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Composite Tiles Produced from Granite Dust and Tree Pruning Using a Sandwiched Method

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ABSTRACT

Projected by the United Nations, a global population surge to an estimated 9.6 billion by 2050 is anticipated, exerting substantial demands on Earth's finite natural resources for construction materials. This research endeavors to scrutinize and fabricate an innovative recycling approach for almond tree pruning as core materials, integrated with granite dust, employing cement as a binding agent in the fabrication of composite tiles measuring 190×98mm. Adhering to ISO standards, the resultant product underwent rigorous evaluation encompassing density, water absorption, flexural strength, compressive strength, and thermal conductivity. The composite tiles manifest a density spectrum spanning from 1.05 to 1.89 g/cm³, coupled with a water absorption capacity ranging from 8.25% to 33.89%. The experimental findings reveal that the integration of almond tree pruning amidst granite dust leads to a reduction in the flexural and compressive strengths of the composite tiles. Nevertheless, Sample A (comprising 78% granite dust, 2% tree pruning, and a 20% cement admixture) attains the pinnacle of flexural strength at 1.256 MPa and compressive strength at 0.421 MPa, thus representing the optimal blend ratio. Additionally, the thermal conductivities of these composite tiles exhibit a variance from 0.022 to 0.3802 W/mK, rendering them ideally suited for applications requiring low-load bearing, insulation, lightweight properties, and energy-efficient construction tiles.

1. INTRODUCTION

Tiles are a widely used building material, serving as both functional and decorative elements for covering flooring, walls, and roofs [1]. They range in thickness from 5 to 30 mm and can be found in square, rectangular, and hexagonal shapes. Tiles are known for their durability, cleanliness, and low-maintenance characteristics [2]. Traditional tiles are usually produced from either clay fired in high-temperature kilns or standard ordinary Portland concrete [3].

Tree pruning is a biomass material in which some forms of its reuse are through energy generation, metallurgical application, or composting [4-8]. According to Faghih et al. [9], the incorporation of fibers in the concrete acts as a solid fortification, reducing plastic shrinkage cracking, building the ductile quality of cement, and changing a soft material into a pseudo-flexible material. An almond tree (*Terminaliacatappa*) is a tropical wood that can serve as fiber in concrete. An almond tree is a large deciduous tree that thrives as an ornamental tree and is found mainly in the tropics. It is readily accessible, and its extraction is economical in Nigeria's ecosystem [10]. Amoo et al. [11] stated that incorporating alternative composite materials, such as natural fibers, in construction projects in Nigeria will meet the growing demand for cost-effective housing solutions.

Similarly, the strategies to present technological advancement necessitate cleaner production, pollutant control, and eco-friendly processes and products [12]. Thus, incorporating biomass wastes (almond tree fibers) in tiles is a means to achieve this purpose. Islam et al. [13] reported that sandwich elements with effective design helped utilize each material component to its ultimate limit, enhancing the structure's flexural rigidity without substantial weight addition, which is of great importance to composite materials such as tiles. Composites, such as structural materials, typically involve various layers of material fixed as one providing exceptional hierarchical *structural* properties at least weight while other multifunctional requirements are satisfied [14]. In most parts of the world, there is a continuous decrease in the characteristic source material to create traditional tiles. For natural protection and sustainability, a broad examination has created tiles from waste materials [15].

Many kinds of research have been done by integrating agricultural residues into building materials [16, 17]. Abdulganiyu [4] investigated municipal tree pruning in tiles production and reported that the best physical and mechanical properties were found in tiles made from a 70:10 mix of granite and tree pruning, with a 20% cement addition. The maximum flexural strength was 1.53 MPa, and the maximum compressive strength was 1.12 MPa. The addition of tree pruning in sample tiles demonstrated excellent thermal insulation qualities, with thermal conductivities ranging from 0.02197 to 0.02213 W/mK, making them a potential substitute for polyisocyanurate foam (PIR). Aweda et al. [18] created paving tiles using laterite, silica sand, and pulverized cow bones, and determined that a 20% cement composition was optimal for enhancing the impact strength of the tiles. Paving tiles were produced by Ajao et al. [19], utilizing cement as a binder along with pulverized corncob charcoal, wood charcoal dust, and granite. The study found that higher proportion of pulverized corncob charcoal resulted in increased water absorption, flexural strength, and compressive strength, while decreasing the bulk density of the tiles. Olusegun et al. [2] developed concrete tiles using locally sourced laterite and granite stones. The tiles were made by chemically bonding the oxide compounds in the laterite, granite, cement, and water to create a tile with a load-bearing capacity of 28.56 kN/mm^2. Zenkert [20] also stated that materials are often chosen based on reasons involving environmental resistance, surface finish, wear resistance, cost, and many more.

