Effect of saw dust, rice husk, and groundnut shell on properties of mubi vimtim clay in Adamawa State Nigeria

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Abstract. Three agricultural wastes namely saw dust, rice husk, and groundnut shell were used as additives to Mubi Vimtim clay to evaluate its properties. The aim of the research work is to compare the properties of Mubi Vimtim clay when additives are added and when additives are not added. PW430 X-Ray was used to determine the chemical properties of the clay with additives and without additives. The results gave the highest % of oxides of \( \text{Al}_2\text{O}_3 \), \( \text{SiO}_2 \), \( \text{SO}_3 \), \( \text{K}_2\text{O} \), \( \text{CaO} \), \( \text{V}_2\text{O}_5 \) to be (19.67% with sample B, 67.7% with sample A, 0.40% with sample C, 4.98% with sample A, 1.33% with sample A, 0.04% with sample A and with sample B, 0.05% with sample C and with sample D) respectively. The highest porosity was found to be 17.50% with 30% sample D addition. Bulk density was highest with 2.87g/cm\(^3\) with clay sample A. The highest refractoriness of the clay was found to be 430\(^{\circ}\)C with sample A and lowest with 950\(^{\circ}\)C at 30% sample D addition. The highest thermal shock resistance was found to be 13 cycle at 10 – 30% sample D addition. The highest breaking load was found to be 380N with sample A. The highest compression strength was found to be 86 Mpa with sample A. The results obtained show the variation of the properties of Mubi Vimtim clay when saw dust, rice husk, and groundnut shell were added.

1. Introduction
Clay is a natural earthy and textured material that is plastic once wet however laborious, stony and compact when baked. It may also be referred as the finest particle size in sediment, soil or rock [1]. The component that made up the clay includes silicon oxide (\( \text{SiO}_2 \)), Aluminium oxide (\( \text{Al}_2\text{O}_3 \)), water (\( \text{H}_2\text{O} \)) and total different oxides of alkali, alkali earth metal and iron that contains some certain substances known as the clay minerals such as feldspar, mica etc [2], whereas the quantity of alkali metal oxides such as \( \text{Na}_2\text{O} \), \( \text{K}_2\text{O} \), \( \text{CaO} \) etc gave their compatibility for making ceramic products and refractory materials [3]. Clay deposits are widely distributed in Nigeria which made its search for utilization the most vital [4]. Clay has wide field of applications such as process industries, Agriculture, Geology [1-4]. The percentage of mineral oxides obtained in clay such as \( \text{Fe}_2\text{O}_3 \), MgO, CaO, and \( \text{Na}_2\text{O} \) determines the area of application of the clay such as bricks, floor, tiles, paper etc. At this time several good materials are used for grade products, and large quantities of helpful raw materials are wasted on the other hand, in several instances insufficient information is available about the potentialities low grade raw materials, small changes of their physical and chemical properties by additives may tend to improve the clay for manufacturing purposes. Change in technology requires standard raw materials properties, and new technology goes with upgrade of raw material
effectiveness of some clay minerals (montmorillonite, vermiculite, illite, and kaolinite) are recorded by several authors [5]. The study of clay minerals determines the properties focusing on the area of application for man use [1, 2, 5].

Groundnut shells are the outer covering or peels of groundnut seed. They are the obtainable agro–industrial waste that decays slowly under natural conditions [6]. Groundnut shells are vital to each animal and humans; it’s used for animal feeds and fertilizers. Most often groundnut shells are burnt or buried which affect the natural being of the environment. Other uses of groundnut shell include plastic, wardrobes, metal casting, insulation board, pesticides as well as activated carbon. The major drawback of groundnut shell is its poor digestion in animals and it’s difficult to decay [7]. It is in the light of the pollution brought about by this waste that the idea of getting into research on how to convert this waste into meaningful product came about. The addition of groundnut shell to Mubi Vimtim clay may produce clay with different properties.

Rice husk is the byproduct of rice milling process which is the outer covering of rice grain. Rice husk is the most widely readily available material in the country. Once not properly handled, it becomes a pollutant to the land and its surrounding. The frequent use of rice husk in commercial quantity is another different way of reducing the disposal problem. Rice husk are greatly utilized in ceramic factories, refractory materials, source of silica, construction industries, steel industries [8].

