COMPRESSIVE STRENGTH OF CONCRETE CONTAINING ITAKPE IRON ORE TAILINGS

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Abstract

The conventional material used as fine aggregate in concrete production is natural sand. However, due to depletion of the environment, as a result of huge consumption of natural sand, there has been extensive research into alternative materials suitable to partially or fully replace natural sand as fine aggregate in concrete. In this research Itakpe Iron Ore Tailings (IIOTs) was used as partial replacement of sand in concrete production. The IIOTs was obtained from different locations at the tailings dump sites of National Iron Ore Mining Company (NIOMCO) in Itakpe, Kogi State, Nigeria. This study hereby looks into the effects of partial replacement of natural sand with Itakpe Iron Ore Tailings (IIOTs) as fine aggregate in concrete. Based on the British Research Establishment method, a normal weight concrete mix was designed with a target strength of 30 N/mm^2. IIOTs was used to replace sand at intervals of 10% ranging from 0% to 40%, resulting in one control sample without IIOTs and four others containing IIOTs. Concrete cubes measuring 150 x 150 x 150 mm were cast and their slump, compacting factor, density and compressive strengths determined. The result showed that concrete sample containing 30 % IIOTs has the optimum compressive strength value of 49.6 MPa at 28 days, while the control concrete recorded the least value of 45.8 MPa.

Keywords: - Itakpe Iron Ore Tailings, Fine aggregate, Natural river sand, Density, Compressive strength.

INTRODUCTION

The present day challenge for the construction industry has to do with the concept of sustainable development, which involves the use of waste materials and by-products at reasonable cost with the lowest possible environmental impact. Rapid increase in consumption of river sand due to increase in construction activities, means that sand mining exploration increased, whereby the river bed is over exploited (Nath and Sarker, 2014)

Environmental issues associated with sand mining are depletion of virgin deposits, collapsing of river banks, water table lowering and water pollution. Rapid increase in consumption of river sand due to increase in construction activities means that sand mining exploration increased, in which the river bed is over exploited. Zeolite is a material which is similar to Iron ore tailings in appearance and texture. Ghourchian *et al*., (2013) examined the feasibility of reusing spent zeolite catalyst, after fluidized catalytic cracking, as a substitute for sand in cement mortars. The tested result shows that spent catalyst can replace up to 10% of fine aggregate without decreasing the mortar strength. In fact, the substituted mortars show higher compressive strength than the control samples. The workability of the fresh mortars decreases with increasing substitution level and the mortars incorporated with spent catalyst show less bleeding (Ghourchian *et al*., 2013). In the hardened state, the water absorption of the resulting mortar increases with longer curing age, higher substitution level and smaller water-to-cement (w/c) ratio. Toxicity characteristic leaching procedure (TCLP) analysis confirmed that the spent catalyst meets the standard, and thus should be classified as general non-hazardous industrial waste (Khare, 1993). Although, Ugama *et al.* (2014); Uchechukwu and Ezekiel (2014), examined the feasibility of using Itakpe Iron ore tailings (IIOTs) as a substitute for natural sand, to serve as fine aggregate in concrete, there is still much need for research about this material due to much variation in its properties. Iron ore tailings may show similar grading, but the parameters cannot be generalized for mines in terms of mineralogy or beneficiation process, hence there is always the need to be specific about the source of the tailings (Oritola et al., 2015).

This research reports the outcome of experimental work carried out, using Itakpe iron ore tailings to partially replace natural sand as fine aggregate in the production of concrete. The global demand to reduce the increasingly high cost of waste disposal and conserve raw material has led to intense global research towards economic utilization of waste for engineering purposes. The successful utilization of Itakpe iron ore tailings (IIOTs) as fine aggregate would turn this waste material into valuable resources, reduction in the strain on the supply of natural sand, and economy in concrete production (Ugama *et al.*, 2014).

EXPERIMENTAL PROGRAM

Materials

The Ordinary Portland Cement (OPC) Dangote 3x brand, was used as binder, river sand and Itakpe Iron ore tailings (IIOT) both of 5 mm maximum size, were used as fine aggregate, and 20 mm size, crushed granite as coarse aggregate were used for the concrete production. The iron ore tailings used for the experiment was obtained from Itakpe mines, located in Okehi LGA, Kogi State, Nigeria. Portable water, obtained within the structural laboratory of Kaduna Polytechnic, Tudunwada, Kaduna State, was used for mixing the concrete. The river sand and crushed granite used were obtained from kabala junction, western by-pass, in Kaduna State. The particle size distribution curve for the Itakpe Iron ore tailings, river sand and crushed granite is shown in Figure 1.

