WOOD RESEARCH
54 (2): 2009
95-100

PHYSICAL - MECHANICAL PROPERTIES AND DURABILITY AGAINST BASIDIOMYCETES OF PARTICLEBOARDS MADE FROM CEMENT AND *CARPINUS BETULUS* L. WOOD PARTICLES

Antonios N. Papadopoulos
Technological Educational Institute of Kavala, Branch of Drama, Department of Forestry and Management of Natural Environment, Drama, Greece

ABSTRACT

Cement bonded particleboards were manufactured from hornbeam (*Carpinus betulus* L.) wood particles. Hydration tests were carried out to determine the inhibitory index in order to characterise wood-cement compatibility. The results revealed that the mixture of hornbeam -cement can be classified as moderate inhibition. Two wood: cement ratios were applied in this study, namely 1:3 and 1:4, for the board manufacture. It was found that an increase of cement-wood ratio resulted in an improvement in all properties examined, except from MOR. All properties of the boards made from 1:4 wood: cement ratio, surpassed the minimum requirements set forth by the building type HZ code. Boards were exposed to brown and white rot fungi, *Coniophora puteana, Trametes versicolor* respectively. Overall, both fungi failed to attack the cement-bonded boards.

KEY WORDS: wood, cement, mechanical properties, decay resistance, *Coniophora puteana, Trametes versicolor, Carpinus betulus* L.

INTRODUCTION

Cement-bonded particleboard has been manufactured using conventional technology, where the boards are kept under pressure for consolidation for several hours. The pressure is necessary because the hydration of the cement is a slow process. The cement hardening is usually completed in three to four weeks. The characteristics that make such type of boards desirable to various construction applications are decay and fire resistance and good dimensional stability (BISON 1978).

A significant problem however, when these products are manufactured, is the compatibility of wood with cement. The term compatibility, when applied in the area of wood-cement composites, refers to the degree of cement setting after mixing with water and with a given wood in fragmented form. Generally, if the chemical process of cement hardening is undisturbed by the presence of wood, it is considered that cement and wood are compatible. On the other hand, if cement hardening is impaired by the presence of wood, then cement and wood are referred as incompatible (Jorge et al. 2004). The latter is commonly expressed by a lowering of the physical and mechanical properties of the final product. Weatherwax and Tarkow (1964), described a method to quantify differences among species by using the term inhibitory index, which compares the extension of wood-cement inhibition based on the percentage increase in setting time. Hofstrand et al. (1984), incorporated maximum temperature and the maximum slope of the temperature time curve of the wood-cement mixture and neat cement, respectively, into the inhibitory index calculations. The inhibitory index of any species can be computed from the values of maximum temperature of hydration, the maximum slope of the exothermic curve and the hydration time needed to reach maximum temperature of the inhibited cement when compared respectively with the values of the uninhibited cement. The lower the inhibitory index, the higher the compatibility between cement and wood. Objective of this communication was to manufacture wood cement particleboards using particles of hornbeam, a less utilized wood species in Greece, and to evaluate the mechanical properties and decay resistance of the boards.

MATERIAL AND METHODS

Hydration test

The hydration tests were carried out as previously described (Papadopoulos 2007). To calculate the inhibitory index (*I*) of the species, the following equation was used:

$$I = 100\ [(\ (t_2 - t'_2)\ /\ t'_2) * ((T'_2 - T_2)/\ T'_2) * ((S'_2 - S_2)/\ S'_2)] \qquad (1)$$

where

t_2 : time to reach maximum temperature of the inhibited cement in seconds (wood-cement-water mixture)

t'_2 : time to reach maximum temperature of the uninhibited cement in seconds (cement – water mixture)

T_2 : maximum hydration temperature of the inhibited cement in ^{0}C(wood-cement-water mixture)

T'_2 : maximum hydration temperature of the uninhibited cement ^{0}C (cement –water mixture)

S_2 : maximum temperature-time slope of inhibited cement ^{0}C (wood-cement-water mixture)