Saw dust is the tiny waste particles obtained from cutting of wood, planning, drilling, chiseling, etc. In Nigeria great quantity of saw dust are produced and if accumulated forms a heap which is often burnt off and result to environmental pollution [9]. Saw dust can be useful as raw materials in the manufacturing industries for light construction works such as shelves, roofing sheets, wood boards and insulators. Saw dust material is however capable of producing briquettes with density above 150-200kgm-3 [9, 10].

The aim of this research work is analyze the effect of groundnut shell, rice husk and saw dust additives to the properties of Mubi Vimtim clay for engineering applications.

2. MATERIALS AND METHODS

2.1 Materials
Mubi Vimtim clay in Adamawa State, Rice husk, Groundnut shell, Saw dust, Laboratory crusher, oven, ball mill, 50µm sieve, water, moulds.

2.2 Sample Preparation
The clay soil was sourced from Vimtim area in Mubi north Local Government area of Adamawa State. The clay sample was grounded and sieved through 75µm mesh. The clay was soaked in water such that deleterious particles were separated by gravity sedimentation. 5 g of the sample was mixed with 1g of sodium tetra – borate (borax) which was used as the binder. The clay sample was passed into the mould under high pressure to form a pellet. It was then dried in an oven at a temperature of 110°C for 30 minutes and finally removed and stored in desiccators for analysis.

In the second phase of the experiment, the same procedure was followed as was done on the base clay except that the clay was thoroughly mixed with varying proportions of saw dust, rice husk and broken groundnut shell of (10, 15, 20, 25 and 30% addition) for the different samples [11].

2.3 Determination of chemical properties
X – Ray florescent spectrometer (XRFS) was used for the analysis. It is an energy dispersive micro–processor controlled analytically and designed for the detection and measurement of elements in the samples of solids, powders and liquid form from sodium to uranium. The sample for the analysis were placed in the spectrometer and switched on to warm up in order to stabilize the optics and the X – ray tube. It was then calibrated to determine the expected elements or compounds present in the clay samples [11].
2.4. Determination of physical properties

2.4.1. Determination of Moisture Content. The empty clean container was weighed as $W_1$. The moist clay was placed in the container and weighed as $W_2$. The moist clay in the container was kept in the oven uncovered and heated at a steady temperature between 1050°C and 1100°C. Furthermore, the constant weight of the container with the dried clay sample was recorded as $W_3$. The procedure was repeated for three other samples and the average percentage of moisture content was calculated as below [12, 16].

\[
\text{Moisture content} \% = \left( \frac{W_2 - W_3}{W_2 - W_1} \right) \times 100
\]

Where: $W_1$ = Weight of empty container in (g)

$W_2$ = Weight of container and moist clay sample (g)

$W_3$ = Weight of dried clay sample and container (g)

2.4.2. Determination of Apparent Porosity. The clay samples were cleaned and air dried for 24 hours. The specimens were then dried in an oven at a temperature of 1100°C for 24 hour then fired at a temperature of 1100°C. It was cooled and transferred to desiccators and weighed to the nearest 0.01g (dried weight) it was then transferred to 250ml empty vacuum desiccators. Water was added to the beaker until the test piece was completely immersed in the water. The water was heated for 30 minutes and propelled to release trapped bubbles. The specimen was then transferred into empty vacuum desiccators to cool. The soaked weight ($W$) was recorded. The specimen was weighed when suspended in air using beaker placed on the balance to give the suspended weight ($S$). The procedure was repeated for three other samples and average percentage porosity was calculated as shown below [12,14,16].

\[
P = \left( \frac{W-D}{W-S} \right) \times 100
\]

Where: $P$ = Apparent porosity,

$S$ = Suspended weight

$D$ = Dried weight

$W$ = Soaked weight

2.4.3. Determination of Bulk Density. The Clay sample was weighed in air using a spring balance and recorded $W_a$. The sample was again weighed in Mercury and the weight was recorded $W_m$. The same procedure was done for the other samples and the average bulk density was evaluated as follows [12, 16].

