Compression Tests on Wood-Cement Particle Composites Made of CCA-Treated Wood Removed From Service

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Environmental Impacts of Preservative-Treated Wood Conference to be held in Orlando, Florida, February 8-10, 2004

Background

- Considerable Amount of CCA treated wood available for disposal

- 2.5 billion to 8 billion board feet per year projected for 2020
- What are we going to do with all the CCA treated wood retired from service and other wood from construction-demolition with contaminants??

Our effort at Michigan State

- To reduce the amount of sound wood that may end up in the landfill
- Options for waste management

Waste Management

- Landfill
  - Cost, ground water contamination,…
- Reused and Recycling
  - (end of service life?)
- Extraction
  - Mechanical, Chemical, biological and biochemical
  - Cost (chemicals, energy, yield,…)
- Reconstituted wood products
  - Adhesion and adhesive, at the end of service life?
  - potential contamination ????
- Combustion/Incineration
  - Air quality, disposal of ash

Raw materials for Wood Composites??

- Sorting, Collection and Transportation costs
- Manufacturing
  - Particles/chips/strands
  - Adhesion
  - Tools and equipment ???
  - Air quality
- Applications and Utilization
  - Leaching in service (wet environment)
  - end of the service life?
  - Leaching in the environment
    - Hardboard, Fiberboard, Particleboard, Oriented strand board, …
      - Waste, cut offs, waste water,….
    - Wood plastic composites
      - Contamination and recycling issues
    - Wood cement bonded particleboard

Wood Cement Bonded Particleboard

- Why wood-Cement
  - CCA treatment at Low pH (acidic)
    - Depletion of wood hemicellulose and extractives at low pH
    - Improvement of Wood-cement compatibility and curing
    - No need for sorting (but creosote or oil based)
  - Limited amount of Cu, Cr and As leached from Portland cement bonded board
    - Formation of
      - insoluble and stable CrIII hydroxide
      - insoluble calcium arsenate V
  - Improved Properties
    - Dimensional stability
    - Mechanical and physical properties
      - Low Density, Bending and Internal bond strength
      - Compressive strength

Objective

- Evaluation of the Compressive strength and falling ball impact test of laboratory manufacture cement bonded wood particles composites for crash barrier applications.

Experimental

- 21 year-old CCA treated southern yellow pine decking boards
- CCA retention (oxide): 6 kg/m3
- Wiley milled to Particles size of 2 to 8 mm to 1mm diameter in a restricted environment to monitor air quality for As, Cr and Cu
- Cement to Wood particles ratios: 4, 3, 2, 1.5 and 1 by weight
- Board size: 35 mm by 315 mm by 315 mm board
- 28 days curing in water

- Testing
  - Chemical analysis (AA and ICP)
    - Cu, Cr and As in air and Water used for curing
  - Mechanical Testing
    - Bending strength
    - Short column Compression ASTM D1037-78
    - parallel and perpendicular to the board thickness

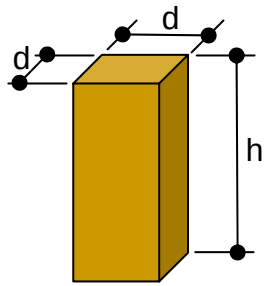
Mechanical properties of CBPB, bending strength flatwise

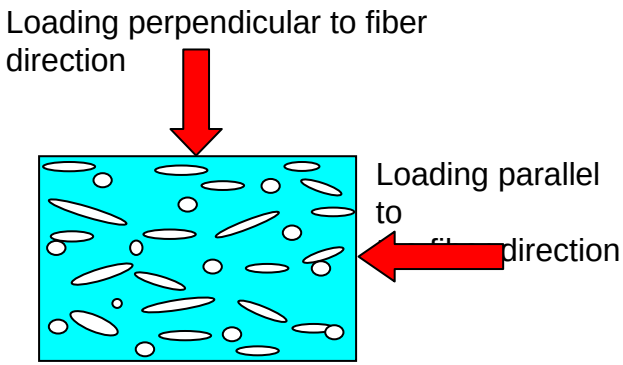
Cement/wood ratio	Density, kg/m3	MOE, GPa	MOR, MPa	IB, MPa
1.0/1	907(52)	1.67(0.18)	5.09(1.08)	0.37(0.10)
1.5/1	935(46)	3.10(0.32)	7.98(0.97)	0.62(0.08
2.0/1	1044(39)	4.50(0.40)	8.45(0.39)	1.13(0.33)
2.5/1	1125(34)	5.44(0.80)	8.44(1.29)	0.95(0.22)
3.0/1	1173(26)	7.95(0.70)	9.52(0.65)	1.10(0.19)
3.5/1	1208(44)	7.28(0.31	9.13(0.29)	1.55(0.24)
4.0/1	1276(31)	7.81(0.84)	8.92(0.71)	1.53(0.37)

