NIPES-Journal of Science and Technology, Research Vol. 7, Special Issue: Landmark University International Conference SEB4SDG 2025, pp. 2466–2471

NIPES - Journal of Science and Technology Research
www.nipes.org

Strength Characteristics of Developed Brake Pad Composites from Shells and Broken Ceramics

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Abstract— The use of asbestos based material for producing brake pad have been found to pose health challenges to user. Agro-based composites depict a viable alternative that is biodegradable and sustainable. In this investigation, eco-friendly brake pad was produced from agro-based feedstocks and ceramic for frictional applications. These materials were processed following established standards. Hammer mill was used for feedstock size reduction with sieve size 1.25 nm for enhanced binding and homogeneity. Formaldehyde (CH_2O_2) was used as a binder while calciumchloridedihydrate ($CaCl_2H_2O$) serves as hardener. The density, water absorption and hardness of the formed samples was analyzed for their strength characteristics. This was used to affirm the best and least of the produced brake pad composites. The study show that increase in the quantity of seashells lead to the production of more denser composites with moderate water absorption rate and relatively uniformly high hardness.

Keywords— Composite brake pad, broken ceramics, waste management and recycling, mix ratio, strength properties.

https://doi.org/10.37933/nipes/7.4.2025.SI291
eISSN-2682-5821| pISSN-2734-2352

I. Introduction

The rapid increase in population, accompanied by a heightened demand for agricultural goods, has led to a substantial increase in the accumulation of agricultural wastes [1]. This surge presents a considerable challenge for farmers in effectively managing, handling, and disposing of these wastes [2,3]. In the context of Nigerian agriculture, these residues typically lack commercial or economic value, posing a significant environmental threat [4,5]. However, there has been several ongoing studies on how these wastes can be exploited [6,7]. These wastes encompass organic compounds derived from both living and deceased plants and animals. Prominient agrowastes that have been used for notable products include snail shells, oyster shells, periwinkle shells, rice husks, straw, oil palm shells, coconut shells, sugarcane bagasse, maize cobs, and husks, groundnut shells, among others [8,9,10]. Conversely, ceramics of every form are non-biodegradable and their improper disposal pose as major environmental pollutant. Recycling them represent wise steps toward valuable products development and sustainability of the eco-system. Ceramic wastes are mostly forms of domestic wastes which includes broken bottles, ceramic plates, floor tiles, kitchen and sanitary wares. Proper wastes disposal has often been a challenge thereby constituting nuisance to the environment. These ceramic materials are known for their strength and biocompatibility [11]. The conversion of these agricultural residues aloong broken ceramic into industrial consumables, such as sandpaper and other tribological products hold significance due to the role of abrasive machining in the manufacturing and industrial sectors of the economy [2, 12]. Throughout history, the development of novel materials stands out as one of humanity's most significant accomplishments, playing a pivotal role in driving progress, prosperity, security, and overall well-being [13]. The development of new materials is the driving force of innovation across numerous fields, such as civil, chemical, construction, nuclear, aeronautical, agricultural, mechanical, biomedical, and electrical engineering [11, 14- 17].

Brake pad represent factor of safety and efficient control in automotive engineering, a major component of vehicle braking system. Due to the stringent working environment, brake pad materials must exhibit characteristics suited for the dynamics of the automotive engineering. Composites are engineered materials with distinct characteristics and superiority than the individual components. Their popularity is anchored on properties such as high strength-to-weight ratio, corrosion and chemical resistance, durability and fatigue resistance, tailored properties, thermal and electrical insulation, vibration damping, among others [11,18]. With their different physical, chemical, and mechanical properties, composites are produced to meet specific requirements for specific purposes. Their applications have cut across the various spheres of human endeavours [11, 19 -21].

Salawu [22] reported on discarded shells which constitute solid waste from restaurants, eateries, or snail vendors, pose a significant hazard to the environment with minimal economic value, often abandoned haphazardly following the extraction of edible meat. Therefore, the effective [23] utilization of these shells holds the potential for substantial economic gains [(Popović et al., 2023). This study address the industry demand for asbestos-free, outstanding-performance brake pad materials that prioritize safety, durability, and environmental conservation. Using shells and ceramics, which are considered waste, is an eco-friendly solutions towards sustainability .

