

PRODUCTION OF CEMENT BONDED CEILING BOARD USING SAWDUST AND WASTEPAPER

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Abstract

Cement bonded composite boards produced from wastepaper and sawdust at densities of 1000, 1200, 1300, kg/m³ and fibre to cement mix ratios of 2:1, 5:2, 3:1 and 7:2 were investigated. The influence of density and mixing ratio on the water absorption (WA), thickness swelling (TS), modulus of rupture (MOR) and modulus of elasticity (MOE) were also determined. Increase in board density and mixing ratio caused decreased in WA and TS and increase in MOR and MOE. Cement bonded composite board samples produced at high board density and mixing ratio levels between 3:1 and 7:2 exhibits highest properties. The WA, TS, MOR and MOE were significantly affected by the board density and mix ratio. Waste materials are suitable for building construction especially the interior components like ceiling installation, partitioning, cladding and table tops for low income Nigerian.

Keywords: Cement Bonded board, Mix ratio, Board density, Physical and Mechanical Properties

Introduction

The introduction of new technology calls for the development of cement bonded composite which is one of the engineered wood products from wastepaper and wood residue (sawdust) for economic growth. The uses of these wastes justify a series of research efforts aimed at achieving different objectives. The development also provides an effective way of using low – grade wood species and any wood residue generated in wood processing industries.

The world is steadily retreating from dependence on asbestos (Nishikawa et al; 2008). The replacement of asbestos with Cement Bonded Composite (CBC) is an added advantage. The global economic meltdown and the dare need of affordable building for the teaming masses call for the sustainable development of engineered wood products for building construction from the present high cost of conventional building materials like polyvinyl/chloride ceiling products.

In 2006, the International Labour Organization (ILO 2006) and world Health Organisation (WHO 2006) jointly declared that the most efficient way to eliminate asbestos – related diseases is to stop using all types of asbestos. Globally, each year, an estimated 125 million people are

occupationally exposed to asbestos, and 90,000 die from asbestos diseases (WHO 2006). In 1983, Iceland became the first country to ban asbestos because of the increasing campaign and recognition of the health risks associated with asbestos exposure. Since then, over 40 countries have adopted its ban (WHO 2006). Examples of such health related diseases include asbestosis, lung cancer, or mesothelioma.

Despite the international actions to stop the use of asbestos, occupational exposure to asbestos continues to be a major health hazard, up to 20,000 asbestos – induced lung cancers, and 10, 000 mesotheliomas occur annually in Western Europe, Scandinavia, North America, Japan and Australia (Anonymous 1997). It is therefore, imperative to adopt the use of CBC so as to ameliorate the health problems associated with asbestos. The popularity and application of CBC in residential markets and construction industries like cladding, panelling and partitioning in the developed countries such as America and Germany, could be attributed to the products perceived environmentally friendly, fire resistance, thermal and acoustic resistance, specific stiffness, fracture, resistance, toughness, strength to weight ratio, flexibility during processing, resistance to biological degrading agents compared to solid lumber, plastic and steel (Ramirez – Coretti; 1998; Dinwoodie and Paxton, 1991). Additionally, it has higher dimensional stability than its competitors.

Unfortunately, not all the countries in the world engage in recycling of waste materials, especially wastepaper and sawdust, large parts of this quantity of sawdust generated in developing countries are normally burnt off in the sawmills or dumped in landfills, while the remaining part is used as fuel. Burning of this sawdust in the open air is likely to cause environmental pollution as carbon dioxide (CO₂) and carbon – monoxide (CO) would be released into the atmosphere as a result of insufficient oxygen in the heap of the sawdust. Also, the aerobic decomposition of either wastepaper or sawdust in the landfills could be a major source of methane emissions. The release of these gasses into the atmosphere changes the climate, thereby resulting in global warming; which is now one of the greatest threats to the world.

Based on this fact, there is the need to find uses for both wastepaper and sawdust generated in the world, especially in the developing countries. Apart from the fact that the use of these wastes will serve as an environmental management system, it will also contribute positively to the economic growth of the society.

This study was carried out to evaluate the physical and mechanical properties of cement – bonded boards made from wastepaper, sawdust and cement.

Materials and Methods

Waste materials procurement

The sawdust was collected from a local sawmill that was purposefully selected from among the numerous operational sawmills at Akure, Ondo State, Nigeria based on the availability of obeche sawdust. The sawdust was air dried for four weeks in order to enhance gradual degradation of starches and sugar contents, which could impede setting of the cement binder.

