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The Mechanical Properties of Ceiling Board Produced from Waste Paper

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Authors' contributions

This work was carried out in collaboration between all authors. Author UEE designed the work, analyzed and interpreted the results. Author ECO collected the literature, carried out the experimental work and wrote the first draft of the manuscript. Authors ASO and ENO analyzed and proofread the article. All authors read and approved the final manuscript.

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ABSTRACT

This work studies the physical properties of ceiling boards produced from waste paper. The ceiling boards were produced using waste paper, fire retardant and cement of varying quantities. The compression of the boards was done using hydraulic press. From the results, it was observed that the ceiling board produced with 100% fiber from waste paper met with the commercial fiber ceiling board standard to about 4/7 of both calculated and measured properties; giving 415kg/m^3 density, 660kpa compressive strength, 809 hardness and 2.5KJ impact strength. The trend of quality of boards produced decreased as follows: 100>70>90>80>60.

Keywords: Waste management; waste paper; recycling paper; mechanical/physical properties; thermal conductivity and resistivity; water absorption; ceiling board.

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1. INTRODUCTION

Waste includes all items that people no longer have any use for, which they either intend to get rid of or have already discarded [1]. Most of these wastes are hazardous both to man and his environment. Majority of these waste emanate from households, commercial activities, and Industries giving rise quantities been produced. Then then the need for proper management is of greater essence in other to prevent the harmful effects of some of these wastes [2].

Paper been an essential commodity in line with its socio-economic importance in the overall development of the country, has its own value, which is directly linked with the industrial and educational growth in the country. This increase in both industrial and education sector development, as well results to increase in demand of paper in the country. With this excessive demand of paper, its abuse is inevitable hence the need of waste paper management. For once a substance or an object has become a waste, it will remain a waste until it has been fully recovered and no longer poses a potential threat to the environment or to human health [3].

Among many methods of *waste management*, recycling and prevention is the best method of waste paper management. *Waste paper* can be recycled into useful materials like fiber boards, paper boards, new paper etc. Paper waste prevention is a practice of reducing or eliminating paper use, so that the potential for paper to be ineffectively used or disposed is prevented [4]. *Recycling paper* is a method of recovering waste paper and remaking them into new paper products. The use of waste paper to produce paper products is a good economics across the world. Recycling of paper is a significant part of the paper manufacturing process in Europe. Monitoring Report 2006 of the Europe Declaration on paper recycling by European Recovered Paper Council (ERPC) has confirmed a high record of paper recycling with a regional rate of 63.4% higher than Asia or America, keeping their target of 66% for 2010.

Fiberboard is a building material composed of wood chips or plant fibers bonded together and compressed into rigid sheets. It is also a type of engineered wood product that is made out of wood fibers. This material is made from a variety of wood products and recycled material. It is commonly made from softwoods like pine, but may also include wood scraps, say dust, cardboard, and paper. This is available in low, medium and high density varieties, though medium density fiberboard (MDF) is most widely used. MDF was first developed in the United State during the 1960s, with production starting in Deposti, New York [5].

Therefore, the utilization of waste paper in *ceiling board* production to a greater extent help in the control of waste and as well provide a cheap ceiling boards for building purposes.

2. MATERIALS AND METHODS [6]

2.1 Materials

Waste papers, sodium hydroxide (NaOH), sodium silicate (Na_2SiO_3), cement, water, kerosene stove, laboratory mesh-sieve, Instron 4260 universal testing machine, charpy impact testing machine – capacity 300J Samuel Benson Limited, Hydraulic Press – serial No. 94030626 Cat C 43/2, Paterson scientific digital balance Sartorius laboratory LC 120003 (MCl), measuring cylinder, stirrer, wooden mold, polyethylene sheet, weighing scale, clean bucket, stop watch, vernier caliper, meter rule, thermometer, scale balance meter.

2.2 Sample Collection

The waste paper collected was mill broke or internal mill waste of classroom writing papers. It was collected personally from two different paper mill printing presses at Onitsha area in Anambra state of Nigeria.