\[
\text{Bulk density} = \frac{W_s}{W_m} \times \text{Density of mercury}
\]

Where: $W_s$ = Weight of clay sample in air

$W_m$ = Weight of soil sample in mercury

2.4.4. Determination of Permanent Linear Change. The length of dry clay sample was measured and recorded as $L_1$. The sample was then placed in a kiln having an oxidizing atmosphere such that the flame does not impinge on the specimen directly from the burner. The three specimens were placed at 4 cm apart from each other and from the kiln wall. The furnace temperature was maintained up to 1450°C for 1 hour, 1150°C to 1200°C for 2 hours and 1250°C for five hours. The test specimen is then cooled to room temperature for over10 hours in the closed kiln itself. The test specimen was removed and its new length recorded as $L_2$. The sample procedure was repeated for the other clay samples and the linear change was obtained as shown below [12, 13, 16].

\[
L = \frac{L_2-L_1}{L_1} \times 100
\]

Where $L$ = Linear change
\[ L_2 \equiv \text{Final length} \]
\[ L_1 \equiv \text{Original length of the sample} \]

2.4.5. **Determination of Refractoriness.** Pyrometric Cone Equivalent (PCE) was employed to test for refactoriness of the clay samples. Each of the clay samples was used to compose a self-made pyrometric cone of standard composition for 1050\(^\circ\)C, 1100\(^\circ\)C, and 1200\(^\circ\)C of 1.16 cm base diameter. The cones were placed inside furnace with a monitoring thermocouple and heated to a temperature above 1200\(^\circ\)C. The cones were closely monitored by the spy hole of the furnace and the temperature at which each cone bent over was recorded to be the refactoriness of the clays. The procedure was repeated for the other samples and the average refactoriness was recorded \[16, 17\].

2.4.6. **Determination of Thermal Shock Resistance.** The clay sample to be evaluated was critically observed for cracks and placed in a muffle furnace. The furnace was heated at a constant rate to attain a temperature of 1000\(^\circ\)C in three hours. This temperature was maintained for 30 minutes and the samples were removed from the furnace and cooled for 10 minutes. The same cycle of heating and cooling were repeated until crack was identified, the first crack was seen at 8 cycles. The procedure was repeated for the other samples and the average shock resistance were recorded \[12, 13, 16\].

2.5. **Determination of mechanical properties**

2.5.1. **Determination of Compressive Strength.** The clay sample was placed on a steel plate and load was gradually applied on it by manually operated hydraulic press through a load applicator until there was a sign of crack on the clay. The process was repeated for the other samples and the average compressive strength was calculated from the formula below \[14, 16\].

\[
\bar{c} = \frac{W}{A} \quad (5)
\]

Where: \( W \) = Maximum load attained (N) and \( A \) = Area of Load applicator

2.5.2. **Breaking Load.** The test method consists of supporting the clay specimen on the ends of three cylindrical rods arranged in an equilateral triangle form and applying a load until the clay specimen failed. The clay strength was the load necessary to cause such clay failure. The clays strength recorded was based on the average values of the clay specimen \[14\].

| Table 1. Result of the Chemical Composition of Mubi Vimtim Clay. |
|---------------------------------------------------------------|
| Oxides | Clay Without Additives | Clay with saw dust % Sample (A) | Clay with rice husk % Sample (B) | Clay with groundnut shell % Sample (C) |
|--------|------------------------|-------------------|-------------------|------------------|
| Al\(_2\)O\(_3\) | 18.1 | 19.67 | 18.95 | 19.25 |
| SiO\(_2\) | 67.7 | 48.24 | 50.2 | 55.25 |
| SO\(_3\) | 0.20 | 0.35 | 0.40 | 0.28 |
| K\(_2\)O | 4.98 | 3.00 | 4.46 | 3.98 |
| CaO | 1.33 | 0.55 | 0.48 | 1.22 |
| V\(_2\)O\(_5\) | 0.04 | 0.04 | 0.05 | 0.05 |
| Cr\(_2\)O\(_3\) | 0.03 | 0.03 | 0.03 | 0.04 |
| MgO | 0.15 | 1.33 | 1.75 | 1.89 |
|       | FeO₂₃ | CuO   | Loss of Ignition | Others | Total |
|-------|-------|-------|------------------|--------|-------|
|       | 3.20  | 0.01  | 4                | 0.26   | 100   |
|       | 3.40  | 0.056 | 9.74             | 13.594 | 100   |
|       | 4.21  | 0.87  | 10.24            | 8.36   | 100   |
|       | 3.96  | 0.69  | 12.65            | 0.74   | 100   |

