International Journal of Chemical, Materials and Biomolecular Sciences
ISSN: 2415-6620
Vol:7, No:9, 2013

Suitability of Newsprint and Kraft Papers as Materials for Cement Bonded Ceiling Board

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Abstract**—**The suitability of Newsprint and Kraft papers for the production of cement bonded ceiling board was investigated. Sample boards were produced from newsprint paper (100%), mixture of newsprint and Kraft paper (50:50) and Kraft paper (100%) at 1:1, 2:1 and 3:1 cement/paper mixing ratio respectively with 3% additive concentration of calcium chloride ($CaCl_2$). Density, flexural and thickness swelling properties of the boards were investigated. The effects of paper type and mixing ratio on the physical and mechanical properties were also examined. The bending properties of the board which include Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) increased linearly with increase in density. Modulus of rupture of boards increased as the density and mixing ratio increased. The thickness swelling property for the two paper types decreased as the board density and mixing ratio increased. Boards made from Kraft paper recorded higher strength values than the ones made from recycled newsprint paper while the mixture of kraft and newsprint papers had the best surface finish. The result of the study will help in managing the large quality of waste from paper converting/carton industry and that the ceiling boards produced could be installed with clout nails or used with suspended ceiling fittings.

Keywords**—** Cement,Kraft paper, Mixing ratio, Newsprint.

I. Introduction

PROVISION of ceiling covering is an essential stage in the building process. It is gradually becoming increasingly difficult to obtain solid wood for this purpose because matured wood is no longer readily available and those available contain large proportion of sapwood which is susceptible to insects and termites attack. Furthermore, the use of asbestos is been discouraged because of its hazardous effect on human. Demand for ceiling boards and other panel products have been on the increase in the recent times due to increase activities in the building industries. Research interests in wood cement-bonded boards are on the increase in developing countries. The interest in wood cement bonded boards can be attributed to the widespread availability of major raw materials mainly wood and cement as well as the simplicity and availability of technology for board production.

Recent effort is focused on how to use the waste generated from paper products for ceiling board production. Waste paper has been a major solid waste problem in Nigeria and only a small percentage of the discarded newsprint are kept in the archives as reference material. Paper re-use will not only solve a disposal problem but also result in reducing production cost as raw materials could be soured cheaply [1]. The production of ceiling board from wastes like old newsprint and kraft paper with cement as binder may provide an alternative to sawn timber or other wood waste like sawdust, wood chips etc. The use of recycled newsprint for the production of panel products will also reduce the demand for wood and wood products for other board production as they are available in large quantity, thereby reducing pressure on forest and ensures sustainable forest management.

It was estimated that average office worker in Nigeria generates about 5kg of wastepaper per month, every ton of paper that is recycled saves about 1.4$m^3$of landfill space and one ton of recycled paper saves about 17 pulpwood tree [2]. The high cost of resins and machinery necessary for the production of resin bonded boards, which are an alternative to cement-bonded board in some application, is another point in favor of cement-bonded wood composites[3]-[7].

In addition, the problem of formaldehyde release often associated with urea formaldehyde bonded boards, which does not occur with cement bonded board. Cement bonded boards have a considerable potential as a construction element for commercial and industrial buildings as well as for low cost houses [8]. The strength and dimensional stability of board is a function of the concentration of additives present in the board that is; they increase with chemical additive concentration [9], [10]. This paper examined the suitability of newsprint and Kraft papers bounded with cement as materials for ceiling board production and investigation on its flexural and thickness swelling properties investigated.

II. Methodology

The materials used for this study included discarded newsprint paper; Kraft paper, cement, Calcium chloride ($CaCl_2$), and water. The newsprint paper materials were collected from a Local Newspaper Seller in Ibadan, Oyo State, Nigeria and Kraft paper from a Paper packaging Company in Akure, Ondo State, Nigeria where a lot of wastes are generated during production process. The papers were transported to Federal University of Technology Akure, Ondo State, Nigeria where facilities for the production are available and production was carried out as shown in Fig. 1.

The newsprint and Kraft papers are soaked separately in water for a period of 3 days and 5 days respectively to ensure adequate softening, after which it is milled to the finest texture using Machine Pulper fabricated at the Department of Mechanical Engineering' Federal University of Technology, Akure for the purpose of this project, Water was added to ensure proper milling of the paper. Both papers were milled separately. After milling process, the milled papers were

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drained in a bag for 24 hours to reduce the amount of water present in the paper slurry.

III. Board Formulation

The quantity of the materials (cement and wastepaper) used for the production of each board specimen having the size 350 x 350mm x 7mm were calculated and measured out on a weighing balance and put into the mixing bowl according to the mixing ratio and blending proportion as indicated below:

- Blending/paper type: Newsprint 100%, Newsprint + Kraft Paper 50:50 and Kraft paper 100%
- Cement/ paper mixing ratio: 1:1, 2:1 and 3:1.