2.3 Sample Preparation

The required amount of the waste paper was cut into smaller size and weighed using a digital weighing balance (Paterson scientific digital balance Sartorius laboratory LC 120003 (MCl) into a metal container. 4M solution of sodium hydroxide (NaOH) which was prepared using a measuring cylinder was added. The mixture was stirred with a stirrer for proper mixing and then boiled on a stove for 6 hours. More water was added as the digestion proceeded. After pulping, the pulp was sieved with mesh sieve and then washed three times to remove all traces of sodium hydroxide. The digest was then soaked in clean water for about 3 hours. At the end of this soaking period, the soaked digest was again sieved and washed several times with clean water to remove the water-soluble sugars and hemicelluloses. The washed and sieved pulped waste paper was sun-dried to remove traces of water in the pulp for 10 minutes. From dried-pulp (deinked), require amount of the fiber was weighed out using the digital weighing balance into a clean bucket containing the required amount of sodium silicate (an additive) and a constant weight of cement, (40g). Water was added into the mixing container for proper mixing of the mixtures. The compositions of mixing proportion are given in Table 1.

After mixing, they were spread in a perforated wooden mold lined with a polyethylene sheet and were sent to the press (Hydraulic Press – serial No. 94030626 Cat C 43/2). This press used for the production was made of metal with top and bottom plates. The extent of the pressing was monitored from the scale balance meter.

It was perforated at the bottom to allow the passage of water out of the slurry through to the outlet.

The pressure was applied manually and the edges of the press were flanged to prevent waste of the slurry. The bottom plate rested on four angled iron stands and the top plate had a relief screw which was used for applying the pressure. After the press, the *ceiling boards* produced was allow to sundry under monitored temperature for two days. Then the boards were measured and trimmed to 600mm^2 area (30L x20W) each using vernier caliper and meter rule.

2.4 Physical Properties Test

These test methods covered some of the physical testing of the waste paper ceiling board produced and they are: compressive strength, impact strength, hardness, water absorption, density, thermal conductivity and resistivity. Machines were used for some properties testing, for instance, charpy impact testing machine for impact strength, instron 4260 universal machine for compressive strength and hardness test.

2.4.1 Compressive strength (CS)

This is the maximum load per cross sectional area of the material. This was done using, Instron 4260 universal testing machine. Its variation with % fiber content is shown in Fig. 1 below.

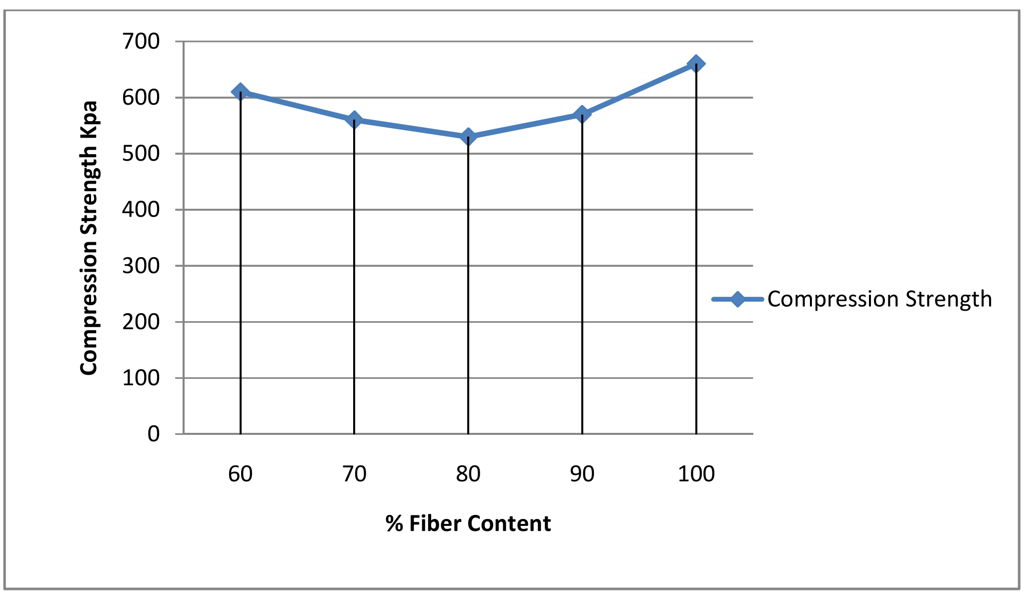

Fig. 1. Compression strength vs % fiber

Table 1. Compositions of mixing

Amount of cement used (G)	Amount of deinked pulp used (G)	Amount of sodium silicate (NA_2SIO_3) used (G)
40	100	0
40	90	10
40	80	20
40	70	30
40	60	40

2.4.2 Impact strength

This measures the amount of energy absorbed by a material during failure. This was carried out using charpy impact testing machine of capacity 300J.Its variation with % fiber content is shown in Fig. 2 below.

