Evaluation of Cement-Excelsior Boards made from Yellow-Poplar and Sweetgum

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ABSTRACT

Previous research conducted in the laboratory pointed out several hardwood species which were either superior, comparable, marginal, or unsuitable for manufacturing cement-excelsior board (CEB). In this study, forty full-sized boards were manufactured in a commercial production facility with the following species: yellow-poplar, sweetgum, southern pine, and sweetgum/southern pine mixture. The properties of hardwood CEB were evaluated and compared with those of standard southern pine CEB. Results indicate that CEB made with yellow-poplar has equal or better properties than southern pine CEB. However, CEB made with all sweetgum or 50 percent sweetgum/50 percent southern pine does not meet the requirement of bending strength.

INTRODUCTION

Cement-excelsior board (CEB) is a wood-based composite made from wood excelsior and portland cement. The boards are usually made with the densities of 30 to 36 pounds per cubic foot (0.48 to 0.58 grams per cubic centimeter). With the porous nature of the surface, this product provides exceptional acoustical and decorative effects making it a suitable material for roof deck, ceiling, and interior wall constructions. In addition, CEB also provides moderate structural strength and thermal insulation (3,4,7). As is the nature of cement-bonded product, CEB possesses greater resistance to fire, moisture, fungi, and insects compared to traditional wood products.

Currently, CEB products are commercially produced in the United States mainly using southern pine and Portland cement. Experiments on using various hardwoods indicated that the properties of cement-bonded wood products are very dependant on wood species (2,5,9). Furthermore, study with various chemical treatments for making the hardwood CEB has shown that cottonwood was an excellent species for CEB production, while yellow-poplar and sweetgum were comparable or marginal, and red oak and white oak unsuitable under laboratory conditions (6). It was also proved that calcium chloride solution was very effective and economical in improving wood-cement bonding.

These studies on use of hardwoods, however, were conducted in the laboratory using a small concrete blender, hand-formed mats, and small test samples. The purpose of this study was, therefore, to evaluate the commercially-produced and full-sized CEB made from two widely available hardwood species of yellow- poplar and sweetgum.

MATERIALS AND PROCEDURES

Approximately three cords of wood for each of yellow-poplar (Liriodendron tulipifera L.), sweetgum (Liquidambar styraciflua L.), and southern pine (Pinus sp.) were cut from the Clemson University Forest, located at Six Mile, S.C. Southern pine, the current wood species used by the CEB industry, was included for comparison. The logs, ranging from 8 to 12 inches in diameter and 63 inches long, were debarked and cut into 20-inch bolts. After dipping in a 5 percent sodium pentachlorophenate preservative solution, the bolts were stacked on pallets for air-drying outdoors for 8 weeks prior to shredding into excelsior. The excelsior was about 0.02-inch thick by 0.08-inch wide and 6- to 20-inches long. Wood excelsior was soaked in a 3 percent calcium chloride solution for about 30 seconds prior to mixing with cement. Type III portland cement (high-early-strength cement) was used for all species and species combination. Altbough Type III cement costs slightly more than Type I, its early strength provides better handling when boards are removed from the molds. Type III cement has been regularly used by the CEB industry. The cement/wood ratio was 2, based on ovendry weight of wood. A commercial manufacturing process for CEB as described in a previous study (3) was followed for making all experimental boards.

Forty full-sized boards (2 inches thick, 32 inches wide, and 96 inches long) were made in the plant with 10 boards for each of the following species: (a) all southern pine, (b) all yellow- poplar, (c) all sweetgum, and (d) 50 percent southern pine/50 percent sweetgum. A temperature recorder was connected to each stack of 10 boards. Boards were cold-pressed and cured under pressure of 20 psi (138 kPa) for 24 hours before removal from molds for post-curing. Three weeks after manufacturing, boards were cut into nine 10- by 32-inch test specimens with the length parallel to the longitudinal direction of the board. For each species, forty-two specimens were selected at random and divided into two groups for conditioning at dry and soak-dry conditions respectively. Dry condition was obtained by placing specimens at 50 percent relative humidly (RH) and 72°F until specimens reached constant weights. Soak-dry condition was obtained by soaking specimens in water for 48 hours and reconditioning them at 50 percent RH and 72°F until reaching constant weights.

