

Suitability of Pulverized Cow Bones as a Paving Tile Constituent

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Abstract- Economic advantage of waste has been clamoured severally in order to improve the environment and reduce pollution. In Nigeria, the common materials used for the production of paving tiles are granite dust and cement, in some cases silica sand is added. This study is aimed at investigating the feasibility of using available raw materials such as laterite, silica sand and pulverized cow bones to develop paving tiles. Tiles of 200 mm × 100 mm × 60 mm were produced and the effects of various materials added were investigated and analysed. The production method employed was casting and curing was done for twenty-eight (28) days. Physical and mechanical analyses of the paving tiles showed that the tiles with mixing ratio of 4:1:3 (laterite: pulverized cow bones: silica sand) with 20% cement stabilization was the optimum mix ratio, producing the maximum compressive strength and modulus of rupture of 5.05 MPa and 1.83 MPa respectively.

Keywords: Cow-bones, Compressive-strength, Laterite, Paving-tiles, Silica-sand

1. Introduction

The need to make judicious use of waste materials in the surroundings for wealth creation has been clamoured in order to reduce cost and sustain the environment. Animal bones disposal has been a major challenge in abattoirs across Nigeria especially in urban cities with huge population. Lagos, a city in south western Nigeria, accounts for 6,000 slaughtered cattle per day [1], in a country producing 13.8 million cattle yearly [2]. The time taken for bones to decay, which could be millions of years [3] add to the defacing of the environment when not properly disposed off. Recently, researchers have developed several ways to economically use animal bones to create wealth, some of which are in stonewares and animal feeds, where they are charred and pulverized. The process of charring, further constitute environmental pollution due to the exhaust caused by burning. Bones consists mainly calcium oxide (32.1%) and phosphorus pentoxide (28.3%) [4], giving it its load bearing capacity, which may be explored as building construction constituents and products.

Kim *et al.* [5] analyzed the average breaking strength of dry bones of cattle, which is the required weight to break a cattle bone such as femur, scapular etc. as 9.9 kg. Also, the potential of bones as pozzollanic substance was also established by [6].

Paving tiles are of different shapes which could be (rectangular, square, polygon), and are of different weights and dimensions [7]. They are also known to be of good load bearing capacity and have proved useful in marshy regions due to its good water absorption and permeability [8]. Conventionally, paving tiles are usually made of granite, silica sand and stone dust with cement as binder [9]. With increase in the rate of urbanization in Nigeria, there is huge demand for paving tiles. Granite one of the core material for production of paving tiles is decreasing, coupled with the high cost of crushing and transportation, therefore, the need to have other local alternative materials to compensate for this problem will be of good economic advantage.



Laterite is found almost everywhere in the tropics [10], so also is silica sand is found at river beds, which is gritty in texture, appropriate for mixing concrete and could be used as soil amendment, making tighter soils looser and could be used as stabilizers [11]. Several locally sourced raw materials which are alternatives to the conventional granite-cement mixture has been used in production of paving tiles. Raheem *et al.* [12] used laterite with cement as binder in the production of paving tiles. Works have been done on the use of agricultural wastes such as palm kernel shell as coarse aggregate [13], and corncobs addition as a substitute in paving tiles [14]. All have proved feasible but provides a gap that the agricultural wastes are seasonal i.e. not available all year round. The conventional materials had proved expensive and fast getting exhausted [7]. Humans are known to consume animal all year round, the cost and availability of laterite, silica sand, also makes the consideration of cow bones as a paving tile constituent sustainable.

This research aims at using available raw materials such as laterite, silica sand and pulverized cow bones, to produce paving tiles and study both its physical and mechanical properties, and its objectives were to analyse effects of various materials on the physical and mechanical properties of paving tiles. Furthermore, the optimum mixing ratio was also determined.

2. Materials and Method

Cow bones used in this study consist of femurs, scapulars and rib of cow, and were procured from Ipata abattoir in Ilorin Kwara State Nigeria. They were washed and sundried for 4 weeks, in order to remove the organic matter in the marrows of the bones. Thereafter they were crushed and pulverized using laboratory ball mill. Laterite, was sourced in the vicinity of University of Ilorin Teaching Hospital and, the physical properties were analysed and determined as colour, specific gravity, moisture content as received, sieve analyses, plastic limit, liquid limit and plasticity index. The laboratory tests carried on laterite were done in accordance with [15].

