

DURABILITY AND STRENGTH OF CEMENT-BONDED WOOD PARTICLE COMPOSITES MADE FROM CONSTRUCTION WASTE

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ABSTRACT

A pilot study was conducted to assess the potential for using southern pine particles derived from construction waste to create a cement-wood composite suitable for exposed structural applications. Panels fabricated from copper chromium arsenate (CCA)-treated as well as untreated particles were cut into individual samples and tested for freeze-thaw durability, strength, and toughness. Results support the premise that these composites can be designed to meet the requirements for highway sound barriers. The results also show that these composites have energy-dissipating properties that could have special applications in structures where impact and dynamic load are a design consideration.

Environmental concern about the disposal of waste materials has focused renewed attention on low density cement-bonded wood composites (CBWCs). These composites, used commercially since the early 1900s are mostly made using wood strands (excelsior) cut from green log sections. They have been used primarily as interior wall and ceiling panels where their appeal is a combination of aesthetics, fire resistance, and sound attenuation. The cement binder also provides a nontoxic shield against decay and termites. Wood particles taken from the waste stream do not have the uniformity or length of excelsior, but they can be used with a cement binder to manufacture construction panels. In addition to providing a value-added use for woodwaste, the cement matrix has improved dimensional stability compared with solid wood, is readily available in most areas of the world at relatively low processing cost, and can be easily reduced to a relatively inert raw material.

The common perception that concrete's strength and durability are unacceptably compromised by the addition of organic material presents a major deterrent to acceptance of cement-wood com-

posites in structural applications. Studies involving cellulose fiber in cement composites have shown strength loss due to alkaline degradation and mineralization (4,7). Chemical treatments such as special coatings or additives to accelerate cement cure have been patented to minimize detrimental effects of cement-wood interaction. Many researchers (5,8,10, 11,13) have shown that it is possible to control negative effects of cement-wood interaction and take advantage of positive ones. Many of the cellulose-cement interaction problems can be minimized or eliminated by tightening controls on the species and condition of the wood particles used. As for long-term durability, Dinwoodie and Paxton (6) found little

sign of deterioration other than a roughening of the surface in a study involving a 7-year exterior exposure of cement-bonded particle boards.

Research to relate properties of the raw materials to the performance of the composite is the first step in developing a new class of materials designed to reuse rather than dispose of woodwaste. For applications such as highway sound barriers, these materials exhibit good sound absorption characteristics, but there is little published data by which to judge the ability of these materials to stand up to established sound barrier freeze-thaw durability or ultraviolet exposure requirements (14).

OBJECTIVE AND SCOPE

This pilot study was conducted to assess the efficacy of using cement-bonded wastewood particle composites in highway sound barriers. Four panels were fabricated, each to a slightly different density, and tests were conducted to assess their ability to meet established requirements. For this study, we concentrated on the use of southern pine construction waste. Of the four panels that were fabricated, three were made with treated wood (CCA). Evaluations

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TABLE 1. —Composite mixes and fabrication pressure used for each of the experimental panels.

No.	Panel description		Composite mix				
	Thickness (mm)	Treatment	Wood	Cement (kg)	CaCl ₂	Water (L)	Pressure (kPa)
1	178	Treated	73	135	5.7	70	60
2	152	Treated	73	128	5.9	68	120
3	160	Untreated	70	130	5.9	91	120
4	152	Treated	70	135	5.6	70	120

included a cyclic freeze-thaw aging test as well as strength and toughness in bending and compression.

MATERIALS

Materials for this study were provided by private contractors interested in exploring potential uses for woodwaste, which currently has a negative value. A recycling contractor located in northern Wisconsin donated the wood particles, which he produced by shredding construction waste using a commercial tub grinder. Cement and calcium chloride (CaCl₂) were donated by the same concrete products company that also manufactured the test panels.

This wood construction waste appeared to be primarily southern pine dimension lumber. The material was presorted (treated and untreated) and stockpiled in the salvage yard for about 1 year. Its moisture content was close to fiber saturation. A laboratory evaluation of the particles collected on site revealed a moisture content of 35 percent and a low concentration of free sugars, which may inhibit cement hydration. The fact that the material was cut from surfaced dimension lumber suggests that it had at one time been seasoned (kiln- or air-dried).

After grinding, the treated material comprised a wider range of particle sizes compared to the untreated material. Our intent was to have particles ranging from 1.6 mm in diameter by 6.4 mm long (1/16 by 1/4 in.) to 6.3 mm in diameter by 25 mm long (1/4 by 1 in.). The treated wood pile, however, contained a large percentage of very fine fiber sized particles. Both piles also contained particles as large as 20 mm in diameter by 50 mm long (3/4 by 2 in.). To remove some of the very fine particles from the treated wood, we used a 6.3-mm (1/4-in.) mesh screen. Particles for Panel 2 were not screened as rigorously as were those for Panel 1, which resulted in more fibers and less void space in Panel 2.

