The International Journal Of Engineering And Science (IJES)
|| Volume || 3 || Issue || 4 || Pages || 35-41 || 2014 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

An Investigation on the Suitability of the Broken Tiles as Coarse Aggregates in Concrete Production

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ABSTRACT
The study reports on experimental investigation on the suitability of the broken tiles as partial or full replacement for crushed granite in concrete production. Two control mixing ratios of 1 : 2 : 4 and 1 : 3 : 6 batched by volume with water – cement ratio of 0.55 were used. The percentage replacement varied from 0% to 100% at intervals of 25%. The slump test was used to assess the workability of the fresh concrete. The compressive strengths and densities of cured concrete cubes of sizes 150mm x 150mm x 150mm were evaluated at 3days, 7days, 14days, 21days and 28days. A total of 150 concrete cubes were cast and tested. Increase in the percentage replacement of crushed granite with broken tiles lowered workability, density and compressive strength. The compressive strengths and densities of both mixing ratio increase with days of curing. The compressive strength and density are maximum for concrete cubes with 100% crushed granite and minimum when broken tiles content is 100%. Compressive strength tests showed that 39% and 57% of the broken tiles in replacement for crushed granite was quite satisfactory with no compromise in compressive strength requirements for both concrete mixing ratio.

***KEYWORDS**: concrete, ordinary Portland cement, broken tiles, crushed granite, compressive strength.*

Date of Submission: 07 February 2014 Date of Publication: 05 April 2014

I. INTRODUCTION

Concrete is a construction material that consists, in its most common form, of Portland cement, aggregates and water. Concrete is used more than any other man made material on this planet. It is a low cost material and can be used for the construction of any type of structure. Aggregates which are one of the materials used in making concrete are chemically inert solid particles of selected sizes, held together by the hardened cement paste, which acts as the binder to aggregates. Aggregates that can be natural gravel, crushed rock or an artificially prepared heavy or light weight material, are available in various shapes, sizes and qualities that may range from fine sand to large, coarse rocky materials. Because cement remains the most expensive ingredient in making a concrete, it is desirable to minimize the quantity of cement and maximize the quantity of aggregate used in concrete production. In a normal concrete, 75 to 85% of the volume of concrete is aggregate that makes the cost of concrete relatively low.

The choice of aggregate is determined by the proposed use and importance of structure, environmental conditions to which the structure will be exposed and the availability of aggregate within an economical distance. Aggregates in concrete serve three main functions: they provide a relatively cheap filler by rigid interlocking with cementitious binders; they serve to provide a cohesive mass of solids that resists the action of applied loads, percolation of moisture, the action of weather, and abrasion and erosion and, they reduce the volume changes resulting from the setting and hardening process from moisture changes in the cementitious paste thus reducing the cracking possibility of concrete.

Owing to liberalization, globalization and privatization, the construction of important infrastructure projects like, buildings, roads, airports etc in Nigeria is increasing year after year. Such developmental activities consume large quantity of precious natural resources. This leads to faster depletion of natural resources on one side and manifold increase in the cost of construction of structures on the other side pose severe problem for the construction sector. This problem is very severe in Nigeria. In view of this, people have started searching for suitable other viable alternative materials which could be used either as a substitute or as a partial replacement to the conventional ingredients of concrete so that the existing natural resources could be saved to the possible extent and could be made available for the future generation.

In this process, different industrial / agricultural waste materials such as fly ash, quarry dust, groundnut shell ash, broken glass waste, waste from ceramic, waste aggregate from demolition of structures etc, have been tried as a viable substitute or partially material to the conventional materials in concrete and has also been succeeded. Weihua, Christian and Stephen (2000) suggested that the use of crushed waste glass as an aggregate in concrete has several advantages in terms of strength. If used in large quantities in compressibility products such as concrete masonry blocks, the solid waste disposal problem faced can noticeably be reduced. Senthamarai and Manoharan (2005) suggested that the compressive, splitting tensile and flexural strengths of ceramic waste coarse aggregate are lower by 3.8, 18.2 and 6% respectively when compared to conventional concrete. Adewuyi and Adegoke (2008) investigated the exploratory study of periwinkle shells as coarse aggregates in concrete works. They suggested that concrete with 35.4% and 42.5% periwinkle shells inclusion can still give the minimum 28 – day cube strength values of $21N/mm^2$ and $15N/mm^2$ expected for concrete mixes 1 : 2 : 4 and 1 : 3 : 6 respectively. Olutoge (2010) investigated the suitability of sawdust and palm kernel shells as replacement for fine and coarse aggregate in the production of reinforced concrete slabs. He concluded that 25% sawdust and palm kernel substitution reduced the cost of concrete production by 7.45%. Olanipekun (2006) compared concrete made with coconut shells and palm kernel shells as replacement for coarse aggregates and concluded that coconut shells performed better than palm kernel shells as replacement for conventional aggregates in the production of concrete.

