EFFECT OF CEMENT/WOOD RATIO ON BENDING PROPERTIES OF CEMENT-BONDED SOUTHERN PINE EXCELSIOR BOARD[1]

Andy W. C. Lee

Assistant Professor
Department of Forestry, Clemson University
Clemson, SC 29631

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ABSTRACT

The price of southern pine excelsior is much higher than that of Portland cement on the weight basis. This study was undertaken to investigate the possibility of using more cement and less excelsior in order to reduce the manufacturing cost of cement excelsior board (CEB). The experimental boards were made at three cement/wood (oven-dry weight basis) ratios: 2.0/1, 2.3/1, and 2.6/1. The results indicated that the bending properties of CEB made at these cement/wood ratios met the requirements of commercial standards. However, the increase of cement/wood ratio above 2.0/1 had an adverse effect on bending properties of CEB.

Keywords: Cement excelsior board, southern pine, Portland cement, cement/wood ratio, bending properties.

INTRODUCTION

Information concerning the properties of wood-cement composite board is very limited. Early research on wood-cement mixtures has revealed that decayed wood, heartwood, and bark could contribute to the longer setting time or complete setting failure of cement (Weatherwax and Tarkow 1964, 1967). Various treatments and additives, especially hot-water extraction of the wood and calcium chloride additive to the cement, have been reported to shorten the setting time of wood-cement mixtures (Biblis and Lo 1968; Moslemi et al. 1983). A preliminary study (Prestemon 1976) indicated that wood-cement composite board made from wood slivers, sawdust, and cement had a higher mechanical strength when the cement/wood ratio was increased from 3/4 to 3/2.

In the South, cement-bonded excelsior board (CEB) is manufactured exclusively from southern pine. Cement and wood are usually mixed by weight at the ratio of 2 parts cement to 1 part wood (oven-dry weight base). Although there is no published literature, it is believed that CEB can achieve the optimum structural properties at this cement/wood ratio. If a lower cement/wood ratio is used, wood excelsior will not receive adequate cement coating, which results in poor bonding. If a higher cement/wood ratio is used, the compaction ratio (mat-to-board thickness ratio) will be reduced, resulting in lower bending strength.

The price of southern pine excelsior has steadily gone up in recent years. A ton of southern pine excelsior (adjusted to 30% moisture content) currently costs $135, while a ton of Portland cement (type I) costs only $53 in southern Georgia (Con-

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crete Products 1984). Obviously, the use of more cement and less wood can reduce the manufacturing cost. This study was undertaken to investigate the effect of cement/wood ratio on bending properties of CEB. The results were compared with the industrial standards and specifications (SCFPA 1970).

MATERIALS AND METHODS

The excelsior was made from southern pine logs that had been debarked, cut to 18 inches in length, dipped in preservative (5% sodium pentachlorophenol), and stored in racks for at least 8 weeks. The excelsior was approximately 0.02-in. thick, 0.08-in. wide, and from 6 to 18 in. long. The cement used in this study was type I Portland cement. Sodium silicate (2% solution) was used to soak the excelsior prior to mixing with cement. Calcium chloride (3% by cement weight) was added to the mixture of excelsior and cement to accelerate the cement hydration. The manufacturing process was described in a previous paper (Lee 1984).

Five boards, 2 in. thick by 32 in. wide by 96 in. long, were made in the mill at each of the following cement/wood (oven-dry weight base) ratios: 2.0/1, 2.3/1, and 2.6/1. The first ratio is normally used in the production. The second and third ratios represent the additions of 15 and 30% more cement. The manufacturing parameters were as follows:

1. Excelsior moisture content (MC): 34 to 38% (green weight basis).
2. Excelsior MC after soaking: 58 to 62% (green weight basis).
3. Mixture MC: 32 to 35% (green weight basis).
4. Target density: 32 pounds per cubic foot (PCF) at 75 F and 50% relative humidity (RH).

After manufacture and cure, each board was cut into nine specimens, 2 in. thick by 10 in. wide by 32 in. long. Five specimens were randomly assigned for equivalent uniform loading, and the remaining four specimens for concentrated loading. All specimens were conditioned to reach equilibrium weights at 75 F, 50% RH and then tested according to ASTM D 2164 (1978). From equivalent uniform load test, the modulus of elasticity (MOE), modulus of rupture (MOR), equivalent uniform load (W), and deflection-span ratio at W = 50 pounds per square foot (PSF) were determined. From concentrated load test, the minimum resistance to a concentrated force was measured. All the spans were 32 in. center-to-center (30 in. clear span). The density was measured based on the weight and volume at 75 F and 50% RH.