The cement used was type I portland. Although there were possible advantages

of using a faster setting cement such as type III, type I is the most commonly used and readily available.

CaCl₂ has been shown to be an effective and economical accelerator for cement hydration (9,12) and has been widely adopted by the cement-wood board fabricators.

PROCEDURES

There are no standards available that specifically address the fabrication and testing of low-density cement composites. Although they are not a new idea, there has been little demand for engineered applications that require the consistency to be gained through the adherence to standards. The panels were fabricated following recommendations found in research publications, and the tests were conducted and analyzed following both standards developed for concrete as well as those developed for wood products.

PANEL FABRICATION

The four panels fabricated for this study had only slight variations in recipe mix. The target recipe included a wood/cement ratio of 1:2 by weight, a CaCl₂/cement ratio of 4 percent, and enough water to maintain wood fiber saturation and support cement hydration. For the first panel, wood particles were rigorously screened to remove very small particles. For subsequent panels, less effort was expended to separate the fines. Added water was limited to 50 percent of the dry weight of the wood plus 25 percent of the weight of the cement. Initially, 9.5 L (2.5 gallons) of water were mixed with the CaCl₂ prior to mixing with the cement-wood mix. Periodic sampling during the mixing process was used to assess the need for water. When the mix was at a consistency that would hold together when squeezed, we stopped adding water. Panels 1,2, and 4, made using the CCA-treated wood, required less water compared to the panel that was fabricated using the untreated particles.

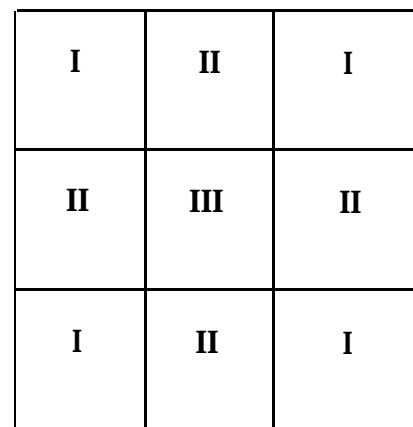


Figure 1. —Test panel sample zones

Actual mix ratios for the four panels are shown in Table 1.

The panel fabrication process involved placing a fairly dry wood-cement mix in a steel form and compacting it by a combination of vibration and low pressure to a uniform thickness. The press included four hydraulic pressing rams, each with a capacity of 44.5 kN (10 kips) and a low-frequency (-0.3 Hz) vibrating table. A bulk volume of roughly 0.34 m³ (12 ft.³) of mix was used to make a panel 1.22 m (4 ft.) square and 152 mm (6 in.) thick. Pressing time ranged from 10 to 15 minutes. The panel was then taken out of the form and moved to a curing table. Within 30 minutes, it was hard enough to handle and was moved to a curing chamber, heated by the cement hydration. Ambient temperature outside the “hydration kiln” ranged from 20° to 30°C. The panels cured for 14 days prior to being shipped to the USDA Forest Products Laboratory (FPL) in Madison, Wis.

The fabrication pressure varied only slightly for Panels 2, 3, and 4. Panel 1 was located at one end of the press with a woodblock on the opposite end so that only half the pressing capacity actually applied to the panel. In this case, the pressure was estimated to be slightly

more than 60 kPa (9 psi). For the remaining panels, the form was moved to the center of the press, giving them twice the pressure or 120 kPa (18 psi). As the mass was being pressed, the press table was also vibrated at a frequency of 0.5 Hz to remove air pockets and distribute wood particles.

TEST SAMPLE PREPARATION

In evaluating these samples, we were interested in assessing material uniformity as well as their strength and durability. We therefore identified samples on the basis of their location within the panel they were cut from. Each panel was divided into nine sections as shown in **Figure 1**. The corner sections were labeled Zone I, the intermediate boundary sections Zone II, and the center section Zone III.

Individual test samples were cut from each panel for three test categories: freeze-thaw aging, compression, and bending. Due to the relative high density and thickness of these panels, we found that the best method of cutting was a carbide-tipped bandsaw blade. Grinding- or pulverizing-type cutting blades such as those normally used for concrete tend to bum through rather than cut the organic fibers, generating heat, dust, and smoke. The carbide-tipped bandsaw made a relatively clean cut on a single pass with little noticeable damage to the blade.

A total of 36 freeze-thaw samples were tested: 12 from each of Panels 1, 2, and 3. Four of these were cut from Zone I areas, 6 from Zone II, and 2 from Zone III. These test samples were each 76 mm (3 in.) thick, 102 mm (4 in.) deep, and 406 mm (16 in.) long, sized to fit within the pans in the weatherometer used for the freeze-thaw tests.

