



Thermal Response and Mechanical Properties of Groundnut Shells' Composite Boards

Nsikak Edet Ekpenyong¹, Sylvester Andrew Ekong¹, Ekong Ufot Nathaniel¹, Jewel Emem Thomas¹, Uduakobong Sunday Okorie¹, Ubong Williams Robert¹, Inyang Anietie Akpabio¹, Nsibiet Uso Ekanem²

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Abstract

Yearly, groundnut shells are generated in vast quantities as waste materials but under-utilised. As a result of inefficient solid waste management system in developing and less-developed countries, their disposal is prevalently done by open burning, unplanned landfilling, and indiscriminate dumping. Any of these practices pose severe adverse effects on environments and public health. This work was designed to devise a way of solving the problem and also get useful materials for building construction. Untreated groundnut shell particles (UGP) and treated groundnut shell particles (TGP) were utilised at 0, 25, 50, 75, and 100 % volumetric levels to fabricate samples. The samples were developed in triplicates and in each case, cassava starch slurry was used as binder at 1:3 ratio to composite mix.

After complete sun-drying of the samples, all of them were subjected to various tests to determine their thermal responses and mechanical properties. Mean increments with increasing fractions of TGP were observed in terms of water absorption (38.55 – 56.95 %), bulk density (716.3 – 770.8 kgm⁻³), thermal conductivity (0.1545 – 0.1742 Wm⁻¹K⁻¹), thermal diffusivity (1.394 – 1.524 x 10⁻⁷ m²s⁻¹), nailability (88.5 – 100.0 %), and flexural strength (1.040 – 2.255 N/mm²). On the contrary, decrements were noticed in the cases of specific heat capacity (1547.3 – 1482.8 Jkg⁻¹K⁻¹), heat penetration time (0.1614 – 0.1476 hr), and solar radiation absorptivity (16.15 – 15.45 m⁻¹) as proportions of TGP increased. It was found that 50 % loading level of TGP could yield sample with the best thermal response and mechanical strength. Generally, the samples exhibited tendencies to perform better than Isorel, asbestos, plaster of Paris, which are widely-used conventional building materials. Hence, utilising groundnut shells as described herein could help to solve their disposal problems and provide suitable

✉Nsikak Ekpenyong: nsikakekpenyong@yahoo.com

¹ Department of Physics, Akwa Ibom State University, Ikot Akpaden, Mkpat Enin, Akwa Ibom State, Nigeria

² Department of Chemistry, College of Education, Afaha Nsit, Nsit Ibom, Awa Ibom State, Nigeria

materials for thermal insulation in buildings.

Keywords: Alkaline treatment; Bulk density; Flexural strength; Thermal conductivity; Heat penetration time; Solar radiation absorptivity

1.0 Introduction

In recent years, interest in research involving development and applications of composite panels has grown greatly. This may be attributed to the fact that such products, as averred by Robert *et al.* (2019a), exhibit improved properties over their distinct components. In this regard, recyclable natural fibres that are discarded as waste materials have been popularly utilised in preference to synthetic or other kinds of fibres. This is because such natural fibres are cheaply available and mostly generated in abundance. Composite insulation panels developed from them are suitable for a number of structural applications depending on their established properties. Reports in previous studies have shown that composite boards made with wood dust/sawdust could be applied as wall partition elements as well as ceilings in building design (Obam, 2012; Saadie, 2016; Hlabano *et al.*, 2018). Also, with the use of rice husk as constituent, composites suitable for application as ceiling (Ataguba, 2016; Guna *et al.*, 2019), partition panels (Shawia *et al.*, 2014; Temitope *et al.*, 2015; Damanhur *et al.*, 2018), in air craft and furniture making (Mohapatra, 2018) can be fabricated. Production of new composite materials that are capable of performing satisfactorily, if applied in buildings, is possible with incorporation of other natural fibres like coconut husks (Robert *et al.*, 2019a), rattan (Oladele and Okoro, 2015), melon seed husks (Robert *et al.*, 2021a), and tiger nut fibres (Okorie *et al.*, 2020) as fractions.