Source: National Metallurgical Develop. Centre Jos, 2018

**Table 2.** Apparent Porosity with % Additives.

| % additives | Clay with 0% additive Sample (A) | Clay with saw dust additive % Sample (B) | Clay with rice husk additive % Sample (C) | Clay with groundnut shell additive % Sample (D) |
|-------------|----------------------------------|------------------------------------------|------------------------------------------|-----------------------------------------------|
| 0           | 13.70                            | -                                        | -                                        | -                                             |
| 10          | -                                | 13.80                                    | 14.20                                    | 16.50                                         |
| 15          | -                                | 14.10                                    | 14.35                                    | 16.66                                         |
| 20          | -                                | 14.25                                    | 14.50                                    | 17.25                                         |
| 25          | -                                | 14.40                                    | 15.55                                    | 17.40                                         |
| 30          | -                                | 14.60                                    | 16.75                                    | 17.50                                         |

Source: National Metallurgical Develop. Centre Jos, 2018

**Table 3.** Bulk Density with % Additives.

| % additives | Vimentin Clay g/cm³ Sample (A) | Clay with saw dust g/cm³ Sample (B) | Clay with rice husk g/cm³ Sample (C) | Clay with groundnut shell g/cm³ Sample (D) |
|-------------|--------------------------------|-------------------------------------|-------------------------------------|--------------------------------------------|
| 0           | 2.87                           | -                                   | -                                   | -                                          |
| 10          | -                              | 2.20                                | 2.45                                | 2.75                                       |
| 15          | -                              | 2.15                                | 2.40                                | 2.50                                       |
| 20          | -                              | 2.10                                | 2.35                                | 2.40                                       |
| 25          | -                              | 2.06                                | 2.31                                | 2.30                                       |
| 30          | -                              | 2.00                                | 2.20                                | 2.20                                       |

Source: National Metallurgical Develop. Centre Jos, 2018

**Table 4.** Refractoriness with % Additives.

| % additives | Vimentin clay °C Sample (A) | Clay with saw dust °C Sample (B) | Clay with rice husk °C Sample (C) | Clay with groundnut shell °C Sample (D) |
|-------------|----------------------------|---------------------------------|-----------------------------------|------------------------------------------|
| 0           | 1430                       | -                               | -                                 | -                                        |
| 10          | -                          | 1300                            | 1250                              | 1200                                      |
| 15          | -                          | 1220                            | 1200                              | 1150                                      |
| 20          | -                          | 1200                            | 1100                              | 1100                                      |
| 25          | -                          | 1100                            | 1050                              | 1050                                      |
| 30          | -                          | 1050                            | 1000                              | 950                                       |

Source: National Metallurgical Develop. Centre Jos, 2018
Table 5. Thermal Shock Resistance at 1200°C with % Additives.

| % additives | Vimtim clay Sample (Cycle A) | Clay with Saw dust Sample (B) | Clay with rice husk Sample (C) | Clay with groundnut shell Sample (D) |
|-------------|-------------------------------|-------------------------------|-------------------------------|-----------------------------------|
| 0           | 8                             | -                             | -                             | -                                 |
| 10          | -                             | 10                            | 12                            | 13                                |
| 15          | -                             | 10                            | 12                            | 13                                |
| 20          | -                             | 10                            | 12                            | 13                                |
| 25          | -                             | 10                            | 12                            | 13                                |
| 30          | -                             | 10                            | 12                            | 13                                |

Source: National Metallurgical Develop. Centre Jos, 2018

Table 6. Compressive Strength with % Additives.

