Original Research Article

Evaluation of Properties of Composite Panels Fabricated Waste Newspaper and Wood Dust for Structural Application

Abstract

In this work, dry forms of waste newspaper pulp, untreated wood dust and treated wood dust were used at varying weight proportions to fabricate composite panels which then served as test samples. With increase in the content of either the untreated wood dust or the treated wood dust in the developed panels, the results showed increase in the mean values of bulk density, thermal conductivity, thermal diffusivity, flexural strength but decrease in the mean values of specific heat capacity and percentage water absorption. Also, at $p < 0.05$, significant differences were revealed in the mean values of bulk density and specific heat capacity between the results obtained for samples with untreated wood dust content and those associated with samples containing the treated wood dust. Again, samples containing the untreated wood dust were found to be better thermal insulators but with lower flexural strength than those of same proportions of the treated wood dust component. From application viewpoint, the findings in this work indicated that the fabricated samples could compete favorably with conventional materials commonly used for thermal insulation in buildings. It is, therefore, obvious that recycling waste newspaper and wood dust into such panels can help to reduce the adverse effect of the waste materials on environment also improve economy by providing building sector with low-cost and environmentally-friendly insulation materials suitable for internal building

Keywords: Alkaline treatment, Bulk density, Flexural strength, Recycling, Specific heat capacity, Thermal conductivity, Thermal diffusivity

1. INTRODUCTION

A composite may be defined as a material that consists of two or more constituents such that its properties are significantly different from those of its components. Whether composite materials are natural or artificial, the individual constituents remain separate and distinct within them. In their research, Ubong et al., 2019 asserted that composite materials posses desired properties and provide a feasible solution to the problem of material selection. For some years now, composite materials have been used in various areas including structural, electronic, environmental, biomedical, thermal, electromechanical applications and so on. The application, however depends on the properties exhibited by a particular composite material.

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Researchers have done a great deal of work in production of composites for engineering applications. In many researches so far conducted, reports have been made on recycling of solid waste into such useful materials. For instance, when applying waste paper as partial replacement of cement in mortar mixes, Zaki et al 2019, observed improvement in the thermal insulation ability of the resulting mortar. Also, it was found by Nourbakhsh and Ashori 2009, that varying wood content in wood-plastic composite could improve flexural strength of the composite material. Again, composite boards developed from reed and wood particles with phenol formaldehyde resin were found to be suitable for use as construction materials in furniture, wall and ceiling paneling, etc. (Hlabano et al 2018).

In this 21st century, the rate of waste generation has been on the increase globally. The famous religious magazine called Awake reported in 1990 that over 400,000 tons of waste were disposed of daily in USA, running into millions of dollars. Reports by Mckinney 1995 have it that approximately 25% to 40% of municipal solid wastes generated globally is made up of paper and paper products. As posited by Callister 2001, generation of solid waste per capita has risen to about 20 tons per year in developing countries. In Nigeria, a study by Ogwueleka 2009 revealed that 25 million tons of municipal solid waste are generated annually and the waste generation rates range from 0.66kg/cap/day in urban areas to 0.44kg/cap/day in rural areas as opposed to 0.7 – 1.8 kg/cap/day in developed countries. Obviously, such wastes include discarded paper materials, wood dust, polythene bags, agricultural wastes among others, and they are common in sight. Due to the problem of effective solid waste management, disposal of the said waste is usually done by burning in open field or dumping in water channels. This practice, no doubt has adverse effect on environment and health. There is need to explore more aspects of recycling so as to curb both the present and pending menace waste accumulation might cause in the nearest future. Thus, this work is designed to recycle waste newspapers and wood dust into composite panel. In order to ascertain the suitability of the developed panel product for structural application, its thermo-mechanical properties will be evaluated.

2. EXPERIMENTATION

2.1 Materials

Sodium hydroxide pellets, waste newspaper (from newspaper vendors), cellophane, discarded wood dust (of wood type called *Edo*, collected from furniture factory), water and epoxy resin with its hardener (K7001) were used as major materials in this work. The epoxy resin was bought from building materials shop. All these materials were sourced in large quantities within Uyo metropolis, Akwa Ibom state, Nigeria.

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2.2 Method

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2.2.1 Processing of the wood dust and waste newspaper

The wood dust was divided into two equal portions. One portion of it was soaked in a freshly prepared 2M solution of sodium and thoroughly washed with water. Also, the waste newspapers were reduced into tiny pieces with the aid of an electrical paper shredder (Rexel V125) and the pieces were immersed in warm water in a plastic bucket. After 18 hours, they were removed from the water and pounded into pulp. The treated wood dust, untreated wood dust and waste newspaper pulp were made to dry completely in air. Figure 1 shows the forms of the materials prior to their use for fabrication of test samples.