Thirty-three samples were cut for compression tests. The compression test samples were 76 mm (3 in.) square by 305 mm (12 in.) long. While we planned to cut 7 samples from each panel (3 from Zone I, 3 from Zone II, and 1 from Zone III), we ended up with 7 for Panel 1, 6 for each of Panels 2 and 3 (only 2 from Zone II), and 14 from Panel 4 (7 from Zone I, 4 from Zone II, and 3 from Zone III).

Forty samples were cut for third-point bending tests. These samples were 76 by 102 mm (3 by 4 in.) in cross section and 810 mm long. They were taken from two zones (I and II). Ten of these were taken from each test panel.

TEST METHODS

Prior to testing, all samples were weighed and measured to get a rough estimate of density. Samples were stored at ambient conditions of 20°C and 80 percent relative humidity (RH) prior to these density measurements. Moisture was estimated to be 8 to 10 percent of the mass.

FREEZE-THAW TESTS

Freeze-thaw tests conducted following the American Society of Testing and Materials (ASTM) Standard C666-96 (3) were slightly more rigorous compared to those described by the Wisconsin Department of Transportation (DOT) certification method of acceptance of sound barrier systems (14). Rather than placing a saltwater solution on one surface of a 0.3-m square specimen, the entire sample was submerged in a 3 percent NaCl₂/water solution. The tests were conducted using a programmable weatherometer. This apparatus comprises refrigeration and heating units, temperature sensors, and a clock, which may be used to control cyclic temperature conditions within a stainless steel chamber. Exposure temperatures ranged from -17° to 4.4°C (0° to 50°F) for the first set of specimens and -12.2° to 12.3°C (10° to 55°F) for the second set. Freezing and thawing cycles were controlled to allow samples sufficient time to attain uniform temperature at extremes of the cycle.

The panels were evaluated on the basis of Wisconsin DOT requirements that a material lose no more than 1 kg mass/m² exposed surface when subjected to 50 freeze-thaw cycles in a saltwater environment. The surface area for each sample was ~0.16 m²; therefore, permissible mass loss was limited to 160 g or 4 to 6 percent of the initial mass.

One set of freeze-thaw durability tests was initially planned. Some samples were damaged, however, while taking stress-wave measurements, which was a means of monitoring material property changes with freeze-thaw cycling. We therefore tested a second set without taking stress wave readings. Each set comprised 18 samples.

The Wisconsin DOT requirements are one freeze-thaw cycle every 24 hours, comprising 16 ± 1 hour freezing followed by 8 ± 1 hour thawing. In this study, one cycle was completed every 8

to 10 hours with 5.5 to 7 hours freezing and 2.5 to 3 hours thawing.

Mass loss was determined on the basis of dry weight before and after cycling. Samples were weighed in the dry condition only: once shortly after cutting and again after 50 cycles and an extended drying period in a conditioning room.

STRENGTH AND MODULUS OF ELASTICITY EVALUATION

Compression tests were conducted in accordance with ASTM D198-96 (2), with some deviation on specimen dimensions. Samples were tested as short columns with no lateral support. The 76-mm- (3-in.-) square by 305-mm- (12-in.-) long specimens had a slenderness ratio of 14, which is less than the ratio of 17 called for in Standard D198. Specimens were geometrically centered on bearing plates supported on spherical seats to assure that they were concentrically-axially loaded. A constant loading rate of 0.76 mm/minute (0.03 in./min.) was used.

Bending strength and modulus of elasticity (MOE) were evaluated using a third-point loading on a 740-mm (29-in.) span (span-to-depth ratio of 7.25). The specimens were supported by metal bearing plates to prevent damage to the beam at the point of contact between specimen and reaction support. The bearing plates were supported on one end by rollers, and on the other end by fixed knife edge reaction. Load was applied at a rate of 0.5 mm/minute (0.02 in./min.).

ANALYSIS METHODS

The analysis of stress and MOE relied on the simplifying assumption that these composites behave as isotropic, uniform materials. Because all samples were assumed to have the same random fiber orientation and a uniform distribution of cement and wood, it is assumed that the error associated with this assumption is part of the material variability. Compressive strength is evaluated as load divided by gross section area, bending strength is assessed as moment divided by section modulus, and MOE was calculated as the slope of the linear portion of the stress-strain curve.

TOUGHNESS

Toughness was evaluated in accordance with ASTM C1018-89 (1). This standard defines three toughness indices that serve as a basis for characterizing flexural toughness of fiber-reinforced concrete. In this study, we evaluated two

of these indices. They are expressed as the areas under the curve to displacements defined at set multiples of the first crack displacement, divided by the area to the first crack displacement.