Agriculture is a sector of economy from which significant volumes of wastes are generated yearly and mostly at processing stages of the

produce. One typical crop under this consideration is groundnut (*Arachis hypogaea L.*). This leguminous oilseed crop is grown in more than 100 countries in the world and is commonly referred to as “king of oil seeds” (Robert *et al.*, 2021a). Its yield could amount to 41.3 million tons from 24.6 million hectares with China, India, Nigeria, USA, and Mayaamer leading in the global production (Ajeigbe *et al.*, 2014). The seeds of groundnut are rich in zinc and proteins (Settaluri *et al.*, 2012; Toomer, 2019). This necessitates crushing of around 50 % of the world’s groundnut production into groundnut oil used for cooking and in food products such as butter, chocolate/confectionery, sauces, baked goods, etc (Biswas and Bhattacharjee, 2019; Robert *et al.*, 2021a). During processing to remove the seeds, groundnut shells are extracted and considered as waste materials. These shells can be used for biodiesel production (Udeh, 2018), production of enzyme (Sarika and Aradhana, 2016; Thota *et al.*, 2018), adsorption of heavy metals (Prabha and Udayashankara, 2014; Shruthi and Pavithra, 2018; Sowmya *et al.*, 2018), formation of carbon nano-sheet (Kanokon *et al.*, 2018), and sculpture making (Sakoalia *et al.*, 2019).

It has been observed that due to growing importance and hence, high consumption of groundnut, there is an accompanying increase in its production. This leads to under-utilisation of vast amount of the residues (groundnut shells) generated. Duc *et al.* (2019) noted that groundnut shells account for approximately 20 % of the dried pot by weight, meaning there is a significant amount of shell residual left after groundnut processing. Lagerkvist and Dehlén (2012) posited that generation of solid waste is the inevitable consequence of all processes where materials are used. All these observations give supports to the estimation by World Bank, as noted by Kaza *et al.* (2018), that if the current situation is allowed to persist,

municipal solid wastes will increase by 70 % and likely reach 3.40 billion tons by 2050. Unfortunately, solid wastes management system in developing and less-developed countries is inefficient, thereby giving rise to adoption of unplanned landfilling, open burning, and indiscriminate dumping for disposal of the wastes. These techniques are detrimental to environment and public health. Thus, this work focuses on how to address the existing challenges by valorising groundnut shells for beneficial purposes. Specifically, thermal response and mechanical properties of composite boards fabricated from untreated and treated groundnut shells will be evaluated to ascertain their suitability for use in building design. To the best of the authors' knowledge, there is a dearth of scientific information on such approach for composite formulations.

2.0 Materials and Methods

2.1 Materials

In this research, groundnut shells, cassava effluent, and sodium hydroxide pellets were utilised as the major materials. The groundnut shells were gathered as waste from assorted sources such as dumpsite, open markets, and relaxation centres. Also, the cassava effluent (otherwise called cassava waste water) was obtained from local cassava processing units. These materials were sourced in large quantities within Uyo Local Government, Akwa Ibom State, Nigeria.

2.2 Processing and Analysis of the groundnut shells

The groundnut shells were soaked in water to remove any accompanying impurities from them. After 10 hours, they were removed from the water and allowed to dry before being subjected to pulverisation by means of Agate mortar and pestle. The particles obtained were screened and the quantity that passed standard US sieve having 2mm openings was used in this work. After that, the screened material was

divided into two large portions out of which one portion was treated using 10 % $\frac{w}{v}$ of freshly prepared sodium hydroxide solution. This alkaline treatment was allowed for 8 hours before the particles were removed from the solution and then washed thoroughly in water. Both the treated and untreated particles were sun-dried completely and separately. In each case, the dried material was analysed for particle size distribution by sieving method (Robert *et al.*, 2021b). Also, chemical composition was determined for each using gravimetric method as opined by Ayeni *et al.* (2015). Figure 1 shows the dry forms of the groundnut shell particles after processing.

2.3 Preparation of binder

The binding agent used in this work was cassava starch slurry. In this case, the cassava waste water was put in a plastic bucket and allowed to remain undisturbed for 24 hours. This was followed by decantation to separate the white residue from the liquid. The residue (starch) was dried completely in air. After that, it was mixed with water in the ratio of 3:10 by weight. The mixture was put in an aluminium container and stirred while being heated by means of an electric hotplate. When the heated mixture became gummy, the heating was discontinued and it was allowed to cool prior to its application as the binder in the present work.

