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# Impact of Firing Temperature on Compressive Strength Characteristics of Lateritic Bricks

[1]Agbede O. A., [1]Oluokun G. O., [1]Olayemi O. K, [2]Jaiyeoba, K.F., [2]Oke A.M,
[1]*Department of Civil Engineering, University of Ibadan, Ibadan, Nigeria.*
[2]*Department of Agricultural Engineering, Adeleke University, Ede, Osun State, Nigeria.*

**Abstract:** This study assessed the impact of firing temperature on compressive strength of lateritic bricks. Twenty lateritic bricks samples of size 290mm x 140mm x 100mm were produced from the lateritic soil sample collected from a borrow pit along Ibadan-Lagos expressway, Southwestern, Nigeria. The geotechnical characteristics and classification of the lateritic soil sample were established. The bricks produced were fired at temperature 0$^o$C to 950$^o$C at 150$^o$C interval after 28days of curing. The compressive strength of the fired bricks was determined. The result of geotechnical test carried out on the soil sample showed that the soil is laterite having a clay content <30%, extremely low gravel <10% and sand content of 83.33%. The Atterberg's limit test gave the liquid limit as 48%and plastic index 18.78%. The soil has natural moisture content and specific gravity of 34.92% and 2.64 respectively. The result further indicated that weight of the brick before and after firing is insignificant and the relationship between the weight and the firing temperature is inversely proportional. The result also revealed that the compressive strength of the fired brick is directly proportional to the firing temperature. Compressive strength of the bricks after firing ranges from 0.92N/mm$^2$ to 2.24N/mm$^2$ for various temperatures ranging between 350$^o$C to 950$^o$C. The result obtained from the tests was compared with the specifications of Nigerian Building and Road Research Institute (2006), Nigerian Building Code (2006), and Nigerian Industrial Standards (2000). The results indicated that the compressive strength of the fired brick at 950$^o$C fall within the range of 225mm and 150mm sandcrete hollow blocks recommended compressive strength for building construction. The value varies from 1.59 N/mm$^2$ to 4.25N/mm$^2$ and 1.48N/mm$^2$ to 3.35N/mm$^2$ respectively, as the curing age increases from 7 to 28 days. Therefore a fired brick at 950$^o$C is recommended for building construction especially as wall partition element. This will help both urban and rural dwellers that cannot afford to build a house with cement block. It will most especially benefit farmers toward building their storage room which could encourage increase in production of crops. This will invariably be helpful at this time of economic recession.

**Keywords:** Geotechnical test, Lateritic bricks, Firing temperature, Fired bricks, Compressive strength.

## I. INTRODUCTION

Nation at large is in a phase of rapid economic and political development. These have given rise to an increase in cost of erection of building structure due to increase in cost of building materials such as cement block [1]. This necessitate a search for a means of cutting the cost of construction by reducing cost of building materials The use of clay for brick production has been explored to reduce construction cost [2]. This product usually has strength challenge and therefore not able to compete favorably with cement block. This challenge has been worked on by different researchers through the use of lime and cement as stabilizing material for laterite to improve its strength [2, 3]. Stabilization as a form of soil reinforcement improved soil material composition thereby increases its strength. This method seems not to have a cost advantage production [2]. In engineering construction especially road (highway construction), laterite has proved to be a good construction material. This can be attributed to its material constituent; mixture of sand, clay and coarse aggregate [4]. Recently, it has also been explored in building industry to lower the cost of building construction [5]. Although, brick/block produced by it was not able to give the strength high enough to compete with cement brick/block except when stabilized with stabilization materials like slag, lime and cement [6]. This study considered the old methodology used by local pot moulders in the strengthening of their clay pot after moulding. The method is firing approach. This firing approach has provento be very effective in making clay pot strengthened, durable and aesthetic. Therefore, firing should be able to improve the strength of laterite made brick.