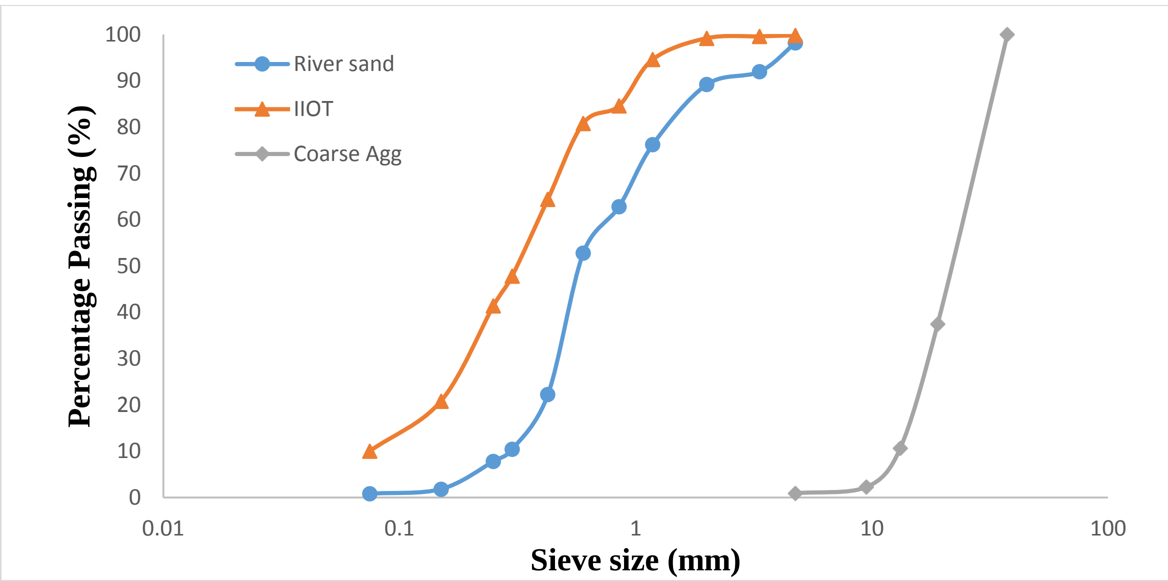

Figure 1: Particle Size Distribution of Aggregates: Sand, IIOTs and Crushed Granite

Method

Based on the British Standard specifications, materials used for concrete production (sand, crushed granite, and iron ore tailings) were tested before using them. Sieve analysis test (BS 812, 1985), determination of moisture content (BS 812-109, 1990) and specific gravity test (BS 812-2, 1990) were conducted in order to arrive at a viable concrete mix design.

Concrete Design

The Building Research Establishment (BRE, 1988) design of normal concrete mixes was adopted in this study for the selection of the proportions of ingredients for concrete, to make the most economical use of available materials and to produce concrete of the required properties for adequate mix. The mix proportion was designed for characteristics strength of 30N/mm^2 maximum aggregate size of 10mm, slump 50mm, based on the procedure of the concrete mix design and using the appropriate design tables and figures, a normal weight concrete mix, with water content 210kg/m^3, cement content 396 kg/m^3, fine aggregate content 645 kg/m^3 and coarse aggregate content of 1009 kg/m^3 was designed using water-cement ratio of 0.53.

Proportioning of Concrete Materials

Five different types of concrete samples (K_0, K_1, K_2, K_3, and K_4) were well-thought-out, with the percentage of tailings used to replace sand as fine aggregate ranging from 0 to 40%. The reference sample is taken as K_0 with no tailings and the four others, containing tailings at 10% intervals. The reference mix adopted is that, which contain sand as the only fine aggregate. The quantities of cement, water and the coarse aggregate were kept constant for all the mix samples, the only variant are the materials used as fine aggregate (sand and Itakpe iron ore tailings). The five different types of concrete samples produced and the details of the concrete mix proportioning of materials, based on water-cement ratio of 0.53, is shown in Table 1.

