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The suitability of crushed over burnt bricks as coarse aggregates for concrete

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Abstract*— The research was conducted to study the suitability of crushed over burnt bricks as alternative coarse aggregates for concrete production. Tests were carried out to determine the physical properties of the crushed over burnt bricks aggregates. Values of 22.8%, 28.2% and 4.4% were obtained for aggregate crushing value, aggregate impact value and aggregate water absorption respectively. The concrete mixes were prepared using crushed over burnt bricks as coarse aggregates at water – cement ratios of 0.40, 0.50, 0.55 and 0.60. Cubes of concrete were prepared and tested to study the compressive strength. The results were compared with concrete made with river wash gravel as coarse aggregates which at present is the only coarse aggregate in Makurdi, Nigeria and its environs. The results indicate that crushed over burnt bricks – sand concrete is medium light weight concrete having a density between 2000-2200 kg/m^3 and compressive strength of up to 29.5 N/mm^2 compared to grave l – sand concrete having density between 2300-2400 kg/m^3 and compressive strength of up to 30.8 N/mm^2. It can be concluded that by reducing the water-cement ratio from 0.60 to 0.40 the compressive strength of crushed over burnt bricks – sand concrete and gravel – sand concrete increase by more than 30%. 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.

***Index Terms*— Coarse-aggregates, Concrete, Crushed over burnt bricks, Suitability.**

I. 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 molded 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.

Since seventy five (75) per cent of concrete is made up of aggregates, its types, quality and general properties determine the quality of concrete [1] – [2].

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 cheap labor. This necessitates the use of alternative coarse aggregates which are locally obtained. One of such coarse aggregate is crushed over burnt bricks obtained from the production of burnt bricks [3].

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 [4] – [5].

Reference [6] investigated the properties of higher strength concrete made with crushed brick as coarse aggregate and found that higher strength concrete (f_{cu} = 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. Reference [7] 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. Reference [8] have showed that

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Volume 3, Issue 1, January 2014
concrete can be successfully produced by using recycled aggregates that have been produced from demolition and construction waste. According to [9] the specific gravity and water absorption of over burnt brick is found out to be 1.71 and 6.502 % respectively.

II. WATER-CEMENT RATIO

Concrete develops its strength by hydration of the cement and addition to form a complex series of hydrates. The initial hydration fixes the cement particles into a weak structure surrounded by a water-filled space. The higher the initial water content, the further will be the average spacing between the cement grains [10]. Where the initial water/cement ratio is high, the resulting pore structure within the hydrates is interconnected and the resulting concrete has low strength, high penetrability and low durability. In practice long-term strength gain will only occur in conditions where the concrete retains or gains sufficient water for hydration to continue. Once dried so that the internal relative humidity falls below 95 per cent [11], further hydration effectively stops. However, if the concrete is rewetted, hydration will start again.

In 1918, after extensive testing performed at the Lewis Institute, University of Illinois, Duff Abrams concluded that there was a relation between water-cement ratio and concrete strength. Today, this inverse relation is recognized as Abrams' water-cement ratio rule; it is represented by the expression below where *w/c* represents the water-cement ratio of the concrete mixture and k_1 and k_2 are empirical constants [12] – [13].

$$f_c = k_1/k_2^{\,w/c} \qquad (1)$$

Reference [14] gives; Strength = $234x^3$ MN/m^2 where *x* is a function of the gel/space ratio and this is independent of the age of the concrete and the mix proportions.

Reference [15] show that due to reduction of water-cement ratio from 0.33 to 0.50, the compressive strength improved by 34.4 and 35.2 %, respectively, while [5] was able to achieve a maximum strength of 23.71N/mm^2 with mix proportion of 1:2:4 and water-cement ratio of 0.5 at 28days hydration. Tests by [16] indicate that by using an appropriate amount of mixing water, penetration of main corrosion causing agents like chloride ions and atmospheric carbon dioxide could be significantly reduced. It is also observed that a water-cement ratio of less than 0.6 shall give better corrosion resistance with increased compressive strength. In their study of the effect of different mix ratios and water cement ratios on sulphate attack on concrete, [17] concluded that lean mixes were more affected than the richer ones; that concretes with the same concrete mix ratio and having more than 0.55 water/cement ratio were more affected in case of exposure to soluble sulphate salts and that compression members were likely to be more affected than the flexural members on their exposure to sulphates.