This study therefore investigated the effect of firing temperature on compressive strength characteristics of lateritic brick as part of a continuing effort at establishing an engineering basis for the use of lateritic soils in building construction industry, especially in the urban areas of Nigeria where they now lack credibility. It is also aimed at bringing down the cost of building construction. This kind of building will be very helpful to farmers especially peasant farmers in the rural areas. Already earthen were structures for them. This earthen were made from laterite which serves them a great purpose in the area of temporary storage of fruits and vegetables. It could further encourage farmers to increase their productivity which is needful in this time of economic recession.

## II. MATERIALS AND METHOD

The material used for this study was lateritic soil obtained from an existing borrow pit at Ibadan, Oyo State, Nigeria (Latitude $7^o25'$ N and Longitude $5^o38'$ E) at a depth approximately 1.2m. The sample was collected using disturbed sampling approach [5]. The geotechnical properties of the lateritic soil were determined according to [7] for the purpose of its classification. Batching of brick materials were moulded and weighed. This was derived by determining the quantity of the lateritic soil that would make a brick size 290 mm x 140 mm x 100 mm. The constituent materials were weighed according to the batching calculations. Materials were mixed thoroughly to achieve a homogeneous mixture using shovel and masonry trowel. Water was added carefully with the intermittent use of sprinkler in order to prevent water from flowing away from the mixture. After thorough mixing of the constituent materials, the mould box of the CINVA-Ram machine was greased with oil to allow easy removal of bricks. Mixed samples were fed into the mould box and covered. It was then compressed by a hand operated toggle level and piston system, which exerted a minimum compacting pressure of about 2 $MN/m^2$. After compression, the cover was removed while the mould box was jacked upward to remove the brick. A total of twenty bricks were moulded. The moulded wet bricks were air dried for three days after which water was regularly sprinkled on them using a watering can, for a period of 28 days for proper curing of the bricks. This was necessary for the brick to attain its maximum strength. Three of the bricks were used for water absorption test.

## III. RESULTS AND DISCUSSION

The result of geotechnical test carried out is presented in the Table 1.0.

- **Particle size distribution:** From grain size analysis curve, coefficient of curvature and uniformity were estimated to be 0.9 and 5.3 respectively. This indicates that the soil is a well graded soil. Also, from the grain size curve, percentage of soil passing sieve 0.075mm and 0.45mm are 83.33% and 10.95% respectively (Fig. 1). The portion retained above 0.45mm sieve is 4.85% (Table 1). This implies that the soil sample is denominated with coarse grained soil (sand) with about 11% clay content. Therefore the sample can be classified as well graded and it is good for making lateritic brick.The little proportion of clay present in the soil may serve as binder for the coarse grain soil portion. Excessive clay in the brick will lead to cracking during curing.
- **Atterberg limits:** The liquid limit value is 48% while the plastic limit is 29.22%. The plasticity index is approximately 18.78% (Table 1). This indicates that the soil is a medium plastic soil which makes it suitable for moulding of bricks [1,7]. The linear shrinkage of the soil is 15% (Table 1) –[9].
- **Compaction:** The maximum dry density for the soil samples is 1.94$Mg/m^3$ while the optimum moisture content is 14.0% (Table 1). This falls within the range of value expected of a lateritic soil dominated by coarse grained sandy soil [9].
- **Specific gravity:** The specific gravity of the soil sample is 2.65, this falls within the range of value of specific gravity of a clay lateritic soil material [11, 7].

**Table 1: Geotechnical Properties of the Soil sample**

| **Properties** | **Description** | | | | | |
|---|---|---|---|---|---|---|
| Natural moisture content (%) | 34.92 | | | | | |
| Grain size Analysis | **Particle Size Distribution** | | | | | |
| | Gravel (%) | Sand (%) | Clay (%) | Coefficient | | Soil Gradation using UCSS |
| | | | | Cc | Cu | |
| | 4.85 | 83.33 | 10.95 | 0.9 | 5.3 | SW |
| Atterberg Limit test | **Liquid limit (%)** | **Plastic limit (%)** | **Plastic Index (%)** | | **Soil classification** | |
| Liquid limit (%) | 48.00 | 29.22 | 18.78 | | Medium plastic soil | |
| Linear Shrinkage (%) | 15.00 | | | | | |
| Specific gravity | 2.64 | | | | | |
| Optimum Moisture Content (%) | 14.00 | | | | | |
| Maximum Dry Density (g/cm$^3$) | 1.94 | | | | | |
| Condition of sample | Disturbed sample /Sun dried | | | | | |
| Colour | Brownish red | | | | | |