S'_2 : maximum temperature-time slope of uninhibited cement ^{0}C (cement –water mixture)

Board manufacture

Hornbeam particles that previously passed the 1 x 1 mm sieve were the raw material used in this study. The bonding agent employed was commercial grade Portland cement, type I. The wood: cement ratios applied in this study were 1:3 and 1:4, based on the oven dry weight. Calcium chloride ($CaCl_2$ - 3% based on weight of cement) was introduced into cement slurry to accelerate cement set during hydration. The boards manufactured according to methodology described in Okino et al. (2004) and Fuwape (1995). A predetermined amount of air-dried wood particles and a $CaCl_2$ distilled water solution were thoroughly blended. Cement was subsequently added and the constituents were mixed until the cement paste was completely hydrated. The quantity of distilled water added, was calculated using a relationship applied by other researchers as well (Fuwape 1995, Moslemi and Pfister 1987, Sudin et al. 1995). In his formulation, the water requirement was determined as follows:

$$\text{water (litres)} = 0.35\ C + (0.30 - MC)\ W \quad (2)$$

where:
C = cement weight (kg)
MC = wood particles moisture content (oven-dry basis) (%)
W = oven-dry wood strand weight (kg)).

After 15 minutes of manual mixing, the cement-wood water mixture was screened onto to a caul. The mat was evenly distributed to provide as uniform a density as possible and pre-pressed to a thickness of approximately 50 mm. Cold pressing took place under an initial pressure of 5 MPa, to a 15mm thickness, after which the board was retained in compression for 24 hours. Target board density was 1200 $kg.m^{-3}$. A total of six boards were made, each measuring 40 x 40 cm. To minimize cement capillary desiccation and enhance hydrartion, boards were misted with distilled water, then wrapped in cellophane before storing for curing at 20^0C and 65% relative humidity for a month. After manufacturing, the boards were conditioned at 20^0C and 60% relative humidity and tested for IB (internal bond, sample size 50 x 50 mm), MOR –MOE (moduli of rupture and elasticity, sample size 300 x 50 mm), TS (thickness swelling, after 24 hours immersion in water, sample size 50 x 50 mm) according to procedures defined in the European Union standards EN 310, EN 317 and EN 319. One way analysis of variance (ANOVA) at 5% level of significance was used to compare the properties of the panels between different wood cement ratios.

Decay tests

60 samples, measuring 50 x 50 x 15 mm, were packed in an argon atmosphere and sterilised by irradiation (2.5 Mrad.) prior to decay tests, using the methods described in DD ENV 12038: 1996. Laboratory pure strains of the brown rot fungus *Coniophora puteana* (No FPRL 11E) and white rot fungus *Trametes versicolor* (CTB 863A) were used, grown on malt agar. 48 blocks (24 for each fungi) were planted on sterile specimen supports placed on the cultures of the test fungus actively growing on 5% malt agar in 500 ml capacity jars. An additional set of 12 sterile control samples were used to assess operational control losses. The closed jars were incubated for 16 weeks, at 22 +/-1^0C and 75 +/-5% relative humidity to evaluate the efficacy of the treatments. After incubation, the samples were removed from the jars, cleaned, weighed, conditioned to constant weight as above and re-weighed. Weight loss (WL) was expressed as a percentage of the initial weight of the sample. Weight losses from sterile controls were subtracted from the decay results to give corrected data.

RESULTS AND DISCUSSION

Hydration test

The results obtained from the hydration test are shown in Tab. 1. From this it can be seen that the mixture of hornbeam-cement was classified as moderate inhibition. When $CaCl_2$ was incorporated, the mixture was graded as low inhibition. The value of inhibitory index is negative, probably due to the capacity of the $CaCl_2$ to buffer or minimize the adverse effect of the soluble sugars and extractives and also to accelerate the cement hardening and setting.

Tab. 1: Inhibitory index of hornbeam wood species used in this study. (Standard deviations in parentheses).