Figure 2 shows an idealized form of a load displacement plot for a ductile material such as these CBWCs. The area labeled A_I in Figure 2 represents the energy required to cause the cement matrix to crack and the material to change from elastic to elasto-plastic. A_{II} is the energy adsorbed between the first crack and a displacement equal to three times that required to cause the matrix to crack. The first index, labeled I_5 is the ratio of the energy to three times the first crack displacement divided by $A_I (A_I + A_{II}/A_I)$. This is called I_5 because the average value for fiber-reinforced cement products is 5. The second index described by ASTM C1018-89 (1) calls for an evaluation at 5.5 times the first crack displacement. Our measurements did not go far enough to include that index in all cases, so we derived a value labeled I_L , which is evaluated at 2.5-mm displacement (areas $A_I + A_{II} + A_{III}/\text{area } A_I$).

RESULTS

Test samples, examined and compared on the basis of physical appearance and density prior to testing, showed some variation between panels but little variation within panels. Physical appearance characteristics noted included dimen-

sions, particle orientation, and particle cement coating. Variation in sample dimensions included width ± 4.5 mm (0.18 in.), length ± 3.0 mm (0.12 in.), and depth ± 2.5 to 3.0 mm (0.1 to 0.12 in.). In general, particles were oriented such that their largest dimension was in the length-width plane of the test sample.

Density ranges within and between panels are given in Table 2. There seemed to be no consistent variation in density by location within the panels;

differences were normally below 0.15 g/cm³. Between-panel densities, however, ranged as high as 0.42 g/cm³. Panel 1, which was given approximately half the fabrication pressure of the other panels, had the lowest values, and Panel 4 had the highest values. Panel 4 had more small fibers and fewer void spaces compared to other panels. Cut surfaces in this panel appeared to be dominated by cement rather than wood particles.

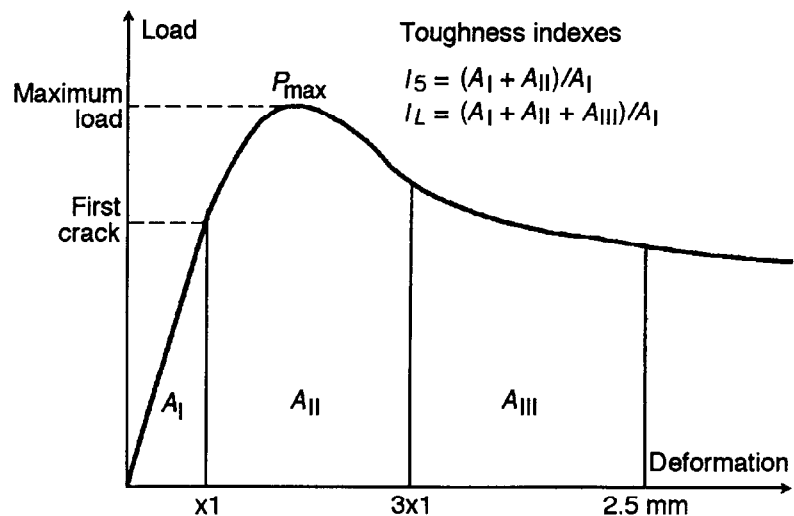


Figure 2. — Characteristic areas under the load displacement curve used to determine the toughness index for bending and compression for cement-bonded wood composite test samples.

TABLE 2. —A summary of density and density distribution parameters of cement-bonded wood composite panels.

Panel	Position within panel ^a	No. of specimens	Zone density mean	Panel density		95% confidence on mean
				Range (min.-max.)	Mean	
----- (g / c m 3) -----						
1	I	8	0.90	0.86 to 0.94	0.89	0.87 to 0.91
	II	7	0.87	0.83 to 0.93		
	III	4	0.88	0.80 to 0.93		
	I & II ^b	10	0.90	0.82 to 0.97		
2	I	10	1.03	0.95 to 1.11	1.02	1.01 to 1.04
	II	10	1.02	0.94 to 1.05		
	III	5	1.02	1.00 to 1.08		
	I & II ^b	10	1.02	0.99 to 1.07		
3	I	10	0.96	0.92 to 0.99	0.97	0.96 to 0.98
	II	10	0.98	0.94 to 1.03		
	III	5	1.00	0.98 to 1.01		
	I & II ^b	10	0.95	0.92 to 0.97		
4	I	11	1.18	1.08 to 1.22	1.18	1.17 to 1.19
	II	9	1.20	1.18 to 1.21		
	III	5	1.19	1.18 to 1.20		
	I & II ^b	10	1.16	1.11 to 1.20		

^a Roman numerals refer to the panel zone from which the sample was taken.

^b These samples are in addition to I and II. They extend across both zones.

