CONSTRUCTION AND DEMOLITION WOOD WASTE USED IN WOOD CEMENT COMPOSITES

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Introduction:

Wood cement composites (WCC) are a new opportunity for recycling post consumer wood and chemically treated wood fiber in the manufacture of building and sound absorbing products. The technology is employed throughout the world to produce stay-in-place insulated wall forms, structural panels, acoustical treatments, and highway sound barriers. However there is no evidence that WCC technology has been applied to C&D wood waste. Our study examines the use of "mulched" wood fiber prepared by hammermills typically found in C&D recycling systems. We are demonstrating that sufficient strength and durability can be achieved to satisfy established building codes and standards.

Specifying a building material in the 90's requires meeting a number of critical concerns: cost, aesthetics, physical properties, labor, availability, and environmental responsibility. There are many benefits to the use of wood-cement composites. The material is naturally fire and decay resistant, acoustically absorbent, and has fair thermal insulating value (R1.75 per inch thickness). Manufacturing and jobsite wastes are easily recycled into new product and a simple manufacturing process makes possible regional manufacturing close to raw materials and markets. These are the qualities of an environmentally sustainable building material that responds to the challenges of today's market.

The Forest Products Market Place - Opportunities for Recycled Content:

This is an era of significant change for the forest products industry. Recent federal logging restrictions in the Pacific Northwest are triggering changes not only in lumber prices but in how we build. This is best evidenced by the remarkable growth in steel framing and the wide spread use of engineered wood products - oriented strand boards and laminated joist. A.D. "Pete" Correll, CEO of Georgia Pacific Corporation, believes that future growth in the industry will be served by recycled fiber. Willamette Industries now uses 15% recycled urban wood waste at two of its three Oregon particleboard plants. Efforts to add recycled content to current products is always a worthy goal, however it might not be sufficient to satisfy the demands of a changing market place.

Norman Johnson, Vice President at Weyerhauser Company, sees wood composites - wood fibers used in combination with cement, plastics, fiberglass, and metals - as the tool for growth at his company, creating new materials and products that are better and more affordable. Mr. Johnson cautions that new products must respond to the market to succeed. What approaches to developing a new recycled wood product have the best chance of success? This is a question that researchers at the U. S. Forest Products Laboratory have focused on for several years (Rowell, R.M. 1993). Their formula for success can be condensed to three simple points.

1. Avoid the structural panel market place. This is a mature industry which offers quality products at very competitive pricing. It will be difficult to introduce new products that can meet the test of lower initial cost. The road is already littered with many who have tried.
2. Focus on a small scale versatile plant that is labor intensive with its lower capital cost. Design for off-the-shelf manufacturing components and locate near your raw materials and markets.
3. Use inorganic binders since they are readily available and lend themselves to low capital installations. They avoid off-gassing problems of VOC binders and they are compatible with other waste derived binders.

Considerations for Environmentally Sustainable Design and Construction:

The *Environmental Building News'* (EBN) checklist for sustainable design and construction lists 33 principles for design, siting, materials, equipment and jobsites. The materials section makes up one third of the list, clearly the most significant component of a sustainable project. While no one material or building system addresses every principle, some come closer than others. This paper discusses stay-in-place insulated wall forms manufactured from post consumer wood waste, cement and other waste derived binders. Using EBN's checklist, the system -

- is a durable material,
- has a reasonably low embodied energy,
- is locally produced,
- is made from recycled materials and is itself recyclable,
- is formaldehyde and VOC free,
- has minimal packaging, and
- can potentially replace the need for pressure treated lumber.

The Wood-Cement Composite:

Wood-cement technology goes back to magnesite bonded boards developed in 1900 (Moslemi, 1989). However much of the research and development since then has focused on the manufacture of structural panels, which is a competitive commodity market. There is a small segment using WCC for the manufacture of stay-in-place insulated wall forms. This application has been used in Europe since the early 70's and enjoys a growing market share of residential and light commercial construction. It is an application well suited for the recycling of meaningful quantities of secondary wood fiber from C&D wastes.

