# PERFORMANCE ASSESSMENT OF MAKURDI BURNT BRICKS

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## ABSTRACT

*This work involved onsite observation of the production process; determination of physical properties and chemical composition of the soil sample used for production of Makurdi burnt bricks (MBB). A total of 22 brick specimens, of the MBB was examined in the laboratory for compressive strength, water absorption and abrasion resistance. The results reveal the soil sample as a true laterite having a Silica-Sesquioxide ratio of 1.01, Silica content of 42.95 and clay content of 27.38 and total clay + silt content of 30.78. The Atterberg's limit test gave the liquid limit as 36.79; plastic limit, 26.11and plastic index, 10.68. Compressive strength was 3.46 N/mm$^2$ and 11.75 N/mm$^2$ for Samples A and B respectively; Average water absorption for Sample B (16.49%) was double that of Sample A (8.58%) while the Abrasion resistance ability of Sample B (33.67%) was four times better than Sample A (9.32%).*

**KEYWORDS**: Burnt Bricks, Performance Assessment, Compressive Strength, Abrasion Resistance, Water Absorption.

## INTRODUCTION

A visit to Makurdi, the Benue State Capital of Nigeria in 2009 for the 39$^{th}$ Annual General Meeting/ Conference of Nigerian Institute of Building (NIOB) tagged "Food Basket 2009" generated a research interest on the Makurdi locally made burnt bricks (MBB). Something of interest is the rampant use and acceptability of the MBB; it is really a display of the residents attempt at meeting the need for shelter using materials that the environment can afford in line with the postulations of Fitch and Branch (1960). Adegoke and Ajayi (2003) posited that a good material for shelter provision must allow participation from the community and thereby improving the economy of that community. This is what they called appropriate technology. Such materials must be readily available, appropriate (economically (i.e. affordable) and physically) to the environmental demands, thermally efficient and socially acceptable (Olusola, 2005).

Makurdi Burnt Bricks can be said to fall specifically to the category of materials fitting into the scenario described by the researchers quoted above. The bricks were not only being adopted for modern building structures as shown in Plates 1 & 2, they are used for incinerators, drainage works, waterlogged sites and free standing walls of fence with little or no treatment as shown in Plates 3 & 4. The use of the MBB was noted not to be limited to private residential houses, public and corporate building structures were not left out. A good example is the wall of fence of J. S. Tarka Foundation Civic Centre in Makurdi.


Plate 1: A modern structure built from MBB.


Plate 2: A modern structure being constructed using MBB.


Plate 3: MBB used to construct an open Incinerator.


Plate 4: MBB adopted for the perimeter wall of a Water Tank Tower.

The MBB were said to be cheap, sold as low as #5/brick at normal period, while the highest price stands at #8/brick during the peak period as against the unit price of #100 and #120 for 150 mm and 225 mm sandcrete blocks respectively, implying masonry unit material cost of #235/$m^2$ to #376/$m^2$ using MBB as against #1000/$m^2$ to #1200/$m^2$ for sandcrete blocks. Hence a saving in masonry material cost of about 70% in wall. This is coupled with the fact that brickwall surfaces are often finished without additional cement/sand rendering. Despite these numerous advantages of the MBB and its high level of public acceptance and use in Makurdi and its environments, there are no empirical data on the Engineering properties of this important masonry unit nor is there a research report on the classification and suitability of the soil being used for its production. This paper thereby presents a report of the critical study of the production process and performance assessment of the MBB with a view at determining the suitability of the soil type used, adequacy of technology adopted for its production, the performance assessment of the MBB at meeting requisite standards and its durability in the prevailing environment.

## LITERATURE REVIEW

Brick is defined in the Encarta English Dictionary (2009) as a rectangular block of clay or similar material (i.e. laterite) that is baked until is hard and is used for building houses, walls or other permanent structures.

