Suitability of Broken Fired Clay Bricks as Coarse Aggregate for Production of Lightweight Concrete

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***Abstract*— This paper presents an investigatory study of the use of broken fired clay bricks which are waste from Shelter Clay Products Minna, Nigeria as local coarse aggregate for the production of lightweight concrete. Eighty concrete cubes with a mix ratio of 1:2:4 and size 150mm were produced and cured for 7, 14, 21 and 28-days respectively. The compressive strengths and densities of these cubes were statistically determined and found to be adequate for lightweight concrete construction. These broken fired clay bricks from Shelter Clay Products can now be used as coarse aggregate for production of lightweight concrete instead of throwing them away as waste which constitutes another environmental hazards.**

***Keywords*— Broken fired clay bricks, Compressive Strength, Concrete cubes, Lightweight concrete**

I. INTRODUCTION

Many highway agencies, private organizations and individuals have completed or are in the process of completing a wide variety of studies and research projects concerning the feasibility, environmental suitability and performance of beneficial reuse of most waste materials (Collins and Ciesiellski, 1993). These studies try to march society's need for safe and economical disposal of waste materials with the structural engineer's need for better and more cost effective construction materials. The spiraling cost of waste disposal may be reduced by the use of some of these materials in construction applications. Shelter being one of the basic needs of man, the problem of providing adequate housing has been a major concern, not only to individuals but to government at all levels as well (Aguwa and Amadi, 2010). The need to research for alternative naturally occuring, local and affordable building materials is pertinent.

Concrete is one of the most common structural materials used in this country Nigeria as well as all over the world. Concrete is generally a mixture of cement, aggregate (fine and coarse) and water. Aggregate according to their meteorological characteristics can be divided into heavy-weight, normal weight and lightweight. Normal weight aggregate are the natural gravels or crushed stones while lightweight aggregate are foam slag, expanded shales, slates and clays. This structural material can be produced in two forms namely as dense or normal concrete and lightweight concrete. A large portion of most buildings in this country is of normal concrete material and no much emphasis is laid on the use of lightweight concrete. This might be as a result of shortage of lightweight aggregates as well as igorance on the specific areas of construction to use it.

Available data shows that 30000 pieces (200m^3) of broken fired clay bricks which can produce 351m^3 of lightweight concrete are thrown away every year as waste from Shelter Clay Products, Minna, Nigeria. By using this broken fired clay bricks for concrete, the life of people around the factory will improve as many of them will go into building low cost houses thereby reducing cost incured by the company on transporting it to a far place as waste, in addition to solving the environmental problem of solid waste deposit.

Bricks can be made with sophisticated factory methods, simple labour-intensive methods or a range of mechanized technologies in between. The labour-intensive production methods are most suitable for rural areas where the demand for bricks is limited. The bricks produced by hand will have relatively lower quality, especially compressive strength, and will tend to have irregular dimensions. However, they are economical and require little capital investment or transportation cost. Bricks made in this manner have been used in buildings which have lasted for centuries. Their longevity has depended on the quality of the ingredients, the skill of the artisans and the climate in which they were used.

The economic importance of this study include; realization of the usefulness of broken fired bricks if adequately proved in contradiction to the common view as waste, production of lightweight concete especially in areas where other lightweight aggregates are far-fetched or rare, reduction of structural weight compared to the normal aggregates, reduction of the environmental problems posed by broken fired bricks as waste and it is locally available and affordable compared to other aggregates (Aguwa, 2009). Lightweight aggregate, even similar in appearance, may produce concretes varying widely in structural properties so that a careful check on the performance of each new aggregate is necessary (Neville, 2000).

The aim of this study is to find out if brken fired clay bricks from can perform adequately as coarse aggregate in the production of lightweight concrete for cnstruction It is hoped that if broken fired clay bricks are proved as good coarse aggregate for production of lightweight concrete, the cost of concrete production wil drastically reduce and the environmental problems posed by them as waste will also be over.

II. MATERIALS AND METHOD

A. Broken fired bricks

The broken fired Clay bricks were collected from Shelter Clay Products Minna, Nigeria. Care was taken during the collection to ensure that there were no impurities mixed with the fired broken bricks.

B. Sand

The sand collected from a river in Minna, Nigeria and used as fine aggregate was clean, sharp, free from clay and organic matter and well graded in accordance with BS 882, (1983).