After conditioning, the specimens were separated into three groups (7 specimens each group) for the three types of load tests: equivalent uniform load, concentrated load, and sustained load, in accordance with ASTM-D2164(1). Equivalent uniform load test, with the samples supported at 2 ends and the load applied at the quarter-points of the span, was used to determine the modulus of elasticity (MOE), fiber stress at the proportional limit (FSPL), modulus of rupture (MOR), and equivalent uniform load (W). Deflection/span ratio at design load was calculated from the load test curve. Concentrated load test was conducted by loading the samples through a 4- by 4-inch square metal plate which was placed on the sample edge at the mid-span. Sustained uniform load (sag) was performed by loading the samples with concrete blocks equal to 120 pounds per square foot (psf) uniform load for 48 hours. Deflections at mid-span were recorded during the tests.

RESULTS AND DISCUSSION

The changes of temperature for 4 groups of CEB during the first 24 hours are shown in Figure 1. Temperature changes are a good indicator for cement hydration and for wood-cement compatibility. It can be seen that southern pine CEB reached

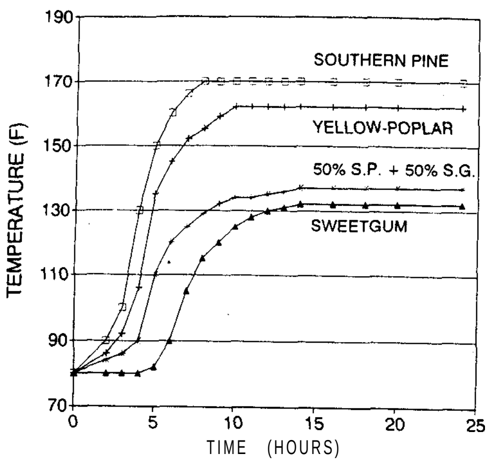

Figure 1. Hydration temperature of cement-bonded excelsior boards made from southern pine, yellow poplar, and sweetgum

the highest temperature of 170°F (77°C) in 8 hours and yellow-poplar CEB reached its maximum temperature of 162°F (72°C) at 10 hours. The CEB containing 50% sweetgum and all sweetgum reached their maximum temperatures of 137°F and 132°F, respectively, at 14 hours mark. Apparently, sweetgum generated a stronger inhibitory reaction with the cement curing.

The average moisture contents (ovendry weight base) of CEB were 9.5 and 10.8 percent, respectively, for dry and soak-dry conditions. The results of equivalent uniform load and concentrated load tests are presented in Table 1. Actual densities of CEB ranged from 30 to 33 pounds per cubic foot (pcf). However, the strength values were adjusted by linear regressions to a common density of 32 pcf, which was the target density for this study and for the previous study (6).

Table 1. Bending properties of cement-bonded excelsior boards made from southern pine, yellow-poplar, and sweetgum.[a]

Property	Wood Species			
	Southern Pine	Yellow-poplar	Sweetgum	50% Southern pine and 50% Sweetgum
	Eauivalent Uniform Load Test			
MOE (1000 psi)	140(22.5)[b] 143(20.0)	130(23.1) 151(26.4)	87(19.0) 107(15.9)	114(22.1) 135(17.4)
FSPL (psi)	163(29.7) 164(24.0)	166(34.2) 220(44.3)	100(14.2) 171(67.4)	125(29.7) 197(31.3)
MOR (psi)	326(59.0) 347(62.2)	347(79.0) 452(61.0)	242(35.9) 296(83.0)	257(30.0) 331(41.1)
Defl./Span at 50 psf	1/737 1/782	1/791 1/929	1/510 1/643	1/623 1/774
Uniform load (psf)	288(57.0) 318(73.5)	328(80.9) 423(49.5)	233(40.3) 286(90.2)	226(29.8) 295(41.8)
	Concentrated Load Test			
Concen. load (lb)	414(81.0) 452(41.5)	485(54.3) 531(68.3)	272(39.8) 345(65.2)	293(76.1) 343(52.3)

a Each value is the average of 7 samples. Values have been adjusted by linear regressions to a common density' of 32 pounds per cubic foot.

b Values in the first line represent the samples conditioned at 72°F and 50% relative humidity. Values in the parentheses indicate the standard deviation.

c Values in the second line represent the samples soaked in the water for 48 hours and then reconditioned at 72°F and 50% relative humidity.

