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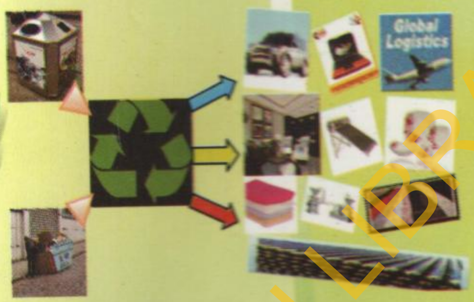

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Strength and Sorption Properties of Some Selected Paper-Cement Boards in Ibadan Metropolis

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Abstract

Paper Cement Boards (PCBs) were obtained from four selected small scale manufacturers in Ibadan, Oyo State, Nigeria. Data on the production process, materials used for production and the paper-cement ratio in the mix were also collected from source. Strength and sorption properties were carried out on the boards. The properties of PCBs were compared with those of the commonly used fibre and gypsum board. One out of the four industries engaged in semi-mechanised production. Analysis of variance showed that boards made from mechanised process were significantly different from the other boards, but the difference between the other PCBs was not significant ($p < 0.05$). The results revealed that boards produced by mechanised process exhibited higher Modulus of Rupture (MOR) and Modulus of Elasticity (MOE) of 3.06N/mm^{2}and 2140.13N/mm^2 respectively and 45.3% water absorption (WA) after 24h immersion. A comparison of the PCBs with gypsum and fibreboards did not prove the PCBs inferior in any of the properties evaluated. All the tested samples had low strength properties and high WA and are hence not suitable for structural purposes and exterior applications.

Keywords: Fibre Cement Composites, Paper Cement Boards, Strength Properties, Sorption Properties

1 Introduction

Fibre Cement Composites (FCCs) are from made from mixtures of processed fibres such as wood (Kraft pulp), glass, steel, Kevlar, asbestos, recycled papers etc. (Moslemi, 2008), cement and water. They are low-cost, environmentally friendly materials that can be machined using simple hand tools, made in myriads of shapes and are adaptable to modular housing construction. The incorporation of uniformly dispersed fibres in cementitious composites strengthen the cement matrix thus improving the structural performance in members under gravity loads, as well as in increasing shear and flexural strengths, toughness ductility, energy dissipation, and damage tolerance in members subjected to reversed cyclic loading (Bayasi and Gebman 2002; Jevtic et al., 2008). These technical benefits can be utilized both in semi-structural elements such as thin sheets, flat sheets, corrugated and cladding panel as well as in load bearing members (Oladele et al., 2008).

The integration of FCCs in housing construction because of their advantageous properties can serve as avenues for providing safe, affordable, environmentally-friendly shelter for the ever increasing world population. It is also a means of converting the abundant waste generated in paper mills / factories to wealth and thus help in cushioning the over-exploitation of dwindling timber resource in many developing countries like Nigeria.

A viable paper cement board cottage industry is currently flourishing within Ibadan, the capital city of Oyo State, Nigeria. These industries utilize waste from paper mills within Ibadan and its environs as raw materials for the production of FCCs. Characterization of these composites in terms of strength and sorption properties will be beneficial to the Nigerian populace who are now utilizing these items in building construction. This work seeks to examine the strength and sorption properties of some selected locally fabricated paper-cement boards within Ibadan metropolis.

2 Materials and Methods

Paper Cement Boards (PCBs) were sourced from four small scale factories in Ibadan, Nigeria, namely: (1) Dele Skylite Nigeria Limited, Apete, Ibadan (2) Mojim Nigeria Enterprises, Abidiodan, Iyana Church, Ibadan (3) Petopeg Ceiling manufacturers, Idito, Sango-Eleyele Road, Ibadan (4) Rasheed Asbestos Nigeria Limited, Iyana Offa, Lagelu, Ibadan. The Materials used by the respective companies for the production of PCBs were carton paper, cement, and water (paper-cement ratio: 50:50); carton paper, newspaper, cement, and water (paper-cement ratio: 60:40); any waste paper, cement, and water (paper-cement ratio: 40:60) and carton paper, cement, and water (paper-cement ratio: 50:50).

The production process entailed soaking of waste papers in cylindrical drums for a period of time depending on the nature of the paper, pulverization of the wet fibre by hammer milling, mixing of the slurry with cement, casting in a mould and curing for 28 days. Close examination of these factories revealed that one out of the four industries (Dele Skylite) engaged in semi-mechanised production process. Also, gypsum and fibreboards were purchased at a local market in Ibadan for comparison with the properties of PCBs.

2.1 Three Point Flexural and Impact Strength Tests

Test samples were cut into 50mm (width) by 150mm (length) and loaded perpendicularly to the direction of casting on a servo-hydraulic Universal Testing Machine (UTM) in accordance with ASTM D 1037-89 (1991). The Modulus of Rupture (MOR) and Modulus of Elasticity (MOE) were thereafter estimated while the Internal bond strength for each test samples was evaluated from the results obtained from the flexural test as follows:

$$\text{Internal Bond Strength} = \frac{Force\ at\ Rupture}{Width\ x\ Length}\ (\text{N/mm}^2)$$

Impact test was based on repeated blows from increasing heights on the flat surface of the boards while noting the minimum height of the ball that caused the failure impact.