Values in parentheses is the standard deviation based on ten samples

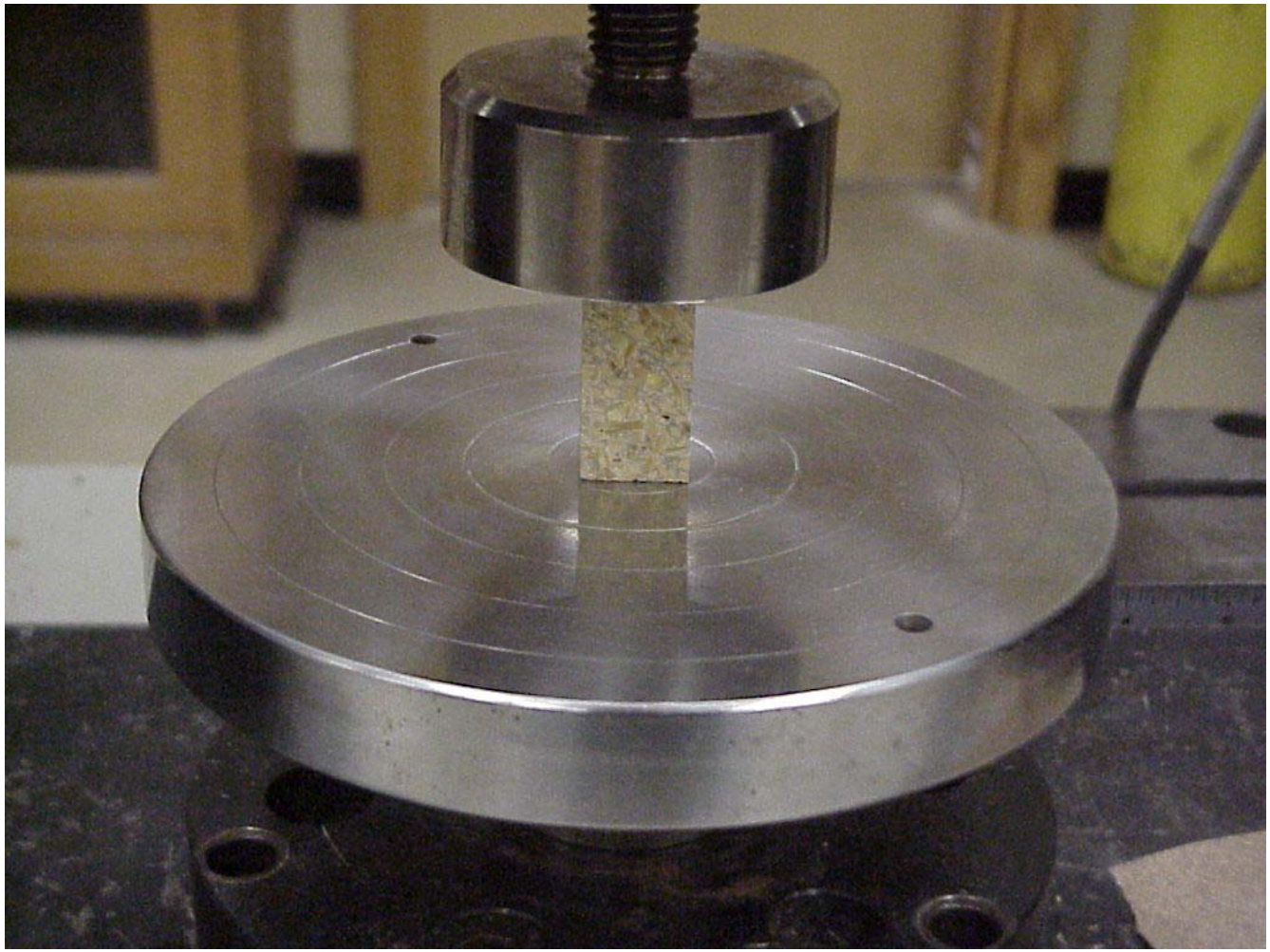
Compression Test

Cement to wood ratio	1.5		1.0
Column aspect ratio (h/d)	2.0	3.0	2.0
Number of specimens	10	10	10
	10	10	10
Dimensions (d x d x h), mm	17 x 17 x 34	17 x 17 x 34	17 x 17 x 34