Water: Tap water was used for the mixing and it was properly examined to ensure that it was clean, free from contaminants either dissolved or in suspension and good for drinking as specified in BS 3148, (1980).

C. Laboratory Tests

Laboratory tests on the sand and crushed bricks for the purposes of characterization and classification include determination of particle size distribution, natural moisture content and specific gravity, were carried out in accordance with BS 1377, (1990). The determination of bulk densities and water absorption of the sand and crushed bricks was carried out in accordance with BS 812 Part 2, (1975).

D. Preparation of Specimens

Mix design is the consideration of the most economical use of available materials to produce concrete of desirable workability, durability and strength. In designing the concrete mix, air entrained concrete under mild exposure conditions was used to improve the workability. A maximum size of 20mm aggregate and a water/cement ratio of 0.53 were adopted, for the desired workability of slump 30mm-50mm. Absolute volume method was used in the determination of the quantity of sand. The mix design resulted in a mix ratio of 1:2:4, which was used in the manual production of 80 concrete cubes of 150 mm size used for the compressive strength test. Preparation of materials, mixing and sampling were carried out in accordance with BS 1881 Part 125 (1986).

III. Slump Test

Before mixing the concrete for casting the cubes, a trial mix was carried out to determine the slump. Slump test is very useful in detecting variations in the uniformity of a mix of a given nominal proportions (Neville, 2000). It is a popular method used all over the world on the day-to-day, hour-to-hour variation in the materials being fed into the mixer or mixing platform if by hand. The slump was determined in accordance with BS 1881: Part 102 (1983)

IV. Hand Mixing

The batch mix of 1:2:4 by volume of materials as designed were mixed by hand on a hard, clean and non-porous galvanized iron tray. The sand and cement were mixed properly before the broken fired clay bricks were added and mixing continued until uniformity was achieved by turning the mixture from one side to another for three times (Aguwa, 2010). Finally, water was added and the mixture turned over again from side to side, until it appeared uniform in colour and consistence. Water was gradually added so that it could neither escape by itself nor with cement (Neville, 2000). Eighty (80) cubes of 150mm size were cast and cured for 7, 14, 21 and 28 days respectively. A total of 0.3m^3 of concrete was prepared to produce 80 cubes in accordance with BS 1881: Pat108 (1983) used for the compressive strength test.

V. Compressive Strength Test

An electrically operated Seidner compression machine was used for the compressive strength test on the concrete cubes in accordance with BS 1881: Part 116 (1983), at the curing ages of 7, 14, 21 and 28 days. Twenty cubes were crushed in each day and the average compressive strength was determined. During the compressive strength test, care was taken to ensure that the cubes were properly positioned and aligned with the axis of the thrust of the compression machine to ensure uniform loading on the cubes (Neville, 2000).

VI. Results and Discussion

A. Identification of Sand and broken fired bricks

The properties of sand and broken fired clay bricks used for the study are summarized in Table 1 while Figures1 and 2 show their particle size distribution curves. The sand was well graded and classified in zone 3 in accordance with BS 882 (1983) classification for aggregates. The fineness moduli of sand and broken fired clay bricks are 4.14 and 6.46 respectively, while the specific gravity of sand is 2.61 and it is in good agreement with the recommendation of BS 1377 (1990) for clean quartz and flint sands. The specific gravity of broken fired clay bricks is 2.4, which is below the range for normal aggregate and it is an indication that broken fired clay bricks from Shelter Clay Products are lighweight aggregate. The compacted and uncompacted bulk densities of the broken fired clay bricks are 961kg/m^{3}and 808 kg/m^3 respectively and they conform to BS 882 (1983) recommendation for aggregates from natural sources for concrete. It is also similar to that of Agbede and Manasseh (2009), who reported that periwinkle shell has a bulk density of 515kg/m^3 and can be used as lightweight aggregate in concrete works. A density ratio of 0.84 which is outside the normal range of 0.87 to 0.96 (Neville, 2000) is a confirmation that broken fired clay bricks is a lightweight aggregate. The water absorption of the broken fired clay bricks which is within the range of 5 – 20% specified for lightweight aggregate, is relatively high hence it has the tendency of maximizing volume changes of the entire concrete due to high absorption ability. The porosities of the two aggregates are low indicating that moderate amount of cement and sand was used in producing the concrete.

Table 1: Properties of Cement, Sand and Broken fired clay bricks.