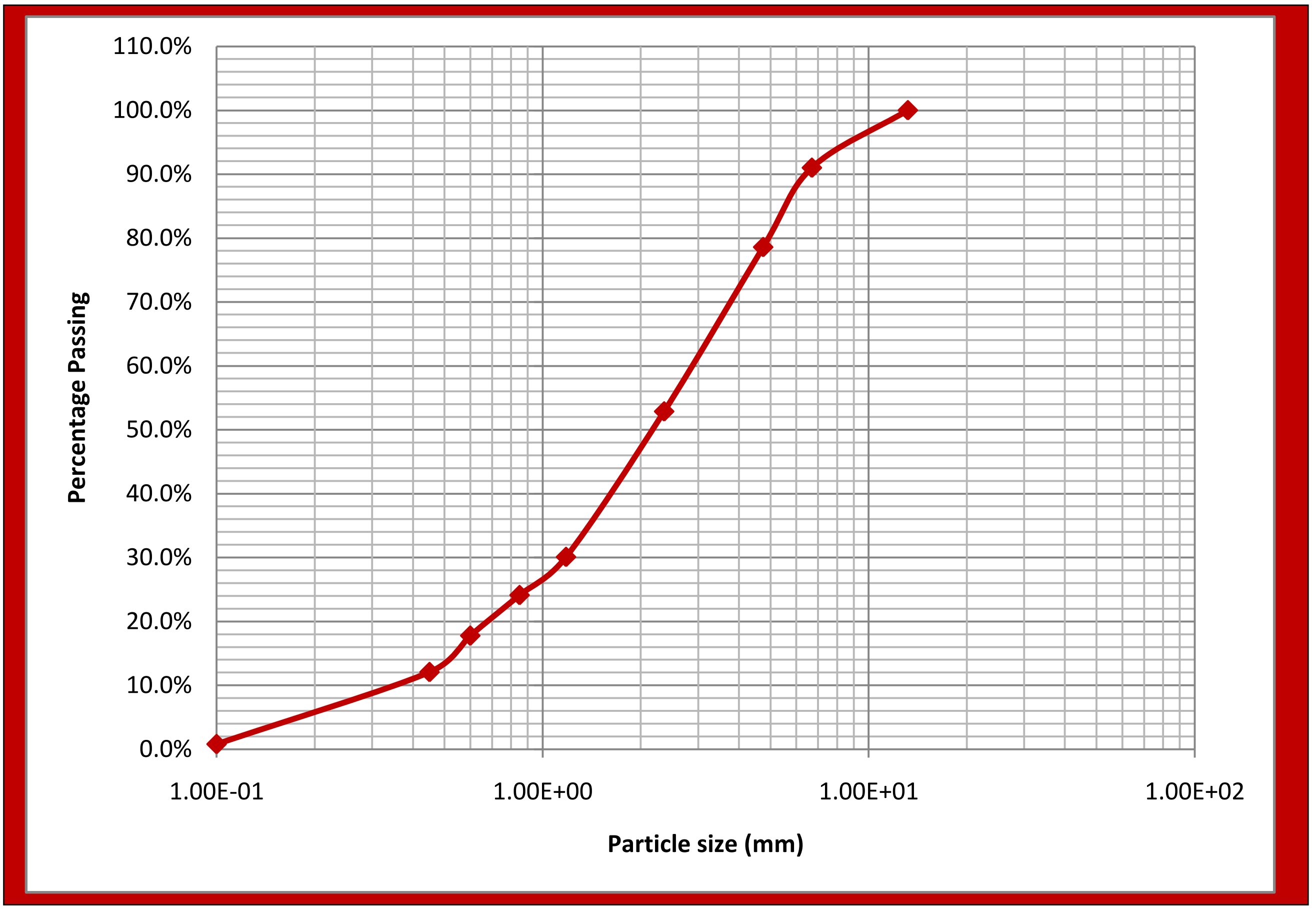


**Figure 1: Grain size analysis curve**

- **Compressive Strength Characteristics of Fired Brick**

Table 2 and 3, presented the results of the compressive strength and physical properties of fired bricks. Fig. 2 represented the result in a graphical form to indicate a relationship between the firing temperature and compressive strength. The compressive strength obtained within the temperature range of 0°C-950°C, range from 0.69N/mm$^2$ to 2.24N/mm$^2$. Minimum compressive strength of 0.69N/mm$^2$ was obtained at 0°C while the maximum compressive strength was obtained at 950°C. At 350°C, 500°C, 650°C and 800°C, the compressive strengths were 0.92N/mm$^2$, 1.08N/mm$^2$, 1.14N/mm$^2$ and 1.65N/mm$^2$ respectively. Fig. 2 indicated that, as the firing temperature increases the compressive strength increases.

The firing temperature also has a specific effect on the physical properties of the brick (weight and colour) but its effect on the size was negligible. The weight of the bricks decrease as the firing temperatures increase and the colour of the bricks became lighter from the deep reddish brown to a lighter reddish brown (Table 3). The final colour change obtained at 950°C appeared aesthetic (shiny –Plate 1) that when it is use for building wall, the structure may not necessarily call for painting. While the weight decreases with increasing firing temperature, the compressive strength increases. The weight decrement experienced by the brick will be an added advantage for its acceptability as a construction material because it will reduce the imposed load and at the same time more convenient to carry during construction.

**Table 2: Compressive Strength Characteristics of Fired Bricks**

| Firing Temperature °C | Weight After Heating (kg) | Compressive Strength (N/mm$^2$) |
|---|---|---|
| 0 | 6.64 | 0.69 |
| 350 | 6.22 | 0.92 |
| 500 | 6.22 | 1.08 |
| 650 | 5.89 | 1.14 |
| 800 | 6.04 | 1.65 |
| 950 | 5.95 | 2.24 |
| | | |

