
ABSTRACT

Increase in the use of concrete in construction industry in Nigeria has led to the rise in the cost of its constituent material. This has necessitated research into the use of alternative material which is cheaper and can produce a comparable level of strength as the conventionally used ones. This paper present the results of an investigation into the compressive strength characteristics of concrete made with ceramic tile waste as coarse aggregates. The percentage of tile waste was varied in steps of 25% from 0 to 100%. For each considered percentage of tile wastes, three (3) set of concrete cubes were cast each for 7, 14 and 28 days curing age which resulted in a total of 45 cubes. The test result indicated that the compressive strength reduces as the percentage of tile wastes increases. The 28th day compressive strength for 25% and 100% replacement were 23.93N/mm² and 21.43N/mm² respectively which is adequate for structural light weight concrete. The specific gravity of tile waste was found to be 2.27 which is comparable to the specific gravity of conventional aggregate. Slump test also showed that workability of concrete decreases with increasing tile waste content.

KEYWORDS: Compressive strength, Ceramic tile waste, Specific gravity, Structural lightweight concrete.

INTRODUCTION

Concrete is the most widely used building material due to its durability, resistance to fire and compressive strength characteristic when compared to other materials such as steel and wood. Constituents of concrete include cement, fine aggregate, coarse aggregate and water. Admixture such as superplasticizer may be added for strength enhancement. The use of concrete in the construction industry has increased drastically in the last decades, consequently, the cost of its constituent material has increased. Besides the rise in the cost of concrete production, continuous mining of granite may result in the depletion of aggregate deposits, environmental degradation and ecological imbalance [1]. To curb the over dependence on conventionally used aggregate and to make construction sustainable, it becomes necessary to source for other material which can give comparable level of strength as the conventionally used ones. One of such material is broken tile waste which is commonly found in construction site.

Construction activities have been known to generate large and diverse quantities of wastes compared to other industries. Stokoe *et al.* [2] reported that construction and demolition (C&D) waste took up about 65% of Hong Kong's landfill space between 1994-1995 and according to [3], a typical UK landfills has over 50% of C&D waste. Craven *et al.* [4] reported that construction activity constitutes about 20 to 30% of all waste deposited in Australian landfills. In the United State, an estimated 170 million tons of building-related C&D waste was generated in 2003 which is about 25% more than the amount generated in 1996, estimated at 136 million tons [5]. Among construction and demolition waste generated in the world, concrete, tiles and mortar are the most quantified in landfills [6].

The global concern of reducing the quantity of waste dumped in landfills and the need to reduce environmental stresses has necessitated research into the use of C&D waste in concrete production. In [7], the mechanical properties of concrete with bricks as coarse aggregate was investigated. It was found that up to 15% replacement did not reduce the strength when compared to concrete with conventional coarse aggregate. Torkittikul and Chaipanich [8] investigated the use of ceramic waste as fine aggregate in fly ash concrete. Their result showed that the density

of concrete with ceramic waste aggregate was much lower than that of concrete with sand while the compressive strength of ceramic waste concrete was higher than that of the control mix. This was attributed to the rough surface of the ceramic waste aggregate when compared with sand. Similar observations were found in another study [9]. Most of these researches focused on using ceramic waste as fine aggregate whereas the study into the use of tile waste as coarse aggregate has not been fully investigated. This paper therefore present an investigation into the strength characteristic of concrete made with tile waste as coarse aggregate.

MATERIALS AND METHODS

Materials

Commercially available Ordinary Portland Cement (Unicem brand) conforming to BS 12 [10] specification was used. Two types of coarse aggrgates, crushed granite and broken tile waste were used. The broken tile waste was sourced from a construction site within Uyo metropolis in Southern Nigeria. The broken tiles were washed to removed unwanted debris and dried for 48hours to achieve approximate saturated surface dry condition prior to crushing with locally made palm kernel machine. Fine aggregate used in the experiment was natural sand. Preliminary investigations were conducted on the aggregates in accordance with BS 882 to ascertain their suitability. The water used for mixing and curing of specimens was potable drinking water obtained from a borehole. Various physical tests were conducted on the materials for their characterization and assessment of conformity with other relevant standards.