compression test



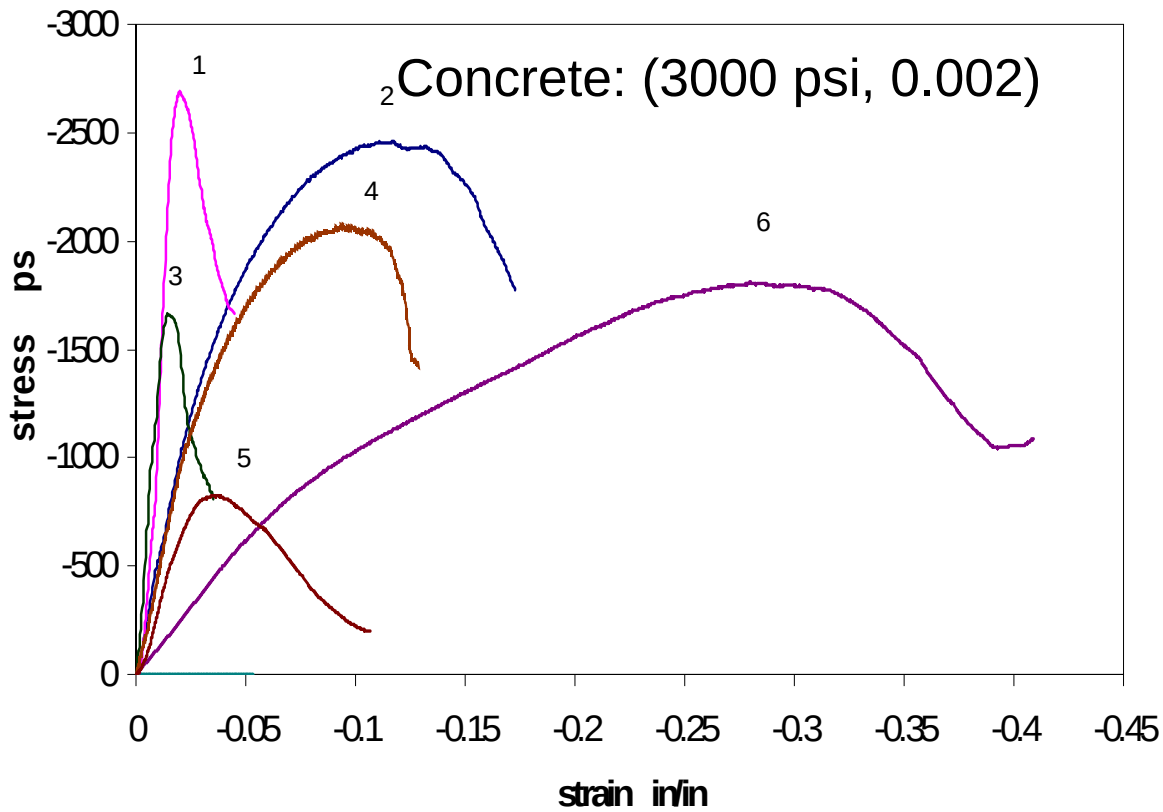
Specimens for Compression Test

After Compression parallel

After compression perpendicular

Stress strain relationship for wood cement bonded composite short column

- 1: **parallel**
  - **C/w: 1.5 and h/d: 2.0**
- **2: perpendicular**
  - **C/w: 1.5 and h/d: 2.0**
- **3: parallel**
  - **C/w: 1.5 and h/d: 3.0**
- **4: perpendicular**
  - **C/w: 1.5 and h/d: 3.0**
- **5: parallel**
  - **C/w: 1.0 and h/d: 2.0**
- **6: perpendicular**
  - **C/w: 1.0 and h/d: 2.0**