For the three blends production factors which were held constant for the board's production were board size of 350 x 350 x 7mm and Pressure of 2:4 N/mm^2.They were all mixed together thoroughly with the machine to enhance proper blending. The chemical additive ($CaCl_2$) of 3% concentration in water dilution was used for each specimen, and the water contain the additives was added to the mixture while blending in the mixer.

IV. Board Formation

The blended paper/cement with additive mixture was run into an already made mould of the size of board to be produced (350 x 350 x 7mm) which was lubricated with engine oil sheets to enhance easy removal and prevent the sticking of the board to the surface of the plate. The mixture was spread out on the plate thereafter; a stainless pipe roller was used to spread the mixture on the mould to allow uniform mat formation after which it was transferred to the press under a pressure of 1.23NM^2 to form the required thickness of 7mm for a period of 24 hours for setting. The boards were removed from the press and from the mould. They are stacked under a controlled laboratory environment to allow for 21 days curing.

V. Testing

The board edges were trimmed with circular saw to avoid edge effect and cut into the required sizes for each test experiment according to the British Standard Method for particle board test (BS D373 1989). The following tests were carried out on all the samples: density, thickness swelling and flexural dimensional properties (MOE and MOR).

Density**:** The board density across the paper- blend type and cement/ paper mixing ratio was determined from board samples of 150x150 x 7mm using:

$$Density = \frac{M}{V} \quad (1)$$

where M is the weight of the test pieces in kg: and V is the volume of the samples in kg/m^3

Thickness Swelling: This was carried out by measuring of the initial thickness (T_1) of the samples with the aid of a digital vernier caliper and final thickness (T_2) after which the test specimens were soaked in water for 24 hours. The thickness swelling was estimated using:

$$T_{SW}(\%) = \frac{[T_2 - T_1]}{T_1} x100 \quad (2)$$

where T_2 is the weight of test samples after soaking (g) and T_1 is the dry weight before soaking (g).

VI. Flexural Test

The samples of 195mm x 50mm x 7mm specimenswere mounted one by one on the Tenso-meter in accordance with British Standard 373 (1989). And load was applied at the center with the aid of a screw jack until when failure occurred. The load applied and deflection values were used to calculate the MOE and MOR:

MOE was calculated using the formula:

$$MOE = \frac{PL^3}{4bd^3H} \quad (3)$$

where: MOE = modulus of elasticity (N/mm^2): P = Ultimate failure 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) and H = Increase in deflection (mm).

MOR was calculated using:

$$MOR = \frac{3PL}{2bh^2} \quad (4)$$

where: MOR = Modulus of rupture (N/mm^2): P= the ultimate failure load (N): L = the board span between the machine supports (mm): b = width of the board sample (mm) and h= thickness of the board sample (mm).

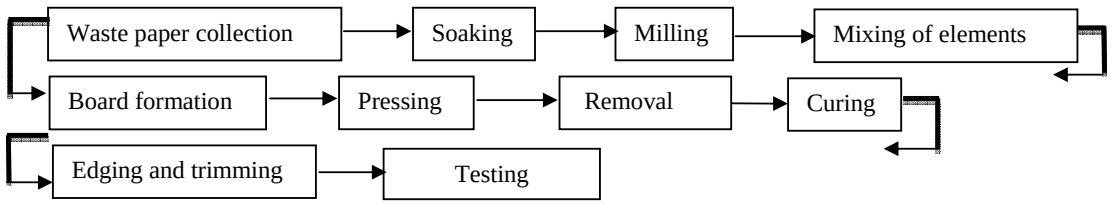

Fig. 1 Flow chart for the manufacture of paper cement bonded board

VII. Statistical Analysis

Statistical Package for Social Sciences (SPSS) was used to analyze the data obtained from the study. Analysis of variance was carried out to evaluate the relative importance of various source of variation on density, thickness swelling, modulus of rapture and modulus of elasticity. The effect of mixing ratio and blending proportion on these variables were examined. The follow-up test (Duncan Multiple Range Test) was conducted at 0.05 level to know the difference between the means and to choose the best treatment combination from the factors considered.