| % additives | Vimtim clay Mpa Sample (A) | Clay with Saw dust Mpa Sample (B) | Clay with rice husk Mpa Sample (C) | Clay with groundnut shell Mpa Sample (D) |
|-------------|-----------------------------|----------------------------------|-----------------------------------|------------------------------------------|
| 0           | 86                          | -                                | -                                | -                                        |
| 10          | -                           | 78                               | 68                               | 59                                       |
| 15          | -                           | 75                               | 57                               | 47                                       |
| 20          | -                           | 68                               | 52                               | 42                                       |
| 25          | -                           | 60                               | 50                               | 38                                       |
| 30          | -                           | 57                               | 48                               | 37                                       |

Source: Civil Engineering Work Shop Uniben 2018

Table 7. Breaking Load with % Additives.

| % additives | Vimtim clay N Sample (A) | Clay with Saw dust N Sample (B) | Clay with rice husk N Sample (C) | Clay with groundnut shell N Sample (D) |
|-------------|--------------------------|---------------------------------|----------------------------------|---------------------------------------|
| 0           | 380                      | -                               | -                                | -                                     |
| 10          | -                        | 370                             | 368                              | 362                                   |
| 15          | -                        | 368                             | 358                              | 354                                   |
| 20          | -                        | 350                             | 342                              | 340                                   |
| 25          | -                        | 345                             | 336                              | 328                                   |
| 30          | -                        | 332                             | 328                              | 318                                   |

Source: Civil Engineering Work Shop Uniben 2018

3. Results and discussion

3.1. Results of the Chemical Analysis

It can be seen from table 1 that the Al₂O₃ was highest 19.67% in a clay sample B and lowest with 18.1% in clay sample A. SiO₂ was highest 67.7% in clay sample A and lowest with 48.24% in clay sample B. Similarly SO₃ is highest 0.40% in a clay sample C and lowest of 0.20% in clay sample A. K₂O is highest with 4.98% in clay sample A and lowest with 3.00% in clay sample B. Calcium oxide
was highest 1.33% in clay sample A and lowest 0.48% in clay sample C. V$_2$O$_5$ has the same value of 0.04% in both clay samples A and B and 0.05% in clay samples C and D. Cr$_2$O$_3$ was found to be 0.03% in clay samples A, sample B and with sample C and the value of 0.04% was found in clay sample D. MgO was highest in clay sample B 1.89% and lowest of 0.15% in clay sample D. Fe$_2$O$_3$ was highest with 4.21% in clay sample C and lowest with 3.20% in clay sample A. CuO was found to be highest 0.89% in clay sample C, and lowest with 0.01% in clay sample A. The lost of ignition was highest 12.65% in a clay sample D as an additive and lowest of 4% in a clay sample A.

3.2. Results of the Physical Analysis

3.2.1. Apparent Porosity. Figure 1 shows the graph of apparent porosity against the % additives. The apparent porosity of the clay with sample D increases with increase in % additives. It has the lowest value of 16.5% at 10% additive and highest with 17.50% with 30% sample D addition. In clay with Sample C, the porosity increases with an increase in % sample C addition. The porosity was highest 16.75% with 30% sample C addition and lowest with 14.20% with 10% addition. In clay with sample B the apparent porosity increases with increase in % sample B addition, which is highest with 14.60% at 30% addition and lowest with 13.80% at 10% addition. The clay sample A additives was measured to have apparent porosity of 13.70%. It can be seen from the analysis that the apparent porosity of the clay increases in all the soils with varying % of additives.

3.2.2. Bulk Density. Figure 2 shows the graph of bulk density against % additives, it can be seen from the graph that, the bulk density increases with decrease in additives in all the clay samples. In clay sample with sample B, the highest bulk density was obtained to be 2.20g/cm$^3$ with 10% sample B addition and lowest with 2.00g/cm$^3$ with 30% sample B. In clay with sample C, the highest bulk density was obtained to be 2.45g/cm$^3$ at 10% addition and 2.20g/cm$^3$ at 30% addition as the lowest. The clay with sample D recorded the highest bulk density of 2.75g/cm$^3$ with 10% addition and 2.20g/cm$^3$ as the lowest with 30% sample D addition. The clay sample A recorded a bulk density of 2.87g/cm$^3$ from table 3. It can be seen that the use of additives reduces the bulk density of the clay sample.