Information regarding studies on concrete made with different wastes is available in different forms in a scattered manner, and has also not adequately reached the large volume of stakeholders engaged in the construction activities across the length and breadth of our country. Due to this, the effective utilization of potential industrial waste materials in concrete has not attained the expected level in Nigeria even today. Hence, there is a compulsion on the part of Civil Engineering community, to take appropriate strategies so that the consumption of such potential waste by the construction industries will be on rise day – by – day leading to a green environment which is of course the need of the hour for our nation.

As part of efforts to make efficient use of industrial wastes available materials, this study was carried out to investigate the influences of volume replacement of conventional coarse aggregates by broken tiles on the workability, density and compressive strength of concrete as well as to assess the suitability of broken tiles concrete as a structural materials.

II. EXPERIMENTAL PROCEDURE

2.1. Concrete Materials

Crushed granite used for the study was of size 20mm. It was obtained from Ayofe quarry in Iwoye near Ede of Osun State of Nigeria. The broken tiles used were sourced from the tiles sellers at Osogbo in Osun State of Nigeria. They were packed in plastic sheets to prevent contact with water.Natural river sand used was obtained from Osun river while Dangote brand of ordinary Portland cement produced at the cement factory located at Obajana in Kogi State of Nigeria as obtained from the open market at Ede in Osun State was used in the concrete production.Water supplied by Osun State water corporation in Ede was used in mixing the materials. The water looked clean and was free from any visible impurities. It conformed to the requirements of BS 3148 (1980).

2.2. Mixing Proportions and Production of Concrete Cubes

The study utilized two control mixing ratio of 1 : 2 : 4 and 1 : 3: 6. Batching operation by volume approach was adopted in the study. A water – cement ratio of 0.55 was used in both mixing ratio.The casting was done in cube steel moulds measuring 150mm x 150mm x 150mm internally. The cube steel moulds were assembled prior to mixing and properly lubricated with used engine oil for easy removal of hardened concrete cubes. Concrete cubes were prepared in percentage by volume of crushed granite to broken tiles as coarse aggregate in the order of 100 : 0, 75 : 25, 50 : 50, 25 : 75 and 0 : 100 ranging from zero to full replacement for crushed granite by broken tiles. The mixture was properly turned with shovel until it reached a plastic state which was then fed into lubricated cube steel moulds. Water curing method was adopted in this study. The concrete cubes were made in accordance with BS 1881 (1983).The concrete cubes cast were removed from the mould after twenty four (24) hours. They were then immersed into a large curing tank measuring 3.0m x 1.5m in order to increase the strength of the concrete, promote hydration, eliminate shrinkage and absorb heat of hydration until the day of test. Concrete cubes prepared were cured for 3, 7, 14, 21 and 28 days. The concrete cubes were weighed before testing and the densities of cubes at different time of testing were measured. Before the testing, the concrete cubes were removed from the curing tank and left in the open air for about two (2) hours before crushing.

The compressive strengths of the concrete cubes were tested in accordance to BS 1881 (1983) using Digital compression machine which automatically evaluates the compression load and displays the results on an LCD screen. In all, 150 numbers concrete cubes were cast and tested.

III. TEST RESULTS AND DISCUSSIONS

3.1. Workability

The workability of concrete batches for different percentages of broken tiles using slump test is shown in Table 1. It can be seen from the Table 1 that for both mixing ratio used, the workability of concrete decreases with increase in the percentage replacement of crushed granite by broken tiles. This is due to the increase the specific surface area as a result of the increase in the quantity of broken tiles and granite is denser than broken tiles, thus requiring more water to make the concrete workable. The workability is lower for concrete mixing ratio 1 : 3 : 6 than that of 1 : 2 : 4 for every trial. From the result obtained, it shows that workability is inversely proportional to the aggregate / cement ratio.