Usage of burnt bricks dates back to the stone age (i.e. 2500 BC) as recorded in the Bible story of "The Tower of Babel" in Genesis chapter 11 verse 3 where the people were said to "make bricks and burn them thoroughly." They had brick for stone, and they had asphalt for mortar (The Maxwell Leadership Bible, 2007 – NKJV).

In pre-modern China, brick-making was the job of a lowly and unskilled artisan, but a kiln master was respected as a step above the latter. The Romans made use of fired bricks and the Roman legions which operated mobile kilns introduced bricks to many parts of the empire. Roman bricks are often stamped with the mark of the legion that supervised its production. The use of bricks in Southern and Western Germany for example, can be traced back to traditions already described by the Roman Architect Vitruvius (Wikipedia, 2011). Brick or Earth for wall construction in Nigeria is of the long proven use, earth bricks are still mostly used for dwellings, which are built without formal authorization such as obtained in the rural housing or uncontrolled low income housing in the urban areas.

The soil used for brick making is often called different names such as earth, clay or laterite but the term "laterite" according to Encarta English Dictionary (2009) originates from the Latin word later meaning brick.

Laterite is defined as red tropical soil: a reddish mixture of clayey iron and aluminium oxides and hydroxides formed by the weathering of basalt under humid, tropical conditions (Encarta, 2009).

Numerous definitions have been given to Laterite depending on the professional inclination of the authors. While some are purely morphological, some are purely physical and some others are purely chemical.

The term “laterite”, according to Hamilton (1995), was first used by Buchanan in 1807 to describe a ferruginous (high iron content), vesicular (contain small cavities), unstratified and porous material with yellow archers caused by its high iron content, and occurring abundantly in Malabar, India. It was used for weathering materials from which blocks are cut, that after drying are used as building bricks. Hence the word “laterite” was derived from the Latin word “later” which means brick or tile. Laterite has also been recognized as the alteration or in-situ weathering products of various materials including crystalline igneous rocks, sediments detrital deposit and volcanic ash. The degree of weathering to which the parent materials have been subjected influences greatly the physical and chemical composition of Laterite soils (Olusola, 2005).

The first to establish the chemical concept of the definitions of Laterite was probably Mallet (1883) as quoted in Osunade (1984), Owoshagba (1991) and Olusola (2005). He established the ferruginous and aluminium nature of lateritic soils. Fermor (1981) defined various forms of laterite soils on the basis of the relative contents of the so-called laterite constituents (Fe, Al, Ti, Mn) in relation to Silica. A chemical definition base on the (S-S) Silica Sesquioxides ratio ($SiO_2$ / $Al_2O_3$+$Fe_2O_3$) had been proposed, the conclusion being an S-S ratio $\leq$ 1.33 implies a true laterite; an s-s ratio between 1.33 and 2.0 refers to a lateritic soil; and an S-S ratio $\geq$ 2.0 indicates a non-lateritic typically weathered soil.

Gidigasu (1976) gave a broad-based definition of Laterite which may be more appropriate for engineering applications. He states that the word laterite should be used to describe “all the reddish residual and non-residual tropically weathered soils, which genetically form a chain of materials ranging from decomposed rock through clays to sesquioxides ($Al_2O_3$ + $Fe_2O_3$) rich crust, generally known as cuirass or carapace”. Cuirass stands for the upper layer of laterite accumulation zone and is particularly enriched in iron oxide minerals. Carapace on the other hand stands for the lower part of laterite accumulation zone. Miller (1999) also describes laterite as heavily leached tropical subsoil which is not fertile and comprises mainly iron and aluminium oxides and kaolinite-clays.

Rajput (2006) stated that brick earth is derived by the disintegration of igneous rocks and that a good brick earth should be easily moulded and dried without cracking and warping. Discussing on the chemical composition, he further stated that it should have the followings:

1. Alumina ($Al_2O_3$) or Clay = 20-30 percent by weight
2. Silica ($SiO_2$) or sand = 35-50 percent by weight
3. Silt = 20-25 percent by weight.