FREEZE-THAW TESTS

Samples subjected to accelerated freeze-thaw tests exhibited a range of responses. In all cases, there was a noticeable deterioration of the exposed surfaces as cement particles were washed away. In some cases, this was the extent of the damage. In other cases, cracks developed and samples broke into two or more large chunks with substantial mass loss between the pieces. This was especially noticeable for the first set of tests where stress wave measurements were sus-

pected of initiating cracking. As a result of this possible influence, these samples were not included in any further analysis of freeze-thaw durability.

All samples exhibited some swelling. In general, swelling was symmetrical with some directional bias. The change in the depth dimension appeared to be greater than that in the length or the width. For samples cut from an outside edge, the cement-coated outer surface did not swell as much as the surface exhibiting exposed wood end grain; for

these specimens, the swollen cross section had a slightly warped appearance. Some specimens swelled enough to bind in the weatherometer pans making them difficult to remove until they dried. As with conventional wood-based composites, the samples did not return to their pressed shape upon drying, but retained a slightly swollen volume.

Of the three panels, samples from Panel 1 exhibited the greatest resistance to freeze-thaw deterioration. For the second set of tests, none of the Panel 1 samples broke into pieces and all retained more than 95 percent of their initial mass for the 50 freeze-thaw cycles.

STRENGTH AND MOE

Both compression and bending tests yielded load displacement curves with the basic characteristics shown in **Figure 2**. The compression curves began with a noticeable stiffening, possibly due to a leveling of a rough or uneven surface. For both types of loading, however, the load displacement plots exhibited a linear region that continued to a load of 60 to 75 percent of the maximum load. This is the point where the rigid cement matrix began to crack. As the matrix began to fail, the material exhibited an elasto-plastic transition, climbing to maximum load and then dropping off to a ductile plastic region where load was maintained between 60 and 75 percent of maximum in compression and 18 to 35 percent of maximum in bending. This continued to a displacement that was more than twice that measured at maximum load. Tests were stopped at this point.

Failure modes were varied for the compression tests, but were initiated predominantly in tension for the bending tests. **Figure 3** shows the modes observed for the compression tests. Speci-

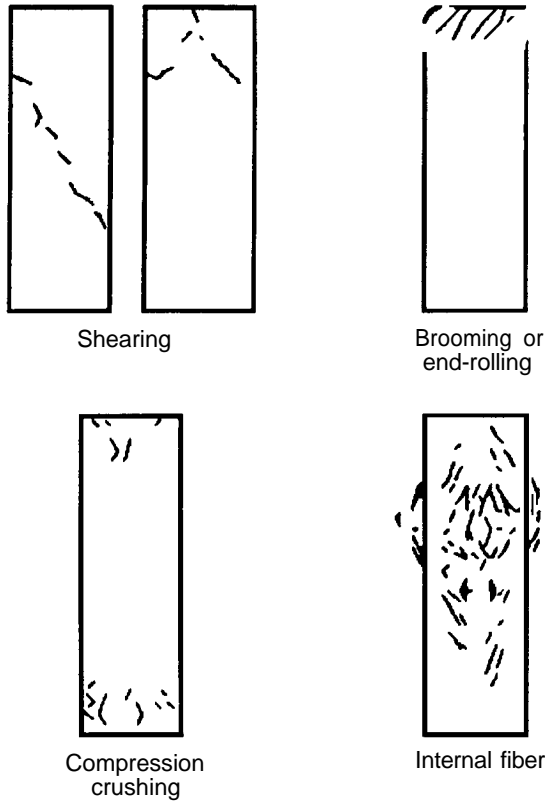


Figure 3. —Four principal modes of failure for compression test of cement-bonded wood composite test samples.

TABLE 3. —Summary of mean strength and MOE values for the four test panels.

Panel	Sample size	Ultimate strength			MOE		
		Average	Low	High	Average	Low	High
		----- (MPa) -----			----- (GPa) -----		
Compression							
1	7	1.80	1.10	2.76	0.59	0.41	0.83
2	6	2.85	2.23	3.36	0.89	0.76	1.18
3	7	2.70	2.45	2.66	0.84	0.76	1.24
4	13	5.50	4.00	6.64	1.69	1.18	2.07
Bending							
1	10	0.87	0.57	1.28	1.14	0.96	1.56
2	10	1.22	0.75	1.65	1.90	1.38	2.48
3	10	1.10	0.71	1.49	1.71	1.31	2.00
4	10	1.31	0.93	1.61	2.60	2.14	3.10

mens with low density exhibited greater crushing, while those with high density showed a combination of shearing and edge splitting-fiber buckling.

Table 3 provides a summary of the strengths and MOE values determined for the various panels. Note the relation between these values and the mean panel densities given in **Table 2**.

ANALYSIS OF RESULTS

The analysis of results indicates that panel strength and freeze-thaw resistance varied with density. Strength and density were positively correlated, but freeze-thaw resistance appeared to be inversely related to density.