Method

A designed mix based on BS 5328 [11] with 25N/mm² targeted strength was achieved with the use of cement, aggregates and water. Following that, the coarse aggregate was replaced with varying percentages of tile wastes at 25, 50 75 and 100%. In each mix, nine (9) no. of 150mm concrete cubes were produced giving a total of 45 concrete cubes. Water to cement ratio of 0.55 was used in all the mixtures. The concrete materials were mixed in a mechanical mixer. Slump test was performed on the fresh mix in accordance to BS EN 12350-2 [12] before it was filled in moulds and compacted in three (3) layers with a 16mm diameter rod. The cast specimens were covered with polythene only to be removed from the mould when it was up to 24hours and cured in water until their appropriate testing ages of 7, 14 and 28 days. The compressive strength was tested using universal compression testing machine. The detail of the mix used in each specimen is shown in table 1.

Table 1. Summary of mix proportion used in this study

Materials	Design quantity (Kg/m ³)	Quantity per trial mix (0.0127m ³)
Cement	418.52	5.32
Water	188.33	2.39
Fine aggregate	681.40	8.65
Coarse aggregate	1111.75	14.12

RESULTS AND DISCUSSION

The result for sieve analysis is shown in figure 1. For fine aggregate the percentages by mass passing sieves 2.36mm, 1.18mm, 600µm and 300 µm were 98, 88, 73 and 38 respectively. These results showed that fine aggregate is well graded and belong to zone 3 since the percentages by mass passing 2.36mm sieve and 300µm are greater than 60% and 5% respectively, as stipulated by BS 882 [13]. For coarse aggregate, the percentages by mass passing sieves 20mm, 14mm and 9.5mm were 68, 11 and 2 respectively. These values indicated that aggregate belong to grade 20mm to 5mm according to BS 882 which is suitable for light weight concrete. For the tile waste, the percentages by mass passing sieves 20mm, 14mm and 95mm were 84, 65 and 32 respectively. This result implies that tile waste are well graded and also fit into the grade 20mm to 5mm according to BS 882.

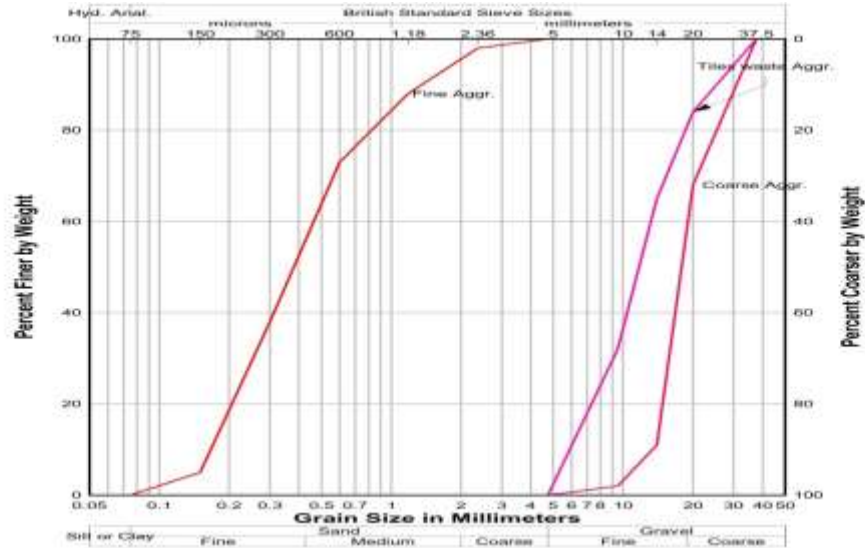


Figure 1: Aggregates particle size distribution curve for fine, coarse and tile waste aggregate

Specific gravity

The specific gravity result of tile wastes based on saturated surface dry (SSD) condition was 2.27, which is 16% less than 2.69 obtained for gravel [14]. The tile waste can be classified as light weight aggregate because the density is between 1- 2.4 [15].