2.4 Fabrication of composite samples

This was carried out by hand lay-up technique. In the research design, varying volumetric proportions of the untreated and treated groundnut shell particles were considered for formulation of the composite mixes as shown in Table 1. The ratio of binder to composite mix was maintained at 1:3 (by volume). Samples to be tested for thermal responses were formed in moulds measuring 110 mm in diameter and 8 mm in thickness whereas those to be analysed for mechanical properties were developed in moulds of dimensions 120 mm x 80 mm x 14

mm. For each formulation, three representative samples were fabricated. Prior to casting, the inner surface of each mould was covered with a clean cellophane material so as to ease removal of the developed sample.

With the aid of a laboratory-made compacting machine, the samples were compacted at 5 kN.

After 8 hours, all of them were de-moulded, subjected to continuous sun-drying and weighing until no further reduction in the weight of each of them was noticed, and then used for the tests intended for them.

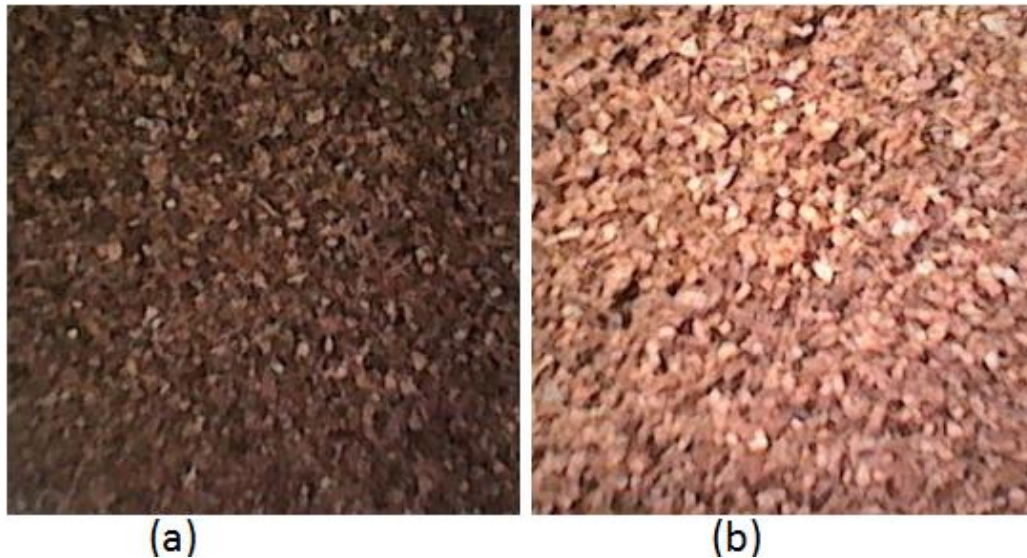


Fig. 1: Dry forms of the groundnut shell particles utilised (a) Untreated (b) Treated

Table 1: Composite mix design

UGP (%)	0	25	50	75	100
TGP (%)	100	75	50	25	0

UGP = Untreated groundnut shell particles; TGP = Treated groundnut shell particles

2.5 Property tests

2.5.1 Water absorption and Bulk density

Assessment of water absorption is necessary since the building materials are likely to get in contact with water from roof leakage or otherwise during their service life. Also, knowledge of bulk density is vital for stress control in building construction. For water absorption test, the samples were cut to reasonable sizes, weighed, and then immersed completely in water initially at 26°C. After 24 hours of immersion, they were removed from the water and placed on a wire-net, allowing

them to surface-dry before their masses were determined again. Using the data obtained, the water absorption in each case was computed according to Etuk *et al.* (2021) in equation 1:

$$WA = \left(\frac{M_f - M_i}{M_i} \right) 100\% \quad (1)$$

where WA = water absorption of the sample, M_i = mass of sample before immersion, and M_f = mass of sample after immersion. In the case of bulk density determination, the mass of dry sample was measured with the aid of a digital weighing balance (S. METTLER – 600g). Also, bulk volume was determined by