According to Akadiri et al. [21], the awareness of using green material instead of synthetic material for the core in sandwich structures helps to encourage the determination to make the best use of the natural product and reduce material wastage. Thus, the material or process costs can be reduced to a certain extent while developing an environmentally friendly material. Birman and Kardomateas [22] reviewed the significant trends in the applicability of novel designed sandwich structures and some difficulties encountered by designers and developers. These challenges encompass common damage, reactions to diverse loads, environmental influences, and instances of fire. Sandwich structures have recently been helpful in numerous engineering applications, such as pleasure boats, aircraft, automobiles, and refrigerated transportation containers. Sandwich structures have also been found helpful in several other engineering applications, such as sandwich concrete (lightly weighted and tough insulated) panels having fiber reinforcement for a roof, floor, and wall structures [23] and in biomedical applications [22].

Globally, there is a growing interest in seeking alternatives to building materials by recycling agricultural residues that are essentially the cause of environmental pollution through improper disposal. The commitment to seek alternative building materials remains the driving force to guarantee economic advantage, lesser costs, increased productivity, sustainability, and eco-friendliness. Therefore, the aim of this study is to create composite tiles made of granite dust and tropical almond tree pruning, which can serve as low-load bearing, lightweight, energy-efficient, and thermally insulating tiles. Thus, converting waste to wealth while managing the waste disposal problem. These experimental composite tiles are subjected to some physical and mechanical properties tests to ascertain the usefulness and durability of these products.

2. MATERIALS AND METHODS

2.1 Preparation of materials

The granite dust depicted in Figure 1 was obtained from rock crushing and was subjected to a drying process for a duration of three days under ambient conditions at a temperature of 23°C to eliminate any residual moisture. The tree pruning material was dried for 21 days with an average temperature of 24°C, then comminated using a Hammer mill (Hm series 54) and further pulverized using a Ball mill (BST/BM10).

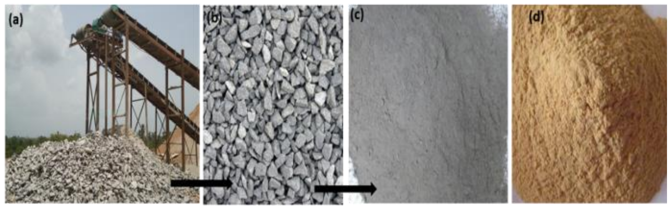

Figure 1. Raw materials for the composite tiles: (a) granite rocks at the quarry; (b) granite rock used; (c) granite dust; (d) tree pruning

2.2 Sieve analysis

Sieve analysis was conducted in accordance with ASTM D422-63 [24] to determine the optimal grain size distribution of granite and tree pruning for composite tile production. Each sample (200 g) was dried for 12 hours at 100°C to eliminate any residual moisture. The filtering procedure utilized a range of BS sieves with diameters of 4.75, 2.36, 1.00, 0.5, 0.25, and 0.15 mm. The samples were positioned on the top sieve and shaken vigorously. Using a digital Camry balance (Model ACS-15-SC71), the material collected on each sieve was meticulously transferred to a pan and weighed. Eq. (1) was then used to determine the fineness modulus (FM).

$$FM = \frac{\%\ of\ total\ weight\ retained\ between\ 4.75\ mm\ to\ 0.15mm}{100} \quad (1)$$

2.3 Mold and rammer design and production

As demonstrated in Figure 2, a welded rectangular mold made of medium carbon steel with a thickness of 5 mm and dimensions of 190 mm×98 mm was used. The mold also featured a detachable metal base plate with a thickness of 2 mm, having dimensions of 220 mm length and 130 mm width, serving as the receiver for the composite tiles. The composite tile's shape was formed by using a rammer, which was constructed from a steel plate with a thickness of 10 mm and dimensions of 190 mm in length and 98 mm in width. The rammer was equipped with a shaft and was utilized to compress the layered mixture into the mold.