Wastepapers were collected from the central store, College of Education, Ikere-Ekiti State Nigeria. Ordinary Portland Cement (OPC) (Manufactured by Lafarge Company) used as binder was bought from a local distributor in Akure from a fresh consignment. The quantity required for the production of each board was weighed, packed and sealed in polythene bags. Calcium chloride (CaCl₂) was purchased from a local chemical supply store (Wintek Scientific Limited) in Akure, Ondo State.

Material Preparation

The sawdust of obeche was soaked in hot distilled water for 4hrs in order to extract the inhibitory chemicals in the sawdust. Both the pulp (from wastepaper) and hot water extracted sawdust were finally spread out in the laboratory environment for 7 days to attain 12% moisture content. The air-dried sawdust was screened with a 2mm sieve so as to remove fine particles in it. The sharp particles were kept in polythene bags inside the laboratory for a week to attain equilibrium moisture content with the environment.

Foreign objects in the wastepaper (stone, office pins) were removed before processing. The collected waste papers were soaked in a large rubber tank for twenty –one days for easy pulping using an improvised mechanical pulping machine.

Water was removed from the pulp and finally kept in the laboratory to attain equilibrium moisture content of 12%.

Board Formation

The quantities of cement, wastepaper and sawdust were weighed using high precision electronics weighing balance.

The mixture of this variable with calcium chloride were spread inside the cauls and stacked. The stack is cold press at certain pressure to obtain the desired thickness and density. Pressing operation is designed to bring into contact all the production variables so as to obtain adequate bonding between the adjacent particles, which were loosely packed.

The reason Simatupang (1988) gave to support this claim was that the water becomes available to the binder after pressing the composite to the desired thickness and forming a coherent material.

Pressure was applied until the specified board size and thickness was obtained. After pressing to the desired thickness, the pressure was sustained for 24 hours. After 24 hours of cold pressing, the board was removed from the cauls and air-dried in the laboratory for three days before it was finally stacked for 28 days.

Mat Laying

A wooden frame of 300mm by 300mm was carefully placed on a metal plate that was covered with cellophane to prevent sticking of the board to the plate. The cement bonded composite produced was of three layers.

The slurry of wastepaper, cement with chemical additives and water that formed the first face was spread uniformly on the mould. Thoroughly mixed sawdust, cement, chemical additives and water was also spread uniformly on top of the first layer.

The slurry of wastepaper, cement with chemical additives and water was spread uniformly on top of the second layer, “stops” (Iron Rod) were used to obtain and maintain 8mm thickness of the board by placing them at the four-edges of the caul-plate.

The felted mattress was finally pressed to a required thickness of 8mm and retained under press for a period of 24 hours before removing the board from the moulds for post-curing evaluation.

The board edges were trimmed on a circular saw machine to avoid edge effect and each test specimen was cut into the required sizes according to the America society for testing and materials (ASTM) 1978.

Samples were cut into 175mm x 50mm x 8mm and 50mm x 50 x 8mm to test for modulus of rupture (MOR), modulus of elasticity (MOE), water absorption (WA), thickness swelling (TS) after 24 hours of soaking in water.

Water Sorption and Thickness Swell

The water sorption behaviours of the CBC produced from pulped waste paper, hot water extracted Obeche sawdust and Portland cement were ascertained. Water absorption and thickness swell tests of the CBC were performed following a modified ASTM D 1037 standard (1999). Specimen of 8mm x 50 mm x 50 mm was used for this test. Five specimen from each CBC type were dried in an oven for 24 hrs at a temperature of $100 \pm 3^\circ \text{C}$. The weight and thickness of dried specimen were measured at an accuracy of 0.001 g and 0.001 mm, respectively. The thickness and weight of the oven dried CBC samples were measured using dial gauge and a high precision electronic weighing balance (GH-V1000A), respectively. The test specimens were submerged in distilled water at room temperature (approximately $23 \pm 2^\circ \text{C}$) in a horizontal position to depth of 25mm for period of 24 hrs. The specimens were later removed and drained for 1 minute so as to remove excess surface water. Thereafter, specimens were weighed and thickness measurement was taken. Water absorption and thickness swell were calculated from the increase in weight and thickness of the specimens as:

$$\text{WA (\%)} = \frac{w_2 - w_1}{w_1} \times 100$$

Where,

WA = Water absorption (%)

w_2 = Final weight after treatment (g)

w_1 = Initial weight before treatment (g)

Also the values of the thickness swell in percentage were calculated using the following equation:

$$\text{TS (\%)} = \frac{T_2 - T_1}{T_1} \times 100$$

Where,

TS = Thickness swelling (%)