Silica sand, was also collected at a river bed along University of Ilorin Teaching Hospital road and its physical properties determined. Ordinary Portland cement was used as binder with varying percentage addition. The mixing proportions of cement, laterite, silica sand and pulverized cow bones are shown in Table 1 with a water cement ratio of 0.7 by volume.

Table 1 Aggregate mix for experimental tiles

Pulverized Cow Bones, % wt	Laterite, % wt	Silica Sand, % wt	Cement, % wt
30	40	10	20
20	25	35	20
10	20	50	20
5	20	55	20
30	35	20	15
20	35	30	15
10	35	40	15
5	30	50	15
30	30	30	10
20	45	25	10
10	50	30	10
5	40	45	10

2.1 Specimen Preparation

Quantity of materials required to cast a single tile, were weighed, mixed thoroughly for each mix ratio before the addition of water. Each tile was mixed separately to avoid rapid setting of the

mixture. The mould of 200 mm × 100 mm × 60 mm was filled to its maximum volume, rammed with 2.5 kg rammer for 28 blows; the surface was levelled and trimmed. This was done in accordance to Agunwa [15]. It was also ensured that the moulds were filled in three layers. to the filling up of the mould, it was smeared with used automobile engine oil, in order to prevent the sticking of the cast to the walls of the mould when demoulding. The paving tiles were demoulded after 24 hours under atmospheric condition and cured in water pond for twenty one days (21) then sundried for another seven (7) days making up an entire curing process of twenty eight (28) days [15].

2.2 Experimental Tests

2.2.1 Water absorption

The mass of each tile specimen was weighed and re-weighed before and after submerging in water for 24 hours. The specimens were taken out of water and the surfaces carefully wiped to remove excess water [16]. The percentage water absorption A was calculated using equation (1):

$$A = \frac{M_S - M_D}{M_D} \times 100\% \quad (1)$$

Where,

M_S = mass of the saturated tile and

M_D = mass of the dried tile

2.2.2 Bulk density

Tile specimens were dried in oven at 110°C for 24 hours [16], and the tile test specimen's dry mass, M_D was determined. The bulk density, B was then calculated using equation (2):

$$B = \frac{M_D}{V} \quad (2)$$

Where;

V = volume of the tile

M_D = dry mass of the tile.

2.2.3 Determination of percentage drying shrinkage

Experimental tiles were submerged in water for five (5) days, and their masses determined as M_{sat} , the specimens were then oven dried at 110°C for 24 hours [16]. The mass of the specimens were then recorded after cooling to room temperature as M_f , the drying shrinkage S_d was then determined [14].

$$S_d = \frac{M_{sat} - M_f}{M_f} \times 100 \quad (3)$$

2.2.4 Modulus of rupture

The specimen was supported horizontally on two vertical supports of known span. The test specimens were centrally loaded by means of wire cord and a hanger suspended from the wire. The specimens were loaded with known masses until failure occurred [17]. The modulus of rupture for each tile specimen was then obtained using equation (4):

$$R = \frac{3PL}{2bd^2} \quad (4)$$

Where:

R = modulus of rupture,

P = applied load at failure,
 L = length between the supports
 b = width of the specimen; and
 d = thickness of the specimen

2.2.5 Compressive strength

The test specimen was loaded into a universal testing machine M500-100AT. The load was slowly and carefully applied centrally on the tile specimens until the first sign of crack was observed and the load was then recorded. The compressive strength of each tile specimen was calculated using equation (5):

$$\sigma = \frac{P_c}{A_c} \quad (5)$$

Where:

P_c = maximum load on the specimen at failure,
 A_c = calculated cross-sectional area of the specimen; and
 σ = compressive strength of the test specimen.