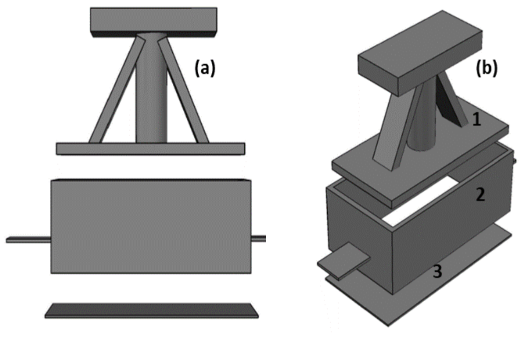

Figure 2. Different views of CAD design of the rammer and mold assembly: (a) side; (b) isometric; 1-rammer; 2-mold; 3-base plate (collector)

2.4 Sample formation and production

According to the sieve analysis results, the 0.50 mm size was selected for the tree pruning, as it had the highest retention of 71.97%. The 2.36 mm size was chosen for the granite dust, with the highest retention of 32.31%. Table 1 displays the different base material formulations employed in the making of composite tiles, including granite dust, tree pruning, and cement. Furthermore, Table 1 illustrates the composition of the different tile layers, which are top, middle and bottom. The tile production process was in accordance with the sequential order depicted in Figure 3. For each layer, the granite dust and tree pruning were mixed with cement and 15% water, as specified in Table 1. The mold interior and ram surface were lubricated using a blend of diesel and lubricating oil, while the mold base was covered with thick nylon for easy tile release. Each tile composition was mixed for 5 minutes prior to adding clean water to prevent lump formation and ensure uniformity in each layer. The bottom layer was added to the mold and compressed with a 25 KN constant load using a manual compression machine. This was followed by adding the middle layer and compressing it with a 25 KN constant load. Finally, the top layer was added and compressed with the same constant load. This step guaranteed a thorough compaction and strong bonding between layers. Afterwards, the composite tile was taken out. The tiles underwent curing by being watered for 7 days and kept at 24°C for 14 days. In the end, they were dried by sunlight for 7 days, completing 28 days curing process [19].

Table 1. Composition of the composite tiles

	Base Layer		Middle Layer		Top Layer	
Sample ID	C_{GT} (%)	C_{CGT} (%)	C_T (%)	C_{CT} (%)	C_{GB} (%)	C_{CGB} (%)
			20% Cement			
C1	40	10	0	0	40	10
A	39	9.75	2	0.5	39	9.75
B	37.5	9.38	5	1.25	37.5	9.38
C	35	8.75	10	2.5	35	8.75
			15% Cement			
C2	42.5	7.5	0	0	42.5	7.5
D	41.5	7.32	2	0.35	41.5	7.32
E	40	7.06	5	0.88	40	7.06
F	37.5	6.62	10	1.76	37.5	6.62

*C_{GT}: Composition of granite dust for the top layer, C_{CGT}: Composition of cement in granite dust for the top layer, C_T: Total composition of tropical almond tree pruning (middle layer), C_{CT}: Composition of cement in tropical almond tree pruning, C_{GB}: Composition of granite dust for the bottom layer, C_{CGB}: Composition of cement in granite dust for the bottom layer.

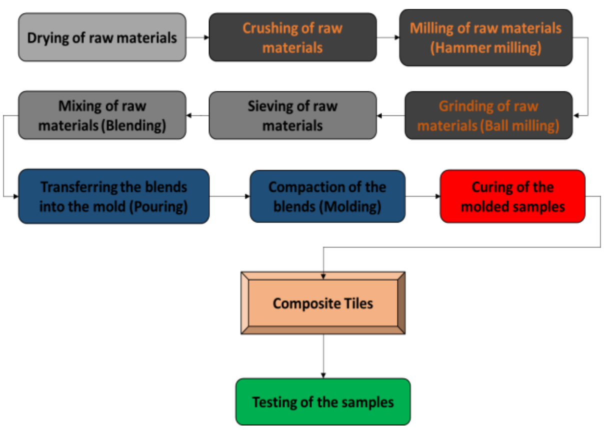

Figure 3. Designed flow process used for the production of the composite tiles

The cement composition by percentage in granite dust in a single tile was obtained using Eq. (2), while the cement composition by mass in tropical almond tree pruning in a single tile was calculated using Eq. (3).

$$C_{CG} = \frac{C_G}{C_G + C_T} \times C_C \quad (2)$$

$$C_{CT} = \frac{C_T}{C_G + C_T} \times C_C \quad (3)$$

where, C_G=total composition of granite dust in tile, C_C=total composition of cement in tile, C_T=total composition of tree pruning in tile, C_{CT} =total composition of cement in tree pruning, and C_{CG}=total composition of cement in granite dust.