T_2 = Final thickness after treatment (mm)

T_1 = Initial thickness before treatment (mm)

Modulus of Rupture (MOR)

This study involved the use of standard test board samples of 8mm x 50 mm x 150 mm on a Hounsfield Tensiometer. The load was applied at the rate of 0.1 mm/s at the center of each board sample until failure of the test sample occurred. The load at which each board sample failed was recorded. MOR of the test board samples was calculated using the formula:

$$\text{MOR (N/mm}^2\text{)} = \frac{3PL}{2bd^2}$$

Where

MOR = Modulus of rupture (N/mm²)

P = The ultimate failure load (N)

L = The board sample span between the machine supports (mm)

B = Width of the board sample (mm)

D = Thickness of the board sample (mm)

Modulus of Elasticity (MOE)

The modulus of elasticity was calculated from the values obtained from the load-deflection graph plotted on the tensiometer machine during the determination of modulus of rupture. The formula employed is given as:

$$\text{MOE (N/mm}^2\text{)} = \frac{PL^3}{4bd^3h}$$

Where,

MOE = Modulus of Elasticity (N/mm²)

P = Load (N)

L = The span of board sample between the machine supports (mm)

B = Width of the board sample (mm)

d = Thickness of the board sample (mm)

h = Slope from the graph

Results

Table 1: Summary of the mean values of mechanical properties conducted on cement bonded composite produced from wastepaper and obeche sawdust.

Board density (kg/m ³)	Mix ratio	Modulus of rupture (mm ²)		Modulus of elasticity (mm ²)	
		Unweathered	Weathered	Unweathered	Weathered
1000	7:2	5.75±0.73	4.00±0.26	3190.3±218.38	2949.7±308.91
	3:1	6.98±0.64	5.11±0.67	2891.7±680.71	2643.6±203.22
	5:2	7.62±0.24	5.58±1.07	2597.5±166.43	2335.9±336.77
	2:1	8.05±0.51	6.88±0.42	2483.5±836.23	1353.0±338.82
1200	7:2	7.07±0.50	5.40±0.39	3459.7±344.52	3091.1±289.06
	3:1	8.00±0.82	6.25±0.66	3428.5±340.82	2925.3±187.16
	5:2	8.63±0.80	6.50±0.64	3212.6±100.96	2619.6±315.27
	2:1	9.14±0.55	7.12±0.47	2547.9±433.69	1710.8±782.07
1300	7:2	8.01±2.70	6.04±0.70	5339.5±210.76	4530.1±412.02
	3:1	9.75±0.38	7.94±0.86	3943.6±400.11	3714.7±679.68
	5:2	10.63±0.64	8.12±0.32	3668.6±309.28	3006.4±281.88
	2:1	11.84±0.83	8.22±0.53	3549.2±459.64	2287.9±495.65

Mechanical Properties of Cement Bonded Composite

Modulus of Rupture and Modulus of Elasticity.

The mean values of modulus of rupture (MOR) and modulus of elasticity (MOE) range from 5.75 to 11.84 N/mm² and 2483.01 to 5339.50 N/mm² respectively Table I.

The MOR of cement bonded composite increased with increase in the fiber content (that is low quantity of cement) and it increased with increase in board density while MOE of Cement Bonded Composite (CBC) decreased with increase in the fiber content (that is low quantity of cement) but it increased with increase in board density.

The MOR obtained in this study compare favourably to mean value of 11.3 N/mm² (Dinwoodie 1978); range value of 8.8 to 12.7 N/mm² (Bison-Werke 1981); range value of 5.22 to 11.12 N/mm² (Badejo 1988) and range value of 4 to 15 N/mm² (Fuwape 1995). MOR decreased with increase in cement/particle ratio but increase in board density. Savastano et al. (2000) also observed increased MOR with increase in fiber content but no significant difference between 8% and 12% fiber content. The higher proportion of wood in the board may enhance the flexural property of the board. Based on this study, the CBC with the lowest board density (100kg/m³) would be preferred for applications that require boards of light weight for ceiling installation. In

addition, the CBC with low cement/particle ratio (2:1 on weight basis) would be more economical because a small quantity of cement is required with a large quantity of particles used in this study (sawdust and/or wastepaper) during CBC production. The procurement of cement is more expensive than that of wastepaper and sawdust.

The large proportion of wastepaper and sawdust in the CBC at reduced cement quantity may be responsible for the high flexural MOR (Fuwape 2007) the average values of MOR obtained in this study compared favourably with those of CBC reported by other researchers (Fuwape, 1995; Fabiyi, 2004; Okino, 2004). MOR obtained in this study indicates that the CBC produced from all the mixing ratio except that of 7:2 at 1300 kg/m³ was above the requirements set forth by Bison for building board.

