

**COMPRESSION TESTS ON WOOD-CEMENT PARTICLE COMPOSITES MADE
OF CCA-TREATED WOOD REMOVED FROM SERVICE**

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ABSTRACT

This research investigates the compressive properties of wood-cement particle composites made of CCA-treated wood retired from service. A total of 22 specimens were fabricated using Portland cement (type I) and wood particles from CCA-treated southern yellow pine retired from service. The specimens were made as rectangular short columns with different column aspect ratios (height/width). The cement to wood ratios by weight of the specimens were 1.5 and 1.0.

The load-deformation curves display significant nonlinearity, and indicate that the wood-cement particle composite has the capability to absorb energy. Further, the mechanical properties were not isotropic and indicate directional dependencies due to the orientation of the wood particles caused by the pressing during the manufacturing process. Short column specimens failed predominantly in shear under compressive loading irrespective of the orientation of the particles in the specimens.

The wood-cement particle composites exhibited a compressive strength comparable to that of normal concrete material. However, the strain at peak load was at least ten fold higher than that of normal concrete. The ability of such composite to sustain large plastic deformations implies that it can be used for applications where energy dissipation is highly required.

INTRODUCTION

In 1993, an estimated 5 billion board feet of wood were CCA treated and will be removed from service after approximately 27 years in 2020. This figure does not include the 72 million utility poles or 15 million ties treated annually with creosote or pentachlorophenol or other oilborne preservatives [1, 2]. A major challenge facing the wood preservative industry today is how to deal with this massive waste wood in the near future.

Based on a 30-year service-life, researchers at the Forest Products Laboratory (FPL) in Madison, Wisconsin estimate that 2.5 billion board feet per year (6 million m³/year) of treated-wood products (all types of preservative treatments) are currently entering the solid-waste stream, and that level will increase to 8 billion board feet per year (19 million m³/yr) by the year 2020 [3].

Recently, the U.S. Consumer Product Safety Commission (CPSC) released a risk assessment of CCA-treated wood on playground structures [4]. This assessment concluded that children playing on playground equipment built with CCA-treated wood might have a slightly increased risk of developing cancer. However, at this time, no further action has been recommended by the CPSC .

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For general public, on the one hand, the landfill disposal may produce environmental problems. It is increasingly difficult to landfill solid wood because it is a high volume material and deterioration is questionable when necessary requirements for biodegradation are not met. On the other hand, Stalker [1] reported a quoted cost by landfill operators of \$150 US per utility pole. The cost of landfill and the current level of environmental awareness will reduce land filling as an attractive alternative [5,6] for disposal of treated wood.

As a result, the disposal of preservative-treated wood products removed from service is problematic. Therefore an attractive solution for the after service disposal of treated wood is reconstituted wood products. Recycled treated wood, if properly managed, can be a good fiber source for engineered wood products such as hardboard, fiberboard, adhesive bonded and cement-bonded particleboard. Recycling wood into wood composite products becomes increasingly attractive because it not only benefits the environment but also has economic value.

A wood-cement particle composite is composed of wood particles, Portland cement and water. The wood-cement composites have a history of several decades in the United States. The flexural strength of the wood-cement composites has been investigated extensively. Little to negligible information is available on the compression strength of cement bonded wood particle composites. The use of wood-cement particle bricks in load bearing walls where the compression is solicited will require information on the compressive load-deformation and toughness as well.

Wolfe [7,8] reported that the characteristics of the compressive load-deformation curve were similar to those for the bending. In their study, the load displacement plots exhibited linear behavior up to 60 - 75% of the maximum load, at which point the rigid cement matrix began to crack. As the material began to fail, the material exhibited elasto-plastic behavior. Research on hardwood-cement particle composites by Blankenhorn [9], revealed that as the amount of red maple and hardwood pulp increased in wood cement particle composite (WCPC), the compressive strength decreased. Sorfa [10] reported that WCPC bricks developed for structural supports in mines exhibited compression properties similar to those of wood loaded at direction perpendicular to the grain. The load-deformation curves were initially linear until the matrix cracking, after which they softened.