2.5 Characterization of the produced composite tiles

2.5.1 Bulk density

The weight of the dried composite tiles was determined using a digital Camry balance (Model ACS-15-SC71) to find the dry mass (Md). The dimensions (length, width, and thickness) of the tile were assessed with a Vernier caliper to calculate its volume (V), conforming to the UNI EN ISO 10545 standard. The bulk density (g/cm^3) of each sample was calculated by dividing its dry mass by volume, using the equation in Eq. (4) [18].

$$B\ (g/cm^3) = \frac{M_d}{V} \quad (4)$$

2.5.2 Determination of water absorption

The water absorption experiment was carried out in accordance with UNI EN ISO 10545 [25]. A digital Camry balance (Model ACS-15-SC71) was utilized in determining the dry mass (Md) of the composite tiles. The specimens were immersed in cold water for 24 hours, taken out, and their surface was dried with a cloth to remove excess water. The weight of the water-saturated tiles was measured with a digital balance and noted as the saturated mass (Ms). The water absorption (A) was computed using Eq. (5) as described by Aweda et al. [18].

$$A = \frac{M_S - M_d}{M_d} \times 100 \quad (5)$$

2.5.3 Determination of flexural strength

Using a Universal Testing Machine (FS5080, Testometric Co. Ltd., UK), the flexural strength of the produced composite tiles was evaluated. The samples were arranged in a horizontal position on the machine, supported by two vertical knife-edge supports, with the distance between them noted as shown in Figure 4. Loading was done centrally through a vertical indenter on the machine until fracture, following ASTM 1609 [26] standard. The flexural strength was then calculated using the equation in Olusegun et al. [27].

$$M = \frac{8PL}{\pi T^3} \quad (6)$$

where, M=Modulus of rupture (MPa), P=load at rupture (N), L=Distance between support (mm), T=Average thickness of the specimen (mm).

2.5.4 Determination of compressive and impact resistance strengths

The ISO 4012 [28] standard was followed in assessing the compressive strength of the composite tiles by using a Universal Testing Machine (FS5080 from Testometric Co. Ltd. in the UK) with a load capacity of 50 kN. The strength was computed using Eq. (7).

The impact resistance of the tiles was evaluated using an Izod Testing Machine (Model LS102DE, Avery Denison) with a capacity of 150 J/300 J, following the ISO 148-1-2016 standard. The average impact value was determined from three repetitions.

$$C_s = \frac{P_c}{A_c} \tag{7}$$

where, C_s=Compressive strength (Pa), P_c=Total load on the specimen at failure (N), A_c=calculated area of the bearing surface on the specimen (m^2).

2.5.5 Determination of thermal conductivity

This test was conducted using a thermal property measuring device called KD 2 Pro (Decagon Devices Inc. USA) [29]. An array of the sample composite tiles is shown in Figure 5. Eq. (8) was utilized to evaluate the thermal conductivity [30].

$$k = \frac{Q\ \Delta L}{A\ \Delta T} \tag{8}$$

where, k =thermal conductivity (W/mk), Q =heater power (W), A=cross-sectional area (m^2), ΔT=change in temperature, ΔL=difference in the hot face and cold face (m).

Figure 4. Flexural strength test set up for the composite tiles

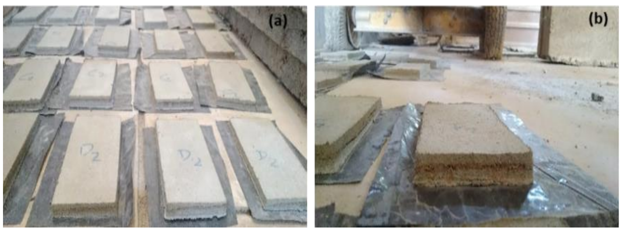

Figure 5. Test specimen for (a) flexural strength; (b) thermal conductivity

3. RESULTS AND DISCUSSION

3.1 Sieve analyses and characterization of the raw materials

Table 2 displays the characteristics of the aggregates utilized in the production of composite tiles, including color, relative density, moisture content, maximum retained mass percentage, and fineness modulus. The granite dust was ash-colored and the tree pruning had a light brown color (as seen in Figure 1). The composite tiles had an ash-colored top and bottom, with a light brownish hue in the middle due to the sandwich material's color (tree pruning). This ash color was more dominant than the light brownish color, which may be as a result of the relative density of granite dust (9.80 g/cm^3) higher than the tree pruning with a relative density of 5.35 g/cm^3. Thus, the material whose particles are more closely packed together determines the prominent color of the resultant composite tile. This is also in agreement with the work of Hamad [4]. Eventually, the tile's higher quantity of granite dust had a higher relative density than the tree pruning, resulting in a lower volume of composite tiles. This pattern was similarly noted for composite tiles modeled by Olusegun et al. [31].