2.2.6 Impact resistance

In order to ascertain the level of shock load the experimental tiles can withstand, impact resistance test was carried out by measuring the coefficient of restitution, of the colliding body, according to ENISO10545 [18]. A steel ball of mass 5 kg was dropped from a distance 1 m, time taken to make impact was recorded and time taking for rebound was also recorded. It was ensured that the mass hit the tiles at the centre of the dimension. The damages visible from 1 m were observed, and the coefficient of restitution was found as thus:

$$e = \frac{V_{fb}}{V_{ib}}$$

(6)

Where:

e = coefficient of restitution

V_{fb} = final velocity of steel ball

V_{ib} = initial velocity of steel ball

3. Results and Discussion

The physical properties of materials used as aggregate in the production of paving tiles are presented in Table 2.

Table 2: Physical properties of aggregates

Physical properties	Lateritic soil	Silica sand	Pulverized animal bones
Color	Reddish brown	Light brown	Whitish ash
Specific gravity	2.50	2.60	1.83
Moisture content as received (%)	24.67	32.72	38.10
Maximum mass retained on sieve (%)	23.20	27.20	92.80
Mesh size of occurrence	1000 μ m	500 μ m	4750 μ m
Liquid limit (%)	39.30	-	-
Plastic limit (%)	25.00	-	-

Plasticity index (%)	14.30	-	-
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Table 2 and Figure 1 shows that the maximum grain size distribution for lateritic soil, silica sand and pulverized animal bones occurring at 1000 μ m, 500 μ m and 4750 μ m sieve sizes respectively; and these were used in the production process in order to maximise the bulk of material resources.

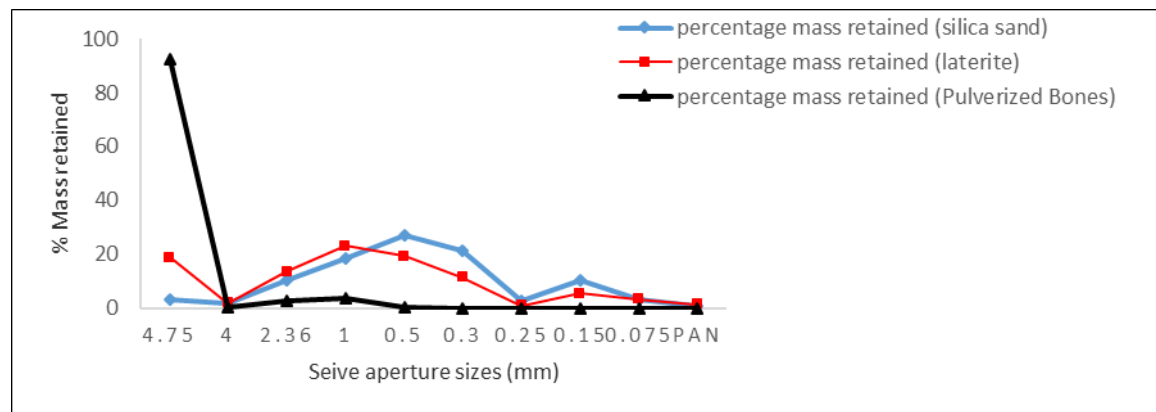


Figure 1: Particle Size Distribution of Aggregates

3.1 Bulk Density

Figure 2 is a graph of bulk density against varying % weight (wt) compositions of cement, laterite, silica sand and pulverized cow bone. The figure shows cement at 20%, 15% and 10% wt compositions at different concentrations of laterite: silica sand: pulverized cow bone. When cement was at 20%, the laterite: silica sand: pulverized cow bone ratios of 40:10:30 produced bulk density of 2.45 g/cm³ and at 20:55:5 ratios the bulk density increased to 2.65 g/cm³, an increase of about 8.16%. For situation when cement content was reduced to 15% wt, similar trend could be seen from the figure as laterite: silica sand: pulverized cow bone ratios of 35: 20: 30 had 2.42 g/cm³ bulk density, and became 2.62 g/cm³ at 30: 50: 5 ratios another increases of 7.85%. Though, there was a similar situation when the cement content was further reduced to 10%, but lower values of bulk density were observed for all the ratios used. For ratios of 30: 30: 30 (laterite: silica sand: pulverized cow bones), the bulk density is 2.38 g/cm³ and increased to 2.58 g/cm³ at ratios 40: 45: 5 giving an 8.4% increase. With the increase in the percentage composition of cement in the aggregate, there is a corresponding increase in the bulk density of the samples. The highest recorded value of bulk density was 2.65 g/cm³ at 20% cement and 20: 55: 5 ratios of laterite: silica sand: pulverized cow bone respectively. It was observed that with increase in the % wt compositions of cement and silica sand in the aggregate, there is corresponding increase in the bulk density. Conversely, with increase in the pulverized cow bone, there is decrease in the bulk density as seen in Figure 2. This shows that an increase in addition of silica sand and cement led to the increase in the bulk density, while an increase in the pulverized cow bone produced a decrease in the bulk density.