3.2. Density

The density of concrete can be used to classify different mixes considering the 28 day density of the broken tiles crushed granite concrete cubes. The densities of concrete cubes with different percentage of broken tiles for both types of mixing ratio are presented in Tables 2 and 3 respectively. The variation of densities of concrete cubes with broken tiles for both mixing ratio are shown in Fig. 1 and 2. It is seen that in both mixing ratio, the density of concrete decreases as percentage content of broken tiles increases. The density of both types of mixing ratio increase with days of curing. The maximum and minimum densities occur at no replacement (100% granite) and at complete replacement (100% broken tiles) respectively. The maximum densities corresponding to 0% broken tiles are 2405kg/m^3 and 2311kg/m^3 for concrete mixing ratio 1 : 2 : 4 and 1 : 3 : 6 respectively while the minimum densities corresponding to 100% broken tiles are 1877kg/m^3 and 1782kg/m^3 for mixing ratio 1 : 2 : 4 and 1 : 3 : 6 respectively. These values for minimum densities fall within the range of light weight concrete. However, it is also apparent that partial replacement for crushed granite with broken tiles investigations up to 50% for the two mixing ratios can still be regarded as Norman weight concrete (> 2000kg/m^3).

3.3. Compressive Strength

The compressive strengths of concrete cube for different percentages of broken tiles are presented in Tables 4 and 5 for concrete mixing ratio 1 : 2 : 4 and 1 : 3 : 6 respectively. The effects of replacement of crushed granite with broken tiles on compressive strengths of the concrete cubes are shown in Fig. 3 and 4 for concrete mixing ratio 1 : 2 : 4 and 1 : 3 : 6 respectively. It can be seen that the compressive strength decreases as the percentages of broken tiles content increases. The compressive strengths of both types of mixing ratio increase with days of curing. The compressive strength is maximum for concrete cubes with 100% granite and minimum when broken tiles content is 100%. The reason for this is that as the percentage of broken tiles content increases, the specific surface area increases, thereby requiring more cement paste to bond effectively with the broken tiles and since the cement content remains the same, the bonding is therefore inadequate. Strength depends to a large extent on good bonding between the cement paste and the aggregates. The 28 day compressive strength of the concrete cubes were in the range 23.36 – 16.60N/mm^2 and 19.21 – 13.76N/mm^2 for mixing ratio 1 : 2 : 4 and 1 : 3 : 6 respectively. However, the minimum 28 – day cube strength values of 20N/mm^2 and 15N/mm^2 according to BS 8110 (1997) expected for concrete mixing ratio 1 : 2 : 4 and 1 : 3 : 6 could be achieved with 39% and 57% broken tiles replacement for granite, respectively.

IV. TABLES AND FIGURES

Table 1: Workability of Concrete Batches Using Slump Test

Granite : Broken Tiles	**100 : 0**	**75 : 25**	**50 : 50**	**25 : 75**	**0 : 100**
Slump 1 : 2 : 4 Mix (mm)	21	19	12	8	6
Slump 1 : 3 : 6 Mix (mm)	17	13	7	4	1

Table 2: Density (kg/m^3) of Concrete Cubes For Different Percentage of Broken Tiles With Mixing Ratio 1: 2: 4

Days of Curing	Percentage of Broken Tiles Replacement (%)				
	0	**25**	**50**	**75**	**100**
3	2153	2129	2088	1736	1592
7	2249	2198	2102	1845	1631
14	2355	2209	2135	1962	1737
21	2378	2294	2145	1973	1821
28	2405	2319	2173	1986	1877

Table 3: Density (kg/m^3) of Concrete Cubes For Different Percentage of Broken Tiles With Mixing Ratio 1 : 3 : 6

Days of Curing	Percentage of Broken Tiles Replacement (%)				
	0	**25**	**50**	**75**	**100**
3	2104	2095	2052	1831	1614
7	2175	2102	2048	1849	1683
14	2193	2143	2033	1890	1695
21	2247	2162	2018	1913	1735
28	2311	2201	2003	1942	1782