Recycled wood fiber is bound in a hydraulic cement matrix using conventional concrete batching equipment. The wood fiber is obtained from source separated C&D debris that has been cleaned of deleterious material, shredded, and screened to a sized of 3 mm by 10 to 25 mm long. The wood is batched volumetrically and mixed with portland cement in a high sheer pan mixer. Typical wood cement ratios by weight range from 1:1 to 1:0.8 for this gradation. Water is added to obtain water cement ratios in the range of 0.4 by weight. Sufficient additional water is required to bring the wood to a saturated surface dry condition. Other waste derived binders can be used with cement, lowering cost and embodied energy. Research indicates that fly ash and flue gas gypsum have been used successfully with appropriate attention given to the mix design (Miller, 1989).

Chemicals present in green lumber are known to interfere with cement hydration. Water soluble sugars, tannins and resins retard development of an adequate cement bond to the wood fibers resulting in low strength and durability. Research on wood's inhibitory affect on cement hydration has been extensive and represents the majority of literary references on wood-cement composites. Conventional concrete accelerators are the traditional solution to counteract the wood's inhibitory affect. Their use results in quality products with consistent strength development (Rahim, 1983). Aluminum sulfate and calcium chloride are two accelerators most frequently mentioned as yielding greatest strength increase for both soft and hardwood species. A water solution of the accelerator is used to saturate the wood prior to mixing with cement. The literature suggests that seasoned woods may not require the use of accelerators, however this manufacturing process benefits from them and their use will most likely continue with C&D fiber (Moslemi, 1987).

Table 1. Properties of cement bonded wood products with 1:1 wood cement ratios

PROPERTY	CHARACTERISTICS
Fire Rating	4hrs (Wall form block elements)
Smoke Development	0
Flame Spread	0
R value	1.3 -1.75/inch thickness
NRC	0.85 @ 2" thickness
STC	47 @ 4" thickness
Weight	36 lbs/cf
Water resistance - below ground 30 years	no deterioration
	Fungi Resistant
	Termite Proof
Tensile Strength	120 psi
Compressive Strength	400 psi
Freeze-thaw	ASTM C666 Methods A & B 300 cycles
Accelerated Weathering	ASTM G23-81 2,500 hours

Manufacturing and jobsite wastes are recycled back into new product after reduction to the original wood fiber size. Construction waste collection is done efficiently since distribution is usually directly from the manufacturer's yard. Pallet crates are used on the job to collect cut-offs and then returned to the plant on a back haul.

Figure 1. **Pallet of job cut-offs ready for recycling into new product.**

Stay-in-Place Insulated Wall Forms:

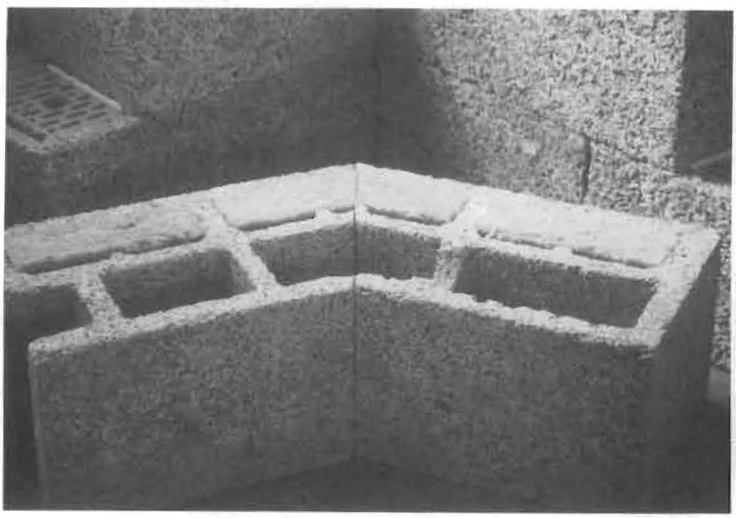

Figure 2. **Plan view of stay-in-place insulated wall form with dry stack wall in background.**

Stay-in-place insulated wall forms (SIP) are a forming system used to form, fur and insulate a reinforced concrete wall. SIP are shaped like large concrete masonry units but they are dry stacked without mortar joints. The forms are filled with a concrete grout and steel reinforcing which provides the bearing capacity of the system. As the name implies, the forms are left in place to provide thermal insulation and/or furring for finishes. There are many SIP systems available. They can be manufactured from wood-cement, concrete masonry, polystyrene, or autoclave cellular concrete.