II. MATERIALS AND METHODS

A. Experimental Materials and Equipment

The base materials used for the production of the composite brake pad were sourced locally. The materials used for the production of brake pad are periwinkle shells, snail shell, palm kernel shells, Ceramic, Calcuimchloridedyhdrate, and Formaldehyde as displayed in Figure 1(a), (b), (c), (d), (e), and (f) respectively. The ceramic wastes were sourced from the Landmark University community consisting mainly of broken tiles. The palm kernel shell was obtained from Ilofa in Oke Ero Local Government Area of Kwara State. Similarly, the periwinkle shells were obtained from Delta State, while the Snail shells were picked from Agbetu, Odeda Local Government Area of Ogun State. The main equipment used are hammer mill, weighing balance, set of sieves, mechanical mixer, mold, L.A. abrasion machine, head pan, hand trowel and water trough.

Figure 1: (a) Periwinkle Shells (b) Snail shells (c) Palm kernel Shells (PKS) (d) Ceramic, (e) Calcuimchloridedyhdrate, (f) Formaldehyde

B. Experimental Procedures and Research Conceptual Framework

The experimental processes followed feedstocks sourcing to raw materials preparation, mold development, sample formulation and strength characteristics testing (Figure 2). The palm kernel shell was milled using a laboratory hammer mill (Armfield FT2-A Hammer mill, 230 V, 50 Hz). The ground sample was sieved with IS 10 sieve size to obtain the needed particle size [24]. The broken tiles were mill at the structure laboratory of the Civil Engineering Department, Landmark University. The mold was designed to meet the configuration of the conventional brake pad and constructed from hard wood (Figure 3). The materials was cleaned to remove all form of debris and dirts after which it was dried under sunlight for 30 mins and 60 mins and in oven for 1 hour and 5 hours at 100°C for snail shell and periwinkle shell respectively. Hammer mill with sieve size 1.25 µm was used to mill the materials. Using volumetric method, the materials were measured and mixed till properly homogenized then poured into the mold of size 160 by 40 mm removing excess from the edge. It was compressed with hydraulic press of force of 294kN for holding time of fifteen minutes and left to air dry for 48 hours after which curing was done for 60 minutes at 150ºC in an electric oven .

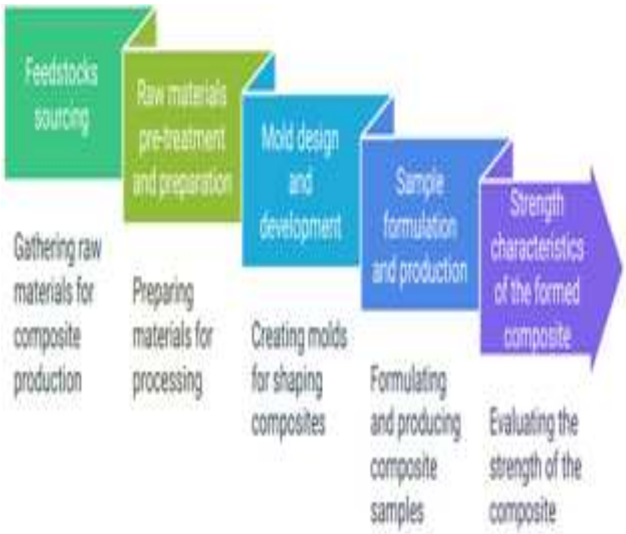

Figure 2: Experimental flowchart for composite formation

C. Experimental Mix Ratio and Sample Formulation

Variations in the different materials were done to pick the one that seems fit for asbestos brake pad replacement. The mix ratio was however determined using Design Expert version 13. Based on the mix ratio (Table 1), the raw materials were measured out into a head pan and poured into a mechanical mixer having stirrer and heating bands. This process permit the homogeneous mixing of the specimen along with the melting operation [6]. The already fabricated wooden mold was oiled and the mixture was poured into it. This was allowed to settle and spread out into the mold with the aid of a wooden stick. The component was allowed to set for 24 hrs before gently removed from the mold compartment. The experiment was carried out in three replicates to minimize random error in specimen analysis.