2.4.3 Hardness

This was the resistance of a material to penetration of its surface. Rockwell hardness test method was used which consist of indenting the testing materials with a diamond cone indenter [7,8]. Its variation with % fiber content is shown in Fig. 3 below.

2.4.4 Water absorption (WA) [9]

All the samples at the end of soaking in water and before soaking were weighed; the weights were noted (W_2) and (W_1) respectively. Its variation with % fiber content is shown in Fig. 4 below.

$$W.A = \frac{W_2 - W_1}{\text{Area}} \times \frac{100}{1}$$

2.4.5 Thermal conductivity, (TC) (k)

This was the quantity of head (Q) transmitted through a unit thickness (L) in a dimension normal to a surface of Unit Area (A) due to a unit temperature gradient (DT) under steady state conditions and when the heat transfer was dependent only on the temperature gradient. The sample thermal conductivity was determined using the equation:

$$TC = \frac{\text{heat} \times \text{distance}}{\text{Area} \times \text{temperature gradient}}$$

The variation of thermal conductivity and resistivity of the boards with the % fiber content is show in Fig. 5 below

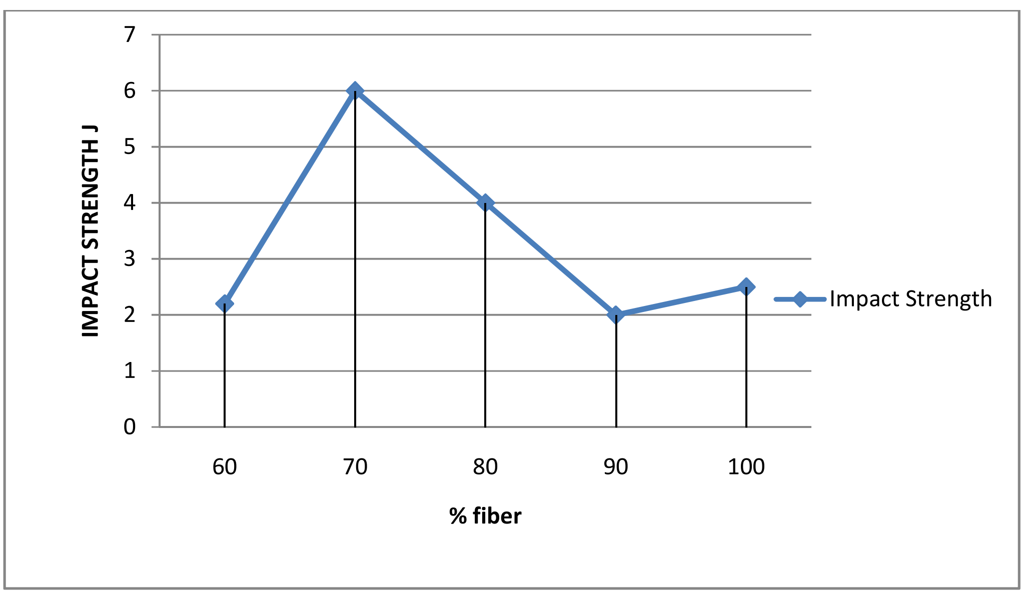

Fig. 2. Impact strength vs % fiber

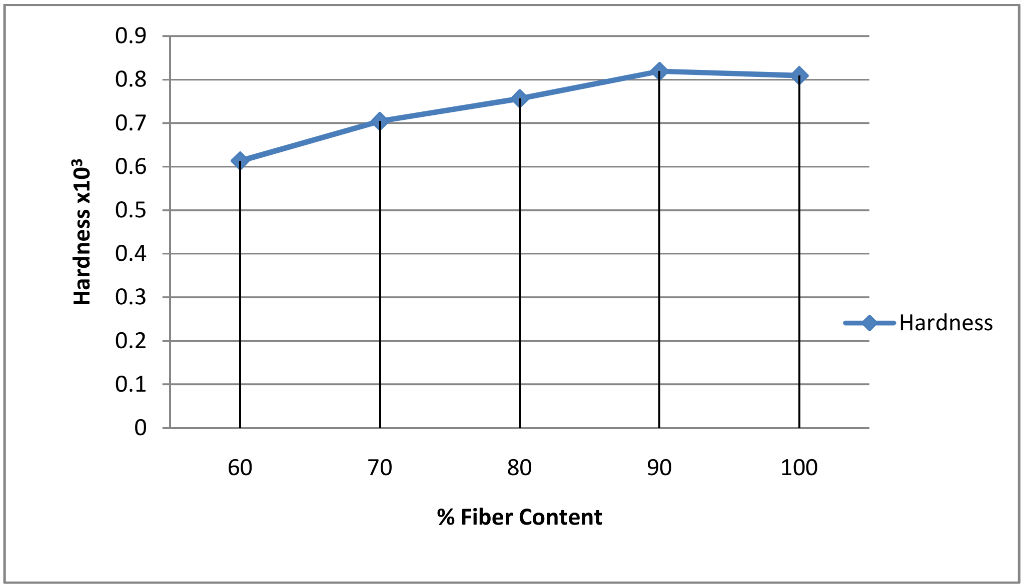

Fig. 3. Hardness vs % fiber

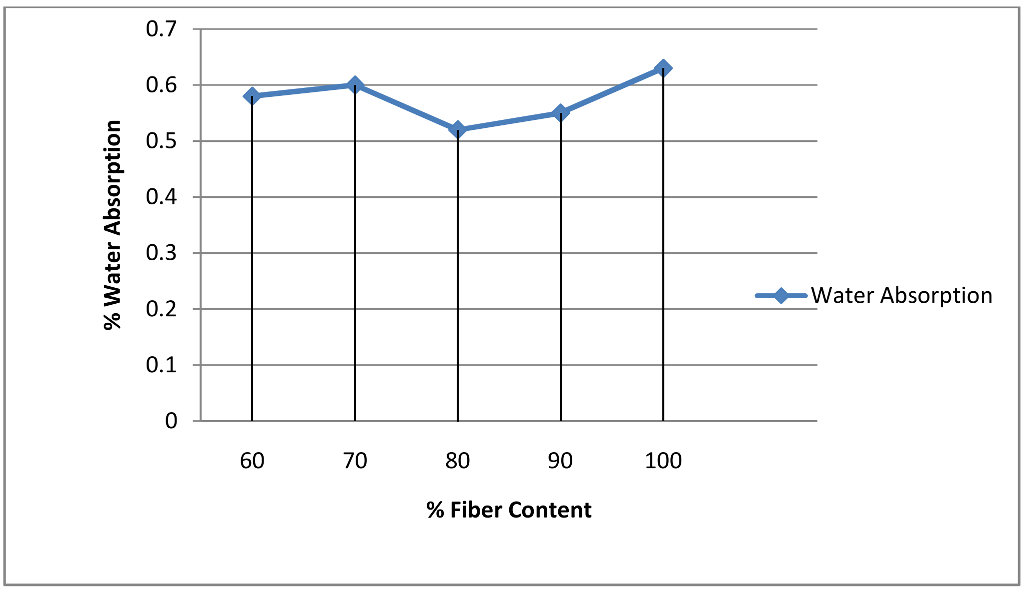

Fig. 4. Water absorption vs % fiber

2.4.6 Thermal resistivity (TR)

This was the reciprocal of thermal conductivity, denoted by Psi with unit of Kelvin-meter per watt.

$\Psi = 1/\kappa$
Ψ = thermal resistivity
κ = thermal conductivity

Table 2 contains the list of Engineering and Material Science standards collected from Standard Organization of Nigeria of which the results gotten were compared.

3. RESULTS AND DISCUSSION

The results of the physical properties determined and mineral fiber ceiling board as standard.

The result of the tests on ceiling boards produced from waste paper as in Table 3 above shows that the increase in percentage fiber

(% pulp) increased the hardness of the board which is the property of a material that enables it to resist plastic deformation, usually by penetration. The compressive strength which is the capacity of a material to withstand axially directed pushing forces was highest at 100% fiber content. From the results also the water absorption increased from 80% fiber – 100% meeting closely the standard value at 100% fiber. The 100% fibre board had a better hardness property than the commercial standard. From the result also the thermal conductivity which depends on the amount of fire retardant added. It increased linearly with the fiber content but decreased linearly as the fire retardant increased. This shows that the value of thermal conductivity depend on the amount of fire retardant additives added. From the Fig. 5 it could be deduced that the amount of fire retardant and percentage of fiber which when incorporated with 40g of cement gave a good conductivity and resistivity was at about 13g and 87% respectively.