VIII. Results and Discussion

The result of density of Paper Cement Bonded Ceiling board (PCBCB) for mixing ratios 1:1, 2:1 and 3:1 cement/ paper and blending proportions of Newsprint Paper, (100%), Newsprint/ Kraft paper (50:50) and Kraft paper (100%) is shown in Table I. The mean density values of PCBCB for mixing ratio were 1440, 1700 and 1730kg/m^3 for 1:1, 2:1 and 3:1 cement/ paper respectively. Density for the blending proportion (BP) showed the same value range revealing that paper type did not have significant effect on the density. The board density is more influenced by the mixing ratio (MR) than the blending proportion (BP) which is a function of cement binder input as reflected in Fig. 2.Therefore, board density increased with increase cement mixing ratio. However, the result of ANOVA showed that there was a significant difference between MR3:1 and MR1:1, while the difference between MR1:1/MR2:1 and MR2:1/MR3:1, were not significant. The density of PCBCB is substantially influenced by the proportion of cement binder used, showing that density is directly proportional to the mixing ratio.

Result for Thickness Swelling (TSW) ranged from 1.30 to 18.17± 2.0 across the MR and BP for the boards produced, (Table I) this showed that the least thickness swelling was recorded for the boards with highest MR of 3:1 cement paper ratio. This is further expressed in Fig. 3. TSW decreases with increase in mixing ratio. This is also enhanced not only with cement but also by additive of $CaCl_2$. The multiple comparison result in Table I showed the interaction among the variables used. There was no significant effect on the interaction between the MR and BP on the TSW of the boards, only the MR has significant effect on the TSW, which means that higher cement mixing ratio produced boards with low thickness swelling. The dimensional stability of cement bonded composite is a function of the quality of cement binder ratio, higher cement binder, low TSW and vice versa. The interaction between density and thickness swelling showed that thickness swellings decreased with increase in density ratio [11].

The result of the flexural properties which is stress at a fracture from a bend under imposed load is shown in Table I. The mean MOE values obtained for this study ranged from 252.58 to 674.42 N/mm^2 for all the 1:1, 2:1 and 3:1 cement mixing rations and blending proportions respectively (Table I) MOE values increased with mixing proportions and density, and decreased with increased thickness swelling a situation which may be principally due to the mixing ratio which determined the quality of board strength and the quality paper type. Kraft paper due to its coarseness and the longer time required for soaking gave an indication of the paper toughness and corresponding higher strength value (Fig. 4) when compared with boards from newsprint. A balanced mixture was obtained in the blending of News Print and Kraft Paper which gave a higher strength values over the Newsprint. The MOR values shown in Table I also ranged from 1:07 – 2.35 N/mm^2 for MR 1:1 to MR 3:1 following an opposite trend with MOE as shown in Figs. 4 and 5. This is in consonance with the assertion that boards tend to be brittle when their MOE value is high and tend to be ductile or flexible when this value is low [12].

However, the study showed that there was significant difference between MR3 and MR1, while the difference between MR2 and MR2 was not significant. Kraft paper recorded high flexural strength than for Newsprint paper because of better fiber content. This is evident as show in Figs. 4 and 5, the fiber contents affects the flexural strength which varies with the amount of fiber [13]. The content of cement highly influences the properties of the PCBCB. The optimum cement contents needs to be balanced against the high cost of Portland cement relative to wood more than it contributes to the weight of the board. The flexural properties of PCBCB are strongly correlated with board density. Also, for any given blending proportion, its bending strength (MOR) is increased by further increase the cement/wood ratio as the density increased.

TABLE I
Results of Mean Values and ANOVA for Density, Thickness Swelling, and Flexural Properties of Paper-Cement Bonded Ceiling Board

Mixing ratio(MR)	Blending proportion (BP)	Density(kg/m^3)	Modulus of Elasticity (MOE)N/mm^2	Modulus of Rupture (MOR)N/mm^2	Thickness Swelling(TS)%
1:1	BP1 100:0	1440^{b}	252.58±36.12 $^{c/a}$	1.07±0.09 $^{c/a}$	18.17±2.07^{b}
	BP2 50:50	1440^{b}	305.99±49.81 $^{c/b}$	1.18±0.23 $^{c/b}$	15.90±0.80^{b}
	BP3 0:100	1440^{b}	498.98±69.00 $^{c/b}$	1.30±0.14 $^{c/b}$	15.10±0.80^{b}
2:1	BP1 100:0	1700^{ab}	390.73±50.32 $^{b/a}$	1.30±0.14 $^{b/b}$	10.33±5.21^{ab}
	BP2 50:50	1700^{ab}	580.77±84.89 $^{b/b}$	1.44±0.14$^{b/b}$	7.93±4.84^{ab}
	BP3 0:100	1700^{ab}	601.48±91.90 $^{b/b}$	2.87±0.54 $^{b/a}$	5.57±5.57^{ab}
3:1	BP1 100:0	1730^{a}	412.37±61.06 $^{a/a}$	2.10±0.27 $^{a/b}$	5.57±5.57^{a}
	BP2 50:50	1730^{a}	620.84±92.02 $^{a/b}$	2.35±0.03 $^{a/b}$	3.16±0.12^{a}
	BP3 0:100	1730^{a}	674.42±95.52 $^{a/b}$	5.01±0.26 $^{a/a}$	1.30±0.10^{a}