RESULTS AND DISCUSSION

Bending properties measured from equivalent uniform load test are listed in Table 1. According to the current industrial standards (SCFPA 1970), the CEB shall meet the two following requirements: W equals 200 PSF or more, deflection-span ratio at 50 PSF equals 1/240 or less. All experimental panels made at the three cement/wood ratios exceeded these requirements.

It was difficult to compare the MOE and MOR of boards made at three cement/wood ratios, because the density varied from board to board. Therefore, linear regression equations were fitted between MOE and density as well as between MOR and density (Table 2). The exponential, logarithmic, and power regressions were also calculated but did not improve the fit. The MOE values, when adjusted

TABLE 1. *Bending properties of southern pine excelsior cement board made at 3 cement/wood ratios.*[1]

Board no.	Density (PCF)	MOE (1,000 psi)	MOR (psi)	W (PSF)	Deflection-span ratio at W = 50 PSF
		Cement/wood ratio = 2.0/1			
1	30.27	112	321	243	1/465
2	31.23	130	342	263	1/562
3	29.15	111	312	268	1/529
4	29.66	103	299	224	1/400
5	30.90	124	371	291	1/571
		Cement/wood ratio = 2.3/1			
6	31.79	122	349	289	1/585
7	32.36	127	356	302	1/575
8	30.84	109	319	240	1/478
9	31.21	110	325	252	1/535
10	31.28	118	328	285	1/532
		Cement/wood ratio = 2.6/1			
11	31.62	102	361	325	1/515
12	32.77	117	350	292	1/629
13	32.14	118	325	245	1/426
14	32.69	115	351	275	1/508
15	33.98	140	411	369	1/699

[1] Each value is the average of 5 specimens.

to a common density of 32 PCF, were 135,000 psi, 123,000 psi, and 109,000 psi for cement/wood ratios of 2.0/1, 2.3/1, and 2.6/1, respectively (Table 2). This indicated that MOE was reduced almost linearly when cement/wood ratio was increased from 2.0/1 to 2.6/1. The MOR values, when adjusted to 32 PCF, were 375 psi, 349 psi, and 342 psi for cement/wood ratios of 2.0/1, 2.3/1, and 2.6/1, respectively (Table 2). Therefore, the increase of cement/wood ratios above 2.0/1 had an adverse effect on bending stiffness and strength of CEB.

The results of concentrated load test are presented in Table 3. These concentrated loads were adjusted to the common density of 32 PCF as previously described. Concentrated loads were 352, 345, and 339 pounds corresponding to cement/wood ratios of 2.0/1, 2.3/1, and 2.6/1, respectively. The increase of cement/wood ratio above 2.0/1 also had an adverse effect on concentrated load carrying capacity of CEB.

In summary, 2 in. thick CEB made at 32 PCF and cement/wood ratios from 2.0/1 to 2.6/1 can still meet the industrial requirements when spanned 32 in.

TABLE 2. *Relationships between MOE and density, MOR and density of excelsior cement board made at 3 cement/wood ratios.*

Cement/wood ratio	Variable Y = a + b (density)	r^2	Y-value (psi) when D = 32 PCF
2.0/1	MOE (1,000 psi) = −213 + 10.88D	0.74	135,000
2.3/1	MOE (1,000 psi) = −271 + 12.32D	0.88	123,000
2.6/1	MOE (1,000 psi) = −360 + 14.66D	0.89	109,000
2.0/1	MOR (psi) = −455 + 25.94D	0.62	375
2.3/1	MOR (psi) = −505 + 26.68D	0.95	349
2.6/1	MOR (psi) = −514 + 26.75D	0.55	342

TABLE 3. *Resistance to a concentrated load of southern pine excelsior cement board made at 3 cement/wood ratios.*[1]

Board no.	Density (PCF)	Maximum concentrated load (lb.)	Concentrated load (lb.) adjusted to 32 PCF
	Cement/wood ratio = 2.0/1		
1	33.77	444	
2	33.44	406	
3	32.06	362	352
4	33.20	384	
5	33.42	414	
	Cement/wood ratio = 2.3/1		
6	32.74	370	
7	31.85	340	
8	33.09	370	345
9	32.80	366	
10	33.24	378	
	Cement/wood ratio = 2.6/1		
11	31.62	340	
12	34.39	436	
13	31.24	288	339
14	31.58	318	
15	33.48	420	

[1] Each value is the average of 4 specimens.

center-to-center. However, the increase of cement/wood ratio above 2.0/1 will directly reduce the MOE, MOR, and concentrated load carrying capacity of CEB. The reductions of MOE and MOR will consequently increase deflection-span ratios and decrease uniform load (W) capacities.

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