Wood species	Inhibitory index (%)	
	Without additive	With additive (3% $CaCl_2$)
Hornbeam	39.15[a] (4.3)	- 0.92 (0.08)

a: Each value represents the mean of four replicates

Mechanical and physical properties

The mechanical properties of the boards are presented in Tab. 2. This Tab. shows that an increase of cement-wood ratio resulted in improvement in MOE, IB and TS properties, and this improvement is significant at 5% level of significance. However, the MOR value was significantly decreased, as the cement-wood ratio increased. This is in line with the observations made by Moslemi and Pfister (1987) and Papadopoulos et al. (2006). They found that the modulus of elasticity, internal bond strength and thickness swell increased linearly with greater cement-wood ratio. The relationship between cement-wood ratio and MOR values is considerably different that of MOE or IBS or TS. The MOR decreased with an increase of cement-wood ratio since higher proportion of wood in the board may enhance the flexural property of the board. When wood occupies more volume in the board, the areas of stress concentration around the component particles are more diffused, resulting in increased to applied stresses (Fuwape, 1984). The results reported here are in conformity with those made by other workers (Moslemi and Pfister 1984; Sudin et al. 1995; Papadopoulos et al. 2006) regarding the use of cement in particleboard, flakeboard and OSB manufacture. All properties of the boards, if we exclude the IB value of boards made from 1:3 wood: cement ratio, surpassed the minimum requirements set forth by the building type HZ code, as shown in the last line of the Tab. 2. This is in line with the results published by Okino et al. (2005). They manufactured cement bonded boards with 1:3 wood: cement ratio and used cypress particles.

Tab. 2: Mechanical and physical properties of cement-bonded hornbeam boards. (Standard deviations in parentheses)

Wood: Cement	Density [a] ($kg.m^{-3}$)	MOR [b] ($N.mm^{-2}$)	MOE [b] ($N.mm^{-2}$)	IB [a] ($N.mm^{-2}$)	TS [a] (%)
1:3	1270 (0.18)	12.68 (0.5)	6009.6 (32.1)	0.35 (0.07)	1.75 (0.6)
1 :4	1280 (0.12)	10.56 (0.8)	7056.4 (199.3)	0.56 (0.04)	0.67 (0.1)
BISON type HZ	*1200*	*9.0*	*3000*	*0.40*	*1.2 – 1.8*

a: Each value represents the mean of twelve replicates
b: Each value represents the mean of eight replicates

Decay resistance

The results obtained after a 16-week incubation period are presented in Tab. 3. Overall, both fungi failed to attack the cement-bonded boards. Visual examination revealed a slight presence of mycelium in the surface of the tested samples. Boards showed weight gain instead of weight loss. This according to Okino et al. (2004, 2005) was a consequence of the final curing process of the cement, at this high cement: wood ratios. Research in durability of cement bonded panels is not very common in the literature. Tests conducted by Dinwoodie and Paxton (1991) and Pirie et al. (1990) suggested that conventionally made cement bonded particleboards are very resistant to the attack of the white rot fungus *Pleurotus ostreatus* and to the brown rot fungus *Coniophora puteana*. Similar results were also reported by Okino et al. (2005) in cement bonded boards made from cypress particles. The present study was the first study, as far as the author is aware, that examined the decay resistance of oriented strand board using cement as a binder.

Tab. 3: Weight loss (WL) of cement-bonded hornbeam boards. (Standard deviations in parentheses).

Wood: Cement	Brown rot	White rot
	WL[a] (%)	WL[a] (%)
1:3	0.85 (0.07)	-1.88 (0.40)
1:4	-2.92 (0.20)	-1.45 (0.66)

a: Each value represents the mean of twelve replicates

CONCLUSIONS

The aim of this paper was to manufacture wood cement particleboards using particles of hornbeam and to evaluate the physical - mechanical properties and decay resistance of the boards. Based on hydration tests, it was found that the mixture of maple-cement can be classified as moderate inhibition. Two wood: cement ratios were applied in this study, namely 1:3 and 1:4, for the board manufacture. It was found that an increase of cement-wood ratio resulted in an improvement in all properties examined, except from MOR. All properties of the boards made from 1:4 wood: cement ratio, surpassed the minimum requirements set forth by the building type HZ code. Boards were exposed to brown and white rot fungi, *Coniophora puteana, Trametes versicolor* respectively. Overall, both fungi failed to attack the cement-bonded boards.