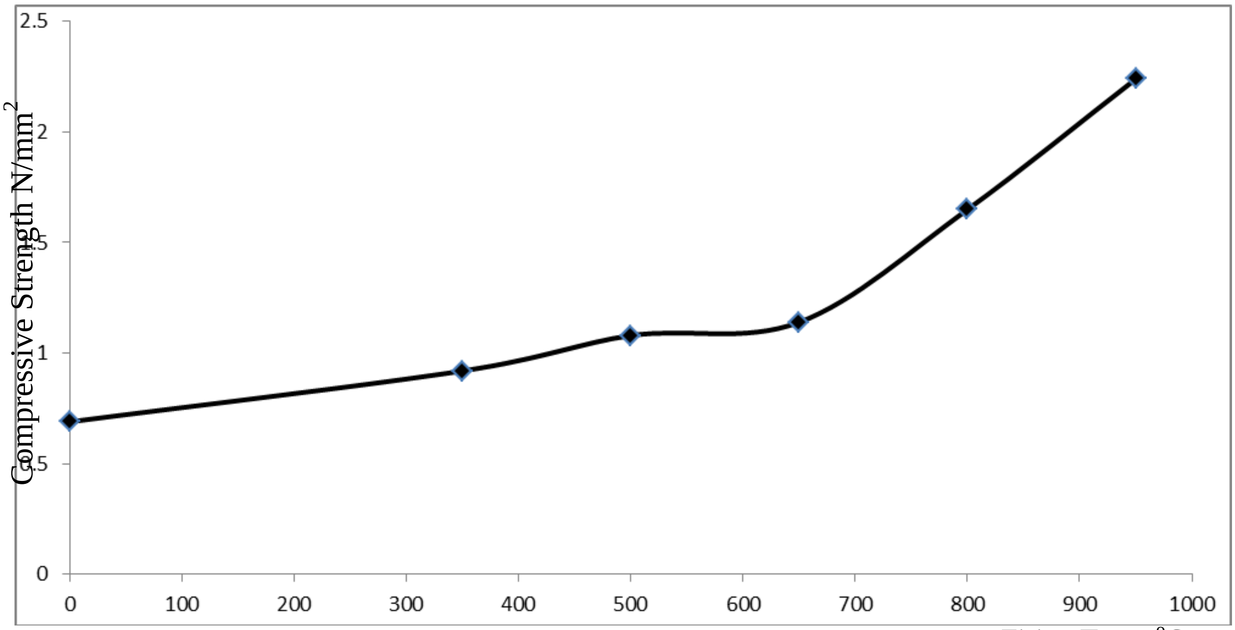


Figure 2: Variation of compressive strength with increasing firing temperature

**Table 3: Physical Characteristics of Brick Produced Before and After Firing**

| Firing Temp °C | Size of Brick | | Colour of Brick | | Weight of Brick | | |
|---|---|---|---|---|---|---|---|
| | **Before Firing (mm)** | **After Firing (mm)** | **Before Firing** | **After Firing** | **Before Firing** | **After Firing** | **% Reduction** |
| 0 | 290*140*100 | 290*140*100 | Reddish brown | Reddish brown | 6.64 | 6.64 | 0.00 |
| 350 | 290*140*100 | 289*139*99 | Reddish brown | Deep reddish brown | 6.62 | 6.22 | 5.97 |
| 500 | 290*140*100 | 289*139*99 | Reddish brown | Dark brown | 6.61 | 6.22 | 5.90 |
| 650 | 290*140*100 | 289*139*99 | Reddish brown | Dark brown | 6.42 | 5.89 | 8.33 |
| 800 | 290*140*100 | 289*139*99 | Reddish brown | light reddish brown | 6.66 | 6.04 | 9.25 |
| 950 | 290*140*100 | 288*138*100 | Reddish brown | Lighter reddish brown | 6.70 | 5.95 | 11.20 |


Plate 1.0: Variation in the colour of brick with firing temperature

- **Cost Comparison**

A cost comparison of fired brick with cement and lime stabilized bricks shows that fired brick is cost effective to cement and lime stabilized bricks (Table 4). It can be inferred from this study that the compressive strength of fired brick can favorably compete with cement bricks at lower cost of production.

**Table 4: Estimate of cost of production of fired bricks and cement block**

| **Description** | **Calculation** |
|---|---|
