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Effect of Water-Cement Ratio on the Compressive Strength of gravel - crushed over burnt bricks concrete.

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Abstract

The research was conducted to study the effect of water-cement ratio on the compressive strength of gravel-crushed over burnt bricks concrete. Trial mixes were prepared using the crushed over burnt bricks as coarse aggregates only (control), mixture of crushed over burnt bricks and river wash gravel as coarse aggregates and river washed gravel as coarse aggregates only (control) at water – cement ratios of 0.4, 0.5,0.55 and 0.6. Cubes of concrete were prepared and tested to study the compressive strength in relation to the water-cement ratio. The results indicate that the concrete having over burnt bricks as aggregates may be termed as medium light weight concrete having a density between 2000-2200 kg/m^3 and that by reducing the water-cement ratio from 0.6 to 0.4 increases the compressive strength from 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.

Key words: Aggregates, concrete, compressive strength, water-cement ratio, crushed over burnt bricks

1.0 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.

Since seventy five (75) per cent of concrete is made up of aggregates, its types, quality and general properties determine the quality of concrete (Neville, 1995, Troxel et al, 1968).

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 labour. 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 (Maher, 1987).

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 (Agbede and Manasseh, 2008 and Waziri et al, 2011).

Rashid et al, (2009) investigated 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, (2009) 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 (2008) 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 (2011), the specific gravity and water absorption of over burnt brick is found out to be 1.71 and 6.502 % respectively.

2.0 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 (Harrison, 1992). 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 (Killoh et al., 1989), 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 (Jankovic et al, 2011, Harrison, 2003).

$$f_c = k_1/k_2^{\,w/c}$$

Powers, (1958) 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.

Shamsai et al. (2012) 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 Waziri et al, (2011) 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 Ahmad and Shabir (2005) 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, Ahmad and Shabir (2005) conclude 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 Naik and Ramme (1989), 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.

3.0 Materials and Method

The sand used for this project was obtained at the River Benue deposits. The sand was prepared according to the standards specified by BS 882 (1992). The grading was carried out to BS 812: 103. The sand belongs to zone C (Neville, 1995). 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, 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.

The concrete was batched and mixed according to BS EN 206-1 (2000). 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 (1983).

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

(Apebo et al, 2013)

4.0 Results and Discussions

4.1 Sieve Analysis

The result of the particle size distribution carried out in accordance with BS 812-103.1 (1985) is presented in Tables 2 – 4.

Table 2: 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 3: 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 4: 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 2 more than 90% of the aggregate passed through sieve 4.75mm which places the aggregate as fine aggregate as BS882 (1992) and the assessment of the particle size distribution revealed that the aggregate is well graded.

4.2 Compressive Strength

The compressive strength results are presented in Figures 1 –5. The 7th day strength increases as the proportion of crushed over burnt bricks increases and the water content reduces, reaching the highest value of 35.0 N/mm^2. This corresponds to gravel – over burnt brick ratio of 2:2 and water – cement ratio of 0.4. Beyond this ratio of 2:2 (gravel to over burnt bricks), the strength decreases with increasing crushed over burnt bricks content, but increases as water content decreases. The 14th and 28th day strength follow the same pattern. The 28th day strength gives a maximum value of 35.9 N/mm^2 for gravel – crushed over burnt bricks ratio of 2:2 and water – cement ratio of 0.4. This shows that the optimum gravel – crushed over burnt bricks ratio is 2:2 as it yields strength higher than that obtained from 4:0 (gravel to crushed over burnt bricks) and 0:4 (gravel to crushed over burnt bricks) at the same water – cement ratio of 0.4. For only crushed over burnt bricks a value of 29.5 N/mm^2 is obtained, corresponding to water – cement ratio of 0.4. Bhattacharjee et al (2011) 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 Rashid et al (2009) 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 1 – 5, over 75% of the compressive strength is attained at the age of 7 days of curing.

Table 6: Summary of Compressive Strength Test Results.

Gravel-Bricks ratio	Density (kg/m^3)	Water-cement ratio	Compressive Strength (N/mm^2)		
			7 Day	14 Day	28 Day
4:0	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
3:1	2320	0.40	33.8	35.6	35.9
		0.50	31.1	32.0	32.7
		0.55	21.7	23.5	24.2
		0.60	19.9	21.3	22.4
2:2	2260	0.40	35.0	35.6	35.9
		0.50	32.5	34.3	35.4
		0.55	20.1	24.0	27.6
		0.60	18.7	22.6	24.9
1:3	2190	0.40	29.9	33.6	34.7
		0.50	27.9	30.2	32.5
		0.55	25.2	29.3	31.3
		0.60	21.0	23.6	27.6
0:4	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