To [18] water-cement ratio can be used to evaluate whether the actual concrete composition complies with the job specifications and also to check the uniformity of the concrete within or between batches. The major advantage of using such a method is that concrete can be analyzed immediately when delivered to the jobsite. Thus, the concrete could be rejected if it does not meet the project specifications before it is an integral part of the project.

III. MATERIALS AND METHODS

The sand used for this project was obtained at the River Benue deposits. The sand was prepared according to the standards specified by [19]. The grading was carried out according to [20]. The sand belongs to zone C [1]. The gravel, like the sand was obtained from River Benue deposits. The over burnt bricks samples were collected at a bricks production site at Ana area of Naka, Gwer West Local Government Area, and Benue State. The maximum size of aggregate used was 20mm. 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.

Specific gravity (G.S), aggregate impact value (AIV) and aggregate crushing value (ACV) tests were carried according to [19], [21] and [22] respectively. Aggregate water absorption (AWA) test was conducted in compliance with [23] while particle size distribution analysis was carried out according to [20]. The concrete was batched and mixed according to [24].

IV. RESULTS AND DISCUSSIONS

A. SIEVE ANALYSIS

The result of the particle size distribution carried out in accordance with [20] is presented in Tables 1 – 3 and Figures 1 – 2.

ISSN: 2319-5967
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Table 1: Particle Size Distribution for fine aggregate (washed sand)

Sieve Size (mm)	Mass Retained (g)	% Retained	% Passing
4.75	5.0	1.0	99.0
2.00	57.0	6.0	93.0
0.60	426.0	47.0	46.0
0.212	382.0	42.0	4.0
0.063	34.0	4.0	0.0
Pan	3.0	0.0	0.0

Table 2: Particle Size Distribution for coarse aggregate (washed gravel)

Sieve Size (mm)	Mass Retained (g)	% Retained	% Passing
37.5	0.0	0.0	100.0
25.4	0.0	0.0	100.0
19.05	325.0	8.0	92.0
12.70	1748.0	45.0	47.0
9.50	1099.0	28.0	19.0
6.70	562.0	14.0	5.0
4.75	122.0	3.0	2.0
Pan	66.0	2.0	0.0

Table 3: Particle Size Distribution for coarse aggregate (crushed over burnt bricks)

Sieve Size (mm)	Mass Retained (g)	% Retained	% Passing
37.5	46.0	1.0	99.0
25.4	1054.0	28.0	71.0
19.05	1002.0	27.0	44.0
12.70	603.0	16.0	28.0
9.50	284.0	8.0	20.0
6.70	240.0	6.0	14.0
4.75	209.0	6.0	8.0
Pan	289.0	8.0	0.0

From Table 1and Figure 1 more than 90% of the aggregate passed through sieve 4.75mm which places the aggregate as fine aggregate according to [19] and the assessment of the particle size distribution revealed that the aggregate is well graded.