Figure 1. Dry forms of (a) Untreated wood dust (b) treated wood dust (c) waste newspaper pulp

2.2.2 Fabrication of samples (composite panels)

In this work, hand lay-up techniques were employed to develop composite panels containing the dry wood dust and waste newspaper pulp. Various weight proportions of the wood dust (untreated as well as treated) and waste newspaper pulp were considered as shown in table 1.

Table 1; Percentage contribution of wood dust and news paper pulp

Comment [aik4]: Table 1 :

Wood dust (%)	0	25	50	75	100
Waste newspaper pulp (%)	100	75	50	25	0

In each case, a 6:5 ratio binder weight to that of the composite mix was adopted. The binder used was a thorough mixture of equal quantities of the epoxy resin and its hardener. During fabrication, casting was done in a 280 mm x 280 mm x 20 mm mold after the inner edge of it had been covered with the cellophane material. Also, a laboratory-made compacting machine was used for compaction at 10kN for 1hour. Then after, the panel was removed and pre-cured in air for 24 hours at room temperature before it was sun-dried to constant weight. The dry panels produced were cut to needed sizes and used as samples for various tests in this work. For each formulation, three samples were developed.

2.3 Samples testing

All the developed samples were subjected to each of the tests performed in this work. In the case of bulk density, the sample mass was measured with an electronic balance (S. METTLER HZ-K600g) and its bulk volume was determined by modified water displacement method (Ubong et al 2019). The data obtained were then used to calculate the sample's bulk density as (Okorie et al 2020)

$$\rho = \frac{m}{V} \qquad 1$$

where m and V are mass and bulk volume, respectively, of the sample.

For evaluation of thermal conductivity of each sample, transient hot plate method was used in an asymmetrical configuration as described by Mbacke et al 2019. Also modified method of mixture and three-point bending technique were applied as decibed by Ubong et al 2019 to determine the specific heat capacity and flexural strength respectively, of each sample. The values of bulk density, thermal conductivity and specific heat capacity obtained for a particular sample were used to compute the corresponding thermal diffusivity of the sampl based on the formula

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$$\lambda = \frac{k}{\rho c} \qquad 2$$

where λ = thermal diffusivity, k = thermal conductivity and c = specific heat capacity

Again, the procedure used by Oladele and Okoro 2015 was adopted to assess the percentage water absorption of each sample after immersion in water for 6 hours. All the tests in this work were performed at room temperature. In each case, the mean and standard error values of the results were computed, tabulated and analyzed.

3. RESULTS AND DISCUSSION

The results of the properties investigated for the developed composite panels (samples) and recorded in table 2. It can be seen from the table that the TWD has the highest mean value of bulk density followed by the UWD and then the NPP. This shows that the NPP is higher than the UWD and alkaline treatment causes enhancement of bonding strength that results in a greater degree of compaction of TWD particles than that of the UWD particles.

Table 2: Statistics of experimental results of the tests performed on the samples.

Comment [aik7]: Table 2.

Composite mix	Mix ratio (%)	Bulk Density, ρ (kgm^{-3})	Thermal conductivity, k (Wm^{-1}K^{-1})	Specific heat capacity, c (Jkg^{-1}K^{-1})	Thermal diffusivity, λ (10^{-8}m^{2}s^{-1})	Water Absorption, WA (%)	Flexural Strength, σ (MPa)
NPP: UWD	100:0	601.72 ± 2.05	0.1209 ± 0.0002	1686.29 ± 1.26	11.91 ± 0.03	41.67 ± 0.17	3.508 ± 0.003
	75:25	611.02 ± 1.76	0.1237 ± 0.0003	1680.45 ± 1.18	12.03 ± 0.02	33.69 ± 0.12	5.348 ± 0.004
	50:50	616.41 ± 1.44	0.1260 ± 0.0003	1678.16 ± 1.01	12.17 ± 0.03	25.79 ± 0.14	7.190 ± 0.002
	25:75	620.98 ± 1.23	0.1289 ± 0.0002	1673.78 ± 1.84	12.39 ± 0.03	17.84 ± 0.10	9.029 ± 0.003
	0:100	628.36 ± 1.04	0.1314 ± 0.0004	1665.94 ± 1.07	12.56 ± 0.02	9.86 ± 0.11	10.879 ± 0.002
NPP: TWD	100:0	601.72 ± 2.05	0.1209 ± 0.0002	1686.29 ± 1.26	11.91 ± 0.03	41.67 ± 0.17	3.508 ± 0.003
	75:25	642.66 ± 2.15	0.1294 ± 0.0004	1628.39 ± 2.50	12.35 ± 0.04	34.81 ± 0.13	6.619 ± 0.002
	50:50	687.52 ± 2.06	0.1388 ± 0.0002	1571.04 ± 2.83	12.84 ± 0.02	28.01 ± 0.08	9.710 ± 0.005
	25:75	726.40 ± 1.94	0.1481 ± 0.0003	1500.81 ± 2.22	13.57 ± 0.04	21.20 ± 0.05	12.803 ± 0.002
	0:100	769.62 ± 1.37	0.1562 ± 0.0003	1441.36 ± 2.71	14.08 ± 0.03	14.29 ± 0.12	15.893 ± 0.004

