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COMPARATIVE ANALYSIS OF THE COMPRESSIVE STRENGTH OF CONCRETE WITH GRAVEL AND CRUSHED OVER BURNT BRICKS AS COARSE AGGREGATES

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Abstract

The research was conducted to study the possibility of utilizing the waste over burnt bricks abundantly available in most parts of Gwer-West Local Government Area of Benue State, particularly Naka, the Local Government capital, as coarse aggregates in structural concrete. Trial mixes were prepared using the crushed over burnt bricks known also as brick bats as coarse aggregates only, mixture of crushed over burnt bricks and river wash gravel as well as using river washed gravel from River Benue. Cubes of concrete were prepared and tested to study the compressive strength. The result indicate that the concrete having brick bats as aggregates may be termed as medium light weight concrete having a density between 2000-2200 kg/m3. To produce the same workability, the brick aggregates concrete requires greater proportion of water than the normal gravel aggregate concrete. Use of broken over burnt bricks as coarse aggregate for structural concrete is recommended when natural aggregate is not easily available, high strength of concrete is not required and the bearing capacity of the soil is low.

Keywords: compressive strength, concrete, crushed burnt bricks, coarse aggregates

1. Introduction

Concrete is a versatile engineering material consisting of cementing substance, aggregates, water and often controlled amount of entrained air. It is initially a plastic, workable mixture which can be moulded into a wide variety of shapes when wet. The strength is developed from the hydration due to the reaction between cement and water. The products, mainly calcium silicate, calcium aluminates and calcium hydroxide are relatively insoluble which bind the aggregate in a hardened matrix. Concrete is considerably stronger in compression than in tension, for structures required to carry only compressive loads such as massive gravity dams and heavy foundations, reinforcement is not required and the concrete is consequently called plain concrete. When the structure is to be subjected to tensile stresses, steel bars are embedded in the concrete.

The requisite quantities of material for a given grade of concrete are usually obtained from mix design. The constituent materials, when properly batched and thoroughly mix, set through the process of hydration and harden into a mass of concrete capable of resisting compressive stresses. The extent to which a given concrete resists the compressive stresses to which it is subjected depends largely on the compressive strength of the concrete which in turn depends on the quality of the concrete. Since seventy five per cent of concrete is made up of aggregates, its types, quality and general properties determine the quality of concrete [1].

Concrete is one of the most widely used construction material. The raw materials from which it is prepared; cement and aggregates, affect both the quality and cost of construction. Aggregates are usually cheaper than cement and constitute over 70% the volume of concrete. The availability and proximity of aggregate to the construction site also affect the cost of construction.

At present, the most commonly used coarse aggregates for concrete production in Benue State of Nigeria is the river washed gravel due mainly to the presence of River Benue and its deposits. But these are not readily available in some local government areas which are not serviced by the river. Thus the cost of transporting gravel to the areas outside the catchment of the river tends to increase the cost of construction even at relatively low labour. This necessitates the use of alternative coarse aggregates which are locally obtained. One of such coarse aggregate is brick bat or crushed burnt bricks obtained from the production of burnt bricks.

In many countries, the need for locally manufactured building materials can hardly be overemphasized because there is an imbalance between the demands for housing and expensive conventional building materials coupled with the depletion of traditional building materials. To address this situation, attention has been focused on low-cost alternative building materials [2, 3].

According to Tse and Akpen [4], a significant decline in the utilization of all cement manufacturing plants in Nigeria since the 1990s has raised the already exorbitant cost of cement above the reach of the average Nigerian thereby encouraging a rise in the emergence of a strong local burnt bricks industry in many parts of Nigeria and Benue state in particular. The raw materials for burnt brick production which comprise predominately of various proportions of sand, silt and clay soils are derived from the deposits along the flood plains of major rivers and seasonal streams. These deposits when mixed, kneaded, compacted in moulds and fired, produce bricks for building construction. It is however interesting to note that burnt bricks fired at a kiln temperature, of 1000°C produce red to reddish brown bricks but beyond this temperature, a dark blue coloured vitrified clinker results which melts and fuses together in a heap usually discarded by natives and referred to as "iron stone".