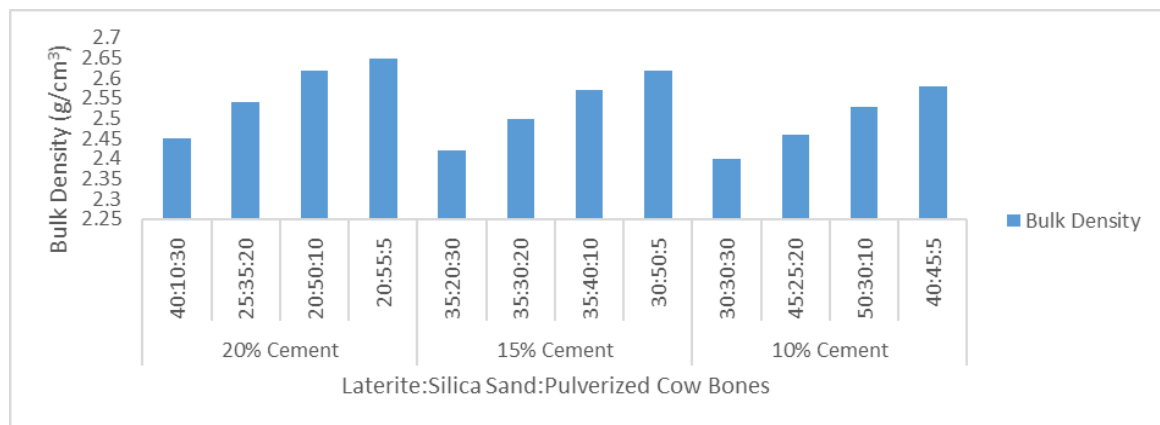


Figure 2: Bulk density of experimental tiles

3.2 Water Absorption

Figure 3 shows a graph of water absorption against varying % wt compositions of cement, laterite, silica sand and pulverized cow bone. With 20% cement weight, laterite: silica sand: pulverized cow bone ratios of 40:10:30 produced water absorption capacity of 3.01%, and at 20:55:5 ratios the water absorption capacity decreased to 2.5%, a decrease of about 16.9%. When cement content was reduced to 15% wt, laterite: silica sand: pulverized cow bone ratios of 35: 20: 30 had 3.93% water absorption capacity and became 3.34% at 30: 50: 5 ratios with a decrease of 15%. When the cement content was further reduced to 10%, for ratios of 50: 30: 10 (laterite: silica sand: pulverized cow bones), the water absorption capacity became 5.85% and decreased to 3.92% at ratios 30: 30: 30 giving a 33% decrease. The highest recorded value of water absorption was 5.85% at 10% cement for 50: 30: 10 ratios of laterite: silica sand: pulverized cow bone respectively. It was observed that with increase in the % wt compositions of laterite in the aggregate, there is corresponding increase in the water absorption. With increase in the silica sand, there is a decrease in the water absorption capacity as observed in Figure 3.