Alphabets to the left denotes the significant difference in mixing ratio, Alphabets to the right denotes significant difference in blending proportion

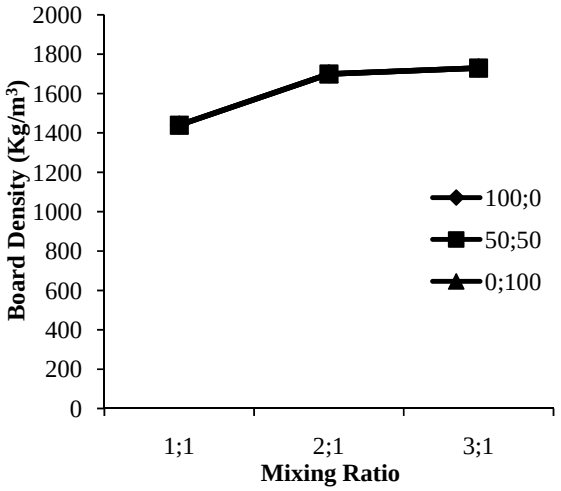

Fig. 2 Effect of mixing ratio and blending proportion on board density

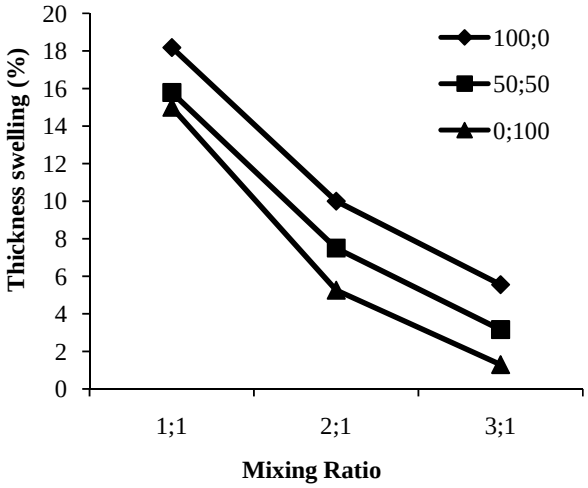

Fig. 3 Effect of mixing ratio and blending proportion on board density proportion on thickness swelling

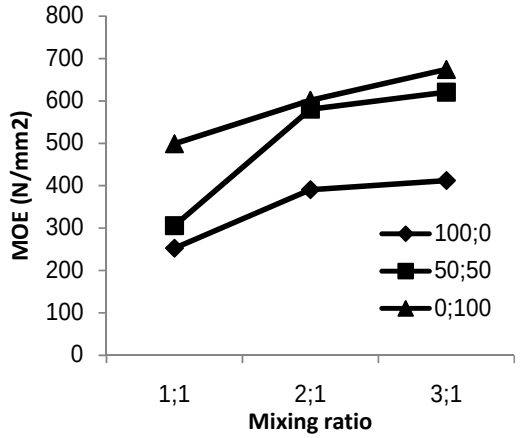

Fig. 4 Effect of mixing ratio and blending on MOE

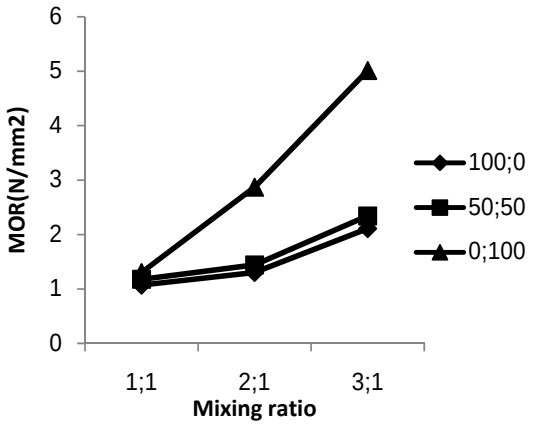

Fig. 5 Effect of mixing ratio and blending proportion on MOR

IX. Conclusion

The results of this study had proved the suitability of Newsprint and Kraft paper types for the production of cement bonded ceiling board and that the blend of the two paper types increased the strength properties and surface quality. Desired board grade could be produced by working out cement and paper ratios carefully. The flexural and thickness swelling properties of the board were affected more by cement mixing ratio than blending proportion, however low density boards with low strength properties could be suitable for wall treatment as insulating boards.

Acknowledgment

The research is financed by the Nigeria Tertiary Education Trust Fund for machine fabrication and Equipment purchase.

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