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(RESEARCH ARTICLE)

Compressive strengths of concrete by partially replacing sand with iron-ore waste

Abdulazeez Rotimi * and Seidu Tijani

Department of Civil Engineering, Faculty of Engineering, Baze University Abuja, Nigeria.

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Abstract

Sand is extracted at a rate more than its restoration. Nevertheless, the availability of sand in the growing demand of the construction industry remains a challenge due to cost and quality problems. This study investigates the compressive strength of concrete by partially replacing sand with iron-ore waste. Experimental investigations were conducted to study the compressive strength, physical, mechanical and fresh property of concrete containing iron-ore waste. During the experiment, concrete cubes were prepared with 10-100% composition of iron ore waste to evaluate their compressive strength. Results from the experimentation revealed that, concrete cubes prepared by partially replacing sand with iron ore waste often yield a better compressive strength than a conventional concrete. More so, the densities of concrete cubes were observed to remain consistent but increased slightly, notably at 10% and 20% of waste replacement. Meanwhile, at 30% waste replacement, there was reduction in compressive strength at 28days curing age and this reduction continued as percentage iron ore increased towards 100%. Also, increase in compressive strength of concrete cubes was observed at 10-20% sand replacement with iron ore. It was therefore established that concrete produced under 10% and 20% replacement, can be utilized for all construction purposes requiring concrete.

Keywords: Compressive strength; Iron ore; Concrete cubes; Density; Sand replacement; Construction

1. Introduction

Historically, the amount of waste generated by humans was insignificant due to low population density coupled with insignificant exploitation of natural resources. Common waste produced during early human history was mainly ashes and human biodegradable waste, and these were released back into the ground locally with minimum environmental impact. Before the widespread use of metals, wood was widely used for most applications[1]. However, use of wood has been well documented. Nevertheless, it is also well documented that reuse and recovery of metals have been carried out by earlier humans. One of the main goals of sustainable solid waste management is to maximize the ability of its recycling and re-use, metals and plastics are the most common of these materials[2]. With increasing environmental pressure to reduce pollution, the concrete industries begin to adopt a number of methods to achieve these goals through the reuse programme thereby preserving natural aggregates which is a matter of sustainable development to ensure sufficient resources for future generation[3]. With the advent of industrial revolution, waste management became a critical issue, this was due to the increase in population and the massive migration of people to industrial towns and cities from rural areas during the 18th century. There was a consequent increase in industrial and domestic wastes posing threat to human health and the environment [4].

The earliest precursor of pollution by life forms would have been a natural function of their existence, but activities of man and the need for technological advancement has had severe consequences on the viability of these life forms and the natural environment, processes that has led to generation of huge industrial wastes (e.g. Iron-ore waste) and the demise of natural habitation thereby drastically causing increasing struggle for survival among nations of the world.

* Corresponding author: Abdulazeez Rotimi
Department of Civil Engineering, Faculty of Engineering, Baze University Abuja, Nigeria.

For human kind, the factor of technology is a distinguishing factor and a borderline separating the most developed, the developed and the developing countries. There are however strong competitive struggles for breakthrough in development amongst these categories of nations, actions which has led to exploration of the ecosystem and the natural habitat, and as a result, the world in the 21st century has been exposed to great danger partly caused by Pollution. Hence, concerns of man ranges from quality of life, management of health hazardous substances, increasing inflated cost of construction, control of pollution amongst others. "The solution to pollution is dilution" a dictum which summarizes a traditional approach to pollution management whereby sufficiently diluted pollution is not harmful[5].

The Itakpe iron ore deposit has a reserve of about 200 million tonnes with an average iron ore content of 36%. Itakpe iron ore processing plant produces a waste material of about 64% of its capacity; [6]. Soframine, [7] showed that the Itakpe project was designed to treat a minimum of 24,000 tonnes of ore per day and operate 300 days per year. The waste to ore ratio is 4:1 [8]. If the tailings are not disposed of, the land will be seized, the environment will be polluted, and the useful resources cannot be fully used. The increasing effect of waste dumps on the environment (e.g. pollution) is on the rise, there is need to proffer ways of tackling this trend, a trend which has subjected the environment and its inhabitants to dangers resulting to high cost of construction/production and maintenance as well as reducing quality of life. The experiment carried out by [9] on sintered wall materials reveals that the iron ore waste can be used very effectively as construction material. The study also showed that due to higher iron content in iron ore tailings and waste rock, the products reduce the sintering temperature and decreased energy consumption[10][11].