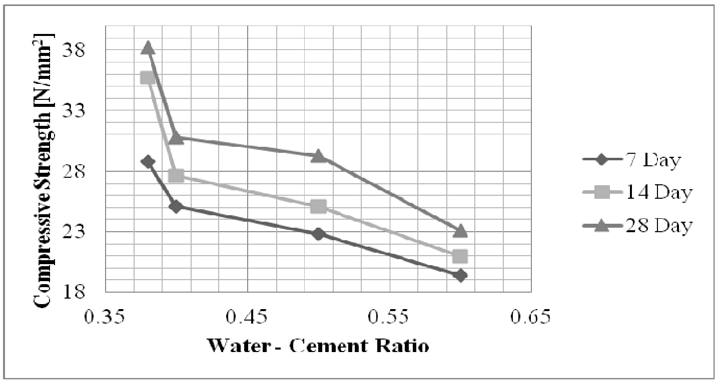

Figure 1: Compressive Strength for various Water-Cement ratios at Gravel-Crushed over burnt bricks ratio of 4:0

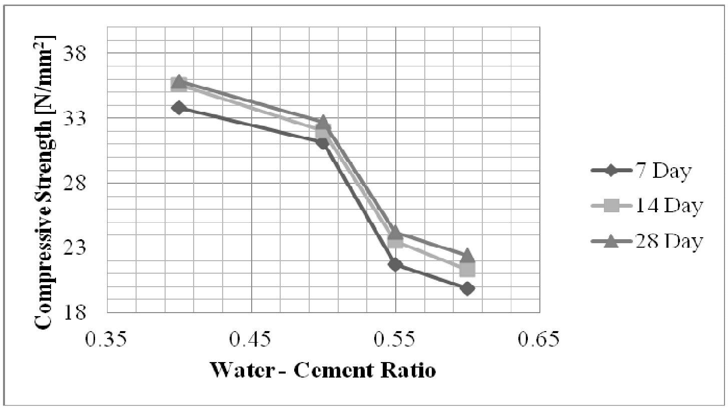

Figure 2: Compressive Strength for various Water-Cement ratios at Gravel-Crushed over burnt bricks ratio of 3:1

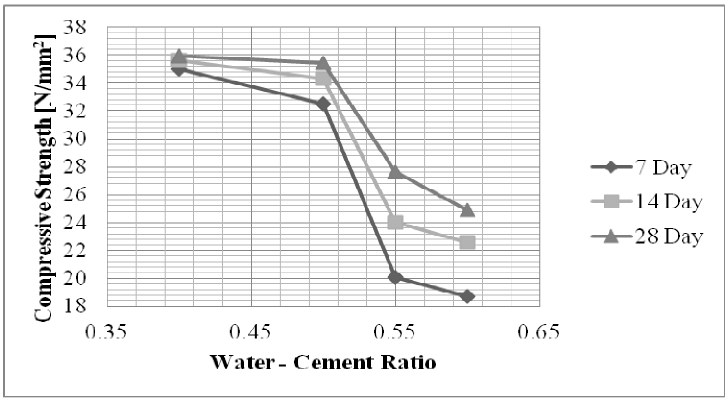

Figure3: Compressive Strength for various Water-Cement ratios at Gravel-Crushed over burnt bricks ratio of 2:2

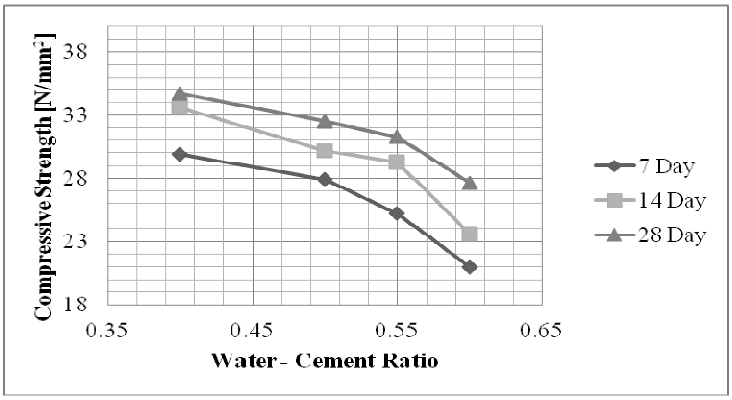

Figure 4: Compressive Strength for various Water-Cement ratios at Gravel-Crushed over burnt bricks ratio of 1:3

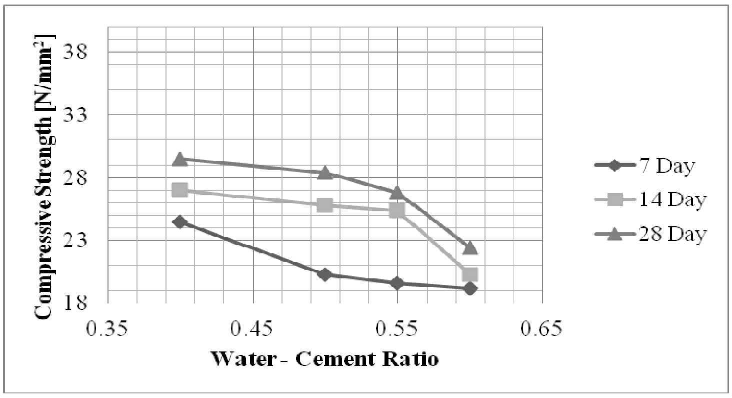

Figure 5: Compressive Strength for various Water-Cement ratios at Gravel-Crushed over burnt bricks ratio of 0:4

5.0 Conclusion

From this study, the following conclusions can be drawn:

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

ii. 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.

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

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

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