Modified water displacement method (Robert *et al.*, 2019b). Based on the conventional formula which several authors including Saadie (2016) and Etuk *et al.* (2018) adopted, the corresponding bulk density value was calculated according to Ekpenyong *et al.* (2022) in equation 2:

$$\rho = \frac{M_s}{V} \quad (2)$$

where ρ = bulk density of the sample, and V = bulk volume of the sample

2.5.2 Thermal conductivity

This property gives information on how well a material could minimise heat transmission across its thickness for a unit rise in temperature when subjected to thermal front. Thermal conductivity was determined for each sample using Modified Lee – Charlton’s Disc Apparatus Technique (Robert *et al.*, 2021c), employing an electric hotplate (Model E4102WH) as the source of heat and cotton wool as lagging material. The discs used were made of nickel and of diameter 110 mm. By means of control dial of the hotplate, the temperature of the disc (in contact with the heating element of the hotplate) was regulated and maintained at about 98°C. After the system had reached a steady state, the temperature – time data for cooling process were obtained. From the function generated by means of Origin software (Version 2019) using the data, the rate of cooling of the disc was determined and the sample’s thermal conductivity value was computed based on the formula:

$$k = \left(\frac{Mcx}{A\Delta\theta} \right) \frac{dT}{dt} \quad (3)$$

where k = thermal conductivity value of the sample, M = mass of the disc, c = specific heat capacity of the disc, x = sample’s thickness, A = cross-sectional area of the sample, $\Delta\theta$ = temperature difference across the sample’s thickness at steady state, and $\frac{dT}{dt}$ = rate of

cooling of the disc.

2.5.3 Specific heat capacity

This property is concerned with the quantity of heat a unit mass of a material requires before a unit change in its temperature is possible. With the aid of SEUR’S Apparatus, specific heat capacity was investigated for each of the samples as detailed elsewhere by Etuk *et al.* (2020). In this research, the plate of sample under test was used alongside aluminium plate and plywood plate (each of which was 8 mm thick, measuring 60 mm x 60 mm) as heat exchange accessories. Three digital and identical thermometers (Model No. 305, calibrated and equipped with type-K probe) were used to monitor/measure temperature of the plates until the system attained thermal equilibrium. At that instant, the amount, Q_a of heat lost by the aluminium plate and the quantity, Q_p of heat gained by the plywood plate were computed. The data obtained were applied to calculate the specific heat capacity, C of the sample in accordance with the relation:

$$C = \left(\frac{Q_a - Q_p}{M_s \Delta T} \right) \quad (4)$$

where ΔT = rise in temperature of the sample under test.

2.5.4 Thermal diffusivity, Heat penetration time, and Solar radiation absorptivity

These thermal transport properties respectively express how well a material can function as a thermal diffuser, the duration for which the absorbed heat will diffuse through its thickness, and tendency for the material to retain the thermal energy incident on it so as to prolong the equilibrium condition of the system in which it is used. Using the bulk density, thermal conductivity, and specific heat capacity values already obtained in each case, the corresponding thermal diffusivity was determined by calculation as (Akpabio *et al.*,

2010; George *et al.*, 2010; Nathaniel *et al.*, 2020; Etuk *et al.*, 2021, 2022):

$$\lambda = \frac{k}{\rho c} \quad (5)$$

where λ = thermal diffusivity of the sample. Also, heat penetration time, t was computed as (Robert *et al.*, 2021d):

$$t = \frac{x^2}{\lambda} \quad (6)$$

The thermal diffusivity value of the sample was then used to calculate solar radiation absorptivity, α_r on a 24-hour periodic basis as (Robert *et al.*, 2021e):

$$\alpha_r = \sqrt{\left(\frac{\pi}{\lambda T_p}\right)} \quad (7)$$

where T_p = periodic time

2.5.5 Nailability

This test helps to provide information on the feasibility of nailing a non-metallic material as a way of joining it to others applied in building or other forms of construction. It was performed by means of an electric hammer known as Finish Nailer (Model D51257K, manufactured by Dewalt). In the design of this nail gun, the hammering force is generated by ordinary springs as the motor rotates two drive axles. Performance of each hammering operation was carried out slowly and methodically with a 2"- nail fired through the thickness of a sample. When either a tiny visible crack was noticed or the nail tip appeared on the opposite side of the sample, the process was discontinued. Except the nail penetrated successfully (in which case, its penetration depth was considered to be the same as thickness of the sample under investigation), the depth of nail penetration was determined as the difference between the overall length of the nail and the length of the nail's portion remaining. The data gathered were used to compute nailability according to

Okorie *et al.* (2020)

$$n_b = \left(\frac{h}{x}\right)100\% \quad (8)$$

where n_b = nailability, h = depth of nail penetration in the sample, and x = sample's thickness