Table 1: Mix Proportions of Concrete Samples

Constituent Materials for 1 m^3 Concrete					
Concrete Samples	Water (kg)	Cement (kg)	Natural Sand (kg)	Itakpe Iron Ore Tailings (kg)	Coarse Aggregate (kg)
K_0	210	396	645.4	0.00	1009
K_1	210	396	580.8	64.5	1009
K_2	210	396	516.2	129.1	1009
K_3	210	396	451.7	193.6	1009
K_4	210	396	387.2	208.1	1009

Testing of Concrete

Based on the design and concrete proportioning outputs, three cubes for each of the concrete samples were cast and cured in plastic tank in accordance with British Standard guidelines BS 1881, (1983). Prior to this, the slump of the fresh concrete was determined in accordance with BS 1881-108, (1983), the compacting factor was also obtained according to the guideline in BS 1881, (1983) and the density of the fresh concrete samples were evaluated following the specifications in BS 1881, (1983). The hardened concrete cubes were tested for compressive strength using the average of three cubes, strength values (BS 1881-116, 1983).

RESULTS AND DISCUSSION

The Slump of Concrete containing Itakpe Iron ore tailings

The slump recorded by the five types of concrete samples K_0, K_1, K_2, K_3 and K_4 are described in Figure 2. The control concrete sample with no tailings K_0, recorded the highest slump value of 60 mm while the concrete sample with 40% replacement of sand by Itakpe Iron ore tailings recorded the lowest slump value of 40 mm. The trend of the result shows that with increasing content of Itakpe Iron ore tailings in concrete, there is gradual reduction in slump values recorded by the concrete samples. This implies that the Itakpe Iron ore tailings has much demand for water, to achieve the concrete workability compared to the natural river sand.

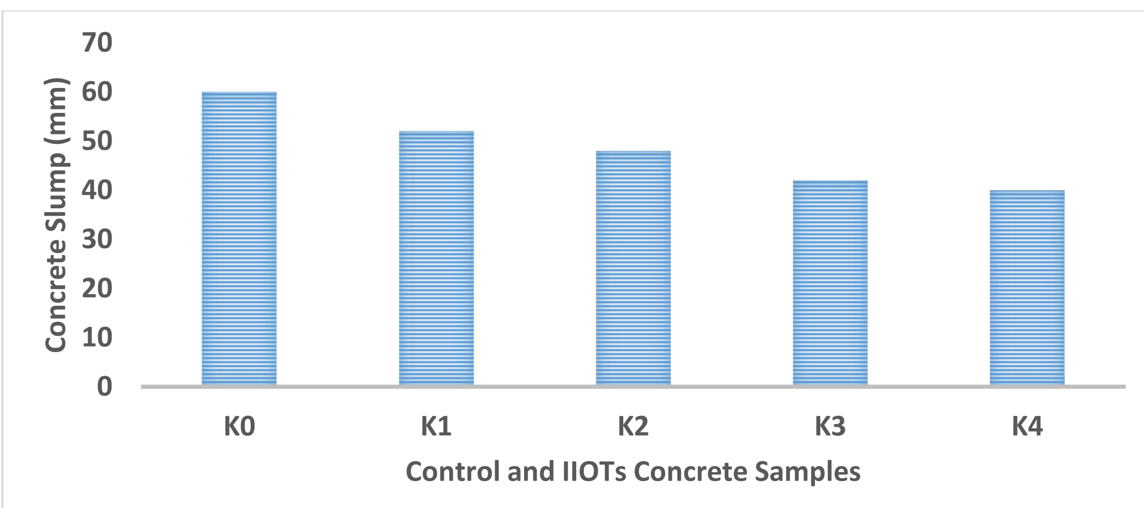

Figure 2: Slump of Concrete Samples

The Compacting Factor of Concrete containing Itakpe Iron ore tailings

The compacting factor recorded by the five types of concrete samples K_0, K_1, K_2, K_3 and K_4 are shown in Figure 3. The control concrete sample with no tailings K_0, recorded the highest compacting factor value of 0.91 while the concrete sample with 40% substitution of sand by Itakpe Iron ore tailings recorded the lowest compacting factor value of 0.83. The trend of the result shows that with increasing content of Itakpe Iron ore tailings in concrete, there is gradual reduction in compacting factor values recorded by the concrete samples. The values of compacting factor recorded by the control concrete sample and those containing IIOTs falls within the range recommended for normal weight concrete (0.8 – 0.92), according to Neville, (2011).