Table 2. Physical properties of the raw materials

Properties	Granite Dust	Tree Pruning
Color	Ash	Light brown
Relative density	9.80	5.35
MC (%)	1.15	8.80
MMR (%)	32.31 (2.36 mm)	71.97 (0.5 mm)
FM	3.37	2.56

*MC: moisture content (dry basis) *MMR: maximum mass retained *FM: fineness modulus

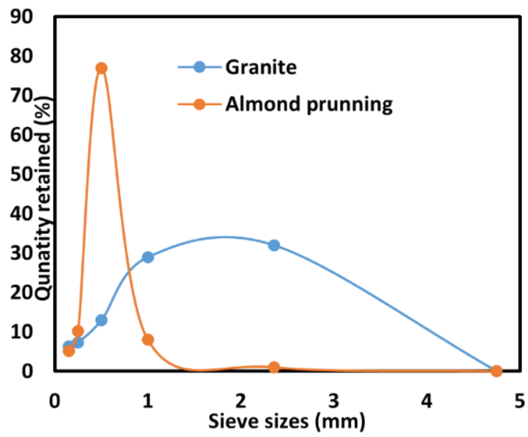

Figure 6. Quantity retained in different sieve sizes for the granite dust and Almond tree pruning

Tree pruning had a higher moisture content (8.8%) compared to granite (1.15%), indicating that tree pruning is a significant factor in determining the moisture content of the composite tiles. It is important to note that excessive tree pruning can lead to biological degradation [4]. However, the average moisture content of tree pruning is below the Fibre Saturation Point (FSP) of wood, typically between 25 and 30%. This means that incorporating tree pruning into the cement-bonded composite tile production process at this moisture level will not add extra moisture to the cement matrix [11]. The combined particle size distribution of granite dust and tree pruning is presented in Figure 5. The granite dust had the highest retention at 32.31% for the 2.36 mm sieve size, while the tree pruning's highest retention was 71.97% for the 0.5 mm sieve size. This resulted in average particle sizes of 2.36 mm for granite dust and 0.5 mm for tree pruning (Table 2). The sieve size of 0.5 mm was used as the maximum particle size for tree pruning, while 2.36 mm was used for granite dust to ensure optimum utilization of the materials as shown in Figure 6 [26, 28].

3.2 Physical properties of the produced composite tiles

3.2.1 Bulk density properties of the produced composite tiles

The properties of composite tiles using different aggregates, including bulk density and water absorption, are displayed in Figure 7. Three factors-physical properties (bulk density, water absorption), dimensional characteristics, and structural soundness-must be met for commercial tile production [32]. Bulk density is calculated by dividing the dry mass of a specimen by its total volume, including pores [33]. Results for the bulk density ranged from 1.05 to 1.89 g/cm^3. The research revealed that as the proportion of tree pruning in the aggregate mixture increased, the bulk density decreased due to the lower density of tree pruning compared to granite dust. Figure 7 displays the bulk density and water absorption of composite tiles with 20% and 15% cement compositions and different proportions of granite dust and tree pruning. The composite tile with 20% cement and a mixture of 78:2% granite dust to tree pruning had a bulk density of 1.38 g/cm^3, while the composite with 70:10 granite dust to tree pruning had a bulk density of 1.05 g/cm^3.

The 15% cement content samples showed similar results. The composite with 83:2% granite dust to tree pruning had a bulk density of 1.39 g/cm^3, while the composite with 75:10 granite dust to tree pruning had a bulk density of 1.06 g/cm^3. As the proportion of tree pruning in the aggregate mix increased, the bulk density decreased while the amount of granite dust decreased correspondingly. This trend is evident in the data shown in the figure. These results show that the reduction in the bulk density reflected the lower bonding strength of the almond tree pruning content. Additionally, the composite tiles with 20% cement showed the highest bulk densities due to stronger bonding among the materials. This observation aligns with the findings of Olusegun et al. [27] and Ajao et al. [19]. When the tree pruning content rises, bulk density decreases while water absorption values increase. In a way, incorporating tree pruning into the composite tiles would help reduce the cost of transporting, handling, and distributing the products due to density reduction. This was also observed by Novais et al. [34].