This paper work is aimed at determining the compressive strengths of concrete by partially replacing sand with iron-ore waste at varying percentages.

- To determine the compressive strengths of concrete cubes (As control Test) for concrete grade 30 at 7, 14 and 28days curing ages.
- To determine the compressive strengths of concrete cubes when fine aggregate is partially replaced by the waste at varying proportions (in the order of 10%, 20%, 30% and 100%) for concrete grade 30 at 7, 14 and 28days curing ages.
- To draw and compare results of the concrete (control test) and concrete cubes which have had its fine aggregate replaced with the waste in those proportions in terms of compressive strengths in accordance to applicable standard specifications. This paper will help to reasonably address the problem of increasing rate of environmental pollution (waste management) arising from increasing iron-ore waste piling and would encourage large scale manufacture of concrete of considerable strength and durability at low cost for different construction purposes and improve quality of life.

2. Theoretical analysis

Iron-ore are rocks and minerals from which metallic iron can be economically extracted, the ores are usually rich in iron oxides and vary in colour from dark grey, bright-yellow, deep-purple, to rusty-red. The iron itself is usually found in the form of magnetite (Fe_2O_3), Hematite (Fe_2O_3), geolite, limonite of siderite. Hematite is also known as natural ore.

Iron-ore consists of oxygen and iron atoms bonded together into molecules. To converts it to metallic iron, it must be smelted or sent through a direct reduction process to remove the oxygen. Oxygen iron bonds are strong and to remove the iron from the oxygen, a stronger elemental bond must be presented to attach to the oxygen. Carbon is used because the strength of a carbon-oxygen bond is greater than that of the iron-oxygen bond at high temperatures. Gordon [12].

In general, mine wastes consist of high volume, low toxicity wastes. The main reason for the high volume of mine waste is the very low concentration of metals contained in ore. Gordon [12]. The Itakpe iron-ore mine is divided into the West pit and East pit. The geological reserve of the ore is 200 million tonnes. The mining method is open cast.

2.1 Previous work on the use of Iron-Ore Waste as partial replacement for sand in the manufacture of Hollow Sandcrete Block

Ugama et al. [13] performed a study that used iron ore tailing (IOT) to partially replace fine aggregate in concrete blocks. These concretes are usually used in making rigid pavement. The control mix constitutes a conventional mixture of concrete whereby sand is the fine aggregate, while the other mixes were partially replaced by 20-100% of iron ore tailing (IOT). Moreover, results from their experiment showed that concrete workability decreases with increasing percentage of iron ore tailing in the mixture. At 20% replacement of aggregate (in concrete) with iron ore tailings, it was reported that the resultant concrete performed better in terms of compressive and tensile strength than for concretes with 0% iron ore replacement.

Alzaed, [14] examined the impact that iron filings have on the compressive strength the concrete mixture. The paper presented an experiment in which the iron filing was delivered to the concrete mix at different percentages for a curing period of 28 days. This experiment was performed to study the effect of percentage composition of iron filings on compressive and tensile strengths of the concrete mixture. The percentages of iron filings studied were 0% (control), 10%, 20% and 30% in the concrete mix. Notwithstanding, the research paper was able to demonstrate that compressive strength of the concrete mix increases constantly with increasing percentage replacement of sand with iron filings. Moreover, a minor effect was observed for tensile strength at percentages above 10%.

In 2015, a researcher performed an experiment in which fine aggregate was partially replaced with iron-ore waste in the manufacture of hollow sandcrete blocks at percentages of 10%, 20%, 30% and 40% of sand. It was then perceived that the compressive strength increases with increase in curing age and percentage of iron tailings [15]. It was also established that Iron ore tailings (IOT) possesses a substantial prospect as a replacement of fine aggregate in sandcrete block production. Invariably, comparing these results with standard specifications (BS 2028 and BS 1364), it can be said that the densities and compressive strengths of the blocks increases with time, this is an evidence to cementitious properties of iron-ore waste encouraged by hydration processes of cement.