This research is therefore important as it tries to compare the compressive strength of concrete made with the conventional gravel and crushed burnt bricks as the coarse aggregates. In recent times there has been significant decline in the capacity utilization of all cement manufacturing plants given rise to the emergence of a strong local burnt bricks industry. The bricks are made in various sizes using a local adaptation of the standards process controlled burnt bricks technology. The raw materials compromise solely of soil deposits found along the flood plains of major rivers and seasonal streams. The process involves excavating the earth material with a hoe, followed by manual mixing with water into a plastic paste. The mix is then kneaded and compacted into wooden moulds, extruded and air dried under the sun and fired with wood fuel. The firing techniques requires the careful arrangement of the sun dried bricks in tabular or pyramid shaped heaps provided with several interconnecting tunnels to allow for circulation of air and heat. The tunnels are then stuffed with dry wood which is the source of fuel and fired until the colour of the bricks turn from natural gray into red at temperatures of between 600°C – 1300°C [4]. At extreme heating to a temperature of not less than 1600°C the burnt bricks changes from red to blue black ceramics colour and in most cases fuses.

According to Chong [5], there are four recognized stages in firing of burnt bricks:

(a) Drying (up to about 100°C). Water of plasticity (shrinkage water) is removed and the clay product becomes rigid but brittle.
(b) Dehydration (between 100°Cand 700°C). The clay minerals lose their water of crystallization.
(c) Oxidation (between 550°C and 900°C). Iron compounds are oxidized to ferric oxides (Fe_20_3) and all carbonaceous impurities are burnt out before the temperature reaches 800°C.
(d) Vitrification (950°C and above). Crystallization of mullite (Al_6 $Si0_2$ 0_{13}) begins the mullite crystals grow as the temperature is increased and the "glassy" phase contracts causing a severe shrinkage.

At the onset of the vitrification, there is sintering of the individual clay particles. During this period dimensional shrinking of up to 15% occurs. Firing ultimately produces a consolidated but porous mass which contains both microcrystalline mullite and vitreous materials, together with unchanged quartz [6]. The vitrified brick can then be crushed and used as coarse aggregate in concrete production.

Rashid et al [7] investigate the properties of higher strength concrete made with crushed brick as coarse aggregate and found that higher strength concrete (fcu = 31.0 to 45.5 N/mm^2) with brick aggregate is achievable whose strength is much higher than the parent uncrushed brick implying that the compressive strength of brick aggregate concrete can be increased by decreasing its water-cement ratio.

Bricks are a versatile and durable building and construction material, with good load-bearing properties. Various researches have been carried out on porosity, permeability and absorption of bricks. Cachim [8] have reported the properties of concrete which use crushed bricks as natural coarse aggregate partial substitute. Experimental investigation has also been done to achieve higher strength concrete using crushed brick aggregate. It has been found that even recycled brick can also be used as coarse aggregate in concrete. Kesegic et al [9] have showed that concrete can be successfully produced by using recycled aggregates that have been produced from demolition and construction waste. According to Bhattacharjee et al [10], the specific gravity and water absorption of over burnt brick is found out to be 1.71 and 6.502% respectively.

2. Materials and Method

The sand and gravel used for this project were obtained at the River Benue deposits. The over burnt

Table 1: Average Specific Gravities of Constituent Materials.

Material	Specific Gravity
Cement	3.11
Sand	2.55
Gravel	2.71
Crushed over Burnt Bricks	2.17
Water	1.00

Table 2: Aggregates Water Absorption.

Aggregate	Water absorption (AWA)
Sand	6.3%
Gravel	1.2%
Crushed over burnt bricks	4.4%

bricks samples were collected at a bricks production site at Ana area of Naka, Gwer West Local Government Area of Benue State. Ordinary Portland cement from Benue Cement Company (BCC), Gboko, Nigeria was used as binding agent and water used for mixing was from the Makurdi water works. The apparatus used are: Specific Gravity Bottle, Balance, Tamping Rod, Ruler, Head Pan, Shovel, 75mm Diameter x 50mm Deep Measuring Cylinder, Timer, Slump Cone, 14mm, 10mm and 2.35mm BS sieves. Others are: Hand Trowel, Compacting Machine, 0.15m × 0.15m × 0.15m Mould, Curing Tank, Scoops, Spanners, Electric Vibrator, Plunger, Base Plate, Compression Machine and Towel as well as stark of BS sieves and sieves Shaker.