Total content of clay and silt is recommended to preferably be less than 50 percent by weight. Rajput (2006) further stated that brick earth must have proper proportions of sand, silt and clay; be homogeneous; have sufficient plasticity and be free from lumps of lime and nodules of kankar. This conforms to the postulations that the material used for brick production falls under other previous authors and researchers' classification of the soil called laterite.

Burning of bricks is one of the popular methods of stabilization; others are introduction of cement and other pozzolanic material such as Rice husk ash, volcanic ash, sugarcane bargash ash and many others. Burning of bricks being possibly the first means of stabilization has to be thorough and uniform for the essence of imparting hardness and strength to the bricks and increasing the bricks density so as to enhance its water resistance tendencies to be achieved. This study thereby examines MBB with a view to determining the physical properties and chemical composition of the soil used in making the bricks, investigate the production process specifically the method of burning and assess the compressive strength and durability properties of the bricks.

## MATERIALS AND METHODS

### Materials Collection

This study involved observation of the production process of the MBB at the local site in Km. 4, Gboko road, Makurdi. Keen attention was given to the burning process of the bricks while some quantity of the soil sample were collected for laboratory analysis for physical and chemical properties with some samples of the finished bricks also collected for determination of compressive strength, abrasion and water absorption.

### Local Production of Burnt Bricks in Makurdi

The stages involved in processing the local burnt bricks as observed in Makurdi are as follows;

The soil was excavated from a boring pit and stacked in heaps in the open for rain to wash out the soluble salts which might later cause white scum on the product. After the soil had been thoroughly washed, it was stored in open storage area until when they are ready for use. Before putting it to use, water was then added to the soil to form a paste.

The laterite paste was then poured into a mould of 270 mm x 110 mm x 80 mm and the bricks were then moulded. The freshly produced bricks were stored in the open air in rows. They were covered temporarily with dried grass to ensure protection against adverse weather condition. This ensures that there is constant drying. This depends completely on the weather conditions and can take as from 4 – 6 weeks of proper or desired drying before burning.

The bricks were only ready for burning at the completion of proper drying. The properly dried bricks were stacked with a provision for firing or heating to develop hardness at the bottom. The staked bricks were covered with a thick layer of soil paste to reduce the loss of heat during firing as shown in Plate 5. The fire was started, heat developed and then after few days of firing the fuel was cut off entirely and the burnt bricks were allowed to cool down naturally. The fuel mostly used in firing is wood.

When the bricks are well burnt, a cherry-red hue develops and this condition is held for about 6 hours. Sufficient fuel must be available when the burning starts as the entire batch of bricks might be lost if the fires were allowed to die down during the operation. Firing with wood took two to five days. The bricks were adjudged to have been thoroughly burnt when a part of the heap starts falling without the bricks breaking as seen in Plate 6. Burnt brick samples were examined by breaking off a part of the brick to see how the inner surface is; bricks not well burnt gave an inner colour of ash as in Plate 7 while well burnt brick gave a uniform yellowish brown colour same as the external surface.

Plate 5: Staked bricks set for firing

Plate 6: Staked bricks after firing


Plate 7: Inner ash colour of brick no well burnt


Plate 8: Stacked burnt bricks around firing channel


Plate 9: Crushed burnt brick (Sample A)


Plate 10: Crushed burnt brick (Sample B)

During the firing, the bricks shrink as much as 10%. As they were taken out of the staked batch after firing, they were sort to different grades with the main criteria being strength, irregular dimensions and sometimes cracks. Two classifications of good bricks always result from this process; well burnt bricks usually adopted for normal building construction (Sample A - those brick not in direct contact with fire source) and the over burnt referred to as iron-bricks - commonly used for drainages and waterlogged areas (Sample B - those brick in direct contact with fire source). Plates 9 and 10 presents Sample A having uniform yellowish brown colour and Sample B in dark grey/black shining charcoal-like colour.