[16] proposed a study that utilises iron ore tailings as replacement for aggregates in concretes. In their experiment, concrete mixes were prepared in the laboratory at different curing ages. The concretes were tested for important parameters like density and compressive strength. However, they concluded from the results obtained that concretes prepared using iron ore tailings showed better compressive strength than for a conventional concrete.

[17] performed an experimental research that employed the use of iron and granite powder (i.e. IP and GP respectively) to partly replace fine aggregate in concrete mix. Replacement of sand by weight was performed at 5%, 10%, 15%, and 20% of IP and GP. It was observed that at 10% replacement by weight, results for compressive and flexural strength was best in contrast with other percentages. In addition, it was reported that compressive strength increased by roughly 30% at 10% replacement by GP when compared to a normal concrete mix. Identical results were also observed for the flexural strength of the concrete mix.

[18] performed a study that investigated the mechanical characteristics of concrete after partially replacing sand with iron waste. An experimental analysis was performed by replacing sand with iron waste by 6%, 12%, 18%, 24% and 30%. Nevertheless, compressive strength and flexural tensile strength of the concrete mix were observed to be most efficient at 12% replacement of iron waste. In addition, they noted that maximum compressive and flexural strength were obtained in the shortest time at 12% replacement of iron waste in the concrete mixture. Conversely, decrease in compressive and flexural strength was observed at percentage iron waste replacement above 12%.

By and large, iron waste is regarded as an industrial by-product that can constitute serious environmental hazard. Thus, it is very important that such waste is either properly discarded or recycled. In compliance with international sustainability goals of recycling industrial waste for the safety of the environment, this study intends to reuse iron waste to improve the strength of concrete mixture. Invariably, considering the number of research performed in iron waste, this study is in no doubt justified to complement existing knowledge, particularly as it considered the impact of Iron waste replacement for sand by up to 100 percent.

2.2 Concrete

Concrete is a composite construction material made primarily with aggregate, cement, and water. There are many formulations of concrete, which provide varied properties, and concrete is one of the most used man-made products in the world. It is widely used for making architectural structures, foundations, brick/block walls, pavements, bridges/overpasses, motorways/roads, runways, parking structures, dams, pools/reservoirs, pipes, footings for gates, fences and poles and even boats. Concrete technology was known by the Ancient Romans and was widely used within the Roman Empire, the Colosseum is largely built of concrete. After the Empire passed, use of concrete became scarce until the technology was re-pioneered in the mid-18th century. Structures made of concrete can have a long service life. As it has a high thermal mass and very low permeability, it can be used for energy efficient housing[19][20].

In the most general sense of the word, cement is a binder, a substance that sets and hardens independently, and can bind other materials together. The word "cement" traces to the Romans, who used the term opus caementicium to describe masonry resembling modern concrete that was made from crushed rock with burnt lime as binder. The volcanic ash and pulverized brick additives that were added to the burnt lime to obtain a hydraulic binder were later referred to as cementum, cimentum, cäment, and cement. Cement used in construction is characterized as hydraulic or non-hydraulic. Hydraulic cements (e.g., Portland cement) harden because of hydration, chemical reactions that occur independently of the mixture's water content; they can harden even underwater or when constantly exposed to wet weather. The chemical reaction that results when the anhydrous cement powder is mixed with water produces hydrates that are not water-soluble. Non-hydraulic cements (e.g. gypsum plaster) must be kept dry in order to retain their strength. The most important use of cement is the production of mortar and concrete, the bonding of natural or artificial aggregates to form a strong building material that is durable in the face of normal environmental effects.[21].