2.5.6 Flexural strength

Ceiling or wall partition panels are unavoidably subjected to stresses that tend to bend them during service; hence, the need for this test. With the aid of Computerised Electro-mechanical Universal Testing Machine (WDW-10), data for determination of flexural strength of each sample were gathered. During each test schedule, three-point bending method was employed in accordance with the standard procedure outlined in ASTM D790 (2017). The sample to be tested was placed on the flexure assembly of the machine and then loaded at the middle of the support span using a test speed of 5.0 mm/min. When the sample failed flexurally, the maximum value of load applied was noted. The flexural strength of the sample was then determined thus

$$f_s = \frac{3FL}{2bx^2} \quad (9)$$

2.5.7 Statistical analysis

Values obtained from the triplicate determinations per formulation of the samples were expressed as mean with standard error in each case of the properties investigated. The results were then tabulated. All the measurements/tests were carried out at room temperature with ± 1.0 °C variations and 53.0 % relative humidity. The mean and corresponding standard error values were calculated and tabulated for each formulation of the developed samples.

3.0 Results and Discussion

The results of chemical analysis performed to investigate the proportions of various lignocellulosic constituents in the UGP and

TGP are presented in Table 2. As can be seen, the two categories of fibres (UGP and TGP) differ in their chemical compositions. This indicates that, behaviourally, they are dissimilar due to the alkaline treatment applied to obtain the TGP. Whereas the proportions of hemicelluloses and lignin are less, the

percentage of cellulose is greater for TGP compared to those of UGP. This is possible because alkaline treatment of fibres usually brings about increase in cellulose content as submitted in other reported studies (Valadez-Gonzalez *et al.*, 1999; Rahman and Khan, 2007).

Table 2: Chemical compositions of the groundnut shell particles

Processed material	Proportion of each lignocellulosic constituent present (%)		
	Cellulose	Hemicelluloses	Lignin
UGP	36.89	27.03	19.61
TGP	45.74	23.52	12.69

In Table 3, the results of tests conducted on the samples are presented. The water absorption of sample prepared with 100 % TGP content is greater than that of the sample similarly developed but with UGP. This, plausibly, is because there is more cellulose but less lignin in TGP than UGP. Meanwhile, cellulose is less water-resistive compared to lignin and though natural fibres have high tendency for water absorption, the levels of lignocellulosic components (cellulose, hemicelluloses, and lignin) are significant determinants of water - absorbing ability of the samples developed from them under same conditions. The maximum mean water absorption value (56.95 %) obtained in this study is far less than the values (100 to 154 %) reported by Tangjuank and Kumfu (2011) for a ceiling board made from Papyrus fibres.

Sample containing 100 % of TGP is found to be denser than its counterpart developed with the UGP by a difference of about 54.5 kgm^{-3} in their bulk densities. This is because the percentage of finer components is greater in UGP compared to TGP as revealed in figure 2.

As the sieve opening becomes smaller in diameter, more quantity of UGP than TGP passes, thus signifying that the number of finer particles in the untreated fibre exceeds the amount in the treated fibre. By increasing the loading level of TGP from 0 % to 25 %, 50 %, and 75 % in the composite mix, the mean bulk density of the resulting samples increases by 2.30 %, 3.42 %, and 5.99 % respectively. The highest mean bulk density value (770.8 kgm^{-3}) obtained for the samples is less than those reported as 1492.8 kgm^{-3} and 1810 kgm^{-3} for conventional ceilings like plaster of Paris (George *et al.*, 2010) and asbestos (Oyekunle, 2018) respectively. This is indicative of the fact that if the samples are applied as ceilings in building design, there could be better reduction in dead loads compared to when the above-mentioned conventional ceilings are used. Comparatively, thermal conductivity of the sample made with 100 % content of TGP is higher than that of sample developed by utilising UGP at similar level. This may be attributed to dissimilarity in the percentages of fineness between UGP and TGP caused by the alkaline treatment applied.