REFERENCES

1. BISON, 1978: Wood-Cement Board. Report. Pp. 1 – 27
2. Dinwoodie, J.M., Paxton, B.H., 1991: The long term performance of cement-bonded particleboard. In: Inorganic bonded wood and fiber materials. 2nd International Conference, Moscow, Pp. 45
3. European Standard EN 310, 1993: Particleboards and fibreboards-Determination of modulus of elasticity in bending and of bending strength
4. European Standard EN 317, 1993: Particleboards and fibreboards-Determination of swelling in thickness after immersion in water
5. European Standard EN 319, 1993: Particleboards and fibreboards-Determination of tensile strength perpendicular to the plane of the board
6. Fuwape, J.A., 1995: The effect of cement-wood ratio on the strength properties of cement-bonded particleboard from spruce. Journal of Tropical Forest Products 1(1): 49-58
7. Hosfstarnd, A.D., Moslemi, A.A., Garcia, J.F., 1984: Curing characteristics of wood particles from nine northern Rocky Mountain species mixed with Portland cement . Forest Products Journal 34(2): 57-61

8. Jorge, F.C., Pereira, C., Ferreira, J.M.F., 2004: Wood-cement composites: a review. Holz als Roh-und Werkstoff 62: 370-377
9. Moslemi, A.A., Pfister, S.C., 1987: The influence of cement-wood ratio and cement type on bending strength and dimensional stability of wood-cement composite panels. Wood and Fiber Science 19: 165-175
10. Okino, E.Y.A., deSouza, M.R., Santana, M.A.E., da Alves, M.V., deSouza, M.E., Texeira, D.E., 2004: Cement-bonded wood particleboard with a mixture of eucalypt and rubberwood. Cement & Concretes Composites 26(6): 729-734
11. Okino, E.Y.A., deSouza, M.R., Santana, M.A.E., da Alves, M.V., deSouza, M.E., Texeira, D.E., 2005: Physicomechanical properties and decay resistance of *Cupressus* ssp. cement-bonded particleboards. Cement & Concretes Composites 27(3): 333-338
12. Papadopoulos, A.N., Ntalos, G.A., Kakaras, I., 2006: Mechanical and physical properties of cement-bonded OSB. Holz als Roh-und Werkstoff 64: 517-518
13. Papadopoulos, A.N., 2007: An investigation of the suitability of some Greek wood species in wood-cement composites manufacture. Holz als Roh-und Werkstoff 65(3): 245-246
14. Pirie, B.J., Glasser, F.O., Schimitts, H., Akers, S.A.S., 1990: Durability studies and characterisation of the matrix and fibre-cement interface of asbestos-free fibre-cement products. Cement & Concrete Composites 12(4): 233-234
15. Sudin, R., Shaari, K., Selamat, S., 1995: Cement-bonded particleboard from pre-soaked oil palm trunk: effects of particle size and chemical additive. Journal of Tropical Forest Products 1(2): 71-77
16. Weatherwax, R.C., Tarkow, H., 1964: Effect of wood on setting of Portland cement. Forest Products Journal 12: 567-570

Antonios N. Papadopoulos
Technological Educational Institute of Kavala
Branch of Drama
Department of Forestry and Management of Natural Environment
Technological Educational Institute of Kavala
Laboratory of Wood and Wood Products
66100 Drama
Greece
TEL: +30 25210 60445
FAX: +30 25210 60411
E-mail: antonios1974@hotmail.com, antpap@teikav.edu.gr