The Modulus of Elasticity MOE values obtained in this study compare favorably to mean values of 2940 N/mm² and range value of 1149 to 3297 N/mm² reported by Bison-Werke (1981) and Fuwape (1995), respectively. MOE increased with increase in cement/particle ratio and increase in board density. Flexural MOE improved with increase in cement/particle ratio and board density. Board density has a significant effect on MOE; the higher the board density, the higher the MOE. This implies that the more the particles (fibers) are closely compacted together, the higher the capacity to hinder failure of the brittle cement, thereby delaying failure in the bond-line resulting in higher flexural stiffness of the CBC produced in this study. The effect of cement/particle ratio on the MOE reported in this study is similar to other reports on CBC (Simatupang) 1979; Oyagade, 1990; Fabiyi, 2003, 2004). Flexural MOE in this study decreased with increase in particleboard production.

Physical Properties of Cement Bonded Composite

Water absorption (WA) and thickness swelling (TS). The mean values for water absorption (WA) and thickness swelling (TS) after 24 hours water soak were shown in table 1.

The mean values for WA and TS ranged from 17.64% to 35.60% and 3.50% to 12.51% respectively. The WA and TS values show decrease with the increase in mixing ratio and board density. The board with the lowest water absorption and thickness swelling rate was obtained from the highest mixing ratio 7:2 (cement / wastepaper and sawdust) and board density of 1300kg/mm².

This therefore suggests that increase in mixing ratio and board density caused decrease in water absorption and thickness swelling. This can be attributed to the increase in cement content in the boards which led to complete coating of the particles as obtained in boards produced from mixing ratio 3:1 and 7:2. A low spring back characteristic exhibited was due to the reduction in the release of compression stress after demoulding and when in contact with water. The highly densified boards produced were due to greater cement/wood compaction, better inter-particle contact and improvement in quality and quantity of bonds in boards.

Water absorption decreased with increase in cement/particle ratio and board density Fig 1. Thickness Swelling decreased with increase in both board density and cement/particles ratio Fig 2.

- **WA decreased With increase in composites' density**
- **WA decreased With increase in cement: fiber ratio**

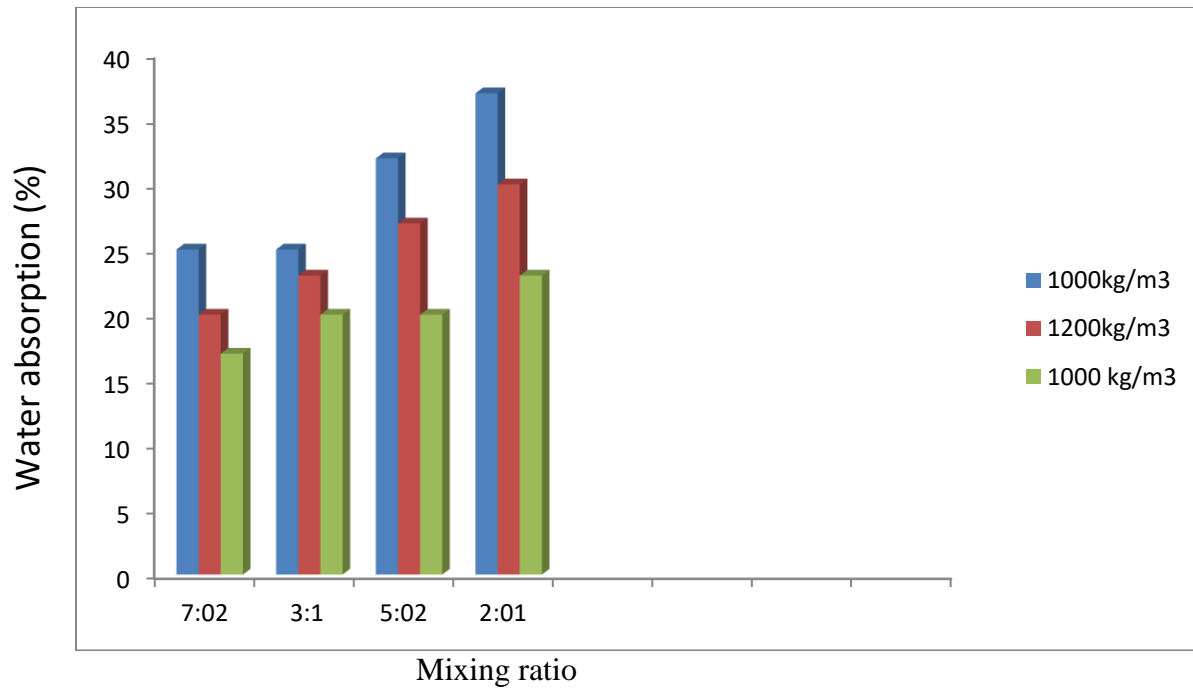


Fig 1: Water absorption after 24hrs soaking in water

- **TS decreased with increase in composites' density**
- **TS decreased with increase in cement: fiber ratio**