Specific gravity (G.S), aggregate impact value (AIV) and aggregate crushing value (ACV) tests were carried according to BS 882[11], BS 812-112[12] and BS 812-110[13] respectively. Aggregate water absorption (AWA) test was conducted in compliance with BS 812-109 [14] while particle size distribution analysis was carried out according to BS 812-103.1 [15]. The result of the specific gravity test is shown in Table 1. While that of water absorption is shown in Table 2.

The concrete was batched and mixed according to BS EN 206-1 [16]. Slump test was carried out on the fresh concrete to determine the workability of the various proportions of the gravel to crushed burnt bricks in accordance with BS 1881-102 [17]. The result of the slump test is shown in Table 3 and Fig. 1.

The cube moulds were cleaned and oiled before each casting. Nine concrete cubes of 150mm were produced for each mix. A mix ratio of 1:2:4 was used. The coarse aggregate was a mixture of crushed burnt bricks and gravel in the proportions of 0:4, 1:3, 2:2, 3:1 and 4:0 of crushed burnt bricks to gravel. Water/Cement ratios of 0.45, 0.50 and 0.60 were used.

Table 3: Mixed Proportion of Gravel to crushed over Burnt Bricks, W/C Ratio and Slump.

Mixed Proportion	Water/ Cement Ratio	Slump (mm)
4:0	0.45	39
3:1	0.50	45
2:2	0.50	35
1:3	0.45	30
0:4	0.50	25

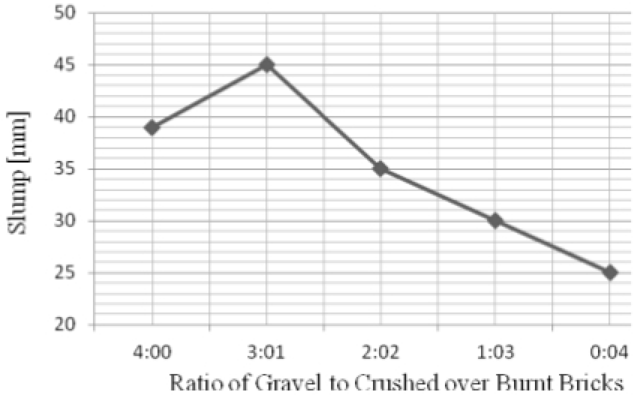

Figure 1: Workability of concrete using gravel and crushed over burnt bricks in various mixed proportions measured by slump.

Demoulding of the cubes was done between 18 hours to 24 hours after casting. The hardened cubes were transferred immediately into the curing tank at room temperature. The cubes were removed at the end of 7, 14 and 28 days from the curing tank and air dried for about 3 hours before testing. The results of the compression tests at 28 days are given in Table 4 and Fig. 2.

3. Results and Discussions

3.1. Sieve analysis

The result of the particle size distribution carried out in accordance with BS 812-103.1 [15] is presented in Figures 2 – 4.

From Fig. 2 more than 90% of the aggregate passed through sieve 4.75mm which places the aggregate as fine aggregate as (BS882) [11], and the assessment of the particle size distribution revealed that the aggregate is well graded.

3.2. Specific gravity

The specific gravity test result of sand, gravel and crushed over burnt bricks were respectively determined to be 2.55, 2.71 and 2.17 as shown in Table

Table 4: Summary of Compressive Strength Test Results of Cubes Cast Using Various Mix Proportions of Gravel and crushed over Burnt Bricks and Cured for 28 days.