3.2.2 Water absorption properties of the produced composite tiles

Water absorption is a crucial factor affecting the breaking strength and modulus of rupture of composite tiles. It also determines the classification of the tile product. Moreover, the sandwich method used was synthesized so that the composite tiles could retain minimum water inside the cells. This is because too much water could decrease their mechanical strength [35]. The composite tiles exhibited a water absorption capacity ranging from 8.25% to 33.89%, which is higher than the comparison material. For 20% cement content, the aggregate mix of 78:2% (granite dust and tree pruning) had a water absorption capacity of 18.96%. The aggregate mix of 70:10 (of granite dust and tree pruning) had a water absorption capacity of 33.15%. For samples with 15% cement content, the aggregate mix of 83:2% (of granite dust and tree pruning) had a water absorption capacity of 23.84%. The aggregate mix of 75:10 (of granite dust and tree pruning) had a water absorption capacity of 33.89%. After soaking the composite tiles in water for 24 hours, the results showed that water absorption increased with more tree pruning in the aggregate, as seen in Figure 7. This indicated that tree pruning was more porous than granite dust. Tree pruning is hydrophilic, which can result in higher moisture absorption in composite tiles with higher tree pruning content [5, 6, 30]. The composite tiles with 15% cement content had higher water absorption than those with 20% cement content. The improvement in water absorption rate for the 20% cement content was due to stronger bonding between cement and aggregate materials, resulting from better curing. This concurs with the findings of Aweda et al. [18]. The findings of this study on water absorption are consistent with those reported by Ajao et al. [19], who utilized pulverized corncob charcoal instead of the lignocellulosic biomass used in this study. Samples A (18.96%) and E (20.05%) showed better water absorption results, as they absorbed less water compared to other composite tiles.

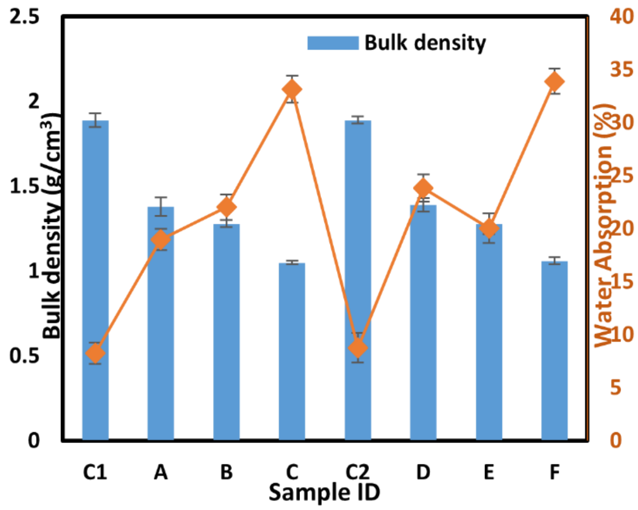

Figure 7. Bulk density and water absorption capacity of the produced composite tiles

3.3 Mechanical properties of the produced composite tiles

3.3.1 Flexural strengths of the produced composite tiles

The results of the flexural and compressive strength tests for the composite tiles are presented in Figure 8. The modulus of rupture (MOR), also known as flexural strength, of the composite tiles was found to be relatively low. For 20% cement content, the aggregate mix of 78:2% (of granite dust and tree pruning) had a flexural strength of 1.256 MPa, while the aggregate mix of 70:10 (of granite dust and tree pruning) had a flexural strength of 0.918 MPa, indicating a decrease of 26.9%. For samples with 15% cement content, the aggregate mix of 83:2% (of granite dust and tree pruning) had a flexural strength of 0.595 MPa, while the aggregate mix of 75:10 (of granite dust and tree pruning) had a flexural strength of 0.304 MPa showing a decrease of 48.9%. Figure 8 displays the composite tile's flexural and compressive strengths. The tiles had low flexural strength or modulus of rupture (MOR), and an increase in tree pruning content in the aggregate up to 10 wt.% led to a decrease in flexural strength, possibly due to the lightweight nature of the tree pruning fibers or changes in water absorption. The flexural strength was in the range of 0.340-6.55 MPa, which is lower than the comparison material but falls within the range for wood-cement composites (0.8-24.0 MPa) reported by Olorunnisola [36]. The composite tiles' low flexural strength indicates they may not be ideal for heavy-duty applications, but rather for non-load bearing walls and floor tiles. Based on Idowu's research [37], sample A, with a flexural strength of 1.25 MPa, is suitable for interior wall construction. The samples containing 20% cement showed improved flexural strength compared to those with 15% cement, due to stronger bonding, as found in studies by Ajao et al. [19], Olusegun et al. [2], and Abdulganiyu [4].