Construction aggregate, or simply "aggregate", is a broad category of coarse particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and geosynthetic aggregates. Aggregates are the most mined material in the world. They are a component of composite materials such as concrete and asphalt concrete; the aggregate serves as reinforcement to add strength to the overall composite material[22]. Due to the relatively high hydraulic conductivity value as compared to most soils, aggregates are widely used in drainage applications such as foundation, septic drain fields, retaining wall drains, and road side edge drains. Aggregates are also used as base material under foundations, roads, and railroads. In other words, aggregates are used as a stable foundation or road/rail base with predictable, uniform properties (e.g. to help prevent differential settling under the road or building), or as a low-cost extender that binds with more expensive cement or asphalt to form concrete. [21].

The aggregate must to be clean and free from impurities so also should be the water. The main common sources of water is the rainfall, this water is ideal for concrete work. However, if there is no main supply available, (stream or well) could be used. There is no clear indication of precise levels of impurity in the water which will render it unfit for concreting purpose, but testing two sets of cement, one set using the intended water supply the other set using distilled water will indicate the compressive strength available and any detrimental effect on the hardening of the concrete.[21] .

3. Material and methods

This section presents all tests carried out and details of all materials and procedures adopted there-in. All tests/experiments were conducted in accordance to applicable standard/specifications in the field of Civil Engineering. The iron-ore waste sample was collected at the National Iron Mining Company, Itakpe in Okene local government area of Kogi State, Nigeria, the iron ore deposit is on the eastern part of the state 10km north of Okene town. The deposit is located within latitude 80^0 and 90^0, longitude 70^0 and 80^0.

Test on Concrete Materials

Test on cement is done in accordance to (BS 4550 Part 3, 1978) and the conducted test include:

- Standard consistency test
- Initial and find setting time
- Soundness Test

Additionally, required test on aggregate is done in conformity with (BS 410, BS 812 Part 103, 1978) and the test conducted include:

- Sieve analysis on fine and coarse aggregate
- Specific gravity test on fine and coarse aggregate
- Standard flakiness and Elongation test on coarse aggregate
- Aggregate Impact Value test (AIV)
- Aggregate Crushing Value test (ACV)
- Sieve analysis on iron ore waste
- Specific gravity test on iron ore waste

3.1 Experimental Procedures

3.1.1 Standard Consistency Test (BS 4550: Part 3, 1978)

400 g of cement sample was carefully mixed with adequate quantity of water starting with W/C ratio of 0.30, this was varied according to the penetration of the plunger. The gauging time was 5 minutes. The mould was filled with the paste in one layer, using gauging trowel the top of the mould was smoothened and adequately positioned under the plunger (Vicat apparatus).

The plunger was then lowered onto the surface of the paste (i.e., from the 40 mm mark), it was released quickly and allowed to settle. The paste which will allow the plunger to sink to within 5 to 7 mm of the bottom of the mould is the standard consistence required. However, this was achieved. The w/c ratio at which this was achieved was recorded.

3.1.2 Initial Setting Time (BS 4550: Part 3, 1978)

Cement paste was prepared as in standard consistency test and placed in the vicat mould. A 1 mm^2 needle was lowered from the vicat apparatus gently onto the surface of the paste, it was released quickly and allowed to sink no further than 5 - 7 mm from the bottom of the mould (this can be read off the scale), Hence, the initial setting time was recorded.

3.1.3 Final Setting Time (BS 4550: Part 3, 1978)

The needle used in the initial setting time test (1 mm^2) was replaced by 1 mm^2 needle with metal annular attachment in the vicat apparatus. The annular attachment was allowed to fall gently onto the surface of the paste. The time taken by the needle to make an impression on the surface of the paste but for the annular attachment to fail to do so was noted. This gives the final setting time and it was recorded accordingly.

3.1.4 Soundness Test of Cement (BS 4550: Part 3, 1978)

Cement paste of standard consistence was prepared. The Le Chatelier mould was placed on a glass plate and filled with the paste keeping the slit of the mould gently closed. The top of the mould was covered and immersed in clean water with known temperature (recorded). Six samples were prepared, after 24 hours, the mould was removed from water and the distance between the pointers was measured (D1), the mould was resub merged in water and boiled in the water heater for 1 hour, the mould was then removed and cooled in an air tight container. Finally, the difference between the pointers was determined (D2).