Table 4: Compressive Strengths (N/mm^2) of Concrete Cubes For Different Percentage of Broken Tiles With Mixing Ratio 1: 2: 4

Days of Curing	Percentage of Broken Tiles Replacement (%)				
	0	**25**	**50**	**75**	**100**
3	14.98	13.35	11.53	10.81	8.44
7	15.77	13.02	12.71	11.35	10.74
14	16.74	15.43	14.96	14.47	13.93
21	20.42	18.14	17.35	15.26	15.96
28	23.36	21.63	18.72	17.81	16.60

Table 5: Compressive Strengths (N/mm^2) of Concrete Cubes for Different Percentage of Broken Tiles with Mixing Ratio 1: 3: 6

Days of Curing	Percentage of Broken Tiles Replacement (%)				
	0	**25**	**50**	**75**	**100**
3	12.18	11.32	10.56	7.47	6.58
7	13.59	12.61	11.78	10.59	9.78
14	15.15	14.47	13.35	12.86	12.79
21	17.62	16.38	14.97	13.83	13.34
28	19.21	17.56	15.42	13.95	13.76

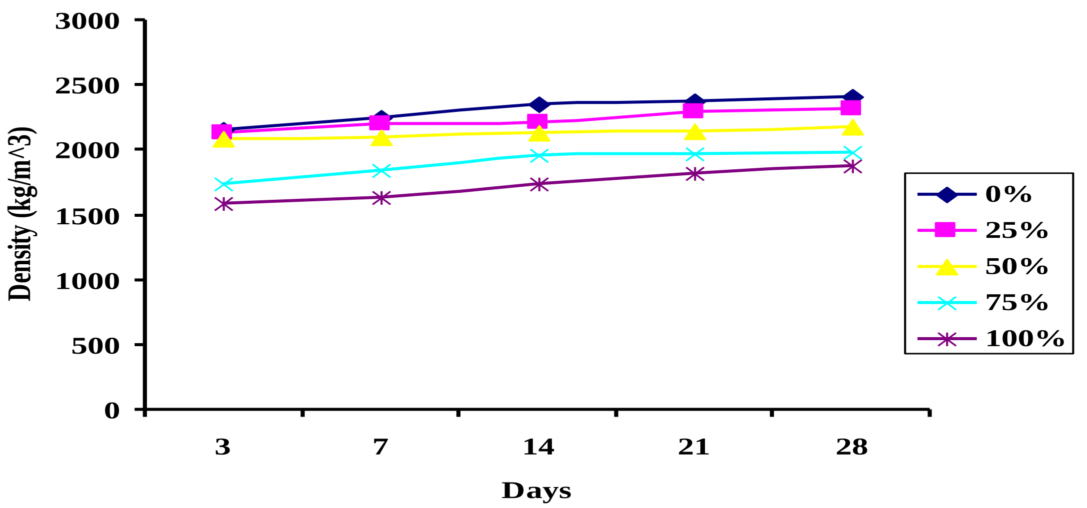

Figure 1: Density – Time Characteristics of Concrete Cubes for Different Percentage of Broken Tiles With Mixing Ratio 1: 2: 4