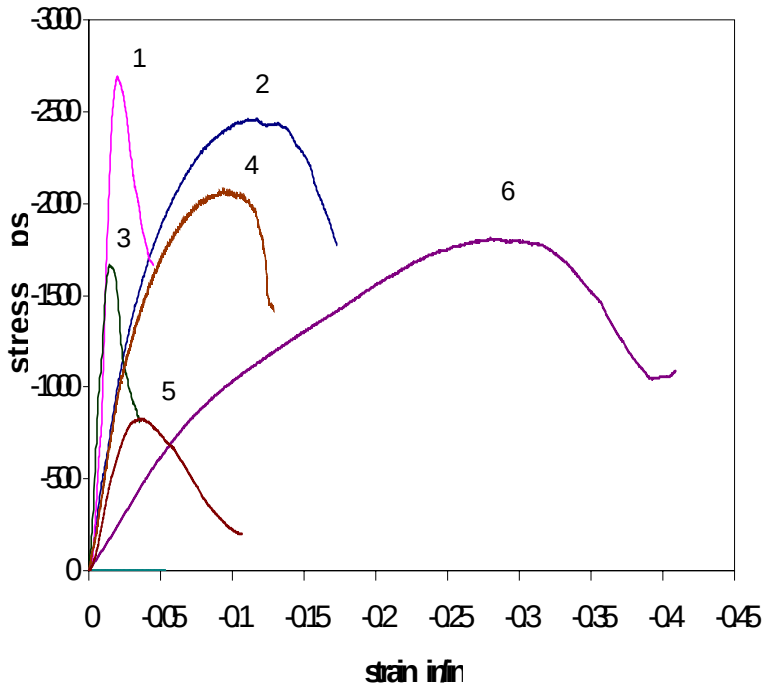


Compressive strength and stiffness of wood cement particle composites

	Compression Strength, psi				Stiffness or MOE compression, 100 psi			
Cement to wood ratio	1.5		1.0		1.5		1.0	
Direction	//	⊥	//	⊥	//	⊥	//	⊥
Average	2600	2511	713	1808	1178	400	402	110
Standard Deviation	243	221	67	192	96	23	34	13

Toughness

- Measure of the energy absorbed per unit area of material
- Area under load deformation curve
- ASTM C1018 used to calculate the toughness indices
- 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.
- Toughness index
  - concrete : 1
  - Steel: 5



Toughness

		Cement/wood ratio		Concrete	Steel
		1.5	1.0		
Toughness I_5	Mean	6.99	7.03	1	5
	SD	0.41	0.37		

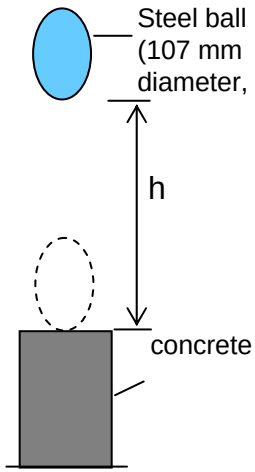
The toughness index (I_5) is defined by the following equation:

$$I_5 = \frac{\text{Area under the load} - \text{deformation curve up to } 3\delta}{\text{Aera under the load} - \text{deformation up to } \delta}$$

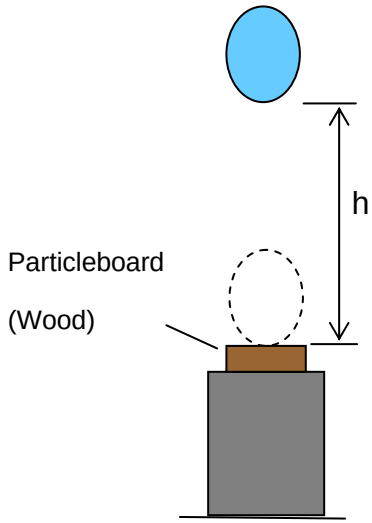
δ is the deformation up to the first crack.

Impact Test

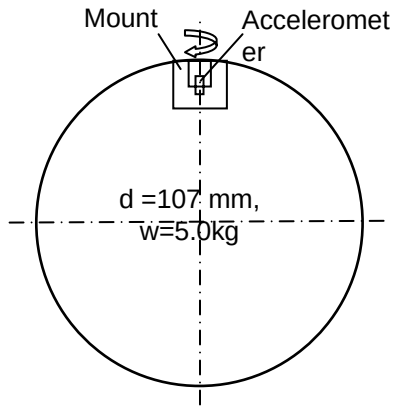
- Impact test to simulate impact on concrete, wood or WCBP