3.1.5 Sieve Analysis (BS 812: part 103)

300 g of the sample (air dried) was passed through a number of sieves of different size openings. The sieves are stacked in order, with the sieve with the largest size opening at the top. The sample was then poured and shaken properly for several minutes. The weight of the particles retained on each sieved was determined, from which the percentage passing each sieve was computed. Sieves for fine aggregate: 4.76 mm, 2.40 mm, 1.20 mm, 600, 300, 150 and 75

For course aggregate: 38.1 mm, 19.5 mm, 9.52 mm and 43.76 mm. weight of sample is 1000 g.

3.1.6 Specific Gravity (Fine and Coarse Aggregate) (BS 812)

A pychnometer bottle was filled with distilled water to full capacity, the outside was dried and its weight determined as P, 500 g of surface dried sample (sand) was introduced into the bottle; this is denoted as B, that is, weight of bottle and sample only. The bottle was refilled with distilled water to full capacity, ensuring complete elimination of trapped air by stirring the sample. The outside of the pychnometer was dried and the total weight (i.e. bottle + sample + water) was determined as Ps. Hence, specific gravity, Gs is given as:

$$G_s = \frac{B}{P + B - P_S} \quad (1)$$

The procedure for coarse aggregate is similar to that of fine aggregate but 1000 g of sample was used. (According to B5 4550: Part3, 1978).

3.1.7 Standard Flakiness and Elongation Tests (BS 812)

Sufficient quantity (200 pieces) of coarse aggregate was obtained through random counting. The flaky materials were then separated from the sample by placing them on the thickness gauge one after the other allowing for free passage, then the total weight in the appropriate slot as applied to ¾ aggregate was determined. The combined weight of the material passing the gauge to an accuracy of 0.1% of the weight of the test sample was determined.

3.1.8 Determination of Aggregate Impact Value (AIV) (BS 812 Part 3)

A sample of aggregate passing through a 12.5 mm B.S sieve and retained on a 9.5 mm B.S sieve was prepared. A 7.6 cm diameter cylinder was then filled with the aggregate in three layers, each layer received 25 strokes of 22.9 cm long metal stamping rod. The surface was then levelled, and its weight determined as A. the whole of the sample was placed in the cup, fixed firmly in position on the base of the impact machine. The sample was then subjected to 15 blows by allowing the hammer to fall freely on the sample. The crushed aggregate was sieved through 2.4 mm sieve and the weight passing was determined as B.

Hence, AIV is given as;

$$AIV = \frac{B}{A} X\ 100 \quad (2)$$

3.1.9 Determination of Aggregate Crushing Value (ACV) (BS 812 Part 3)

The aggregate sample was sieved to pass through a 12.7 m sieve and retained in the B.S sieve 9.5 mm. the cylindrical (ACV mould) mould was then placed on a base plate and filled with the aggregate in three layers with each layer receiving 25 blows, the surface was then levelled with the tamping rod and its weight determined as A. The mould was then placed on the compression machine allowing the plunger to rest directly on the aggregate. Load of 40 KN per minute was applied for 10 minutes. The material was then removed and sieved on a 2.4 mm BS test sieve. The weight of fine passing the 2.40 mm sieve was determined as B.

Hence, aggregate crushing value is given as;

$$ACV = \frac{B}{A} X100 \quad (3)$$

4. Results and discussion

Particle size distribution of sand and iron ore samples were measured before experimentation and results of measurements are presented in Appendix A. These measurements were performed in order to evaluate the physical properties of sand particles and waste iron ore used in this study for improving the compressive strength of concrete. However, results obtained from series of tests performed (such as elongation test, flakiness test, aggregate impact test etc.) are illustrated in Appendix B.