A total of Thirty (30) bricks – Fifteen (15) for each Sample specimens were collected from No 4 Gboko road, Makurdi and taken to F.U.T, Minna for assessment in the laboratory.

**Instrumentation**

The chemical analysis of Laterite sample was carried out at the Sagamu Works Department of Lafarge Cement (West African Portland Cement Company -WAPCO) via an X-ray Fluorescent Analysis using a

Total Cement Analyser model ARL 9900 XP. The physical properties test on the soil sample; compressive strength and water absorption on the MBB were carried out in the Department of Building laboratory, FUT, Minna and Abrasion test on the MBB was carried out at the Civil Engineering Laboratory of Federal Polytechnic, Bida using the Los Angeles Abrasion Testing Machine. Furthermore all mass measurements were taken on weighing balances available in the various Laboratories of the Federal University of Technology (FUT), Minna and Federal Polytechnic, Bida.

## Experimental Procedure

### Determination of Chemical Composition of Laterite Sample

The Laterite sample was prepared in F.U.T, Minna and then taken to WAPCO, Sagamu Works for analysis. About 150 g of the Laterite sample was packaged in small nylon bag and sent to the Chemical Laboratory of WAPCO.

The determination of the chemical composition at WAPCO in accordance to ASTM C311 – 2008 involved drying, grinding, pressing and analysing. The materials were dried in an oven at 100 $\pm 10^{o}$C for about two hours until a constant weight (±0.01 g) was obtained after which the sample was placed in a desiccator to cool for about 30 minutes before grinding commences. In order to aid grinding and to prevent sticking of the sample to dish, 0.8 g of stearic acid was weighed into sample dish before adding 20.0 g of the material (VA sample) into it. Grinding was done on a gyro-mill grinding machine (Model HSM 100H, Serial Number MA 11566-5-1, 2004), which stops automatically after grinding for a pre-set time of 3 minutes. The sample was then ready for pressing.

The ground sample plus 1.0 g of stearic acid to ensure adequate binding, was used to fill the pellet cup to the brim. The pellet cup was then centrally placed in an automatic hydraulic operated press (Model TP 40/2D), pressed at 20 tons load and 30 seconds hold time. On completion of pressing, the pressed pellet was carefully removed from the cylindrical pressing die and transferred into the X-ray analyser sample holder ready for analysis.

The analysis was carried out using X-Ray Fluorescent Analyser called Total Cement Analyser (Model ARL 9900 XP), is connected directly to a computer system. The pressed pellet was loaded in the sample port of the analyser and the assembly left for about three minutes after which the values of elements concentration were displayed on the monitor. This was saved directly on the system and the printed out as the result of the analysis.

**Physical Properties of Laterite Sample**

The physical properties tests carried out on the Laterite soil sample included sieve analysis to determine the particle size distribution; Atterberg limits tests (i.e. liquid and plastic limits) to determine the plastic index of the soil sample. Also determined were the specific gravity and the moisture content of the soil sample. The tests were carried out in accordance with the requisite current British standards (i.e. BS EN 933 – 1:1997 and BS EN 12620 – 1:2002 for sample grading; BS EN 1377 – 2:1990 for Atterberg limits; BS EN 1097 – 6:2000 and BS EN 1097 – 5:1999 for moisture contents).

**Performance Assessment of the MBB**

The major tests carried out on the MBB are the compressive strength, abrasion and the water absorption. A total of twenty two (22) numbers of the burnt bricks were used for these tests in accordance with the appropriate British Standards.

The compressive strength in accordance to BS EN 12390 – 3:2000 involved subjecting a total of ten bricks (five numbers for each brick specimen type) to crushing on an ELE compression machine (maximum capacity 2000KN, Model No JYS 2000A CLASS 1 Serial No. 16) while the crushing force was noted and average of the compressive strength calculated for five specimen giving the compressive strength value of the brick sample. Plates 9 and 10 presents the two sample types of brick crushed.