Property	Cement	Sand	Broken Bricks	
Natural moisture content (%)			24.21	10.4
Water absorption (%)			0.19	18.7
Void ratio			0.54	0.67
Porosity (%)			14.45	15.7
Fineness modulus			4.14	6.46
Specific Gravity	3.15		2.61	2.4
Compacted bulk density kg/m^3)			1407	961
Uncompacted bulk density kg/m^3)			1247.26	808.3

VII. SLUMP

In this study, a slump of 45mm was measured in accordance with BS 1881: Part 102 (1983) and it satisfied the value (35 – 65mm) adopted in the design. This slump implies that the concrete produced was of moderate workability as a result of the water/cement ratio used and the fact that work done by gravity is always small for lighter materials.

VIII. COMPRESSIVE STRENGTH

Compressive strengths and densities of the concrete produced with broken fired clay bricks as coarse aggregate are shown in Table 2 for 7, 14, 21 and 28 days of curing age. The value for 28 days is adequate for concrete construction and it is in conformity with the recommendation of 6.9 to 17.2N/mm^2 specified range for moderate density lightweight concrete. Also Neville (2000) stated that lightweight concrete and masonry concrete usually have compressive strengths in the range of 0.3 to 40N/mm^2. The density of the concrete at 28 days is below the range for normal concrete of 2200kg/m^3 to 2600kg/m^3 and this is a confirmation that the concrete produced was lightweight concrete.

Table 2; Compressive Strengths and Densities at 7, 14, 21 and 28 days age of curing

Age of curing (days)	Compressive Strength (N/mm^2)	Density (kg/m^3)
7	11.3	1707
14	12.3	1769
21	13.48	1826
28	14.02	1976

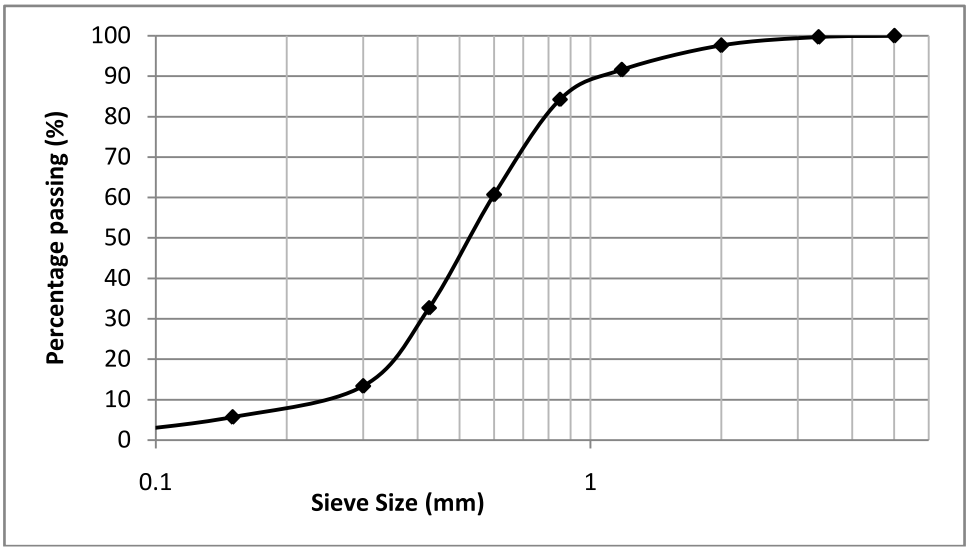

Figure 1: Particle Size Distribution curve for the sand used for the concrete production