Concrete workability

The workability of concrete was measured with slump test. Table 2 shows that measured slump decreased with increase in percentage of tile waste. Rate of decrease in slump reduced as the percentage of tile waste increased. For instance, the slump reduced by 27% when the percentage of tile waste was increased from 0 to 25 and reduced by only 12% when the percentage of tile waste was increased from 75 to 100.

Table 2. Slump for different replacement percentagea

Granite: Tile waste ratio (%)	Slump (mm)
100:0	48
25:75	35
50:50	28
72:25	25
0:100	22

Density of Concrete

The variation of concrete density at 7, 14 and 28 days for different percentages of tile waste aggregate is shown in figure 2. This result shows that concrete density decreased with increased in percentage of tile waste aggregate. This is similar to the findings recorded in [7]. At 28 day curing age, concrete with 100% tile waste aggregate decreased by 9.7% when compared with concrete with conventional aggregate.

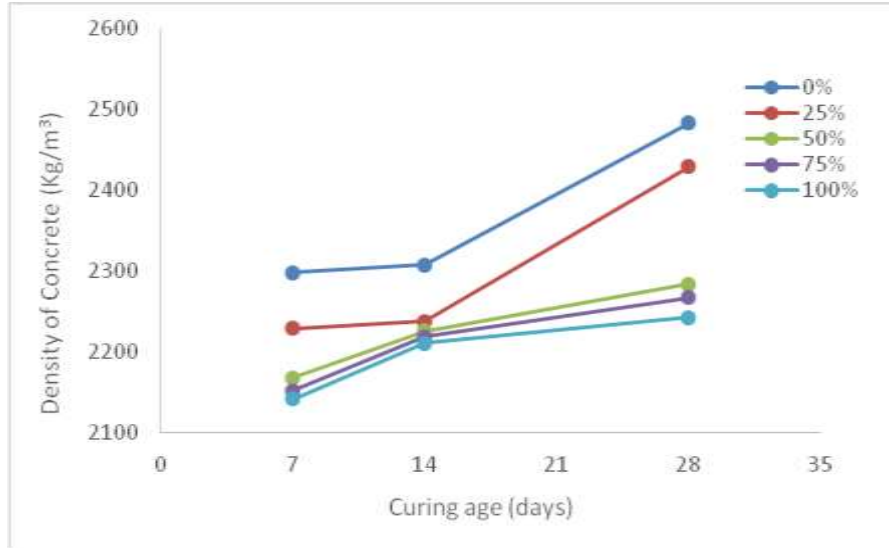


Figure 2: Variation of density with curing age

Compressive strength

Figure 3 shows the variation of compressive strength with different percentages of tile waste aggregate. The 28 days average compressive strength of 23.92N/mm² at 25% replacement was less than 32.15N/mm² reported by [16] with ceramic waste aggregate as partial replacement for granite.