Abrasion test and water absorption are both durability measures to determine the ability of the brick to resist wearing away by erosion and other environmental conditions (i.e. abrasion) one hand; while water absorption properties on the other hand is a measure of the suitability of a brick for construction works. Rajput (2006) specifies that the water absorption of a good brick should not exceed 20% weight of the dry brick.

The water absorption in accordance to BS 1881 - 122:1983 was carried out using a total of six brick samples (three each for each sample type). The specimen bricks were first weighed dry, and then immersed in water for a period of sixteen hours (16 hrs) and weighed again; the difference in weight indicated the water absorbed by the brick. The average of three replicates for each sample type gave the water absorption value of the brick.

The compressive strength and water absorption tests were carried out at the Building Laboratory of Federal University of Technology, Minna.

The abrasion test in following the concept spelt in BS 1881 – 122:1983 was carried for a total of six specimen of the MBB adopting three each for Samples A and B respectively in Civil Engineering Laboratory of Federal Polytechnic, Bida using the Los Angeles Abrasion Testing Machine available. The test involved weighing the brick sample before inserting the machine and then subjected to 500 revolutions and weighed again. The difference in weight calculated in percentage (%) gives an indication of the % durability of the brick sample while the average of three replicate was adopted in this study as the % durability.

## RESULTS AND DISCUSSION

### Constituents of the Soil Sample

The result of the chemical analysis carried out on the Laterite sample as shown in Table 1. It reflects Silica – Sesquioxide (S-S) Ratio tagged SR in the Table, as 1.01 implying a **true laterite.**

**Table 1: Result of Chemical Analysis of Laterite Sample**

| **Elements** | **% Composition by weight** | **Others** | **Values** |
|---|---|---|---|
| $SiO_2$ | 42.95 | $Cl^-$ | 0.00 |
| $Al_2O_3$ | 27.38 | L.O.I | |
| $Fe_2O_3$ | 14.95 | SUM | 83.76 |
| CaO | -0.65 | LSF | -0.34 |
| MgO | -0.62 | SR | 1.01 |
| $K_2O$ | 0.32 | AR | 1.83 |
| $Na_2O$ | 0.23 | $C_3S$ | -487.34 |
| $P_2O_5$ | 0.03 | $C_2S$ | -481.23 |
| $TiO_2$ | 1.14 | $C_3A$ | 16.92 |
| $Mn_2O_3$ | 0.16 | $C_4AF$ | 36.45 |
| $SO_3$ | -0.14 | $Al_2O_3+Fe_2O_3$ | 42.33 |
| Total $SiO_2+Al_2O_3+Fe_2O_3$ | 85.28 | | |

The laterite sample was noted to be light brown in colour and have a high quantity of Silica ($SiO_2$ = 42.95 %), average Iron Oxide and Aluminium content ($Fe_2O_3$ = 14.95 % and $Al_2O_3$ = 27.38 %) and can be classified to be Aluminium Laterite but not bauxite in line with Tietz (1997) classification since the Aluminium content is higher than the Iron content. The soil thereby conforms to Rajput (2006) requirement for a good brick making earth on basis of the Alumina ($Al_2O_3$) or clay and Silica ($SiO_2$) or sand content.

The result of Liquid and Plastic Limit are shown in Table 2 and 3 while Fig.1 shows the plot of the Liquid Limit gotten via the use of Microsoft Excel.