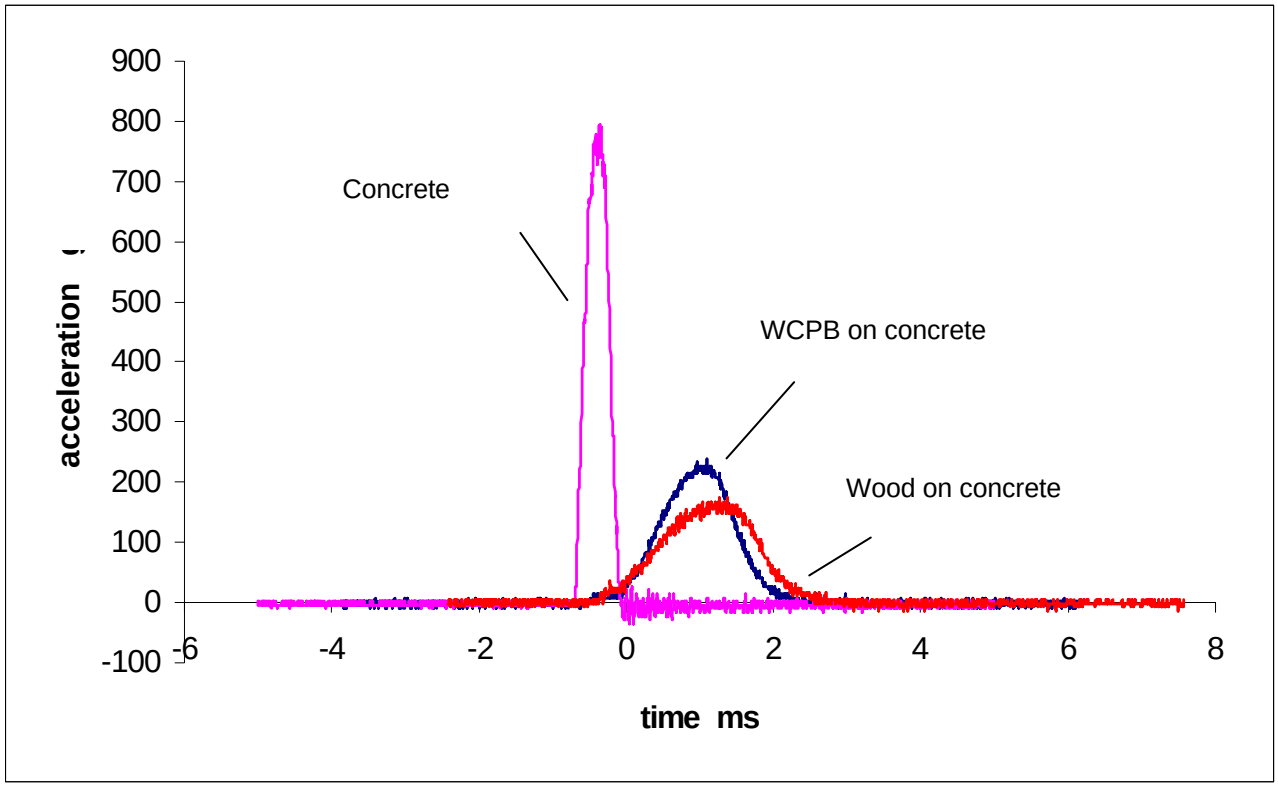
Impact on concrete



Impact on CBP



Ball Acceleration time history



Impact acceleration reduced by 70%

Chemical Analysis

- Used Water generated during the curing of wood cement bonded particleboard
  - Cu: 0.5-2 mg per liter
  - Cr: 0.6 to 3 mg per Liter
  - As: 0.8 to 4 mg per liter
- Static Leaching of ¾ inch blocks for two weeks in DI water
  - cu : 0.7 μg per 100 square cm per day
  - Cr: 1.3 to 2μg per 100 square cm per day
  - As: 1.7 to 3 μg per 100 square cm per day

Speciation of As and Cr from leachate

- Within 10 minutes of the collection of leachate to limit potential arsenic oxidation (time sensitive)
- Cr speciation
- UV-VIS Diphenyl carbazide
  - 95-99% Cr (III)
- Ion exchange (Flores del Pino et al. 2004)
  - Cation exchange pre-column to remove free copper
  - pH adjusted at 2.5-3.5 (HCL or NH4OH)
  - Chromosorb cartridge (silanized diatomaceous dioctyltin dichloride) for As (V)
  - As(III) in the neutral form in the effluent
  - Elution of As(V) with acid.
  - ICP
  - 80-70% As (v) and 20-30% As (III)

Conclusions

- Composites with a cement/wood ratio of 1.5 exhibit a compressive strength comparable to that of normal concrete
- Strain at peak load
  - 10 to 50 fold larger than the strain at peak load of normal concrete

- Impact test
  - Impact acceleration reduces by 70%
- The toughness index
  - 7 fold larger than that of normal concrete.

- Leaching of Cu, Cr and As to be monitored in the waste water generated during the WCBP manufacturing
- Leaching of Cu, Cr and As from WCBP
- Treatment needed to reduce the leaching in the environment
- Uses in applications where compressive strength, energy dissipation and impact are desirable.
- Applications: Highway crash barriers/dividers