



Durability and microstructure analysis of CO₂-cured cement-bonded wood particleboard



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ABSTRACT

Dry-processed cement-based wood composites are reconstituted wood products with desirable longevity, fire resistance and life cycle cost. In this study, the effects of accelerated aging on the performance of CO₂-cured cement-bonded wood particleboards were investigated. The accelerated aging conditions considered simulated natural aging phenomena. Repeated wetting–drying and freezing–thawing cycles led to increased stiffness and somewhat reduced toughness. X-ray diffraction and thermogravimetric analyses indicated that aging effects led to increased CaCO₃ and decreased Ca(OH)₂ contents in CO₂-cured cementitious composites. Mercury intrusion porosimetry test results indicated that CO₂ curing reduced the capillary pore volume in both unaged and aged boards.

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1. Introduction

Cement-bonded wood particleboards are reconstituted wood products with desirable longevity, fire resistance and life-cycle economy. The low productivity of cement-based wood composite production plants, resulting from the slow setting and hardening of cement, has led to relatively high initial cost of the product. Early exposure of cement binders to carbon dioxide (CO₂) can substantially reduce the setting and hardening times of cement based materials [1–3]. The processing and properties of wood–cement composites are sensitive, among other factors, to the specific wood species. Efforts towards substantially increasing the setting and hardening rate of cement should still provide sufficient “open time” during which the wood–cement–water furnish stays plastic to be mixed, formed and pressed.

The predominant chemical reaction occurring with carbonation of cement hydrates involves reaction of CO₂ with the Ca(OH)₂ resulting from hydration of cement, yielding CaCO₃. Rapid carbonation reactions may reduce the curing time of cement-based materials in the presence of carbon dioxide. This value-added use

carbon dioxide also reduces greenhouse gas emissions due to the consumption of the polluting CO₂ [4–7].

The utilization of carbon dioxide gas in accelerated curing of cement-based materials transforms calcium hydroxide into calcium carbonate. Calcium carbonate is less soluble in water than calcium hydroxide, and there is a drop in porosity and an increase in hardness and impermeability associated with the formation of calcium carbonate [8]. These changes in composition and structure enhance the durability characteristics of cement-based materials. CO₂ curing also reduces the alkalinity of pore water in cementitious materials [9,10]. In the case of cement-bonded wood particleboard, the cementitious matrix of reduced alkalinity is more compatible with wood particles. The aim of this paper is to assess the long-term durability characteristics of CO₂ cured cement-bonded wood particleboard subjected to repeated cycles of freeze–thawing and wetting–drying, and to investigate the effects of accelerated aging on the flexural performance characteristics and structure of cement-bonded wood particleboard specimens. The experimental procedures followed BS 5669 [11] and ASTM C1185 [12].

2. Experimental program

2.1. Materials and specimens preparation

A softwood (Southern Pine, S.P.) and hardwood (Aspen) were used in this study. Particles have been made using a hummermill,

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Fig. 1. Appearance of wood particles.

Table 1
Wood particle dimensions.

	Southern pine	Aspen
Length (mm) means (st. dev.)	5.32 (1.73)	4.97 (1.66)
Width (mm) means (st. dev.)	1.2 (0.67)	1.25 (0.47)
Thickness (mm) means (st. dev.)	0.4 (0.15)	0.5 (0.22)

Table 2
Chemical composition of the Type I Portland cement used.

Chemical composition	% By weight
Tricalcium silicate (C_3S)	43.3
Dicalcium silicate (C_2S)	26.3
Tricalcium aluminate (C_3A)	11.0
Tetracalciumaluminoferrite (C_4AF)	8.6
Insoluble residue	0.12

and then screened to a final of 0.65 to 3.35 mm particle size (passing through No. 6 sieve and staying on No. 20 sieve). The average moisture content of these particles was about 5% (oven dried basis). Fig. 1 shows a picture of wood particle. The average length, width and thickness of wood particles were measured using image analysis procedure and shown in Table 1. Type I Portland cement with chemical composition of Table 2 was used in the mixtures of this investigation. Agricultural grade of calcium hydroxide ($Ca(OH)_2$) at 7.5% by weight of cement was also used when curing was accomplished using CO_2 gas. In this case, calcium hydroxide replaced an equivalent weight of cement.