Manufacture of wood-cement forms starts with batch mixing of composite as already described. The mix is then transported by forklift to a block production machine known as an "egglayer". Egglayers mold block products and deposit them directly onto the plant floor. This method is required because the wood-cement mix is not cohesive and tends to slump with stationary block machines. The blocks are left to air cure on the plant floor for 48 hours before cubing. They are then cured indoors for an additional four days before machining. After the initial seven days of curing, blocks have developed sufficient strength to be machined to the close tolerances necessary for dry stacking. A custom implementation of resaws used by the wood pallet industry does the machining with economical carbide cutters. The absence of hard aggregates makes this possible.

On the jobsite production is efficient with 0.3 m^2 blocks. Because of wood-cement's low unit weight, large blocks can be produced that weigh only 20 kg, light enough for one worker to handle but heavy enough to stay where placed. Typical dimensions are 1,150 mm long by 250 mm high. Forms come in at least two configurations - corners and stretchers. Corners have one closed end and are used at square corners and openings. Stretchers abut the corners and are used to fill in the wall. The forms are cut, nailed, screwed and shaped with ordinary carpentry tools.

Figure 3. Condominium project built with wood-cement stay-in-place insulated forms

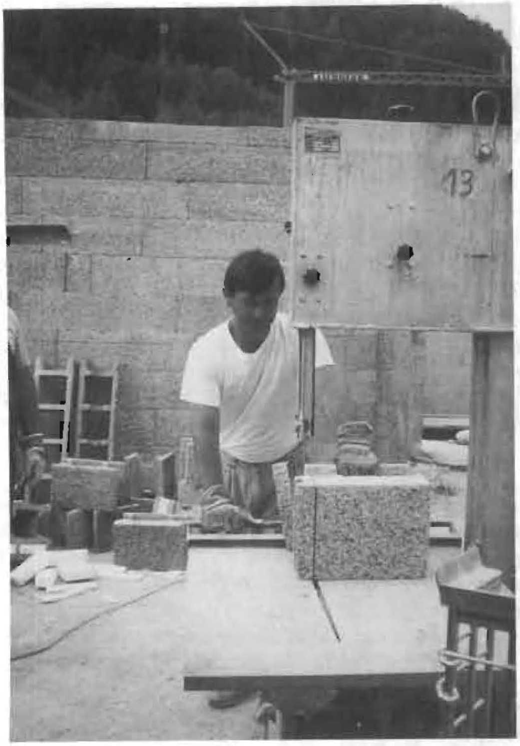

Figure 4. Cutting wood-cement with regular band-saw.

Forms are dry stacked in a running bond pattern, the cores lined up vertically and then toe-nailed to keep them in place. Openings are framed as the courses are stacked. Odd length pieces are easily cut to size with a carpenter's saw. Temporary shoring and bracing are required at lintels, cantilevers and wall sections weakened because of cutouts. Once the walls are erected, the cores are filled with concrete. Utilities can be installed directly into the cores or in groves cut into the forms after grouting. Horizontal reinforcing is place while stacking the forms. Vertical steel is added during grouting. Reinforcing requirements are determined by standard ACI concrete design procedures for thin section reinforced walls. Many manufacturers develop pre-engineered design charts for load and non-load bearing walls. The charts include selected construction details and configurations that are characteristic of typical residential and light commercial construction.

Wood-cement composite SIP lend themselves to any type of exterior or interior finishes. Stucco, plaster and acrylic cements make best advantage of the form's properties while minimizing waste and transportation costs. The results are durable walls of lasting quality.

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