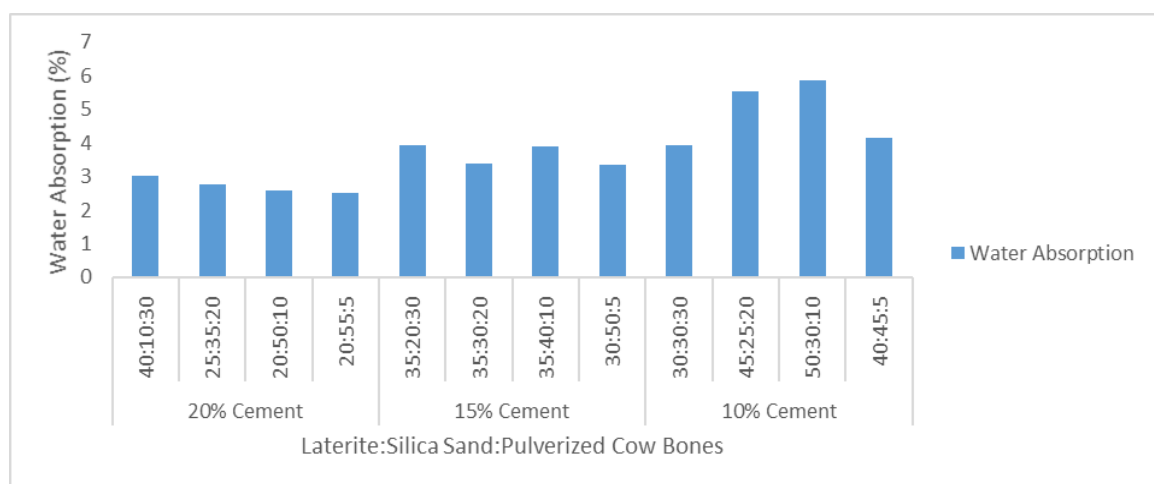


Figure 3: Water absorption capacity of experimental tiles

3.3 Drying Shrinkage

Figure 4 represents the graph of drying shrinkage against varying % wt compositions of cement, laterite, silica sand and pulverized cow bone. Determined different drying shrinkage levels, with cement at 20%, the laterite: silica sand: pulverized cow bone ratios of 40:10:30 had drying shrinkage value of 3.53% and at 20:55:5 ratios the drying shrinkage decreased to 2.78%, a decrease of 21.25%. For condition when cement content was reduced to 15% wt, similar trend could be seen from the figure as laterite: silica sand: pulverized cow bone ratios of 35: 20: 30 had 4.2% drying shrinkage and rose to 3.82% at 30: 50: 5 ratios another decrease of 9.05%. When the

cement content was further reduced to 10%, for ratios of 50: 30: 10 (laterite: silica sand: pulverized cow bones), the drying shrinkage was 6.21% and decreased to 4.19% at ratios 30: 30: 30 giving a 32.53% decrease. As the percentage composition of laterite in the aggregate increased, there is an increase in the drying shrinkage capacity of the samples. The peak recorded value of water absorption was 6.21% at 10% cement and 50: 30: 10 ratios of laterite: silica sand: pulverized cow bone respectively. It was observed that with increase in the % wt compositions of laterite in the aggregate, there is corresponding increase in the drying shrinkage.

The drying shrinkage, was observed to follow same pattern as that of the water absorption tests, which was also observed by [14], however the percentage of shrinkage is slightly higher than that of the water absorbed, which is in agreement with [7].