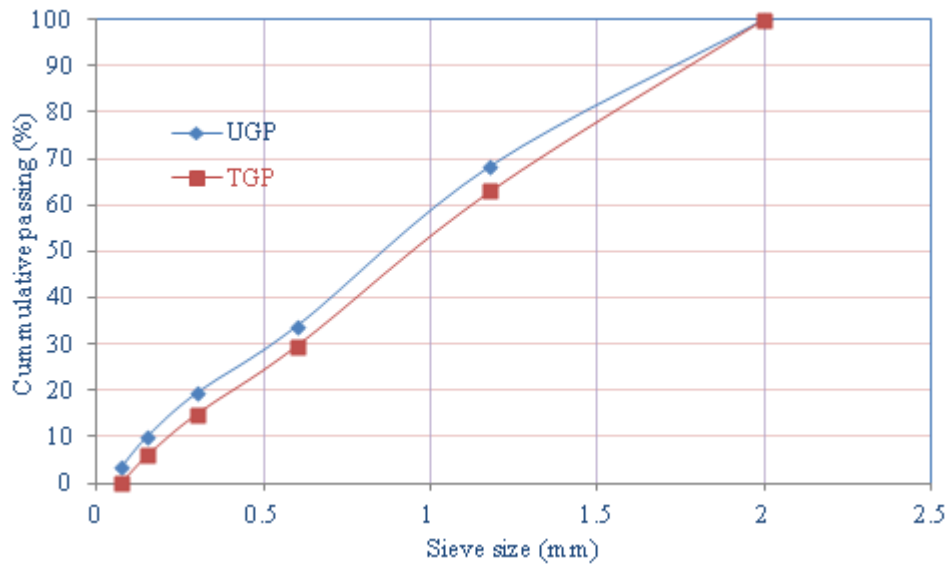


Fig. 2: Particle size distribution curves for the groundnut shell particles

Stating in other words, the presence of finer particles enhances existence of a larger number of interstices in UGP compared to the case of TGP. It is noteworthy that all the samples are porous, completely dry, of same dimensions, and were compressed under same conditions. Thus, the interstices are filled with air and consequently, air volume in them correlates with the number of interstices present in each sample. Since air is a very poor thermal conductor, utilisation of UGP yields a sample that has larger volume of air/number of interstices, thereby resulting to a lower thermal conductivity than in the case of making use of the TGP. However, the studied samples have thermal conductivity values that fall within the range recommended by Rajput (2015) as 0.023 to $2.900 \text{ Wm}^{-1}\text{K}^{-1}$ for heat-insulating and construction materials. Research reports have shown that convectional ceilings like Isorel, asbestos, and plaster of Paris have thermal conductivities of $0.4498 \text{ Wm}^{-1}\text{K}^{-1}$ (Gesa *et al.*, 2014), $0.2261 \text{ Wm}^{-1}\text{K}^{-1}$ and $0.3171 \text{ Wm}^{-1}\text{K}^{-1}$ (George *et al.*, 2010) respectively. On the basis of such reports, it can be adjudged that the samples are capable of ensuring a better thermal insulation in buildings in order to

enhance thermal comfort for occupants.

The specific heat capacity test reveals that incorporation of TGP can enable a faster unit increase in temperature compared to the case of utilising UGP for a kilogramme mass of the sample. Increase at 25 % loading levels of TGP causes specific heat capacity to decrease by about 0.95 %, 2.27 %, 3.17 % and 4.17 %. This also supports the assertion above that a better thermal insulation tendency of the samples is possible with UGP compared to the use of TGP. Consequently, as the content of TGP increases in the composite mix, thermal diffusivity increases. This is because the sample becomes less thermally-insulating, thus enhancing fast heat diffusion and temperature propagation within the samples. The fact of the matter here is that, as fraction of TGP increases, the resulting sample becomes more conductive and so, less able to delay temperature rise thus giving rise to fast spread of the absorbed heat.

Figure 3 depicts variation in thermal conductivity and thermal diffusivity with proportions of TGP. This, accordingly, leads to heat penetration time decrease with increasing content of TGP in the composites. It could be

submitted that thermal insulation performance improves as heat penetration time is prolonged. In this case, it is suggestive that since the penetration depth is same as thickness of the panel and heat penetration time depends directly on it as a factor, the highest duration obtained in this study could be improved by increasing thickness of the samples (assuming other parameters like bulk density, thermal conductivity, and specific heat capacity are unaltered). Similarly, solar radiation absorptivity becomes greater with increasing UGP content than in the case of TGP. Empirically, eq. 7 gives credence to the fact that solar radiation absorptivity relates inversely with thermal diffusivity. Furthermore, the 100 % nailability obtained by utilising at least 50 % of TGP in the composite mix means that the resulting samples can be successfully nailed to suitable materials in the course of their application. The failure of those produced with less percentages of TGP may be due to the concentration of the binder used. Understandably, how viscous/gummy a binder is has significant influence on the bonding strength that controls fibre adhesion in the composite mix. For instance, Robert *et al.* (2021a) developed panels with Topbond as binder and observed 100 % nailability for all the samples. This, however, was not the case when Okorie *et al.* (2020) applied 10 % $\frac{w}{v}$ cassava starch slurry as binder at 0.8 % ratio to fabricate composite boards containing waste carton paste and tiger nut fibre. In their study, they found that 100 % nailability was achievable only when tiger nut fibre was incorporated up to at most 12.8 % into the composite mix. These observations further lend credence to the fact that adhesive (binder) type has a remarkable influence on mechanical adhesion panels (Özcan *et al.*, 2013; Bal, 2017).