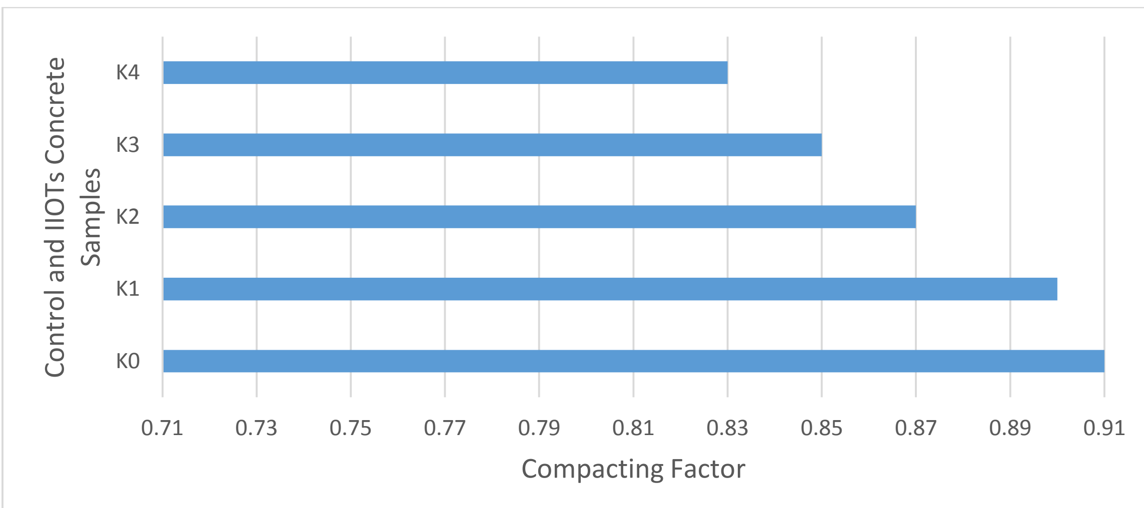

Figure 3: Compacting Factor of Concrete Samples

The Density of Fresh Concrete

The density of the fresh concrete, for the five types of concrete samples K_0, K_1, K_2, K_3 and K_4 are depicted in Table 2. The control concrete sample with no tailings K_0, recorded the least density value of 23.5 kN/m^3 while the concrete sample with 40% replacement of sand by Itakpe Iron ore tailings recorded the highest density value of 24.5 kN/m^3. The trend of the result shows that with increasing content of Itakpe Iron ore tailings in concrete samples, there is gradual increase in density values recorded by the concrete samples. This suggest that the Itakpe Iron ore tailings, due to its much fine particles, is able to fill much void in concrete compared to natural river sand. In fact, the denseness of the concrete samples are enhanced by the Itakpe Iron ore tailings compared to the natural river sand.

The Compressive Strength of Hardened Concrete

The 28 days compressive strength of the hardened concrete, for the five types of concrete samples K_0, K_1, K_2, K_3 and K_4 are depicted in Table 2. The control concrete sample with no tailings K_0, recorded the least compressive strength value of 45.8 MPa while the concrete sample with 30% replacement of sand by Itakpe Iron ore tailings recorded the optimum compressive strength value of 49.6 MPa. The trend of the result shows that with increasing content of Itakpe Iron ore tailings in concrete samples, there is gradual increase in compressive strength values, up to the optimum at 30 % replacement level of river sand by IIOTs. Although there is a drop in strength to 46.8 MPa recorded by K_4, the compressive strength of K_4 is still higher than that of control sample. The Itakpe Iron ore tailings, due to its texture and availability of oxides such as Silica, Calcium oxide and Aluminum oxide is able to improve the compressive strength of concrete compared to natural river sand.

Table 2. Density and Compressive Strength of Itakpe Iron ore tailings Concrete

Concrete Samples	Density of Concrete (kg/m^3)	Compressive Strength of Concrete (MPa)
K_0	23,500	45.8
K_1	23,650	46.5
K_2	23890	47.8
K_3	24000	49.6
K_4	24500	46.8

Conclusion

Based on the outcome of experimental work carried out in this study, the following conclusions can be made.

- The grading of Itakpe Iron ore tailings is similar to that of natural river sand and the texture of the duo is similar in nature. Therefore, the use of Itakpe Iron ore tailings in concrete as partial or full replacement for river sand is feasible.
- The workability of concrete produced, using Itakpe Iron ore tailings as partial replacement for river sand, is within the range prescribed for normal weight concrete.
- The Itakpe Iron ore tailings improved the density of concrete. Concrete produced with 30 % Itakpe Iron ore tailings and 70 % river sand, constituting the fine aggregate, can find

application where dense concrete structure are required and the strength will not be jeopardized.

- Inclusion of Itakpe Iron ore tailings in concrete as partial replacement for sand up to 30 % optimum level recorded the highest compressive strength of 49.6 MPa.
- The disintegration of landfill and leachate of farmland by Itakpe Iron ore tailings can be reduced drastically, if the IIOTs material is used in the production of concrete.

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