Slump (mm)	**Proportion of Gravel**	**Proportion of Crushed over burnt bricks**	**Average Weight** (g)	**Average Crushing Load** (kN)	**Density** (kg/m^3)	**Compressive strength** (N/mm^2)
39	4	0	8628	470	2557	21
30	1	3	7918	560	2346	25
35	2	2	7851	490	2326	22
45	3	1	8154	520	2416	23
25	0	4	7529	570	2233	26

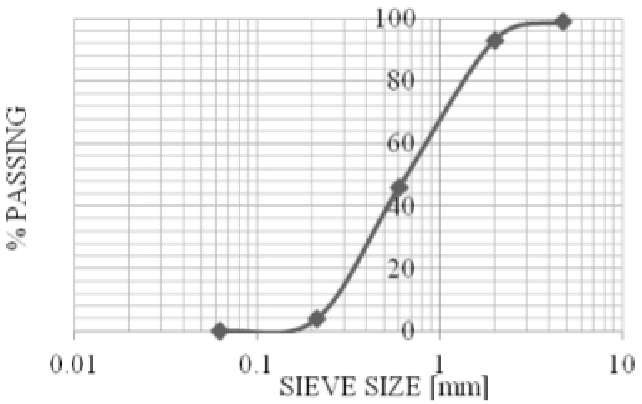

Figure 2: Particle size distribution for fine aggregate (sand).

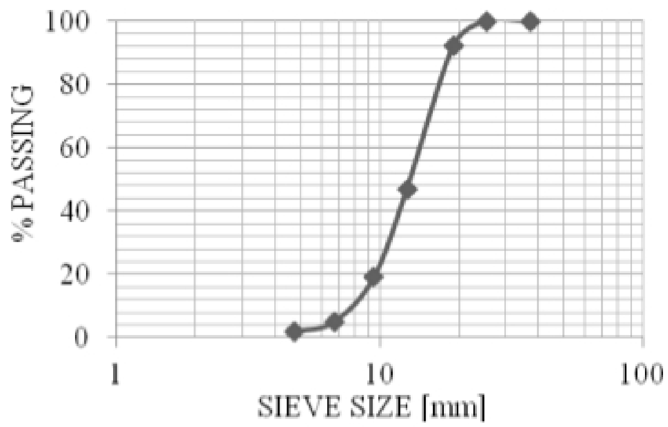

Figure 3: Particle size distribution for coarse aggregate (gravel).

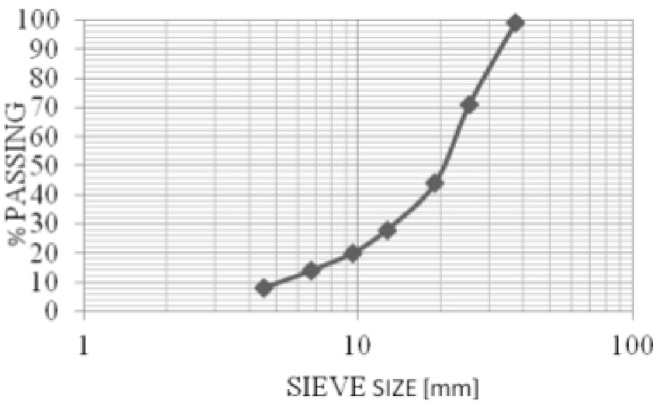

Figure 4: Particle size distribution for coarse aggregate (crushed over burnt bricks).

1. The specific gravities of sand and gravel were within the values reported by Bowles [18]. Crushed over Burnt Bricks however, had a low specific gravity of 2.17 probably because it is an artificial aggregate whose strength and density depend on those of the clay brick it is produced form. Bhattacharjee et al [10] reported a value of 1.71.

3.3. Aggregate impact value

The result of aggregate impact value test for crushed over burnt bricks is 28.2%. This mean impact value falls within the acceptable limits. BS 882 [11] prescribes maximum value of 45% for aggregate to be used in concrete for non-wearing surfaces. The aggregate impact value is inversely related to the toughness of the aggregate, hence, the higher the value of the impact, the lower the toughness.