Hence, it is one of the determining factors of internal bond strength of such materials as reported in some studies. For example, Damanhuri *et al.* (2018) observed that bonding strength of particleboard is greater with the use of wood glue compared to when corn starch is used as binder. Also, Kowaluk and Fuczek (2009) noticed that particleboards produced with polyvinyl acetate have lower bonding strength than those prepared by utilising urea-formaldehyde as binding agent. According to Iswanto *et al.* (2018), particleboard made from sorghum bagasse has lower internal bond strength with urea-formaldehyde as binder than in the case of using isocyanat.

In buildings, ceilings are usually exposed to stresses that tend to bend them. For the studied samples, TGP enhances stronger interfacial adhesion in the composites. As such, both nailability and flexural strength increase with increasing percentages of the TGP (Figure 4). Because the surfaces of TGP are rougher than those of UGP, the internal bond strength varies positively with the loadings of TGP. Beyond 25 % TGP content level, a sharp bend is observed in the nailability of the samples. This signifies that fibre adhesion in the matrix is significantly strong. Also, at 50 % loading level of TGP, a slight change in flexural strength is noted in which case, the strength increases sharply. By comparing with flexural strengths of other boards such as 0.263 N/mm² for sugarcane board (Etuk *et al.*, 2021) and 0.573 N/mm² for coconut leaflet board (Robert *et al.*, 2021d), it means that the samples could perform more satisfactorily either as wall partition materials or ceiling boards.

Table 3: Results of property tests performed on the Samples

Composite mix (%) UGP:TGP	Water absorption, WA (%)	Bulk density, ρ (kgm^{-3})	Thermal conductivity, k ($Wm^{-1}K^{-1}$)	Specific heat capacity, C ($Jkg^{-1}K^{-1}$)	Thermal diffusivity, λ ($10^{-7}m^2s^{-1}$)	Heat penetration time, t (Hrs)	Solar radiation absorptivity, α_r (m^{-1})	Nailability, n_b (%)	Flexural strength, f_s (N/mm^2)
	38.55	716.3	0.1545	1547.3	1.394	0.1614	16.15	88.5	1.040
100:0	± 0.08	± 0.7	± 0.0003	± 0.3	± 0.001	± 0.0001	± 0.01	± 0.2	± 0.002
	41.76	732.8	0.1580	1532.6	1.407	0.1599	16.08	99.8	1.314
75:25	± 0.06	± 0.6	± 0.0002	± 0.2	± 0.001	± 0.0001	± 0.01	± 0.1	± 0.003
	49.19	740.8	0.1639	1512.2	1.463	0.1538	15.77	100.0	1.594
50:50	± 0.05	± 0.3	± 0.0002	± 0.3	± 0.002	± 0.0002	± 0.01	± 0.0	± 0.002
	53.36	759.2	0.1708	1498.2	1.502	0.1498	15.56	100.0	1.944
25:75	± 0.07	± 0.3	± 0.0003	± 0.3	± 0.002	± 0.0002	± 0.01	± 0.0	± 0.003
	56.95	770.8	0.1742	1482.8	1.524	0.1476	15.45	100.0	2.255
0:100	± 0.08	± 0.2	± 0.0002	± 0.2	± 0.001	± 0.0001	± 0.01	± 0.0	± 0.002