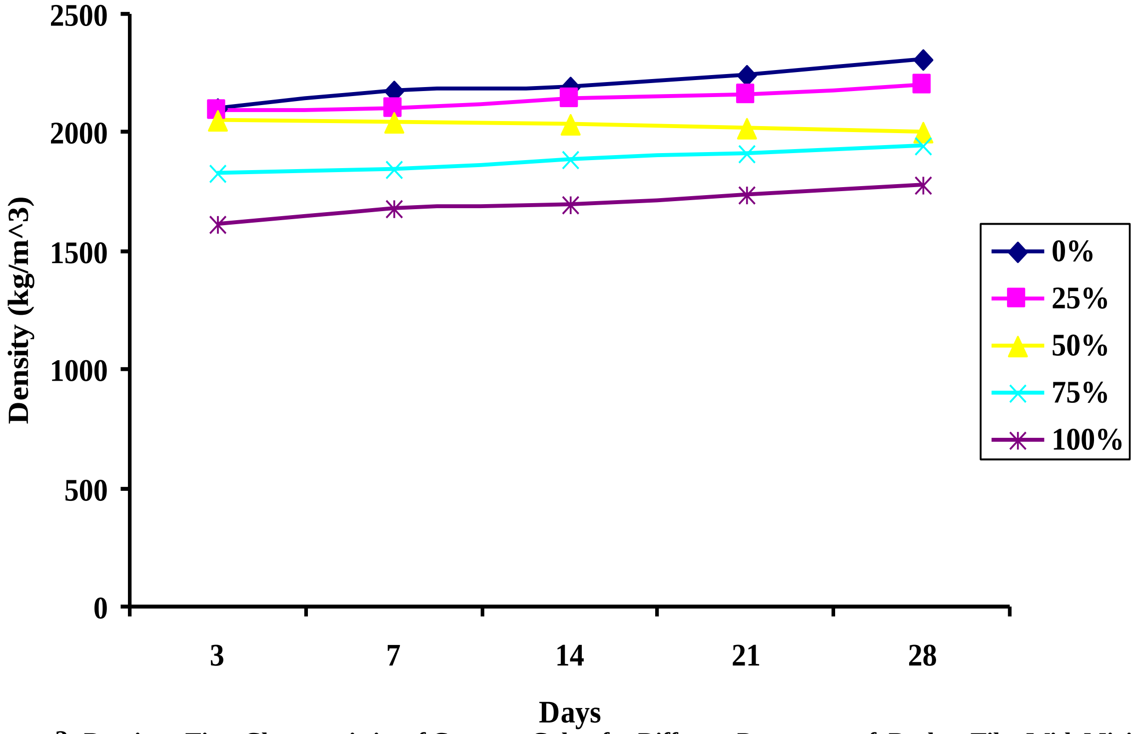

Figure 2: Density – Time Characteristics of Concrete Cubes for Different Percentage of Broken Tiles With Mixing Ratio 1: 3: 6

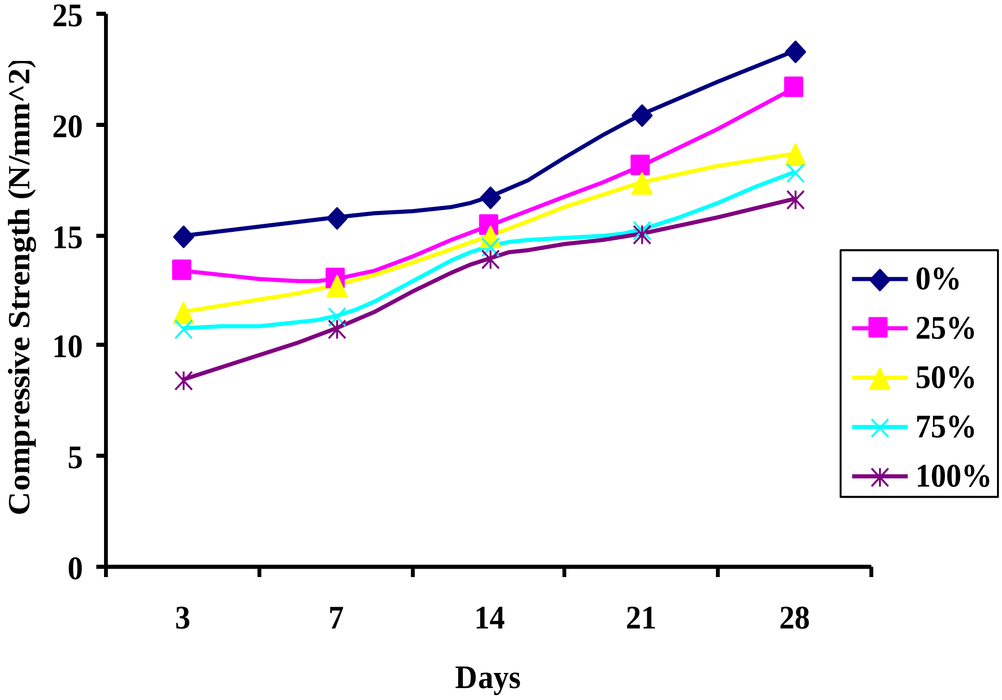

Figure 3: Compressive Strength – Time Characteristics of Concrete Cubes For Different Percentage of Broken Tiles with Mixing Ratio 1: 2: 4