DENSITY

The process used to fabricate the test panels gave fairly uniform properties within each panel but significant variation between panels. The total weight of materials going into the panels was estimated to range from 270 kg (600 lb.) for Panel 2 to 295 kg (650 lb.) for Panel 3. Controls on the pressure and vibration time, however, were limited to a visual assessment of the compacting. This resulted in a wide variation in density between panels.

The summary of the density values given in **Table 2** shows little within-panel variation but suggests that these panels represent four distinctly different densities. Confidence intervals for mean density that were calculated assuming a student's *t* distribution show no overlap.

FREEZE-THAW RESISTANCE

Figure 4 provides a comparison of the freeze-thaw performance of the three test panels. Each bar in this chart represents the average performance of six samples. Panel 1 was the only one for which all test samples met the Wisconsin DOT requirements of a mass loss less than 160 g. Panels 2 and 3 exhibited mass losses five to six times that permitted. The most obvious difference between Panels 1, 2, and 3 was density or void volume. The superior freeze-thaw performance of Panel 1 may have been due to a greater void volume, which provided space for freewater to expand on freezing without cracking the cement matrix. While one successful panel test does not justify a Wisconsin DOT certification for sound barrier applications, it certainly suggests that the potential exists. Further research in this area should consider the possibility that greater void volume would improve this potential. CBWCs are cur-

rently being produced commercially using a ribbon-like wood particle called excelsior with densities as low as 0.6 g/cm³. This most likely represents the low end of what can be produced with wastewood particles such as those used in the test panels.

STRENGTH PROPERTIES

Table 3 summarizes the strength and MOE values measured for compression and bending. The strength and MOE of the test samples vary with density. The scatter plots shown in **Figures 5** through **8** suggest that compressive strength and MOE are fairly strongly correlated to specific gravity. Bending strength, however, is much more variable and does not appear to be strongly related to density. This may have been due in part to the test configuration used. The tests were con-

ducted using a shear span to depth ratio of less than 5, meaning that shear stresses were high relative to the bending. It is possible that some shear displacement caused an initial cracking of the cement matrix and a shifting of the neutral axis without being detected. Once this occurs, the simple bending stress equation commonly applied to isotropic uniform materials would be even less appropriate for this application and did not give a good estimate of the actual extreme fiber stress in bending at the point of failure. The strength and MOE properties of this composite material are only on the order of 10 percent of those properties of solid wood.

Toughness may provide a more meaningful measure of the engineering value of this material compared to its strength. Basically, toughness is a measure of the

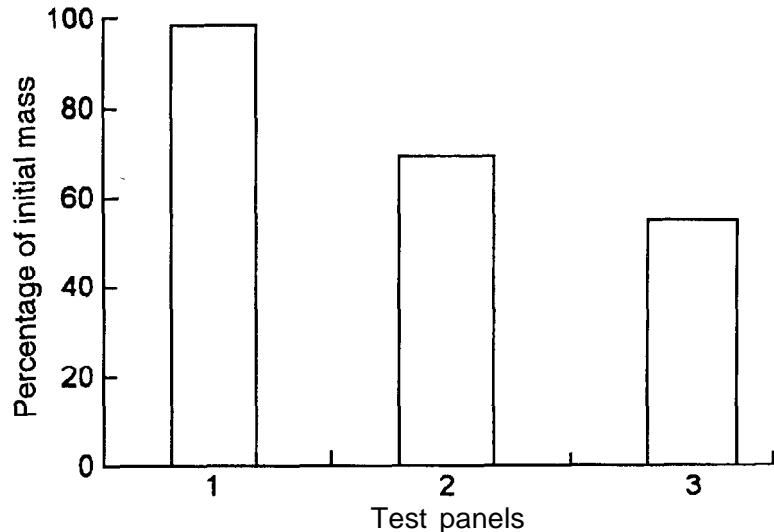


Figure 4. — Percentage of initial mass remaining after 50 freeze-thaw cycles measured in second test set.

TABLE 4. —Summary of toughness values determined for compression and bending.

Panel	No.	I_5^a		I_L^b	
		Mean	COV	Mean	COV
Compression					
1	5	6.0	0.11	9.1	0.38
2	5	6.5	0.03	9.7	0.09
3	5	5.6	0.18	7.5	0.23
4	5	6.2	0.18	8.4	0.32
Bending					
1	10	6.1	0.20	13.9	0.57
2	9	6.8	0.14	15.8	0.41
3	8	5.7	0.18	10.9	0.32
4	10	6.5	0.13	18.2	0.53

^a I_5 = ratio of energy to three times the first crack displacement divided by $A_1(A_{II} + A_{II}/A_1)$.

^b I_L = toughness evaluation at 2.5-mm displacement.