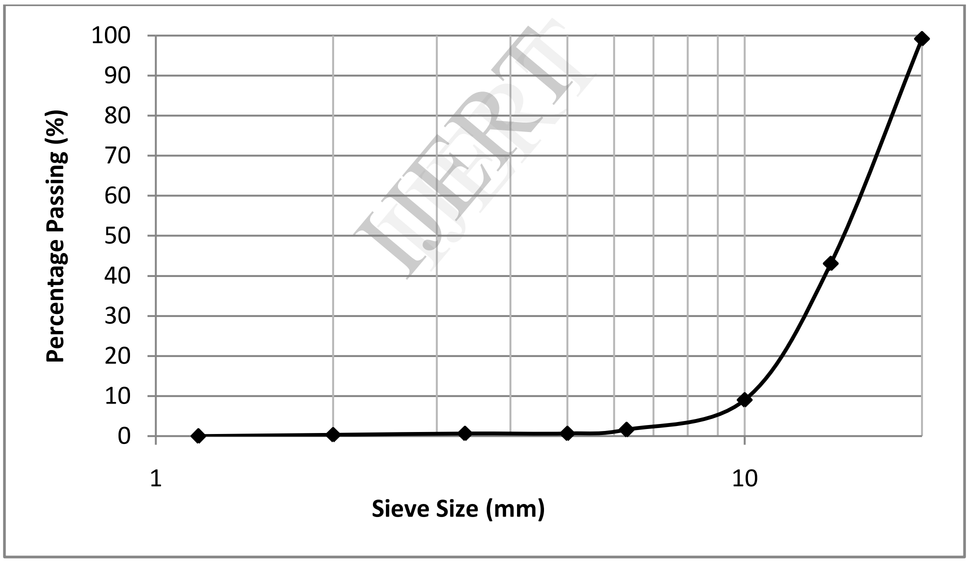

Figure 2: Particle size distribution curve for the broken fired clay bricks used for the concrete

Figure 3 shows the relationship between the compressive strength and the age of curing and it conforms to the usual trends reported in most literatures. Also there is appreciable increase in density with age of curing of the concrete as shown in Figure 4.

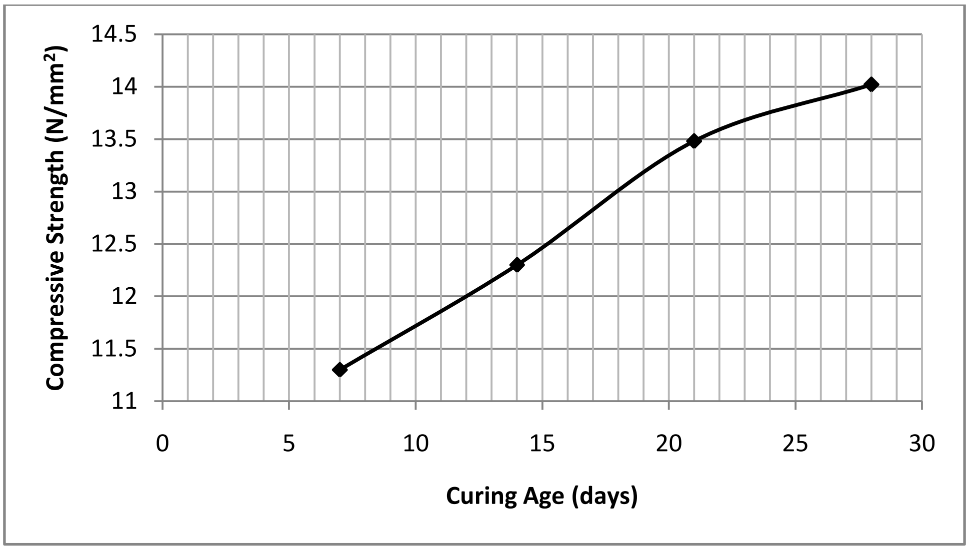

Figure 3: Compressive strength – Age of curing relation for the lightweight concrete