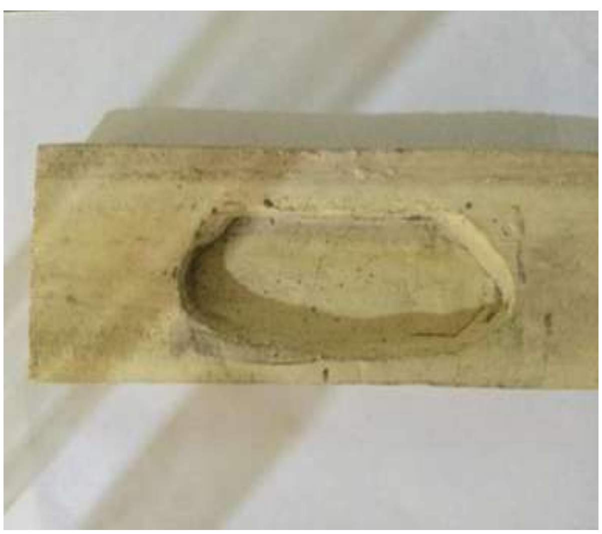

Figure 3: Experimental Mold for sample Formation

Table 1: Experimental mix ratio for composite formation

	ix	Periwinkl	Snail	Palm K	Broken	inder	otal
.	PSPC-1	44.80	28.00	25.20	14.00	28.00	140.00
.	PSPC-2	44.80	28.00	22.40	16.80	28.00	140.00
.	PSPC-3	50.40	25.20	25.20	14.00	25.00	140.00
.	PSPC-4	50.40	25.20	22.40	16.80	25.20	140.00
.	PSPC-5	56.00	22.40	25.20	14.00	22.40	140.00

Where: PSPC represents Periwinkle, Snail shell, Palm kernel, Ceramic respectively

D. Some Physical and Mechanical Properties Determination

Density: The density of the developed brake pad was determined using Archimedes principle used to calculate the volume and density by measuring the mass in air and volume when submerged to water. Density represents the mass per unit volume, expressed using Equation (1). Due to the irregularity of the sample shape, using Archimedes principle suit the determination of the density (Figure 3). This test allows us to determine if the sample would flow in air or sink in water. It is an important parameter in brake pad production that is determined by the compositions used, the method of mixing and molding, and likewise the density varies due to the material properties and proportions as well as the additives used [25]. It is an important factor to determine the stability, safety and durability of brake pad as well as determine the physical and frictional properties.

$$\text{Density} = \frac{Mass}{Volume} \quad (1)$$

Water Absorption Test: Water Absorption is a test done to determine the vulnerability and porosity of the sample when submerged in water for a period of time.(Adekunle et al., 2022). The initial weight is measured as W_1, in other to determine the absorption rate as shown in Equation 2. The samples were immersed in water for 30 mins, 50 mins, 2 hrs, 4 hrs and 24 hours. The samples are cleaned after removed from water and the weight was measured and recorded as W_2. Equation 2 helped to determine the percentage of water absorption [26].

$$\mathbf{AR} = \frac{W_2 - W_1}{W_1} * 100 \quad (2)$$

Where: AR = Absorption rate, W_1 = Initial weight, W_2 = Final weight

Figure 3: Sample during water absorption test

Hardness Test: The hardness test was determined using Vickers Hardness Tester. Vickers Hardness test was done to determine the resistance of a material to deformation, particularly permanent deformation, indentation, or scratching using Vickers hardness tester Model No. MV1-PC Serial No 07/2012-1329 (Figure 4). The samples were cut into specific sizes and the hardness provides the ability of the material to withstand deformation or wear when load is applied [27]. Equation 3 shows the formula used in calculating the hardness.

$$HV = \frac{1.8244F}{d_{mean}^2} \quad (3)$$

Where F= Force; d = diameter

Figure 4: Sample Hardness test

III. RESULTS AND DISCUSSION

A. *Physical Properties of the Composite*

The density of the samples varies across all samples, where Sample 2 is the lowest and sample 5 is the highest. Sample 5 indicates the presence of denser composite materials which will influence the performance of the brake pad as regards wear and also thermal properties, it will be suitable for commercial vehicles that requires long lasting brake pads. On the other hand, sample 2 indicates presence of less dense materials and might be suitable for city driving where extreme performance is not crucial (Figure 5).