| **Cost of Fired-Brick Production** | |
| Cost of laterite per $m^3$ | = ₦1145.00 |
| Volume of laterite for 1brick produced (290 mm x 140 mm x 100 mm in size) | = $0.00406m^3$ |
| Cost of laterite to produce 1brick | = ₦4.65 |
| Labour cost per brick | = ₦10.00 |
| Cost of Firing in an oven per brick | = ₦10.00 |
| **Total cost of production** | **= ₦24.65** |
| **Cost of Cement stabilized brick** | |

| | |
|---|---|
| Cost of laterite to produce 1brick<br>Labour cost per brick<br>Cement of cement to produced 1brick<br>**Total cost of production** | = ₦4.65<br>= ₦10.00<br>= ₦43.75<br>**= ₦58.40** |
| **Cost of Lime stabilized brick** | |
| Cost of laterite to produce 1brick<br>Labour cost per brick<br>Cement of lime to produced 1brick<br>**Total cost of production** | = ₦4.65<br>= ₦10.00<br>= ₦71.25<br>**= ₦85.90** |

## V. CONCLUSION

The study made use of lateritic material borrowed from a borrow pit along Lagos-Ibadan express road, Oyo State, southwestern Nigeria. The geotechnical properties test carried out on the soil sample showed that the soil is dominated by sandy soil with low fraction of clay and gravel. The soil is medium plastic. This criteria fall within the physical properties obtained for laterite soil. The result of compressive strength indicated that the strength increases as the firing temperature increases. The study therefore recommends fired brick produced at 950$^o$C for building construction especially in partition wall.

## VI. Acknowledgements(11 Bold)

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