3.2.3. Thermal Shock Resistance. Table 5 gave the result of thermal shock resistance with varying % additives. The thermal shock resistance of clay sample A was found to be 8 cycle at 1200$^\circ$C. The clay sample with sample B as an additive gave a constant of 10cycles at 1200$^\circ$C with all the % additives. Clay sample C gave a thermal shock resistance of 12cycles at 1200$^\circ$C with all the varying sample C addition. Similarly clay sample D gave a thermal shock resistance of 13cycles at 1200$^\circ$C with different % of sample D addition. It can be seen that increase in additives increases the thermal shock resistance of all the clay samples.

3.2.4. Refractoriness. Figure 3 shows the graph of refractoriness against % additives, it can be seen from the graph that, the refractoriness of the three clay samples with additives namely sample B, sample C and sample D shows decrease in refractoriness with % additives. Clay sample B additive gave the highest refractoriness of 1300$^\circ$C at 10% sample B addition and lowest with 1050$^\circ$C at 30% sample B addition. In clay sample C addition, the highest refractoriness was found to be 1250$^\circ$C at 10% addition and lowest with 1000$^\circ$C at 30% sample C addition. In the clay sample D, the highest refractoriness was recorded to be 1200$^\circ$C at 10% addition and lowest with 950$^\circ$C at 30% sample D addition. The reason may not be far from the fact that introduction of additives tends to lower the refractoriness of the clay sample. The refractoriness of the clay sample A was measured to be 1430$^\circ$C in table 4.
3.3. Results of the Mechanical Properties

3.3.1. Breaking Load. Figure 4 shows graph of breaking load against the % additives. It can be seen that, the breaking load of all the clay decreases with increase in additives and increases with decrease in additives. It can be seen that clay sample B recorded the highest breaking load of 370N at 10% addition and lowest with 332N at 30% addition. In clay sample C, the highest breaking load was recorded to be 368N at 10% addition and lowest with 328N at 30% sample C addition. In a clay sample D, the highest breaking load was recorded to be 362N at 10% addition and lowest with 318N at 30% clay addition. The clay sample A was recorded to be 380N. This variation in breaking load may be due to the fact that additives increase the pore spaces in the clay sample and affect its strength.

3.3.2. Compressive Strength. Figure 5 shows the graph of compressive strength against % additives, it can be seen that, the compressive strength of the clay sample A was measured to be 86 MPa. The compressive strength increases with decrease in additives in all the three clay samples. In a clay sample with sample B additive, the highest compressive strength was obtained to be 78 MPa at 10% addition and 57 MPa at 30% sample B addition. In clay sample C, the highest compressive strength was obtained to be 68 MPa at 10% addition and lowest by 48 MPa at 30% sample C addition. In a clay sample D additive, the highest compressive strength was obtained to be 59 MPa at 10% addition and lowest 37 MPa at 30% sample D addition. The decrease in compressive strength in all the samples may be as a result of increase in pore in the micro structure.
4. Conclusion

It was observed that for good compressive strength and breaking load the clay should be used singly without any additives. Similarly for high refractoriness the clay should be used without any additive. It was also discovered that for high refractoriness the clay should be used without any additive. For high thermal density and high thermal shock resistance the clay should be used without any additives. It was also observed that when the clay to be used requires high porosity groundnut shell should be added.

It was also discovered that when the clay to be used requires high aluminium oxide groundnut shell should be added. Similarly when high silicon oxide is required nothing should be added. When the clay to be used requires sulphur trioxide rice husk should be added. For high potassium oxide and calcium oxide nothing should be added. For clay to be used that requires high vanadium pentaoxide rice husk and groundnut shell should be added. When the clay to be used requires chromium oxide and magnesium oxide groundnut shell should be added. Similarly when the clay to be used requires iron III oxide and copper oxide rice husk should be added.

A recommendation is put across that further research should be conducted with powdered rice husk, powdered ground nut shell and powdered saw dust to compare the properties with the ungrounded additives and see whether it will have effect or change in the properties of Mubi Vimtim clay.

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