**TABLE 2: Liquid Limit of Laterite Sample Used**

| | **LIQUID LIMIT** | | | | |
|---|---|---|---|---|---|
| Penetration (mm) | 15 | 17 | 19.5 | 22.5 | 24.5 |
| Can Number | A | B | C | D | E |
| Weight of Can (g) | 24.1 | 24.3 | 24.6 | 23.9 | 25.4 |
| Weight of Can + wet Soil (g) | 29.6 | 29.9 | 30.1 | 30.2 | 31.7 |
| Weight of Can + dry soil (g) | 28.5 | 28.6 | 28.8 | 28.4 | 29.5 |
| Weight of wet soil (g) | 5.5 | 5.6 | 5.5 | 6.3 | 6.3 |
| Weight of dry soil (g) | 4.4 | 4.3 | 4.2 | 4.5 | 4.1 |
| Moisture Content (%) | 25.0 | 30.2 | 31.0 | 40.0 | 53.7 |

**TABLE 3: Plastic Limit of Laterite Sample Used**

| | **Plastic Limit** | |
|---|---|---|
| Can Number | 20 | 10 |
| Weight of Can (g) | 24.9 | 24.3 |
| Weight of Can + wet Soil (g) | 26.2 | 25.4 |
| Weight of Can + dry soil (g) | 25.9 | 25.2 |
| Weight of wet soil (g) | 1.3 | 1.1 |
| Weight of dry soil (g) | 1.0 | 0.9 |
| Moisture Content (%) | 30.0 | 22.2 |
| Average | 26.11 | |

Using the equation of the line of best fit given as **y = 2.725x – 17.71 and $R^2$ = 0.882**

Hence Liquid Limit (L. L .i.e. Moisture Content at 20 mm penetration) = **36.79.**

Table 3 present the Plastic Limit=**26.11,** while the Plastic Index = L. L – P. L =**10.68**, all this shows the laterite sample has Atterberg limits conforming to the range as specified by the findings of Abidoye (1977).

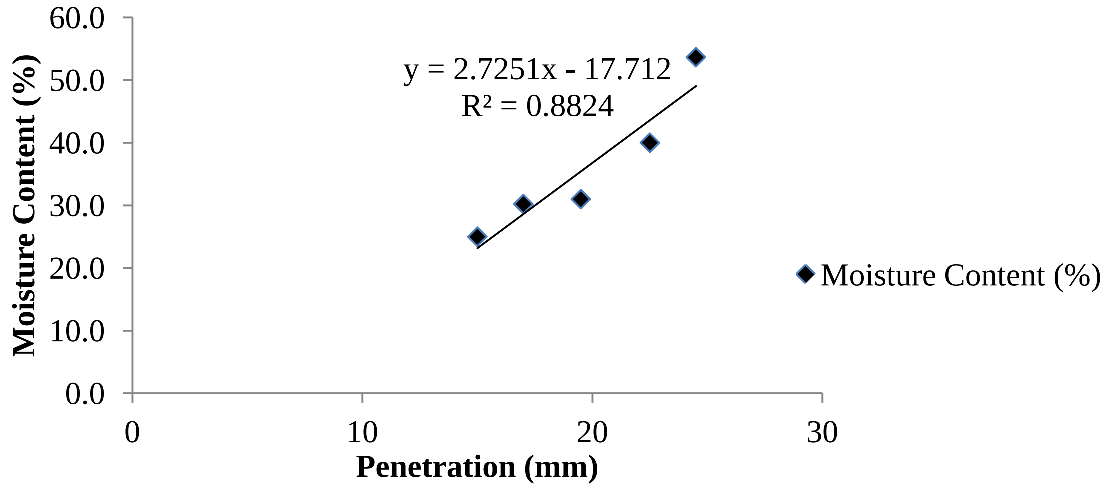


**Fig. 1: Liquid Limit of Laterite Sample Used**

Table 4 present result of the sieve analysis of the Laterite sample.