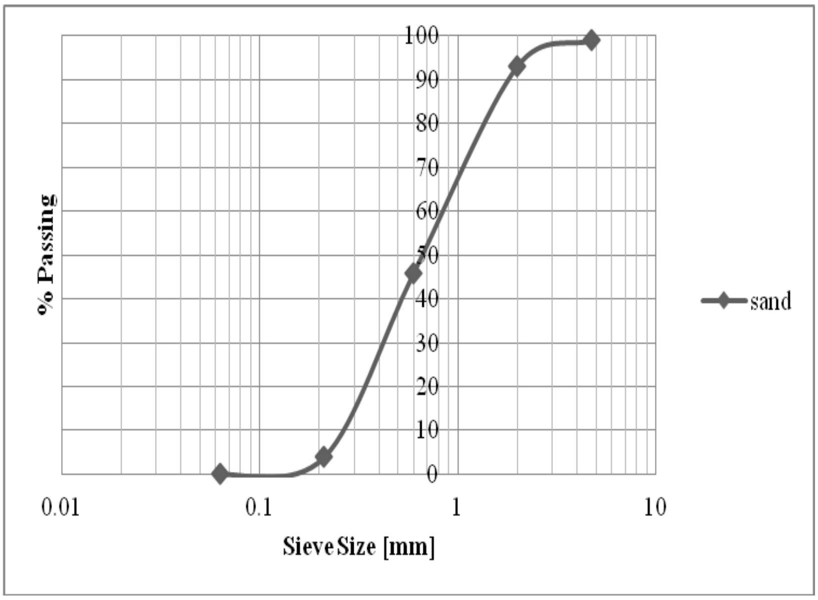

Fig 1: Particle Size Distribution for fine aggregate

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 3, Issue 1, January 2014

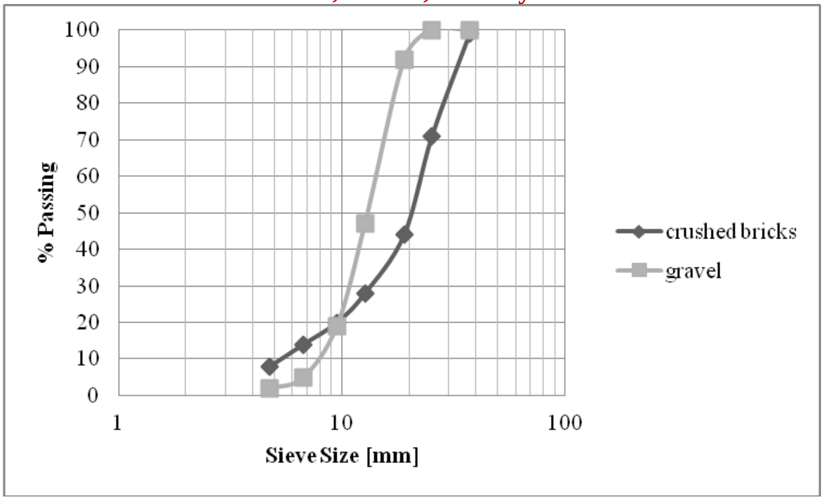

Fig 2: Particle Size Distribution for coarse aggregate

B. 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 4. The specific gravities of sand and gravel were within the values reported by [25]. 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. Reference [9] reported a value of 1.71.

Table 4: 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

C. 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. Reference [19] 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.

Table 5: Properties of crushed over burnt bricks

Property	Value
Aggregate Crushing Value (ACV)	22.8%
Aggregate Impact Value (AIV)	28.2%
Aggregate Water Absorption (AWA)	4.4%

D. 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 [19]. Although there is no direct relationship between aggregate crushing value and the compressive strength of concrete, the test is a guide to the expected strength of a concrete.

E. AGGREGATE WATER ABSORPTION

The test result of aggregate water absorption for crushed over burnt bricks is 4.4% (refer to Table 5) which is about half of the maximum of 8.0% allowed for uncrushed bricks by [26], implying that the aggregate will be stable and durable even in wet condition.

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F. COMPRESSIVE STRENGTH

The compressive strength results are presented in Table 5 and Figures 3 –4. The 7th day strength increases as the water content reduces. The 14th and 28th day strength follow the same pattern. The 28th day strength gives a maximum value of 30.8 N/mm^2 for gravel – sand concrete at water – cement ratio of 0.4. For crushed over burnt bricks – sand concrete a value of 29.5 N/mm^2 is obtained at the same water – cement ratio of 0.4. Reference [9] 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, while reference [6] investigated the properties of higher strength concrete made with crushed bricks as coarse aggregate and found that higher strength concrete (f_{cu} = 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.
As seen from Figures 3 – 4, over 75% of the compressive strength is attained at the age of 7 days of curing.

Table 5: Summary of Compressive Strength Test Results.

Concrete	Density (kg/m^3)	Water-cement ratio	Compressive Strength (N/mm^2)		
			7 Day	14 Day	28 Day
Gravel – Sand concrete	2370	0.38	28.8	35.7	38.2
		0.40	25.1	27.6	30.8
		0.50	22.8	25.1	29.3
		0.60	19.4	21.0	23.1
Crushed over burnt bricks- Sand concrete	2100	0.40	24.5	27.0	29.5
		0.50	20.3	25.8	28.4
		0.55	19.6	25.4	26.8
		0.60	19.2	20.3	22.4