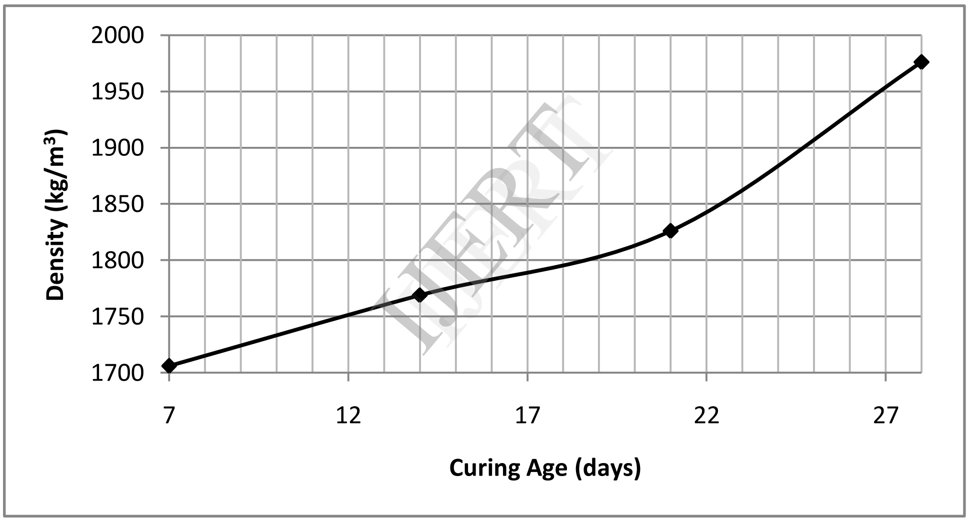

Figure 4: Density – Age of curing relation for the lightweight concrete

IX. Statistical Analysis

A. Confidence Limits for the Mean

95%, 99% or other confidence intervals can be defined by using the table of the student's distribution. In this manner it can be estimated within specified limits of confidence the population mean μ. This is to confirm the authenticity of the mean of the compressive strengths determined from tests. The limits commonly used are the 95% and the 99% confidence limits.

For small sample theory, N<30, the confidence limits are calculated from equations 1 and 2, from Spiegel (1972)

95% Confidence Limits are $\mu \pm t_{0.975} \frac{S}{\sqrt{N-1}}$ (1)

99% Confidence Limits are $\mu \pm t_{0.995} \frac{S}{\sqrt{N-1}}$ (2)

$t_{0.975}$ and $t_{0.995}$ are percentage values for student's distribution with v degrees of freedom.

The confidence limits for the mean of the compressive strengths determined are shown in Table 3. For each age of curing, the mean strength from test falls within the range of confidence intervals calculated for 95% and 99% respectively. This confirms that the mean strengths from tests are the true ones.

Table 3: Confidence Limits for the Mean of the Compressive Strengths

Age of curing	Mean strength	95% Confidence	99% Confidence
7 days	11.3	11.00 and 11.55	10.88 and 11.72
14 days	12.3	12.05 and 12.60	11.94 and 12.66
21 days	13.48	13.34 and 13.62	13.29 and 13.67
28 days	14.02	13.54 and 14.50	13.36 and 14.68

B. Confidence Limits for standard deviation

95%, 99% or other confidence limits and intervals can be defined for χ^2 distribution. In this manner it can be estimated within specified limits of confidence the population standard deviation σ in terms of a sample standard deviation S. This is to confirm the authenticity of the standard deviation of the compressive strengths determined from tests. The limits commonly used are the 95% and the 99% confidence limits. . For small sample theory, N<30, the confidence limits are calculated from the equations 3 and 4, from Spiegel (1972)

95% Confidence Limits are given by $\frac{S\sqrt{N}}{\chi_{0.975}}$ and $\frac{S\sqrt{N}}{\chi_{0.025}}$ (3)

The values $\chi_{0.025}$ and $\chi_{0.975}$ represent respectively the 2.5 and 97.5 percntile values.

For the degree of freedom, V = N – k, 99% Confidence Limits are given by

$\frac{S\sqrt{N}}{\chi_{0.995}}$ and $\frac{S\sqrt{N}}{\chi_{0.005}}$ (4)

where v is the degree of freedom, N is the number of samples and k is the number of parameters determined in the test and used in the calculation. Here only the standard deviation is the parameter calculated and used. The confidence limits for the standard deviation of the compressive strengths determined are shown in Table 4. For each age of curing, the standard deviation for the failure compressive strengths from test falls within the range of confidence intervals calculated for 95% and 99% respectively. This confirms that the standard deviations for the failure compressive strengths from tests are the true ones.

Table 4: Confidence Limits for the Standard Deviation for Compressive Strengths

Age of curing	Std deviation	95% Confidence	99% Confidence
7 days	0.63	0.49 and 0.94	0.45 and 1.08
14 days	0.51	0.40 and 0.76	0.37 and 0.87
21 days	0.29	0.23 and 0.43	0.21 and 0.50
28 days	1.00	0.78 and 1.50	0.72 and 1.71

X. Conclusion

The over all conclusion emerging from this study is that broken fired clay bricks from Shelter Products Minna have satisfactory properites as good coarse aggregate for production of lightweight concrete. Lightweight concrete produced with broken fired clay bricks as coarse aggregate has adequate compressive strength for masonry concrete construction and the strength development is similar to that of normal concrete. The use of this broken fired clay bricks as coarse aggregate will reduce the cost of concrete production especially for people around the factory and at the same time solve the problem of environmental waste transportation and deposition.

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