**Table 4: Results for Sieve Analysis on Soil Sample**

| **Sieve Sizes** | **Weight of sieve (g)** | **Weight of sieve + sample retained (g)** | **Weight of sample retained (g)** | **% retained** | **% Passing** | **Cumulative % retained** |
|---|---|---|---|---|---|---|
| 5.00mm | 478.6 | 507.2 | 28.60 | 5.72 | 5.72 | 94.28 |
| 3.35 mm | 468.9 | 499.7 | 30.80 | 6.16 | 11.88 | 88.12 |
| 2.00mm | 423.4 | 493.0 | 69.60 | 13.92 | 25.80 | 74.20 |
| 1.18mm | 387.9 | 481.0 | 93.10 | 18.62 | 44.42 | 55.58 |
| 850 µm | 356.3 | 415.6 | 59.30 | 11.86 | 56.28 | 43.72 |
| 600 µm | 468.6 | 531.5 | 62.90 | 12.58 | 68.86 | 31.14 |
| 425 µm | 436.2 | 476.0 | 39.80 | 7.96 | 76.82 | 23.18 |
| 300 µm | 314.2 | 351.6 | 37.40 | 7.48 | 84.30 | 15.70 |
| 150 µm | 421.1 | 459.6 | 38.50 | 7.70 | 92.00 | 8.00 |
| 75 µm | 405.3 | 428.3 | 23.00 | 4.60 | 96.60 | 3.40 |
| PAN | 272.2 | 289.3 | 17.00 | 3.40 | 100.00 | 0.00 |
| Total | | | 500 | | | |

Summary of the grading curves gives $D_{60}$ = 1.22, $D_{30}$ = 0.59, $D_{10}$ = 0.20 and hence Coefficient of Uniformity (Cu) = $D_{60}$/ $D_{10}$ = 1.22/0.20= **6.16**; Coefficient of covalence (Cc) = $D_{30}^2$ /$D_{60}$ x $D_{10}$ = $0.59^2$/1.22x0.20 = **1.52**. This infers the laterite sample is well graded.

A close look at Table 4 reveals the proportion of the soil sample passing 75 µm sieve representing silt particles in the soil sample is 3.4% (same as % retained in the pan). This added to the proportion of

Alumina ($Al_2O_3$) also known as clay in the soil sample (=27.38%) gives a total of 30.78% < 50% by weight indicating the soil sample fits well into Rajput (2006) specifications for a good brick making earth.

The Specific Gravity of the soil was found to be 2.54, the average natural moisture content was 16.54 and the Fineness Modulus value of 2.79, indicating a medium fine grading.

**Compressive Strength of MBB**

The result of the compressive strength test carried out on the MBB is as presented in Table 5 revealing average compressive strength values of **3.46 N/mm$^2$** for Sample A and **11.74 N/mm$^2$** for Sample B. Sample B was noted to be very strong and harder than Sample A. Implying the compressive strength of Makurdi locally manufactured burnt bricks fall within the limits and ranges stipulated for building construction by the **NIS 87:2004**. The standard stipulates a compressive strength value of **2.8 N/mm$^2$** for bricks to be used for load bearing walls and **2.0 N/mm$^2$** for non-load bearing walls. Thus, the MBB adequately meet the purpose of construction of buildings. Sample B can be adjudged to fall to classification of engineering bricks on basis of its compressive strength value.

**Table 5: Results for Compressive Strength Test of MBB**

| Sample No | Weight (Kg) | Crushing load (N) | Area (mm) | Compressive Strength (N/mm$^2$) | Average Compressive (N/mm2) |
|---|---|---|---|---|---|
| A1 | 3.81 | 10700 | 2970 | 3.60 | |
| A2 | 3.83 | 10400 | 2970 | 3.50 | |
| A3 | 3.75 | 10200 | 2970 | 3.43 | 3.46 |
| A4 | 3.68 | 9500 | 2970 | 3.20 | |
| A5 | 3.70 | 10600 | 2970 | 3.57 | |
| B1 | 4.27 | 34155 | 2970 | 11.50 | |
| B2 | 4.21 | 31200 | 2970 | 10.51 | |
| B3 | 4.16 | 35640 | 2970 | 12.00 | 11.74 |
| B4 | 3.97 | 37700 | 2970 | 12.69 | |
| B5 | 4.23 | 35700 | 2970 | 12.02 | |

**Water Absorption Characteristics of the MBB**

Table 6 presents the result of the water absorption test carried out on MBB. It reveals an average value of 8.58% for Sample A and 16.49% for Sample B both falling within the limit of 20% by weight specified by Rajput (2006) for building bricks. It was however noted that Sample B absorbed twice the quantity of water absorbed by Sample A; this can be as a result of the over-heating. The samples however do not dissolve nor melt in water.