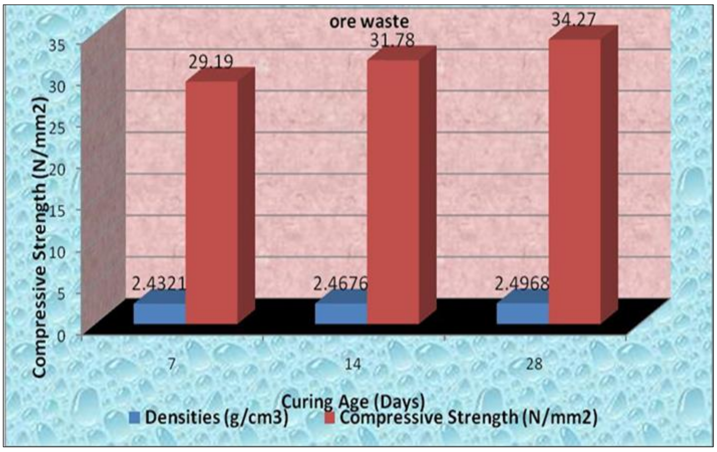

Figure 1 Summary of Compressive strengths and densities of concrete cubes at 0% replacement of fine aggregate with the iron-ore waste

Invariably, Tables 12, 13, 14, 15, and 16 in Appendix B, show all the results obtained from concrete cube test in terms of compressive strengths and densities. Figure 1 represents results obtained for compressive strength and density at 0% sand replacement with waste iron ore. This result is necessary as it serves as a basis for comparison with cases with higher percentage of sand replacement with waste iron ore. Compressive strength was observed to be 34.27 N/mm$^{2.}$ at 0% sand replacement with waste iron ore with respect to 28 curing days.

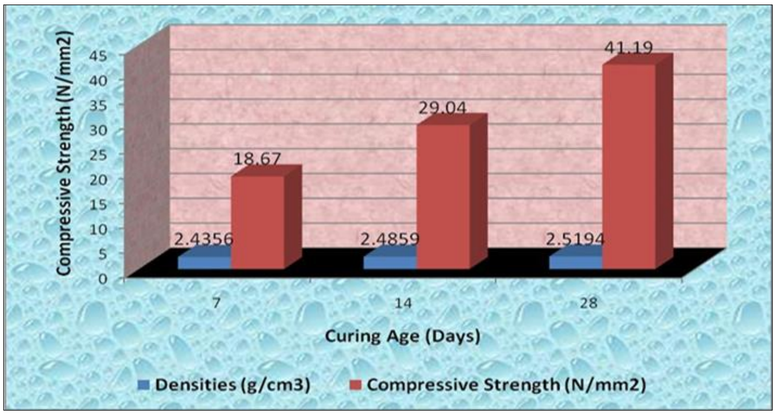

Figure 2 Summary of Compressive strengths and densities of concrete cubes at 10% replacement of fine aggregate with the iron-ore waste

As seen in figure 2, magnetite (Fe_3O_4) and Hematite (Fe_2O_3) which form part of the major constituents of iron ore waste, influences the overall strengths and densities of the concrete cubes at 10% percentage sand replacement with waste iron ore. Comparing Figure 2 to Figure 1, it is evident that replacing sand at 10% with waste iron ore yields a higher compressive strength than that with 0% sand replacement. Nevertheless, it is important to note that the variations in densities and compressive strengths is due to the particle size distribution of the waste which is finer than the sand fine aggregates (see Tables 1 and 2 in Appendix A), the period of curing and other physical properties of the waste which includes density and specific gravity.

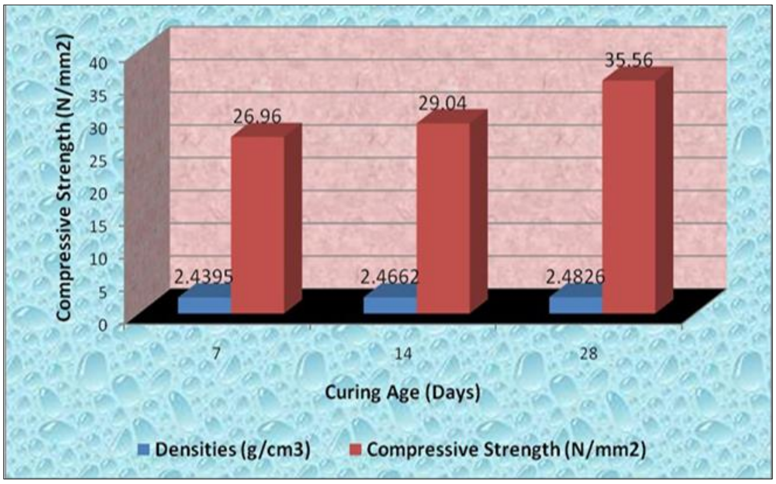

Figure 3 Summary of Compressive strengths and densities of concrete cubes at 20% replacement of fine aggregate with the iron-ore waste