NPP = Newspaper pulp; UWD = Untreated wood dust; TWD = Treated wood dust

Based on the results as presented in the table, about (22.48 ± 0.28) % and (18.87 ± 0.38) % increase in bulk density and thermal conductivity are observed respectively as a consequence of alkaline treatment of the wood dust. The highest recorded bulk density (769.62 kgm^{-3}) is less than the bulk density values for conventional ceilings like Isorel (898.25 kgm^{-3}) and Plaster of Paris (876.55 kgm^{-3}) reported by Gesa et al 2014. The results of thermal conductivity test show that samples containing the UWD have lower values than their counterparts fabricated with the TWD. This may be due to the fact that the UWD contains more dusty particles and dead air space than the TWD. Since air is a poor conductor of heat, the results mean that the samples developed with the UWD offer higher resistance to heat transmission than those containing the TWD. This is in line with the observed trend in bulk density, thereby indicating that as bulk density increases, thermal conductivity of the samples increases. Notwithstanding the observed differences, the mean values of thermal conductivity of the samples lie between 0.023 $\text{Wm}^{-1}\text{K}^{-1}$ and 2.900 $\text{Wm}^{-1}\text{K}^{-1}$ being the range of values recommended by Twidell and Weir 1990 for good heat insulating and construction materials.

Figure 2 shows the plots of variations of bulk density and thermal conductivity of the samples with various proportions of the wood dust content. It can be observed from the said plots that as the coconut of either the UWD or TWD increases in the samples, the bulk density and thermal conductivity increase as well. It may not be wrong to opine that a sample containing between 0 % and 25 % of the TWD could be similar to the one produced with 75 % content of the UWD, as far as bulk density and thermal conductivity are concerned.

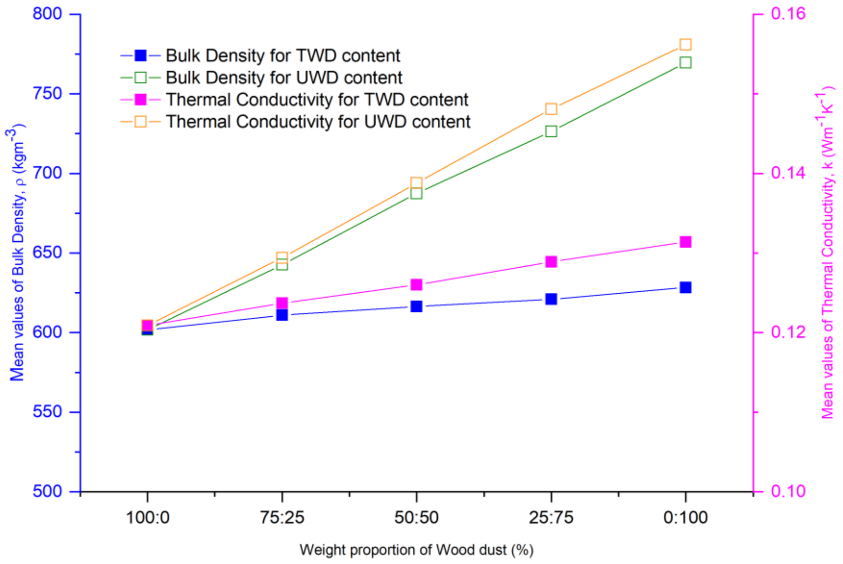

Figure 2. Variations of Bulk Density ad Thermal Conductivity of the samples with proportion of the wood dust

Though the results obtained in this work reveal decrease in mean values of specific heat capacity but increase in the mean values of thermal diffusivity with increasing proportion of either the UWD or TWD in the samples, the use of the TWD yields samples with lower mean values of specific heat capacity and higher mean values of thermal diffusivity compared to the samples developed with the UWD as content of similar proportion. As can be seen in the table, this is possible because the NPP has the highest mean value of specific heat capacity and the value obtained for the TWD is lower than that of the UWD. Such exhibited tendency in the specific heat capacity with respect to the proportion of the wood dust in the samples implies that as the content of either the UWD or TWD increases, less amount of heat is required by the sample to change the temperature of its unit mass by one kelvin. This is clearly manifested in the recorded values of thermal diffusivity showing that the rate at which the absorbed heat spreads within the sample in order to alter its temperature increase with the proportion of the UWD or TWD in it.