2.2 Water Sorption Test

The test specimens were cut into 50mm (width) and 50mm (length) square samples, weighed and thereafter immersed in distilled water at room temperature for 2 hours and 24 hours after which the samples were removed from the water, allowed to drain for a period of about 10 minutes and re-weighed. The percentage water absorption for each test sample was calculated as follows:

$$Water\ Absorbtion\ (\%) = \frac{M_1 - \mathrm{M}_0}{\mathrm{M}_0}\ x\ 100$$

M_1 = Final weight , M_0 = Initial weight

3 Results and Discussion

3.1 Density and Internal Bond Strength

The mean values of the densities and internal bond strength of the locally manufactured cement composites as compared with gypsum and fiberboards are shown in Figures 1 and 2. It was observed that for gypsum and fibreboards the densities had a direct relationship with internal bond strength with mean values ranging between 0.28 and 0.78g/cm^3 and 0.0052 and 0.0102N/mm^2

respectively. The density and internal bond strength of the paper cement boards however seemed to be a function of the composite mix, decreasing as the paper content increases. This agrees with the findings of Moslemi (2008) who found that increasing the quantity

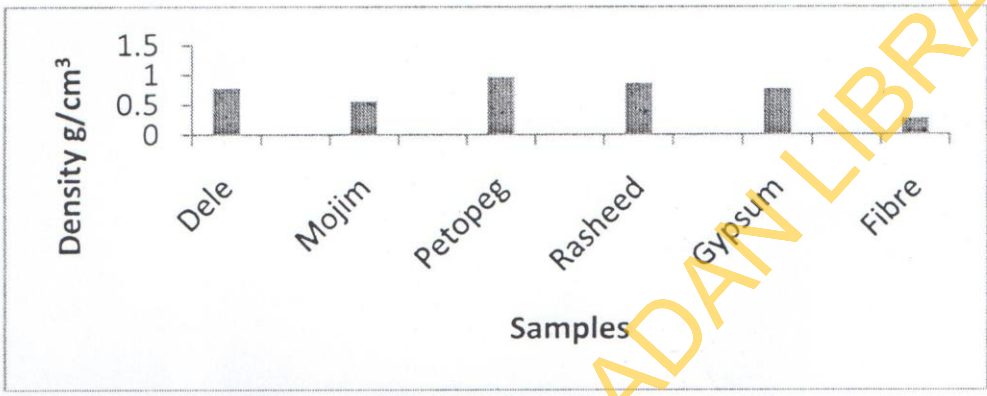

Fig 1: Densities of Selected Ceiling Boards

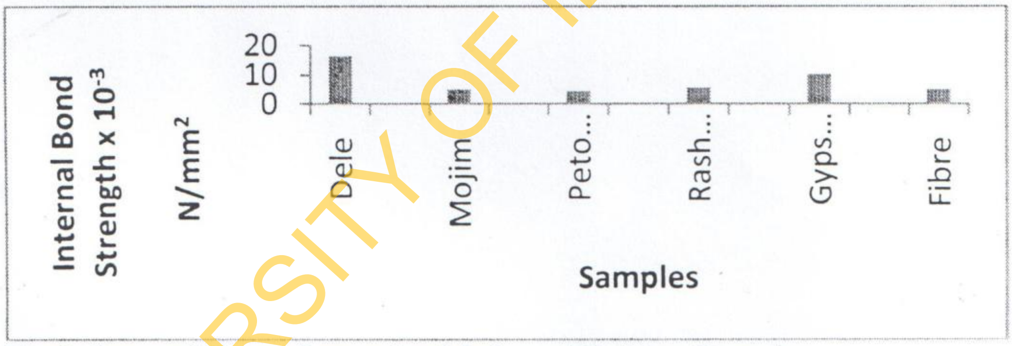

Fig 2: Internal Bond Strength of Selected Ceiling Boards

of fibres in a cement matrix decreases the density of the composites since fibres tend to have lesser density. Also, the pattern of variation in the locally manufactured paper boards revealed an inverse relationship between the density and internal bond strength. The mean densities and internal bond strength were between 0.56 to 0.97g/cm^3 and 0.0046 to 0.0165N/mm^2 respectively.