Up to now, WCPC were assumed to be isotropic, few studies proposed the evaluation of the properties with the orientation of the particles.

We propose to laboratory manufacture cement bonded wood particle composites from CCA treated wood removed from service. The compressive properties of the WCPC in directions parallel and perpendicular to wood fiber, the compressive failure modes, compressive stress-strain correlations, and the energy dissipation will be investigated.

MATERIAL AND PROCEDURES

Southern yellow pine boards with CCA and used for 21 years as decking were removed in service in Lansing, Michigan. A wiley mill was used to reduced the boards into particles with size varying from 2 to 8 mm in length by 1 mm in diameter. A sieve was used to screen the particles.

The wood-cement composite specimens were made by mixing wood particles with cement at a ratio of cement to wood of 1.0 and 1.5 by weight. The amount of wood particles, water and cement required to produce particleboard measuring 35 mm in thickness by 315 mm wide by 315 mm long were calculated for a each given cement/wood ratio. The mixtures were placed in a mold and pressed using manual hydraulic press for 24 hours. After curing in room temperature for 28 days, the particleboards were cut into rectangular short column specimens for compression test.

The composite short column specimens were tested in compression parallel and perpendicular to the thickness of the board. The specimens were soaked in water at $20 \pm 3^\circ \text{C}$ for 24 hour before the test and were tested immediately upon removal from the water. The test matrix of the compression tests is shown in Table 1.

COMPRESSION TESTING

The compressive tests were conducted on INSTRON machine at a loading rate of 0.15 cm per minute. The sizes of the specimens used for testing are listed in Table 1. The specimens were tested with load parallel and perpendicular to the board thickness. The procedures in ASTM D1037-78 [11] were followed in the compression tests.

RESULTS AND DISCUSSION

Compressive Strength

Figure 1 shows the failure mode of specimens loaded parallel and perpendicular to the fiber directions with a column aspect ratio of 2.0 and a cement/wood ratio of 1.5. The failure modes on all samples were irrespective of the cement to wood ratios and column aspect ratios used in this study. The compressive failure typically occurred along diagonal bands similar to compression-shear failure on concrete columns. It can be concluded that short column specimens failed predominantly in shear under compressive loading irrespective of whether the wood particles were oriented along the direction parallel or perpendicular to the thickness.

Figure 2 shows the stress-strain curves of wood-cement particle composites for parallel and perpendicular compressions. The stress-strain curves obtained in the tests display significant nonlinearity, and indicate that the wood-cement particle composite has the capability to absorb energy. Further, the mechanical properties were not isotropic and indicate directional dependencies. The directional anisotropy were due to the orientation of wood particles caused by pressing during the manufacturing process.

In general, based on strain-stress test results, three significant findings can be reported: WCPC in direction parallel the particle orientation is much more stiffer than it in the perpendicular direction. Second, the deformation of the specimens in the perpendicular direction is much larger than in the

Table 1 Test matrix for compression on specimens

Short column specimens				
Cement/wood ratio		1.5		1.0
Column aspect ratio (h/d)		2.0	3.0	2.0
Number of specimens	Parallel	4	4	3
	Perpendicular	4	4	3
Dimensions (d×d×h), (mm)		17 x 17 x 34	11.7 x 11.7 x 35	15 x 15 x 30

