**SG**[e]
Virgin	7.0±0.2	145±5.6	11.6±0.7	9.3	1.8±0.2	0.7
CCA	6.2±0.1	255±43.6	11.8±1.8	8.6	1.7±0.2	0.8
Remediated	6.9±0.3	157±14.2	10.1±2.2	8.4	1.3±0.3	0.8±0.1

[a]modulus of elasticity, n=4

[b]modulus of rupture, n=4

[c]moisture content, n=4

[d]internal bond, n=5-8

[e]specific gravity, n=4

Average internal bond values were higher than ANSI minimum values ($0.45 N/mm^2$=65psi) for M-2 grade medium density particleboard, however, direct comparison of PB prepared from the various chip types showed differences (NPA 1993). Due to improper adhesion in some specimens, internal bond values from an average of 5-8 specimens from two panels per chip type were evaluated. A 6% decrease in IB was observed in CCA-treated PB compared to virgin chip PB. The 28% decrease observed in remediated chip PB compared to virgin chip PB may be related to pressing parameters used in this study, but a more likely cause of the decreased IB is embrittlement of the remediated chips due to exposure to oxalic acid in the initial remediation step.

Percent thickness swell after two-hour submersion was greatest in virgin chip PB control panels (28%), followed by 26% in the remediated chip PB (Table 3). Likewise, percent water absorption was greater for control panels (54%) than remediated chip panels (49%) after 2-hour submersion. CCA chip PB is resistant to water absorption and initial thickness swell, but after 24-h submersion, percent thickness swell was 26% and water absorption was 43% for CCA chip PB.

After 24-h, remediated chip PB thickness swell and water absorption were both greater than in control PB (39 and 34% TS, respectively; 75% and 66% water absorption, respectively). UF bonded wood composite products are not water resistant (Meyers 1984), so water absorbing capacity and thickness swell increases can be expected in virgin chip PB . The comparative differences, however, between the remediated chip PB and control PB showed a 5% increase in thickness swell and nearly 9% increase in water absorbing capacity for the remediated chip PB compared to virgin chip PB. These differences may also be due to the caustic effect of the acid extraction step in the remediation process.

Table 3. Water absorption and thickness swell characteristics of particleboard panels.

Chip type	**Water absorption**[a]		**Thickness swell**[b]	
	2-hour	24-hour	2-hour	24-hour
Virgin	53.6±3.3	65.6±3.0	28.1±0.9	33.5±1.8
CCA	19.1±4.6	42.5±4.9	11.8±1.5	25.7±0.7
Remediated	49.0±10.5	74.5±8.6	26.3±4.9	38.6±2.8

[a]percent weight, n=4

[b]percent, n=4

Conclusions

The observations in this study were made on a limited number of specimens and panels with a single set of pressing parameters. Though some optimization of pressing conditions could alter the findings, the authors believe the oxalic acid treatment may have caused a slight embrittling of the fiber before pressing as MOE increased, while MOR and IB decreased. We also believe that the increase in thickness swell and water absorbing capacity after 24-h submersion may be related to the chip exposure to oxalic acid, even though extraction time and oxalic acid concentration had been optimized in a previous study to limit the exposure of the wood to the caustic effects of acid extraction (Clausen, in press). Ideally, bioremediation of CCA-treated wood should be limited to microbial removal or bioleaching of metals if the wood fiber is intended for reuse in other applications.

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