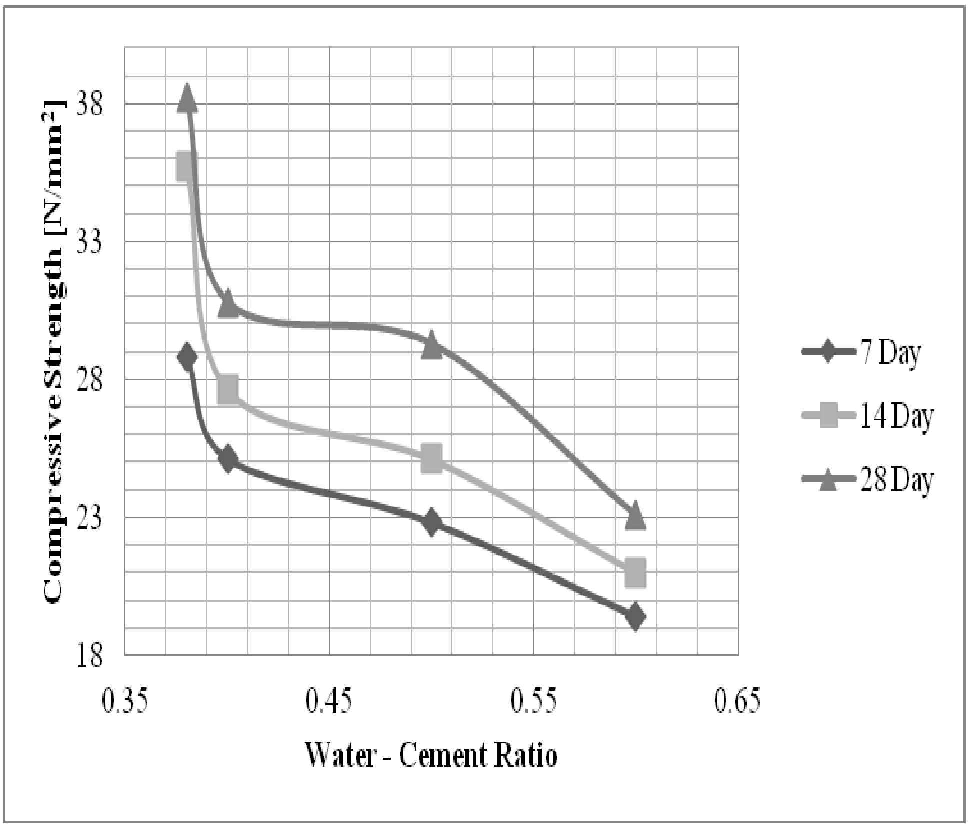

Fig 3: Compressive Strength of Gravel - Sand Concrete at various water - cement ratios

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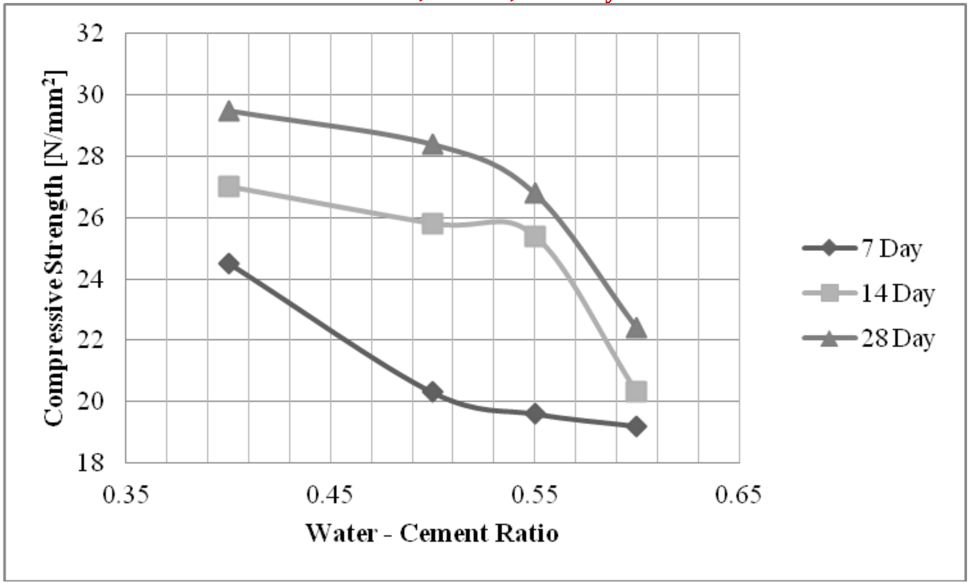

Fig 4: Compressive Strength of Crushed over Burnt Bricks - Sand Concrete at various water - cement ratios

V. CONCLUSION

Based on results of experimental investigation concerning the properties of crushed over burnt bricks as coarse aggregates for concrete, the following observations are made:

A. Crushed over burnt bricks can be used in place of river gravel in concrete production.

B. 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.

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

D. Reducing the water-cement ratio increases the compressive strength.

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Volume 3, Issue 1, January 2014

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