3.2 Strength Properties

The moduli of ruptures and elasticities (MORs and MOEs) and the impact strength of the paper cement boards as compared to those of fibreboard and

Gypsum board are presented in Table1 and Fig 3. The strength properties of the PCBs are generally low and are only suitable for non-structural applications (Olorunnisola, 2006). As shown, the mean MOR and MOE were

lowest in fibreboard with values of 1.13N/mm^2 and 164.42N/mm^2 respectively while the impact strength was highest with a value of 1.5Nm. This may be due to the fact that fibres increase the absorption of energy under impact load. Boards obtained from Dele skylite exhibited higher strength properties with MOR, MOE and impact strength values of 3.06N/mm^2,

2140.13N/mm^2 and 1.37Nm respectively. This observation is in line with the report of Mohr et al (2004) who noted

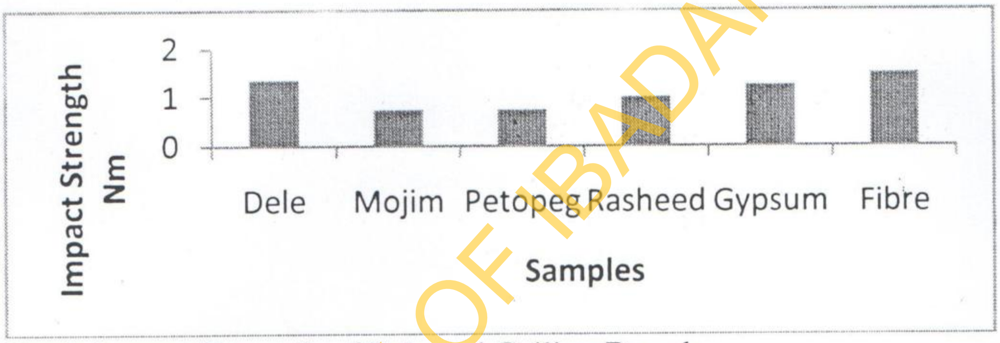

Fig 3: Impact Strength of Selected Ceiling Boards

Table 1: Moduli of Rupture, Elasticity and Water Absorption of Selected Fibre Composites within Ibadan Metropolis

Fibre Composites	MOR (N/mm^2)	MOE (N/mm^2)	WA 2 Hr (%)	WA 24 I (%)
Gypsum	4.8^A	1106.3^B	54.7^{AB}	58.7^A
Fibreboard	1.1^C	164.4^E	25.9^{BC}	69.7^A
Dele Skylite	3.1^B	2140.1^A	43.1^{ABC}	45.3^{AB}
Rasheed	1.6^C	966.8^{CB}	42.2^{ABC}	45.5^{AB}
Mojim	1.4^C	799.7^{CD}	63.5^A	72.4^A
Pentopeg	1.2^C	569.2^D	16.0^C	18.6^B

Means with the same letters are not statistically different

Table 2: Analyses of Variance of Moduli of Rupture and Elasticity and Water Absorption of Selected Fibre Composites within Ibadan Metropolis

Source	Df	Mean Square			
		MOR (N/mm^2)	MOE (N/mm^2)	WA 2 Hr (%)	WA 24 Hr (%)
Fibre Composites	5	6.25*	1335303.59*	931.03	1186.23
Error	12	0.09	18168.25	340.51	420.6

- Significant at 0.05 level of probability

that the properties of fibre cement composites are largely controlled by the manufacturing process. Also, Soroushian and Marikunte (1990) reported that increasing the fibre content increased flexural strength and toughness as well as impact resistance. However, the strength properties of boards from Petopeg factory were the lowest with mean MOR, MOE and impact value of $1.22N/mm^2$, $569.23N/mm^2$, and 0.75Nm respectively. This may be attributed to the poor fibre quality employed in the manufacturing process.

Analysis of variance and Duncan's multiple tests revealed significant differences ($P < 0.05$) in the MORs and MOEs of the tested composites (Table 2). Except for composites obtained from Dele Skylite, the strength properties of products obtained from other factories were not significantly different from each other.

3.3 Water Absorption

The water absorption (WA) values are shown in Table 1. As shown, the paper cement and gypsum boards had high initial WA rate (2 hours) and a subsequently low WA rate after 24 hours. What this implies is that the PCBs are not dimensionally stable and thus are not suitable for exterior applications (Olorunnisola, 2006). This could possibly be due to the presence of air spaces and voids which are quickly filled up as a result of water uptake resulting in subsequent disintegration of the samples. Samples obtained from fibreboard absorbed more water (about 2.5 times) after 24hrs (69.66%) in comparison with results obtained after 2hrs (25.90%). This observation could be possibly due to the absorptive role of fibres.

Boards from Mojim factory had the highest water absorption with a mean value of 63.53% after 2hrs and 72.39% after 24hrs, while boards from

Petopeg factory had the least water absorption with a mean value of 16.03% and 18.5% after 2hrs and 24hrs respectively. This observation is in line with those of Oladele et al. (2009) who noted that increase in fibre content enhances the water sorption of FCCs.
Statistical analyses revealed that the sorption properties of the tested composites were generally not significantly different ($P < 0.05$) from each other (Tables 1 and 2).

4 Conclusions

It can be deduced from this work that:

(i) The paper cement boards manufactured locally were not inferior to the commonly known gypsum and fibreboards in the properties evaluated.

(ii) The paper cement board are only suitable for non-structural application especially in interior applications.

(iii) Processing methods and product mix play significant role in composite performance in terms of strength and sorption properties.

(iv) Paper cement ratio of 50:50 proved to be effective in improving both strength and sorption properties of the boards.

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