More so, the alkaline treatment of the wood dust causes the samples with the TWD content to absorb water more than those containing the UWD of same proportion. This simply indicates the fact that the chemical process involved in the treatment removes water repelling constituents of the wood dust and then makes the resultant particles (treated) to be hydrophilic. However, figure 3 shows that the effect of varying the wood dust content in the samples is opposite to the case with flexural strength. Meanwhile the ability of the samples to withstand bending stress before yielding increases with added proportion of the UWD or TWD whereas their ability to take in water decreases. It can as well be inferred from the figure that with the TWD as component of the samples, greater mean values of flexural strength are obtained compared to the results for samples with the UWD content. Since flexural strength depends on a material’s density, this can be remarked to be due to increase in the bulk density of the samples as a result of the chemical treatment given to the wood dust. The findings on the bulk density of the samples in this work are in good agreement with the reports of Hashim et al 2011, and those in relation to the flexural strength of the samples enjoy full support of the research report by Nourbakhsh and Ashori 2009.

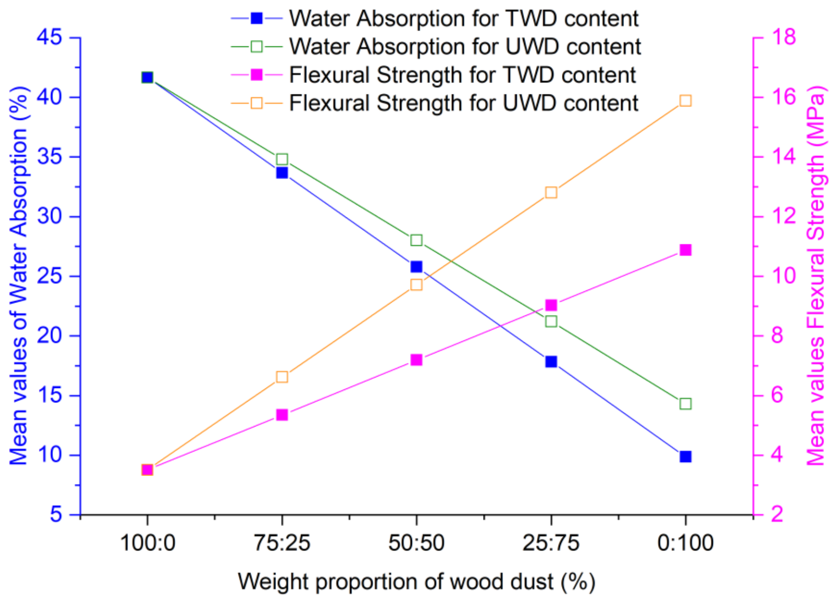

Figure 3: Variation of Water Absorption and Flexural Strength of the samples with proportion of the wood dust

Statistically, one-way analysis of variance performed at $P < 0.05$ reveals that the mean values of bulk density and specific heat capacity obtained for samples with the UWD content are significantly different from those got for samples developed with the TWD as component. Such differences further confirm the influence of the chemical treatment on the properties of the samples examined in this work. Generally, samples containing the UWD have lower mean values of bulk density, thermal conductivity, thermal diffusivity, percentage water absorption and flexural strength but higher mean values of specific heat capacity than those fabricated with the TWD. By considering the values of percentage water absorption obtained in this study the samples can therefore be adjudged to be suitable for use as insulation materials for interior building design. A balance in the investigated properties appears to be exhibited with 75% content of the UWD or 25% proportion of the TWD.

4. Conclusion

Based on the results of the experimental investigation carried out in this work, composite panels containing untreated wood dust were found to be more thermally insulating than their counterparts developed with treated wood dust content. Also, composite panels containing treated wood dust showed improvement in flexural strength over those with untreated wood dust component. Again, bulk density, thermal conductivity and flexural strength were observed to increase with increasing content of untreated or treated wood dust in the panel products. In general, the developed composite panels exhibited properties showing favorable comparison with known conventional materials commonly used for thermal insulation in building design.

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