3.4. Aggregate crushing value

The test result value for crushed over burnt bricks is 22.8%. The value lies within maximum prescribed value of 45% for ordinary concrete used for non-wearing surfaces by BS 882 [11]. Although there is no direct relationship between aggregate crushing value

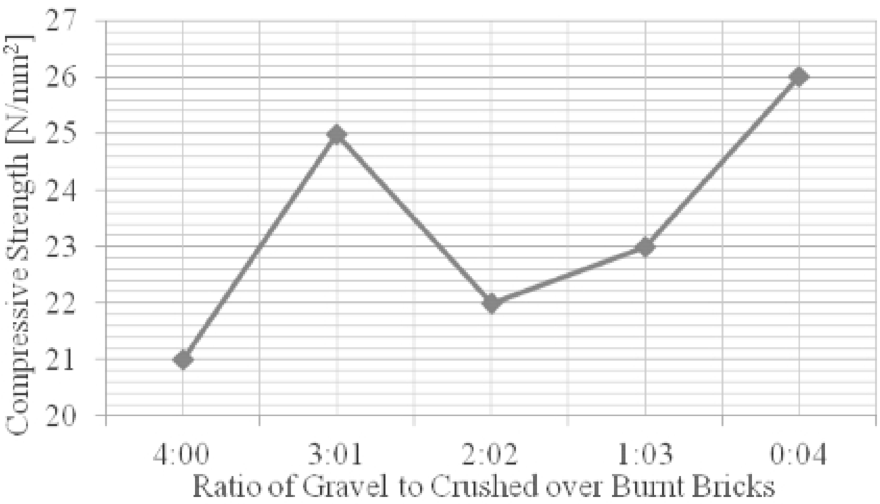

Figure 5: The 28th day compressive strength as a function of the proportion of gravel to crushed over burnt bricks.

and the compressive strength of concrete, the test is a guide to the expected strength of a concrete.

3.5. Aggregate water absorption

The test result of aggregate water absorption for crushed over burnt bricks is 4.4% which is about half of the maximum of 8.0% allowed for uncrushed bricks by Brick [19], implying that the aggregate will be stable and durable even in wet condition.

3.6. Slump

The result of the slump test presented in Table 3 revealed a slump value of 39 mm at the W/C ratio of 0.45 for gravel to make the concrete workable. At the gravel to crushed over burnt brick ratio of 3:1 and a W/C ratio of 0.50, the slump increased to 45 mm. This increment in W/C ratio is due to aggregate water absorption of the crushed over burnt bricks introduced. Furthermore, it can be seen that even with a high W/C ratio of 0.50 for exclusive crushed over burnt bricks (0:4), the workability has a slump value of 25 mm also indicating that much of the water may have been absorbed by the crushed over burnt bricks. Figure 1 shows a relationship between slump and the mixed ratio of gravel to crushed over burnt bricks depicting the trends in the relationship.

3.7. Compressive strength

The 28th day result is presented in Table 4 and it shows exclusive crushed over burnt bricks (0:4) having the highest strength of 26 N/mm^2 while exclusive gravel (4:0) ended up with the least strength of 21 N/mm^2. Bhattacharjee et al [10] achieved compressive strength of 29.16 N/mm^2 by using a mix of 1: 1.24: 2.48 with w/c ratio of 0.48 with crushed over burnt bricks at 28th day. This result may probably be as a result of absorbed water in the crushed burnt bricks which sustained the hydration process over time thereby increasing the compressive strength of the concrete, bearing in mind that compressive strength increases with the age of concrete. The variation of the compressive strength with mix ratio of crushed over burnt bricks to gravel is shown in Figure 2.

4. Conclusion

The following conclusions can be drawn from this study:

1. Crushed over burnt bricks can be used as partial replacement for river gravel in concrete production.

2. Crushed over burnt bricks can be used to produce concrete with lower weight and hence lower dead loads as such can be used on low bearing capacity soils.

3. Crushed over burnt bricks can also be used to produce concrete with higher compressive strength with reduced weights if the bricks are properly and thoroughly burnt.

4. Recycling of crushed over burnt bricks could aid in sanitizing the environment.

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