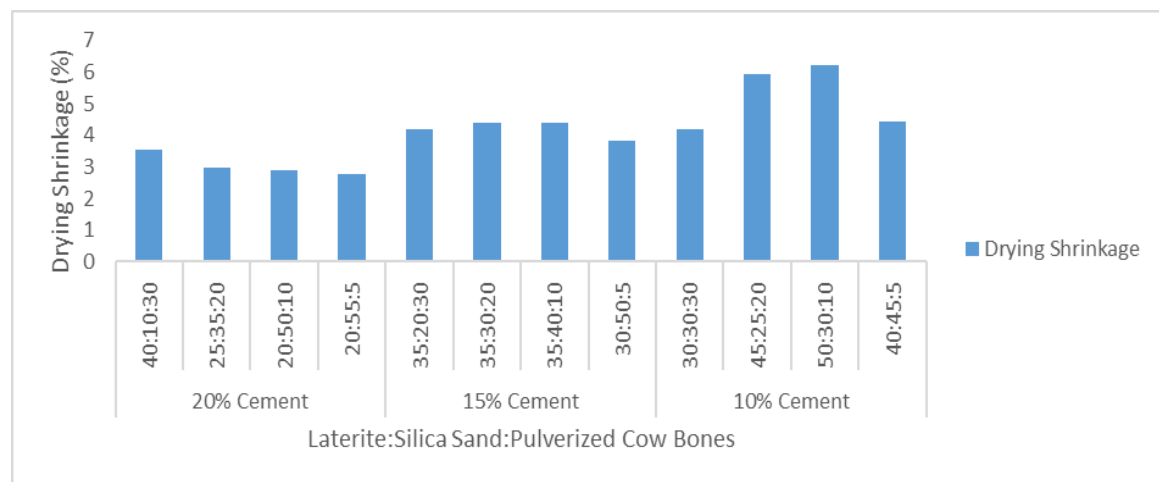


Figure 4: Percentage drying shrinkage of experimental tiles

3.4 Modulus of Rupture

Figure 5 represents a graph of cement at 20%, 15% and 10% wt compositions at different concentrations of laterite: silica sand: pulverized cow bone. When cement was at 20%, the laterite: silica sand: pulverized cow bone ratios of 40:10:30 produced modulus of rupture of 1.83 MPa, and at 20:55:5 ratios the modulus of rupture decreased to 1.7 MPa, a decrease of about 7.1%. But, with reduced cement content to 15% wt, laterite: silica sand: pulverized cow bone ratios of 35: 20: 30 had 1.21 MPa modulus of rupture, and dropped to 0.86 MPa at 30: 50: 5 ratios, another decrease of 28.93%. Similar situation was observed when the cement content was further reduced to 10%, but lower values of modulus of rupture were observed for all the ratios used. For ratios of 30: 30: 30 (laterite: silica sand: pulverized cow bones), the modulus of rupture is 0.26 MPa and decreased to 0.08 MPa at ratios 40: 45: 5 giving a 69.23% decrease. With the increase in the percentage composition of cement in the aggregate, there is increase in the modulus of rupture of the samples. The highest recorded value of modulus of rupture was 1.83 MPa at 20% cement and 40: 10: 30 ratios of laterite: silica sand: pulverized cow bone respectively. It could be observed that with increase in the % wt compositions of cement and pulverized cow bones in the aggregate, there is corresponding increase in the modulus of rupture. This shows that increase in addition of pulverized cow bones and cement led to the increase in the modulus of rupture. Cow bones been a good reinforcement material, and provides enhanced bonding strength with other additives.