3.3.2 Compressive strengths of the produced composite tiles

Composite tile compressive strength may vary between 0.058 and 1.83 MPa. This is stronger than the material being compared, which consists of 20% granite dust and 15% tree pruning, as illustrated in Figure 8. For 20% cement content, the aggregate mix of 78:2% (of granite dust and tree pruning) had a compressive strength of 0.421 MPa. In contrast, the aggregate mix of 70:10 (of granite dust and tree pruning) had a compressive strength of 0.099 MPa. For samples with 15% cement content, the aggregate mix of 83:2% (of granite dust and tree pruning) had a compressive strength of 0.187 MPa, while the aggregate mix of 75:10 (of granite dust and tree pruning) had a compressive strength of 0.058 MPa.

As the amount of tree pruning in the aggregate mix increases and the quantity of granite dust decreases, the compressive strength of the composite tiles decreases. This decrease is due to the lack of compression capabilities in tree pruning compared to traditional aggregates. This was also observed by Hamad [4]. Results also showed that the composite tiles with 20% cement content had higher compressive strength than samples with 15% cement content. This may result from a better curing and hardening process in tiles with higher cement content [2, 28]. The compressive strength of Sample A (0.420 MPa) slightly outperforms 0.392 MPa, which was suggested by Varela et al. [38]. Most composite tiles exhibited mechanical properties in low-load-bearing indoor and outdoor applications [37].

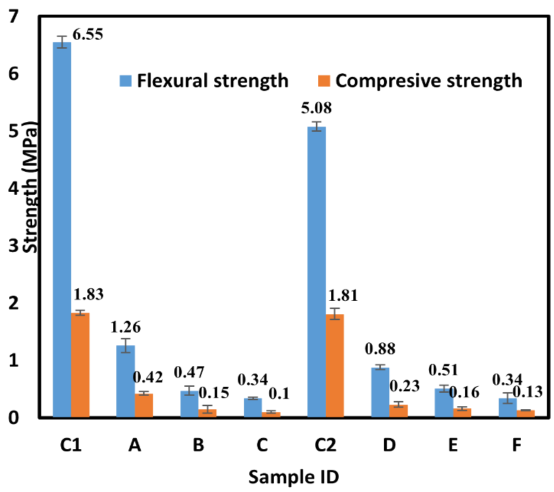

Figure 8. Flexural and compressive strengths of the composite tiles

3.3.3 Impact resistance of the composite tiles

Figure 9 displays the impact strengths of the composite tiles. Sample F showed the highest impact strength at 85 J, while sample C2 had the lowest at 71.5 J. The data suggests that as the proportion of tree pruning and granite dust in the aggregate mix decreases, the impact strength of the composite tiles improves. Additionally, it was noticed that the samples with a 20% cement content had a greater impact resistance than those with a 15% cement content. This implied that a stronger bond was formed with higher cement content, which enabled better resistance to sudden force or load. The results obtained in this study are in tandem with the study by Aweda et al. [18], which reported better impact strength at 20% cement content for the paving tiles produced with cement as an additive.

3.3.4 Thermal conductivity of the produced composite tiles

The thermal conductivities of the produced composite tiles are presented in Figure 10. For 20% cement content, the aggregate mix of 78:2% (granite dust and tree pruning) had a thermal conductivity of 0.3802 W/mK. In contrast, the aggregate mix of 70:10 (of granite dust and tree pruning) had a thermal conductivity of 0.2030 W/mK, decreasing by 46.61%. For samples with 15% cement content, the aggregate mix of 83:2% (of granite dust and tree pruning) had a thermal conductivity of 0.2501 W/mK. Conversely, the aggregate mix of 75:10 (granite dust and tree pruning) had a thermal conductivity of 0.2100 W/mK, a 16.03% decrease. As the proportion of tree pruning in the aggregate mix increases, there's a decrease in the thermal conductivity of the composite tiles. The thermal conductivity of the tiles ranges from 0.0221 to 0.3802 W/mK, higher than the comparison material. The thermal conductivity of the composite tiles falls within the range of Polyurethane foam board (PUR), which is a commonly used material for insulation, floor protection coating, and construction adhesive. The thermal conductivity of Polyurethane foam board (PUR) typically ranges from 0.22 -0.29 W/mK. Studies by Shawia et al. [39] also indicated that the composite tiles possess desirable heat-resistant capabilities, suggesting they could be a potential alternative to Polyurethane foam board (PUR) [40].