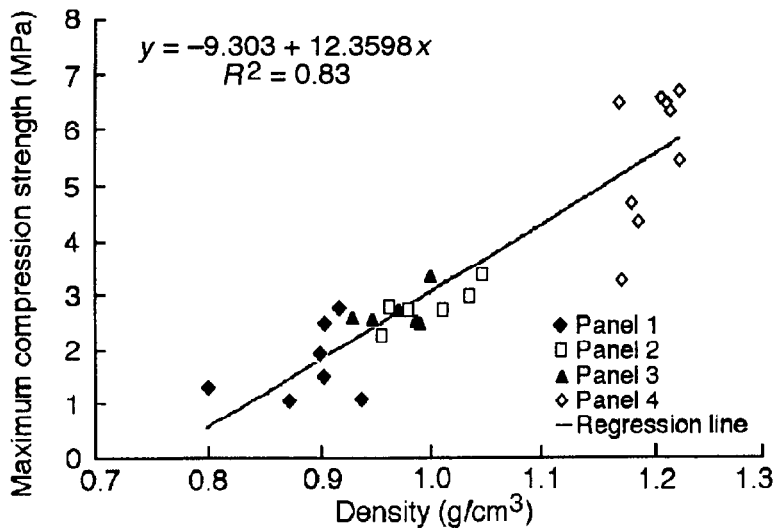


Figure 5. — Relation between maximum compression stress and density of the cement-bonded wood composite test samples.

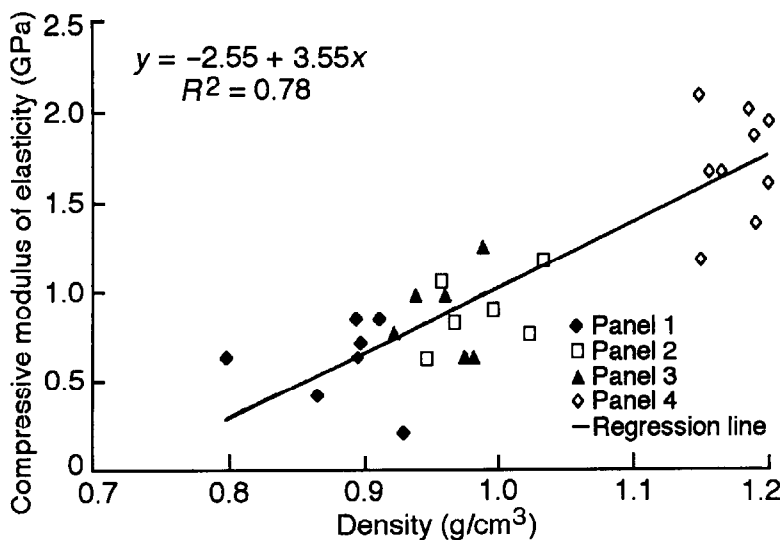


Figure 6. — Relationship between the compressive MOE and density of cement-bonded wood composite test samples.

energy capacity of a material and is represented by the area under the load versus displacement curve. Toughness indices provide a convenient basis for comparing the toughness attributes of these composite materials. For brittle materials, such as unreinforced concrete, where the area beyond maximum load is essentially zero, the toughness index is equal to 1.0. For many fiber-reinforced concrete products, the I_5 index has an average value of 5 (the I_5 index was derived for fiber-reinforced concrete products). Tests of these cement-wood composites yielded values more than 5.5 in all cases (Table 4). For

three of the four panels tested, the average index was at least 6.0 in both compression and bending.

Comparing toughness values for the effects of treatment, we found that the untreated material from Panel 3 had the lowest average indices in both compression and bending. Review of the individual test data shows that in 40 percent of the treated wood sample bending tests, maximum load occurred at a displacement beyond three times the first crack displacement. This suggests that a superior bond between the wood and cement enabled the cement to continue to con-

tribute to strength of the material well beyond the point at which the matrix began to fracture. The higher water content used in the mix for Panel 3 may have contributed to a lower bond strength. We cannot conclude that the superior performance of the treated wood composites is due solely to the CCA treatment.

For structural applications requiring sound absorption and energy dissipation, the low values for strength and MOE are not necessarily limiting. For example, durability results suggest that this material could be refined for use in exterior applications such as highway sound and crash barriers. In these cases, mass is advantageous and larger section properties may offset weaknesses in strength and stiffness. In structural applications where there is a high probability of catastrophic events such as seismic loading, heavy wind, fire, or flooding, this material may serve as a structural fuse to dissipate the energy, thus extending the time available for egress.

CONCLUSIONS

CBWCs fabricated from wood-construction waste particles and portland cement exhibit a potential for engineered use, but not as a direct substitute for conventional structural materials. Their strength as an engineering material appears to lie in their ability to adsorb energy. Materials similar to those tested in this study have been used in applications requiring sound absorption and fire resistance. This study suggests that they also exhibit exceptional behavior in the dissipation of mechanical energy or toughness.