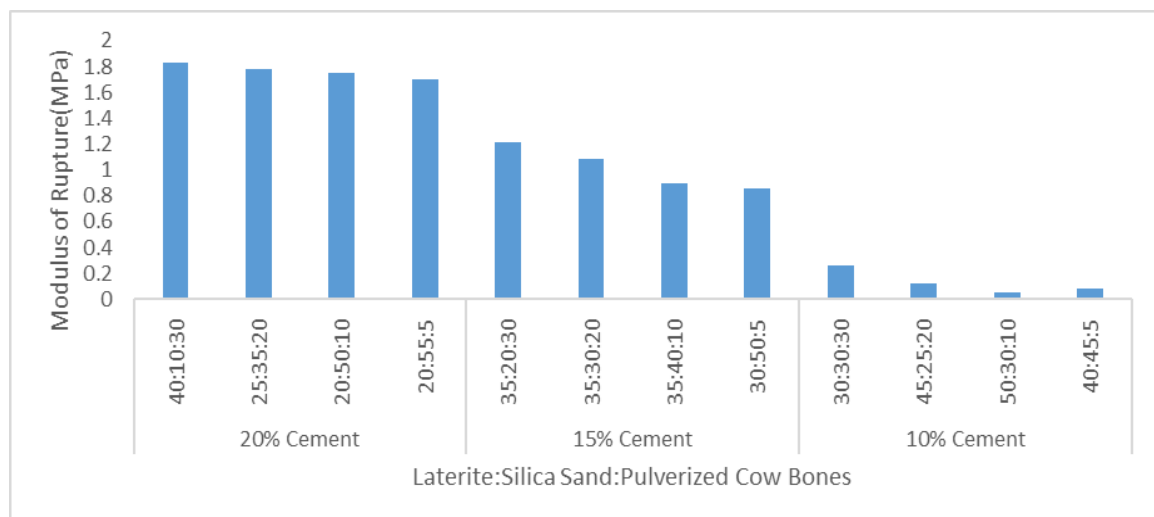


Figure 5: Modulus of Rupture of experimental tiles

3.5 Compressive Strength

Figure 6 is a graph of compressive strength against varying % wt compositions of cement, laterite, silica sand and pulverized cow bone. The figure shows cement at 20%, 15% and 10% wt compositions at different concentrations of laterite: silica sand: pulverized cow bone. When cement was at 20%, the laterite: silica sand: pulverized cow bone ratios of 40:10:30 produced compressive strength of 5.05 MPa, and at 20:55:5 ratios the compressive strength decreased to 2.42 MPa a decrease of about 52.08%. When cement content became 15% wt, similar trend could be seen from the figure as laterite: silica sand: pulverized cow bone ratios of 35: 20: 30 had 5.05 MPa of compressive strength and reduced to 2.4 MPa at 30: 50: 5 ratios another decrease of 52.48%. Though, there was a similar situation when the cement content was further reduced to 10%, but lower values of compressive strength was observed for all the ratios used. For ratios of 30: 30: 30 (laterite: silica sand: pulverized cow bones), the compressive strength is 3.08 MPa, and decreased to 2.38 MPa at ratios 40: 45: 5 giving a 22.73% reduction. With the increase in the percentage composition of cement in the aggregate, there is increase in the compressive strength of the samples. The highest recorded value of compressive strength was 5.05 MPa, at 20% cement and 40: 10: 30 ratios of laterite: silica sand: pulverized cow bone respectively, and that of 15% cement of ratios 35: 20: 30 of laterite: silica sand: pulverized cow bone of same compressive strength value. It was observed that with increase in the % wt compositions of cement and pulverized cow bone in the aggregate, there is a corresponding increase in the compressive strength.

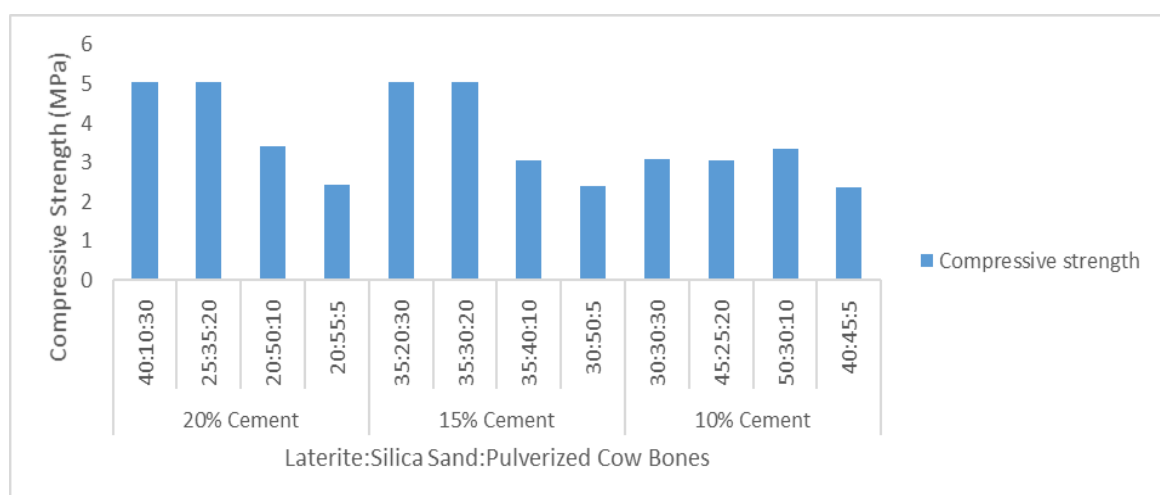


Figure 6: Compressive strength of experimental tiles

3.6 Impact Resistance

Impact resistance was analysed, the coefficient of restitution was calculated for each mix and was plotted against varying % wt composition of materials. From observation, tiles with 20% cement had better resistance to impact than those of 15% and 10% cement content.