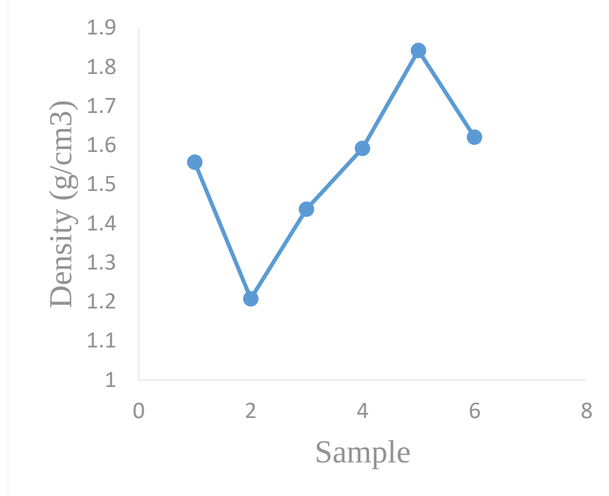

Figure 5: Density characteristics of the formed brake pad composite

B. *Water Absorption properties of the bio-based Composite*

The chart in Figure 6 indicates the different variability in the absorption characteristics of brake pad samples. Sample with low water absorption as in Sample E may offer a better performance and durability which also indicates resistance to moisture and consistent performance in wet conditions. Sample D however with the highest water absorption can be detrimental to the brake pad performance thereby reducing the friction and increasing wear.

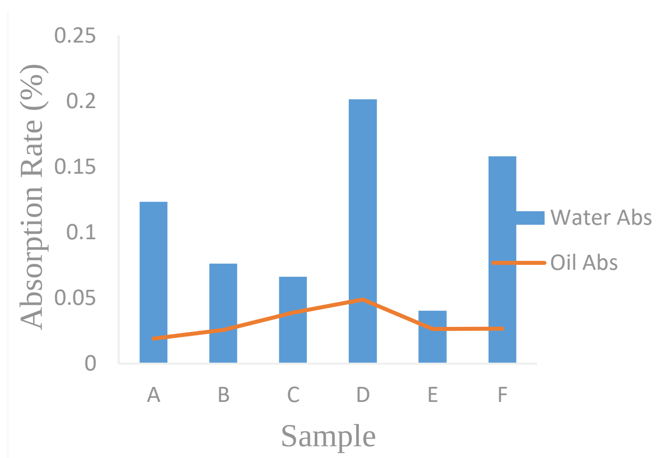

Figure 6: Water Absorption Characteristics at varied sample composition.

C. *Hardess Test Results for the sample formed*

The hardness of all samples was determined using Vickers hardness test at five different indentations. Samples 1, 3, 4, 6 have intermediate hardness values suggesting that they may offer a form of balance between the wear resistance and properties like noise. Sample 5 has the highest and most consistent hardness across the five indentations making it very suitable for brake pad applications (Figure 7).

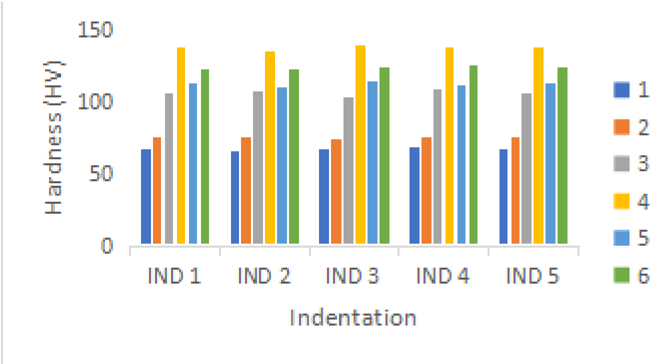

Figure 7: Sample hardness test properties

D. *Comparison between control sample and best produced sample*

The resistance value for each sample is shown in Figure 4.

Parameters	Control	Produced Sample
Density g/cm^3	1.533	1.557
Water Absorption %	3.113	12.34189
Hardness	154.3 BHN	67.20 HV

The produced brake pad composite performed fairly in term of the density with a value of 1.557 g/cm^3 as against the control having 1.533 g/cm^3. There is the need to reduce the water absorption properties and improve hardness characteristics of the formed composite. Moisture absorption reduction can be achieved through modifying the composite's matrix, fiber treatment, and surface characteristics to make it more hydrophobic and less porous [28,29]. Similarly, hardness characteristics can be enhanced through surface treatment of agro-fibers, hybridization with stronger fibers, use of nanomaterials or microfillers, matrix modification, fiber orientation and loading, processing conditions, and post-processing treatments [30,31].

IV. CONCLUSION

The research indicates that the presence of seashells is a suitable material in the production of brake pads. The density, water absorption and hardness are all part of the characteristics needed to determine a good replacement for asbestos and Sample 5 or E had better performance in these factors than the other samples indicating it as the best replacement for asbestos.

Acknowledgment

The authors sincerely appreciate the Management of Landmark University for the conference sponsorship and payment of the article processing fee. The inputs of the experts and professionals involved in the publication process are highly acknowledged.

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