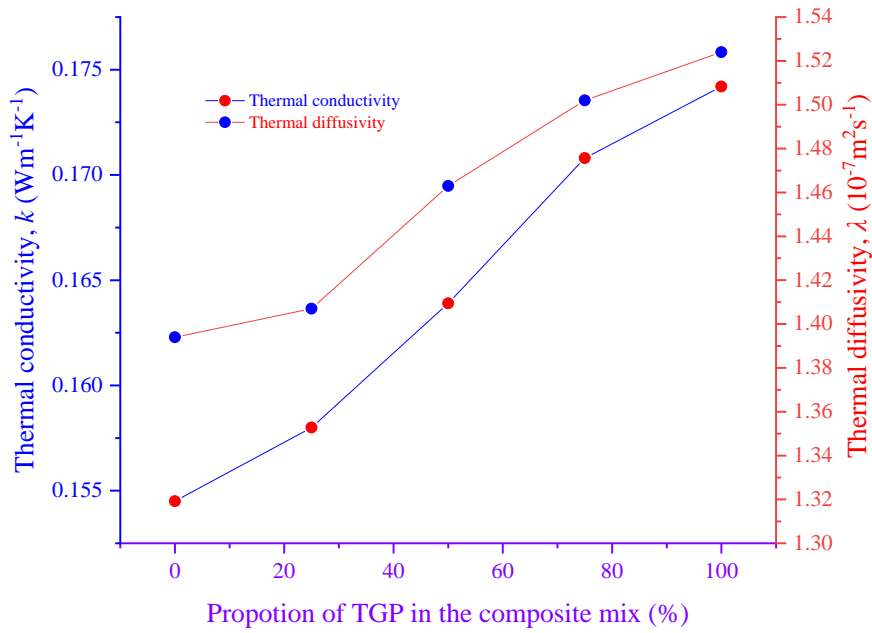


Fig. 3: Trends of thermal conductivity and thermal diffusivity with proportion of TGP

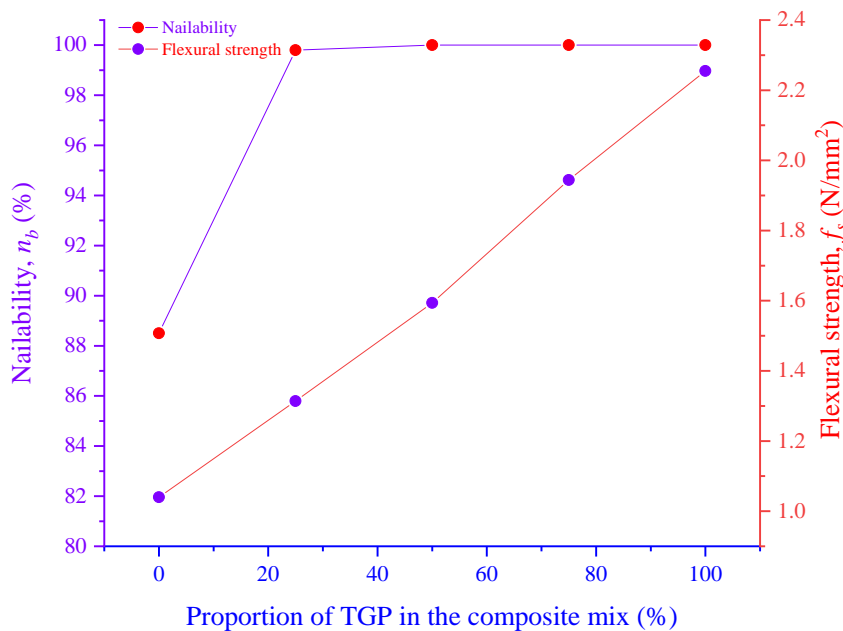


Fig. 4: Trends of thermal conductivity and thermal diffusivity with proportion of TGP

4.0 Conclusion

It has been revealed from this study that value-added composite panels could be successfully developed using untreated groundnut shell particles (UGP) and treated groundnut shell

particles (TGP). Whereas increase in UGP content could enhance improved thermal insulation performance, it was found that utilisation of more TGP favoured improvement in nailability and flexural strength of the

studied samples. However, the optimum level of TGP incorporation for a balanced performance in terms of thermal response and strength was found to be 50 %. Comparatively, the samples exhibited better thermal insulation tendencies than conventional ceilings such as asbestos, and plaster of Paris, as well as wall partition material like Isorel. Interestingly, the samples are lighter and so, applying them in building design could enhance reduction in dead loads. Hence, putting groundnut shells into production cycle could serve as a scientifically-safe way of solving the associated disposal problems while availing building industry with promising raw materials for development of thermal insulation materials suitable for structural applications.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

Not applicable

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