Other characteristics that are important to future efforts in developing this material include vibration as a means of compacting a relatively dry composite mix during fabrication, resistance to freeze-thaw cycles, and the compatibility between cement and CCA-treated wood. Compaction by means of low-frequency vibration served to distribute particles uniformly within the panel giving a fairly uniform density distribution. The resulting dryer mix appeared to facilitate a faster cure to the point that the panels could be moved via conveyor to a hydration kiln for extended curing within 30 minutes of the forming operation. Freeze-thaw resistance of the lower density panel met the requirements of the Wisconsin DOT, which suggests potential for exterior applications. The fact that

CCA-treated wood particles and cement exhibited no incompatibility problems suggests that this may provide a use for recycled CCA-treated wood.

RECOMMENDATIONS

Further study is warranted to reveal the full potential of this material.

1. The effect of fabrication variables must be more fully studied to provide the guidelines necessary to adequately control the fabrication process and give material properties within a tolerable range.

2. Future studies should consider a range of densities from 0.6 g/cm³ to 1.0 g/cm³ and also evaluate effects of load duration and exposure to ultraviolet radiation.

3. In addition to further study of the potential for using this material in sound barrier applications, some effort should be given to its evaluation for applications requiring energy-dissipating materials.

Toughness is an important attribute of CBWCs, and a standard indexing procedure such as that described in ASTM C1018-89 (1) should be adopted by researchers studying these composites.

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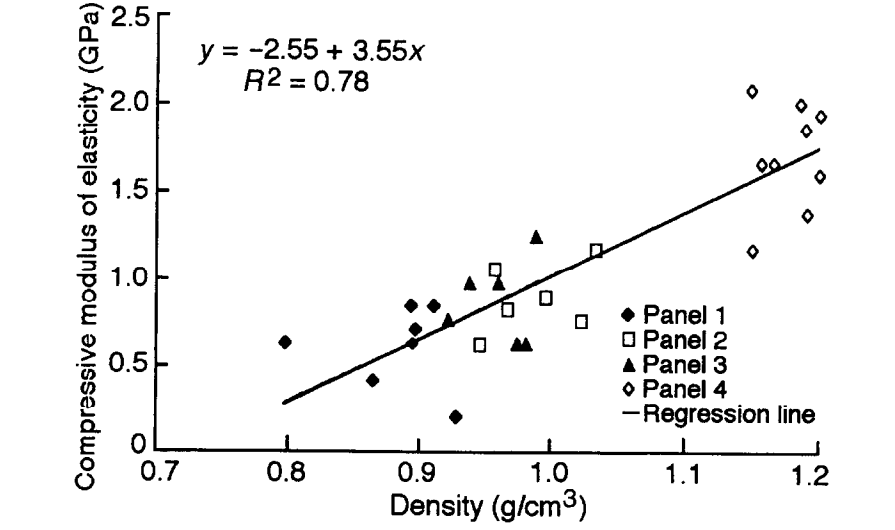


Figure 7. — Effect of panel density on bending strength of cement-bonded wood composite test samples.

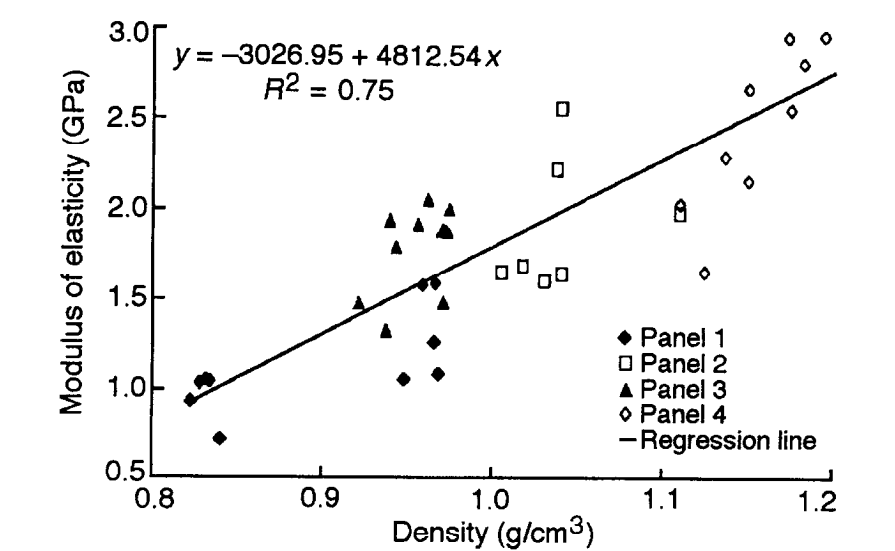


Figure 8. — Effect of panel density on bending MOE measured for cement-bonded wood composite test samples.

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