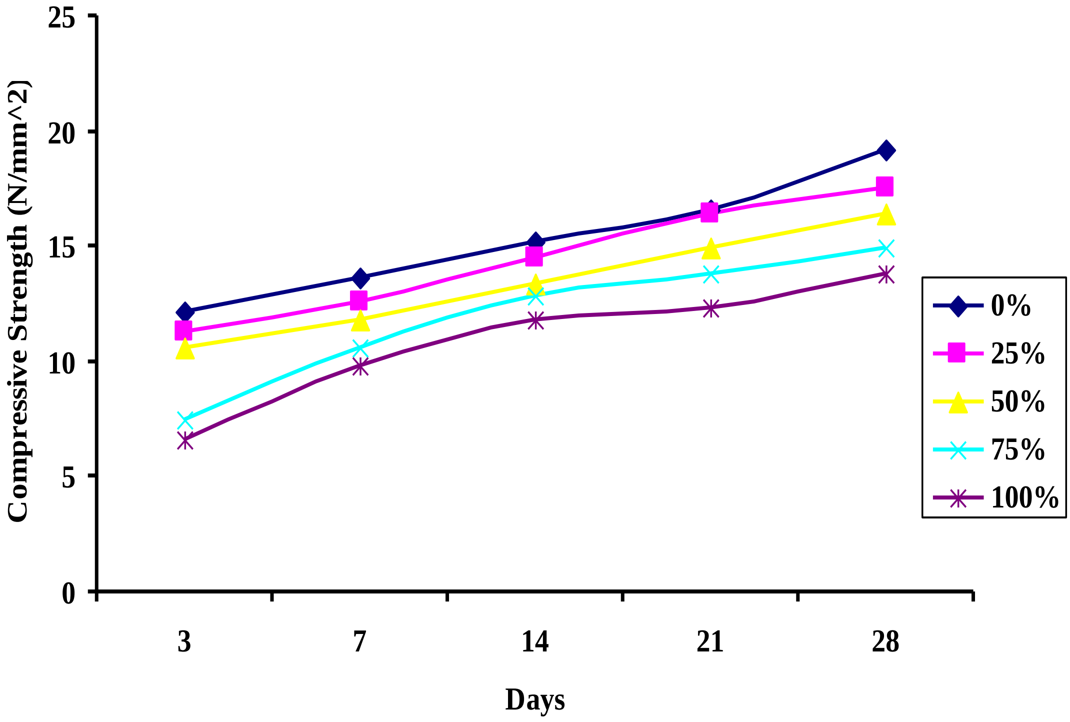

Figure 4 : Compressive Strength – Time Characteristics of Concrete Cubes For Different Percentage of Broken Tiles With Mixing Ratio 1 : 3 : 6

V. COST IMPLICATION

The results got have indicated that it is possible to use broken tiles to replace crushed granite in concrete since broken tiles are acquired at virtually no cost, about 39% of the cost of crushed granite in mixing ratio 1 : 2 : 4 and 57% of the cost of crushed granite in mixing ratio 1 : 3 : 6 can be saved. As a result of this, cost of producing concrete would be reduced as crushed granite is replaced by broken tiles.

VI. CONCLUSIONS

Based on the investigation and experimental results, the following conclusions can be made:

[1] There exists a high potential for the use of broken tiles as coarse aggregates in the manufacture of lightly reinforced concrete.

[2] Broken tiles concrete batched by volume replacement of coarse aggregate with broken tiles show similar trends in the variation of workability, density and strength with increase in percentage replacement.

[3] There exists a potential cost reductions in concrete production using broken tiles as partial replacement for crushed granite.

[4] Based on the results obtained, replacement of 39% or less crushed granite by broken tiles in mixing ratio 1 : 2 : 4 can be used in reinforced concrete construction whereas replacement of 57% or less crushed granite by broken tiles in mixing ratio 1 : 3 : 6 can be used in reinforced concrete construction.

VII. RECOMMENDATIONS

Based on the investigation and experimental results, the following recommendations can be made:

[1] Though the results indicated the possible use of broken tiles as a structural material, it is

[2] recommended that its long - term behaviour should be investigated to evaluate this possibility.

[3] Further research should be conducted to solidify the use of broken tiles as structural material.

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