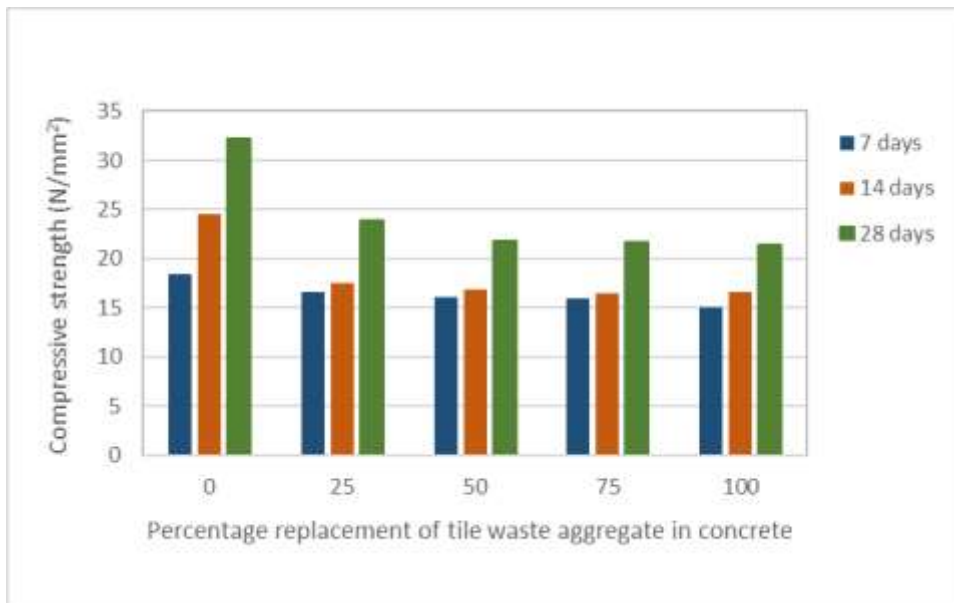


Figure 3: Variation of compressive strength with percentage of tile waste replacement at different curing ages

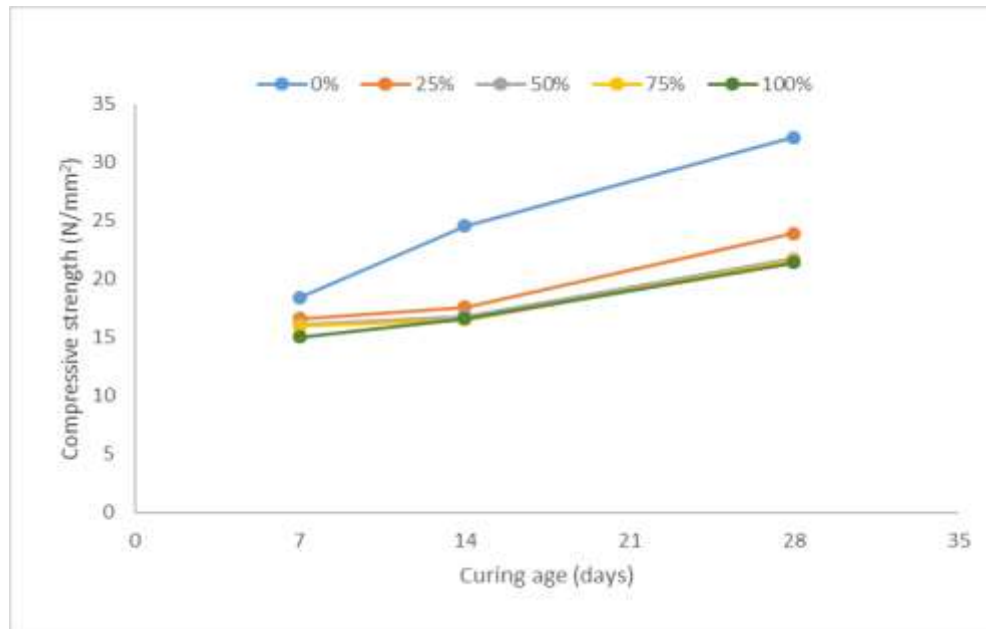


Figure 4: Variation of compressive strength with curing age in concrete with different percentage of tile waste

Figure 4 clearly shows that the rate of increase in strength in concrete with partial or full replacement of tile waste is small when compared to concrete made with conventional aggregate. For instance, the gain in strength between concrete with 25% and 100% tile waste aggregate replacement was only 10.5% at 28th day. This value was far less for 7 and 14 days.

CONCLUSION

This study investigated the compressive strength characteristics of tile waste concrete. The following conclusions can be deduced.

- Tile waste has a specific gravity of 2.27, a little less than 2.7 for granite.
- The compressive strength of concrete increase with curing age and decrease with increase in tile waste content in the concrete.
- The workability of concrete decrease with increase in tile waste content in the concrete.
- Concrete made with 100% replacement of granite with tile waste can be used as structural light weight concrete in mass concreteting.

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