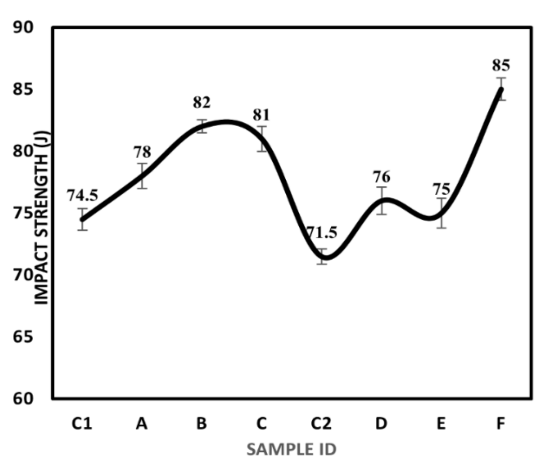

Figure 9. Impact resistance of the composite tiles

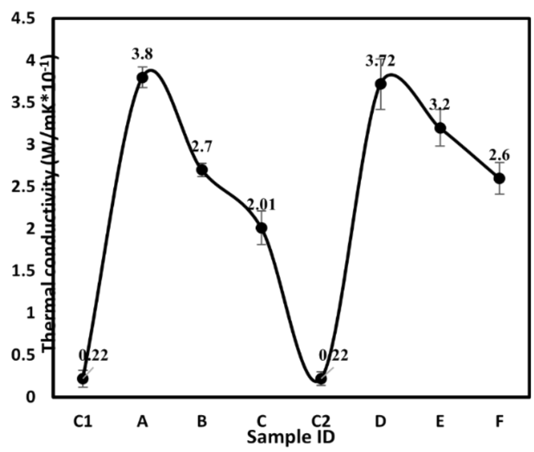

Figure 10. Thermal conductivity of the composite tiles

4. CONCLUSIONS

In this study, we investigated the physical and mechanical properties of composite tiles produced by blending granite dust with almond tree pruning, offering an innovative approach to sustainable building materials. The results of our analysis provide valuable insights into the potential of this novel composite material:

The bulk density of the composite tiles ranged from 1.05 to 1.89 g/cm³, depending on the composition. Notably, a higher proportion of tree pruning led to reduced bulk density, an advantageous outcome in terms of transportation, handling, and distribution costs.

Water absorption capacity was examined and found to vary from 8.25% to 33.89%. This variation correlated with the amount of tree pruning in the mix, reflecting the hydrophilic nature of tree pruning. This characteristic, however, did not compromise the mechanical properties of the tiles.

We identified Sample A, composed of 78% granite dust, 2% tree pruning, and 20% cement, as the optimal mix ratio. This sample exhibited the highest flexural strength at 1.256 MPa and the highest compressive strength at 0.421 MPa. These results suggest that Sample A holds promise for interior wall construction and other non-load-bearing applications.

The impact resistance of the composite tiles was assessed, with Sample F demonstrating the highest impact strength at 85 J. This indicates that the tiles possess the ability to withstand sudden forces or loads, making them suitable for various applications.

The thermal conductivities of the composite tiles ranged from 0.0221 to 0.3802 W/mK. This thermal performance places the tiles in a range comparable to commonly used insulation materials like Polyurethane foam board (PUR), suggesting their potential as an alternative in thermal insulation applications.

Overall, this study highlights the feasibility of using almond tree pruning as a sustainable material in composite tiles. These tiles offer a range of physical and mechanical properties suitable for low-load bearing, lightweight, and thermally insulating applications. By transforming waste materials into valuable construction resources, this research contributes to the broader goal of achieving economic advantages, reduced costs, increased productivity, sustainability, and eco-friendliness in the construction industry.

In conclusion, the successful development of composite tiles from granite dust and almond tree pruning underscores the potential for eco-friendly alternatives in construction materials, offering a step toward waste reduction and sustainable building practices. Further research and development in this area could open new avenues for environmentally conscious construction solutions.

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