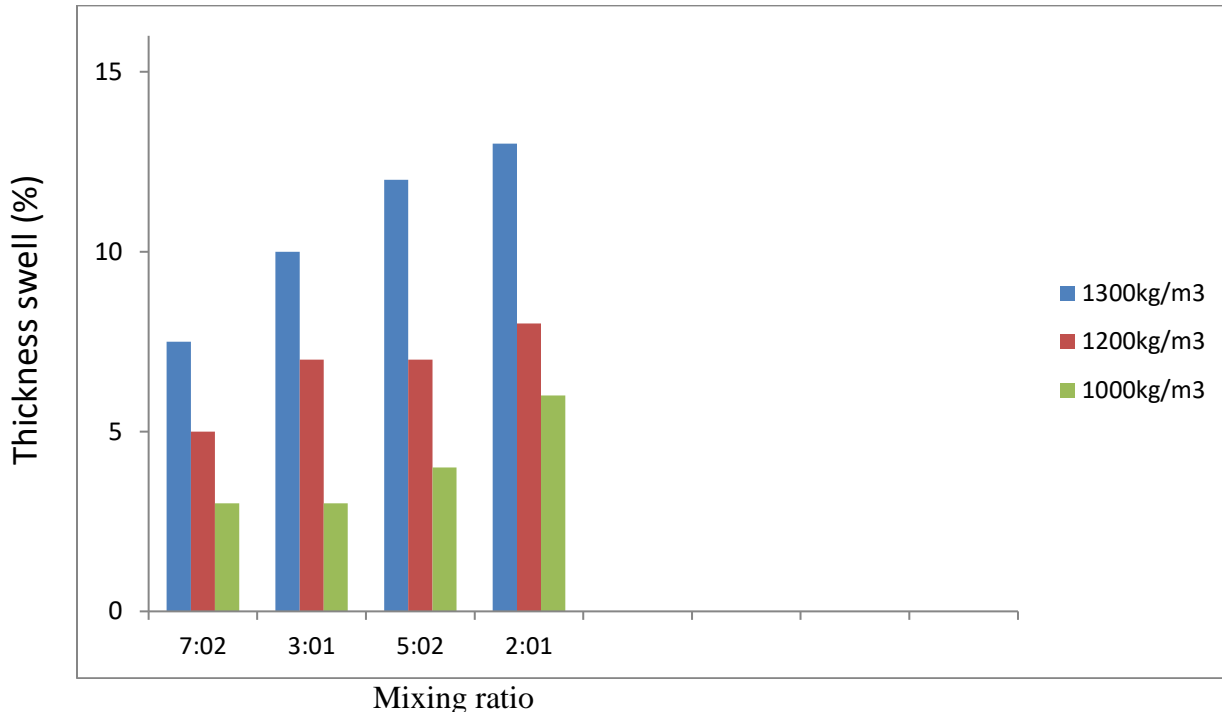


Fig 2: Thickness Swell after 24 hrs Water Soaked

Conclusion

The study showed that cement – bonded composite could be produced from waste at different mix ratio and board densities. Cement bonded composite is suitable for use in low and what cost housing and construction works. The decreases in WA with increases in board density indicate that water could not easily penetrate through the faces of the highly densified board. Finally it moved that Obeche wood sawdust and pulped waste papers treated with calcium chloride are compatible with Portland cement in the production of Cement Bonded Composite (CBC). The use of cement/wastepaper and sawdust mixing ratio at increasing levels between 3:1 and 7:2 resulted in the production of strong and stiffer CBC. On the basis of bending strength, board stiffness cement/wastepaper and sawdust composite CBC produced at 7:2 and 3:1 are suitable for building construction especially the interior components like ceiling installation.

Abbreviations

MOE: Modulus of Rupture
 MOR: Modulus of Elasticity
 WA: Water absorption
 TS: Thickness absorption
 CBC: Cement Bonded Composite
 OPC: Ordinary Portland Cement

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