**Table 6: Result of Water Absorption Test**

| Sample No | Initial Wt. of Specimen $w_1$ (g) | Final Weight of Specimen $w_2$ (g) | % Water Absorption $=\frac{(W_2 - W_1)100}{W_1}$ | Av. %Water Absorption |
|---|---|---|---|---|
| A1 | 3480.0 | 3810.6 | 9.50 | |
| A2 | 3275.2 | 3545.4 | 8.25 | 8.58 |
| A3 | 3145.0 | 3396 | 7.98 | |
| B1 | 3250.0 | 3753.8 | 15.50 | |
| B2 | 3300.0 | 3852.1 | 16.73 | 16.49 |
| B3 | 3275.0 | 3839.6 | 17.24 | |

**Abrasion Resistance of the MBB**

The result of Abrasion resistance test as presented in Table 7 reveals average % Durability values of **9.32** and **33.67** for Samples A and B respectively. Implying Sample B is about four times as durable against wear effect and abrasive attack as Sample A. This confirms the choice of the residents at adopting Sample B for construction works in areas where there could be tendencies for erosion effect on the walls by rain and other sources of contact of the brickwall surfaces with water while Sample A is limited to only wall construction in buildings.

**Table 7: Results of Abrasion Resistance Test of MBB**

| Sample | Initial Wt. of Specimen $w_1$ (g) | Wt. after 500 Revolutions $w_3$ (g) | % Durability $D=100 - \frac{(w_1-w_3)100}{w_1}$ | Av. Durability |
|---|---|---|---|---|
| A1 | 3250.0 | 334.5 | 10.29 | |
| A2 | 3300.0 | 260.3 | 7.89 | 9.32 |
| A3 | 3275.0 | 320.5 | 9.79 | |
| B1 | 3480.0 | 1369.8 | 39.36 | |
| B2 | 3275.2 | 1123.2 | 34.29 | 33.67 |
| B3 | 3145.0 | 860.1 | 27.35 | |

## CONCLUSION AND RECOMMENDATION

The result affirms that soil sample used for production of Makurdi local burnt brick is a true laterite having a Silica – Sesquioxide ratio of 1.01, Silica content of 42.95 and clay content of 27.38 and total clay + silt content of 30.78 and is thereby suitable for the production of burnt bricks. The two brick samples has average compressive strength values (Sample A, 3.46 N/mm2 and Sample B, 11.75 N/mm2) meeting **NIS 87:2004** stipulation of **2.8 N/mm$^2$** for bricks to be used for load bearing walls and **2.0 N/mm$^2$** for non-load bearing walls. Sample B can even be adopted for use as engineering brick on basis of compressive strength. The two Sample types were found adequate for building construction on basis of water absorption and abrasion resistance properties.

The general acceptability of the MBB in Makurdi can be linked to the observed usage of the bricks for public buildings by the State Government and other corporate organizations in the State. Government at the three tiers in Nigeria should emulate this practice as noticed in Makurdi, Benue State and encourage the patronage of alternative building materials emanating from various research works in our Universities and other Institutions of learning in Nigeria. Further studies on MBB targeted at developing improved local kiln for better and proper burning of the bricks is highly necessary, while excavation of lateritic soil for local brick making should be controlled by the Local Authorities to avert erosion and environmental degradation due to indiscriminate excavations.

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