Current industrial standards (8) specify that CEB must support a maximum uniform load of 200 psf and deflection must not exceed 1/240 of the center-to-center span at the allowable design load of 50 psf. According to these requirements, all experi- mental boards met these standards. However, it was observed that some of the boards were up to 10 percent thicker than the target thickness of 2 inches. A more accurate comparison should be based on an MOE value of 53,400 psi and an MOR value of 268 psi as reported in a previous study (6). Comparison of these values with, values in Table 1, one would find that there were two MOR values which did not meet the requirement, (i.e. one with sweetgum and the other with 50/50 mix of southern pine and sweetgum under dry condition). Nevertheless, if these boards were soaked for 48 hours and then redried at 50% relative humidity, they could meet this standard (Table 1). A t-test comparison revealed that soaking and redrying significantly improved the bending strength (MOR) of the hardwood CEB. It is believed that water soaking may have helped the completion of cement hydration in hardwood CEB.

Currently, there is no industrial requirements for the concentrated load carrying capacity. However, from the viewpoint of construction safety, a minimum concentrated load should be specified. In the authors' opinion, a concentrated load of at least 350 pounds is required. This provides at least a safety factor of 2 for an average person weighing 175 pounds.

Deflections of CEB subjected to sustained uniform load (sag) are shown in Table 2. It was noticed that the initial deflections for CEB containing sweetgum were 20 to 50 percent higher than those of southern pine and yellow-poplar CEB. This indicates that under heavy load (120 psf) these 2 types CEB will have excessive sagging.

Table 2. Deflection of cement-bonded excelsior board subjected to sustained uniform load of 120 pounds per square foot.

	Wood Species			
Property	Southern pine	Yellow-poplar	Sweetgum	50 % Southern pine and 50% Sweetgum
Initial defl. (inch)	0.098[b] 0.087'	0.102 0.076	0.130 0.104	0.149 0.109
Additional defl. after 48-hour loading (inch)	0.063 0.028	0.055 0.017	0.090 0.064	0.041 0.036
Residual defl. l-hour after load removal (inch)	0.087 0.037	0.071 0.023	0.095 0.069	0.058 0.045

[a] Each value is the average of 7 samples. Values have been adjusted by linear regressions to a common density of 32 pound per cubic foot.

[b] Values in the first line represent the samples conditioned at, 72°F and 50% relative humidity.

[c] Values in the second line represent the samples soaked in the water for 48 hours and then reconditioned at 72°F and 50% relative humidity.

A statistical comparison using Duncan's multiple range test is listed in Table 3. Comparison among 4 types of boards reveals that yellow-poplar CEB is as good as,

Table 3. Duncan's multiple-range comparisons of properties of cement-bonded excelsior boards made from various wood species.

Property	Wood Species			
	Southern pine	Yellow-pine	Sweetgum	50% Southern pine and 50% Sweetgum
MOE	A[a] A	A A	B B	A A
MOR	AB B	A A	C B	BC B
Uniform load	AB B	A A	B B	B B
Concentrated load	B B	A A	C C	C C
Initial defl. due to 120 psf load	A B	A A	B C	C C
Additional defl. due to 48-hour sustained load	AB AB	AB A	B C	A B

[a] Letter "A" indicates the best property among four types of boards. Same letter in the row indicates no significant difference at the 5% level. The first line represents the tests of samples at 72°F and 50% relative humidity. The second line represents the tests of samples with 48-hour water soak and reconditioned at 72°F and 50 % relative humidity.

or better than southern pine CEB. Boards containing all sweetgum or 50% sweetgum have significantly lower values of MOE, MOR, concentrated load, and higher sagging deflection when compared to southern pine CEB. Therefore, it is concluded that yellow-poplar can be used as a raw material for CEB production. Addition of 50 percent sweetgum to southern pine or use of all sweetgum significantly reduced strength properties and increased sagging deflection of CEB. If it is necessary to use sweetgum for production, further experiments must be conducted to determine the acceptable level of sweetgum in replacement of southern pine.

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