Figure 7 shows the impact resistance of various mixes, the figure shows cement at 20%, 15% and 10% wt compositions at different concentrations of laterite: silica sand: pulverized cow bone. When cement was at 20%, the laterite: silica sand: pulverized cow bone ratios of 40:10:30, 0.55 maximum value of coefficient of restitution was observed and ascertained to be sufficient for low stress use following the European standard [18], and decreases to 0.22 at 20:55:5 ratios, a decrease of 60%. For situation when cement content was reduced to 15% wt, similar trend could be seen from the figure as laterite: silica sand: pulverized cow bone ratios of 35: 20: 30 had value of 0.4 and decreases to 0.21 at 30: 50: 5 ratios, another decrease of 47.5%. Though, there was a similar situation when the cement content was further reduced to 10%, but lower values of coefficient of restitution was observed for all the ratios used. For ratios of 30: 30: 30 (laterite: silica sand: pulverized cow bones), the coefficient of restitution is 0.28 and decreased to 0.08 at ratios 40: 45: 5 giving a 71.43% decrease. Cement was observed to play a major role in this, due to the good bonding strength it provides, as cement content reduces, the impact resistance reduces.

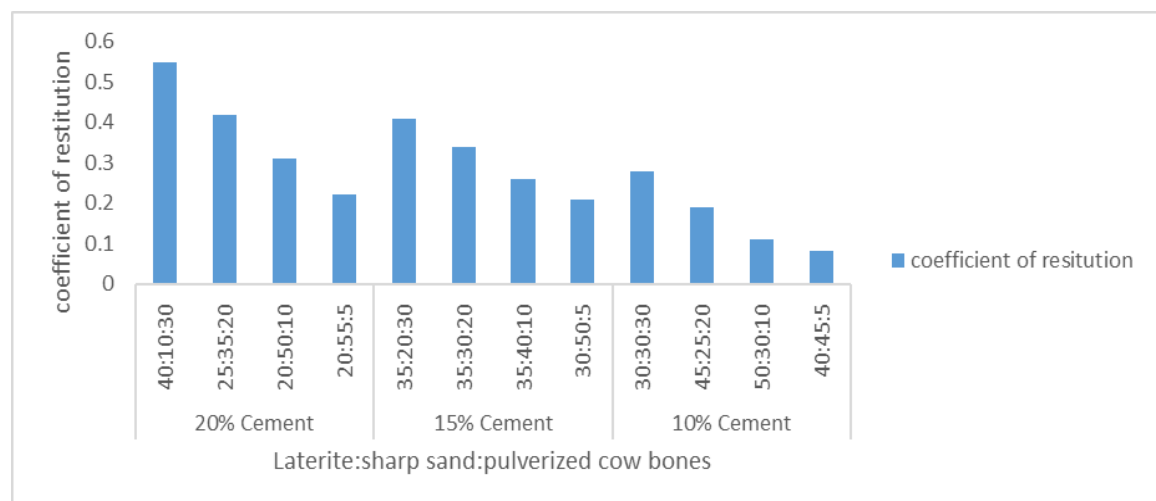


Figure 7: Impact resistance of experimental tiles

3.7 Quality of Paving Tiles

Enhanced mechanical and physical strength were observed with 30% pulverized bones and 20% cement additions. Tiles with ratio 4:3:1:2 of laterite: pulverized cow bones: silica sand: cement, were observed to have the highest mechanical and physical strength of 5.05 MPa of compressive strength and 1.83 MPa of modulus of rupture.

4. Conclusion

1. The capacity of lateritic based tiles to absorb water is same as its ability to loose water i.e. the increase in laterite content corresponds to an increase in water absorption capacity and drying shrinkage, in agreement with Ohijeagon *et al.* [7].
2. The bulk density of experimental tiles was greatly affected by the presence of silica sand, where higher percentage content leads to increase in bulk density. Pulverized cow bones did

not contribute significantly in the bulk density determination, due to the lower specific gravity it possesses.

3. The maximum compressive strength and modulus of rupture were found to be 5.05 MPa and 1.83 MPa respectively. Resulting in an optimum ratio of 4:1:3 of laterite:pulverized cow bones:silica sand mixed with a 20% cement content respectively, compared to Owolabi [13] who used palm kernel shells, an agricultural waste and obtained a compressive strength of 4.7 MPa in an optimum mixing ratio of 1:4 of kernel shells:laterite respectively and compressive strength of plain laterite of 4 MPa after 28 days of curing.
4. The impact strength of the used pulverized cow bones was observed as there was improved strength of experimental tiles in terms of compressibility, and modulus of rupture with increase in pulverized cow bones percentage in the mix. Cement composition of 20% was found as optimum for pulverized bones addition in the composition of paving tiles.

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