The manufacturing process of cement-bonded wood particle-board was similar to that used by Soroushian et al. [1]. It involved mixing of the constituents in a mortar mixer, and placing the blend into a 305 mm (12 in.) square wooden box. Wood/cement weight ratio of 0.28 or 0.35, and water/cement weight ratio of 0.25, were used in the process, targeting 12 mm thick boards. The mix was spread in the box between two fine screens, and was then placed in a press, and the wooden box was removed. Fig. 2 shows the cement-bonded wood particleboard processing system for CO_2 curing. To produce various concentrations of CO_2 gas in air, as seen in Fig. 2, two gas cylinders (one CO_2 and the other air) were used. Each cylinder was connected to a flow meter which controlled the gas flow level and thus the CO_2 concentration. A CO_2 gas heating element was used in the CO_2 pressure supply line to prevent the gas from freezing. Pressure was applied on boards using a 50-ton capacity press. In the unsealed press, the platens were perforated with 2.38 mm (3/32 in.) diameter holes drilled in a 13×51 mm (0.5×2 in.) spacing pattern which covered an area of 305×305 mm (12×12 in.). The top and bottom perforated plates were connected to the CO_2 , air and vacuum lines. The set-up is capable of applying any combination of CO_2 , air and vacuum on either side of the board. A constant carbon dioxide (CO_2) gas concentration in air, 25%, was used. A metal screen was used above the bottom plate. Moisture traps were used to prevent any potential damage to the vacuum pump by moisture. Fig. 3 shows the typical appearance of cement-bonded wood particleboard.

The experimental program followed in this paper is intended to provide further insight into effects of wood–cement ratio and wood species on various aspects of board performance

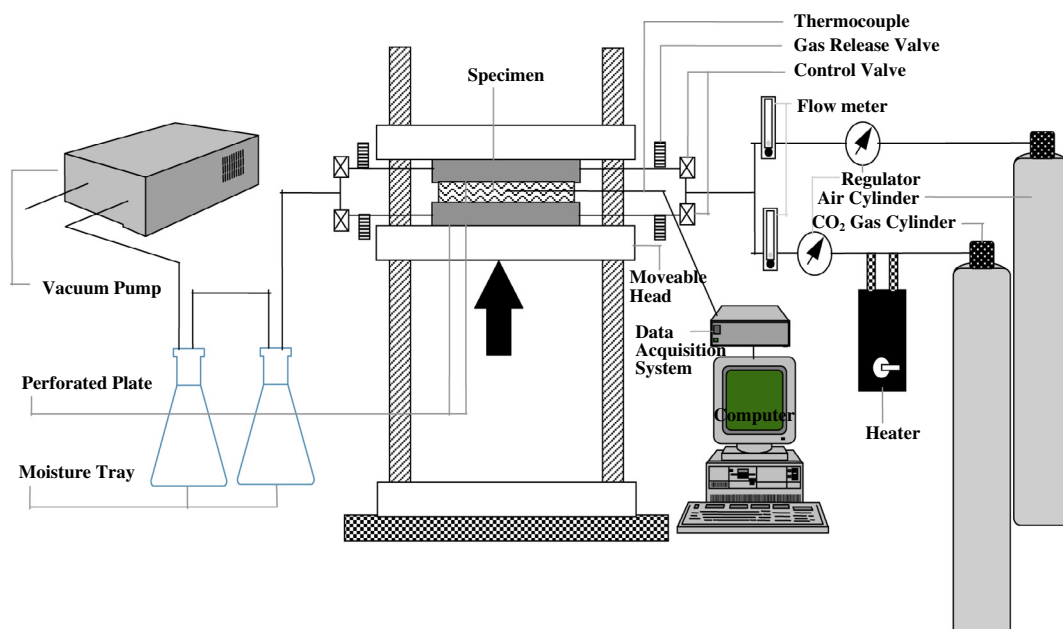


Fig. 2. Processing system incorporating CO_2 curing [1].

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