Table 2. Engineering and material science standards for ceiling boards

% Fiber	Density (KG/M^3)	Compression strength, cs (KPA)	Impact strength (J)	Hardness × 10^3	Water absorption, WA (%)	Thermal conductivity (W/M.K)	Thermal resistivity (M.K/W)
Standard	350-400	448 – 868	–	0.800	0.64	0.052-0.057	17.5 – 19

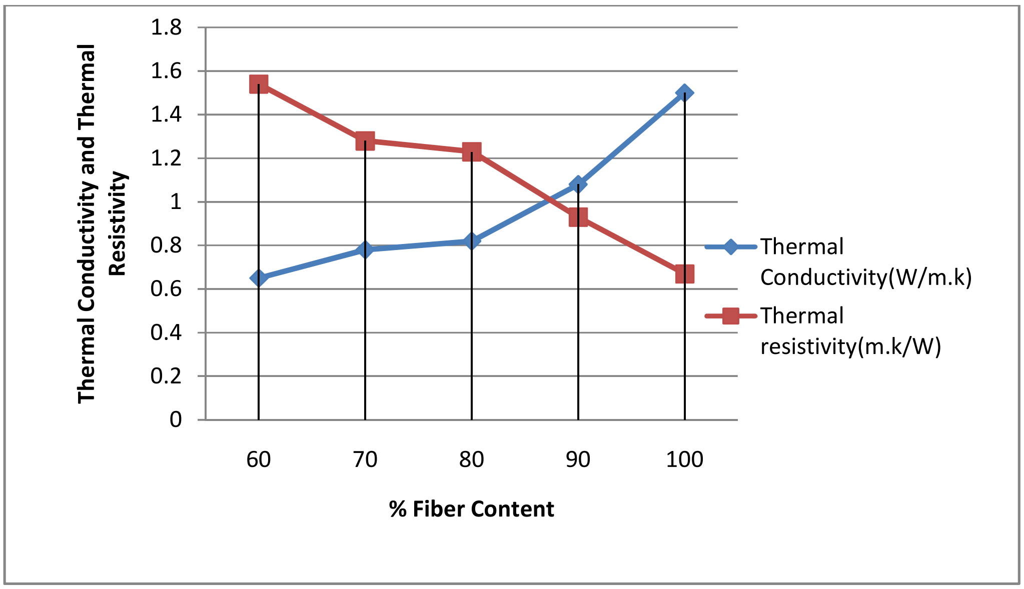

Fig. 5. Thermal resistivity and conductivity vs fiber

Table 3. Result of some physical property tests determined

% Fiber	Density (KG/M^3)	Compression strength, CS (KPA)	Impact strength (J)	hardness × 10^3	Water absorption, WA (%)	Thermal conductivity (W/M.K)	Thermal resistivity (M.K/W)
100	415.0	660	2.5	0.809	0.63	1.50	0.67
90	317.0	570	2.0	0.819	0.55	1.08	0.93
80	505.0	530	4.0	0.756	0.52	0.82	1.23
70	495.0	560	6.0	0.704	0.60	0.78	1.28
60	356.0	610	2.2	0.613	0.58	0.65	1.54
Standard	350-400	448 – 868	–	0.800	0.64	0.052-0.057	17.5 – 19

4. CONCLUSION

From the results of the boards produced from waste paper, it was found that the boards had a good hardness property, compressive strength and a special water resistant property which can find usage in humid areas because of its low value of percentage water absorption. Thermal conductivity and resistivity varied linearly, as it should because of its dependency on the amount of fire retardant been added. The value when compared with the commercial board is much higher and lower respectively. But by increasing the amount of the additive, the board will assume to meet the commercial standard result.

The waste paper which is regarded as a waste can be recycled and be used in an interior roofing decoration as a means of controlling the excessive waste of paper, improving on the health of humans and enhancing economic growth of the country.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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