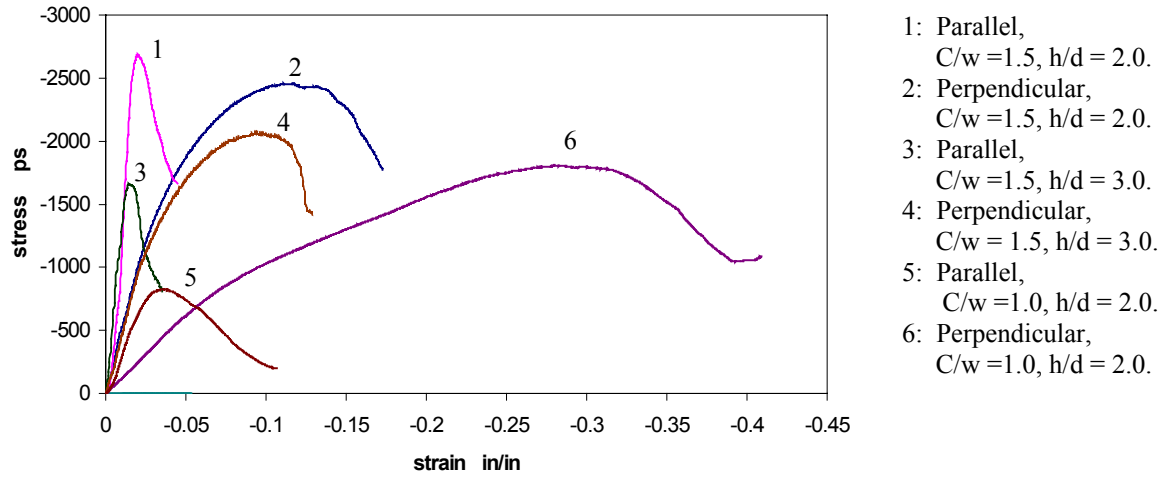


Figure 2. Stress-strain relationships of the wood-cement composite short columns

The ability of the composites to sustain such large plastic deformations implies that it has a strong potential to dissipate energy.

Toughness

The toughness is a measure of the energy absorbed per unit area of material; it is also defined as the area under load deformation curve. ASTM C1018 [12] is often used to calculate the toughness indices. ASTM C1018 defines a set of toughness indices for fiber reinforced concrete, which is defined as the area under the load-deformation curve up to the deformations of 3, 5.5 and 10.5 times the deformation at first crack divided by the area under load-deformation curve up to the first crack. In concrete industry, the toughness index of plain concrete is 1.0 and the toughness index of steel fiber reinforced concrete is about 5.0.

In this study ASTM C1018 procedure for toughness index (I_5) was used to define the compressive toughness of the wood-cement composites. The toughness index (I_5) is defined by the following equation:

$$I_5 = \frac{\text{Area under the load - deformation curve up to } 3\delta}{\text{Area under the load - deformation curve up to } \delta} \quad (1)$$

Where, δ is the deformation up to the first crack.

Table 2 shows the calculated toughness index I_5 for wood-cement particle composites with two cement/wood ratios under uniaxial compression tests. The calculated toughness indexes (I_5) of the

Table 2 Compressive toughness of wood-cement particle composites

		Cement/wood ratio	
		1.5	1.0
Toughness I_5	Mean	6.99	7.03
	St. Dev.	0.41	0.37

wood-cement particle composites are closed to 7.0. In Figure 2, apparently, the energy dissipation ability of the wood cement composite in perpendicular to fiber direction is stronger than that of the composites in the direction parallel to fiber direction. The toughness index I_5 for sample with a cement wood ratio of 1.5 was 6.98 irrespective of the orientation. Same results were obtained for samples with a cement/wood ratio of 1.0. The toughness index (I_5) of the composites with cement/wood ratio of 1.5 was lower than that of the composites with the cement/wood ratio of 1.0.

CONCLUSION

Compressive tests conducted on wood cement particle composites show a tremendous nonlinearity. the composite specimen fails in shear under compressive loading in either doirection parallel to or perpendicular to wood fiber direction. Composites with a cement/wood ratio of 1.5 exhibited a compressive strength comparable to that of normal concrete, the strain at peak load was more than ten to fifty times larger than the strain at peak load for normal concrete depending on the direction of the compressive loading. The ability of the composites to sustain such large plastic deformations suggests that WCPC has a strong potential to dissipate energy. The toughness index I_5 for the composites with either a cement/wood ratio of 1.5 or 1.0 was about 7.0, which is seven times larger than that of normal concrete.

This study suggests that CCA-treated wood removed from service can be used for manufacturing wood cement particle composites for use in applications where compressive strength and energy dissipation are desirable properties.

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