Meanwhile, the slight increase in the compressive strengths of the concrete notably at 10% and 20% replacement of fine aggregate may be attributed to adequate blending of all the components at that level (meets the standards specified in BS 1881, 1978). From figure 3, it can be concluded that the compressive strengths and densities attained maximum or best values at 10% and 20% sand replacement with waste iron ore. Moreover, the compressive strengths were observed to decrease gradually with increasing percentage sand replacement (see Figures 4 and 5). The decrease is attributed to the continuous accumulation of finely graded material contributed by the waste (properties of the waste much of which is finely graded silica, 38.60% by composition), thereby reducing the coarseness of the mix except for the unchanged composition of coarse aggregate.

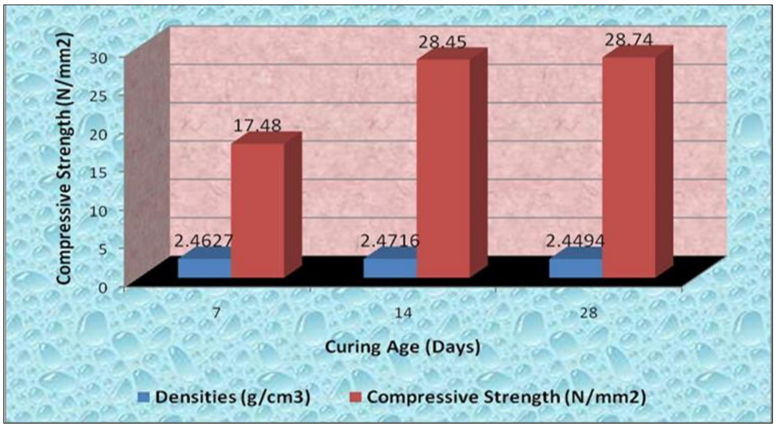

Figure 4 Summary of Compressive strengths and densities of concrete cubes at 30% replacement of fine aggregate with the iron-ore waste

More so, notable increase in densities is indicated in Figure 1 through Figure 5 at all percentage replacements influenced by the accumulated weight of the concrete over time due to curing. The densities of sample concrete cubes were observed to have dropped slightly as the percentage of waste increased (See Figures 4 and 5). Notwithstanding, all densities obtained conformed with the conventional standard (i.e., greater than 2.4 kg/cm^3). Figure 6 shows summary of all results at 28days curing age at all percentage replacements of fine aggregate with the ore waste for compressive strengths and densities.

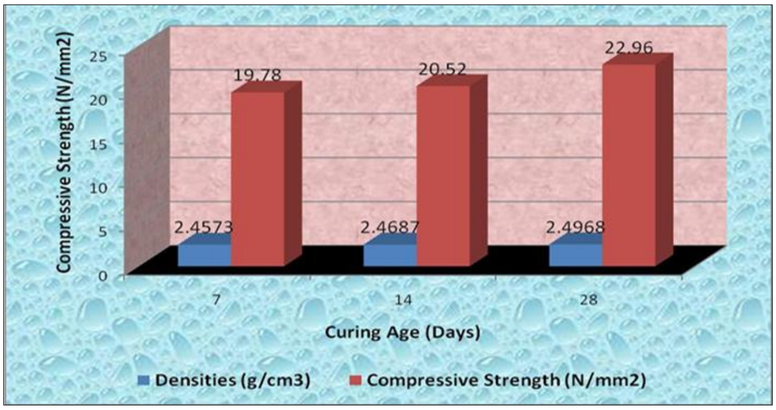

Figure 5 Summary of Compressive strengths and densities of concrete cubes at 100% replacement of fine aggregate with the iron-ore waste

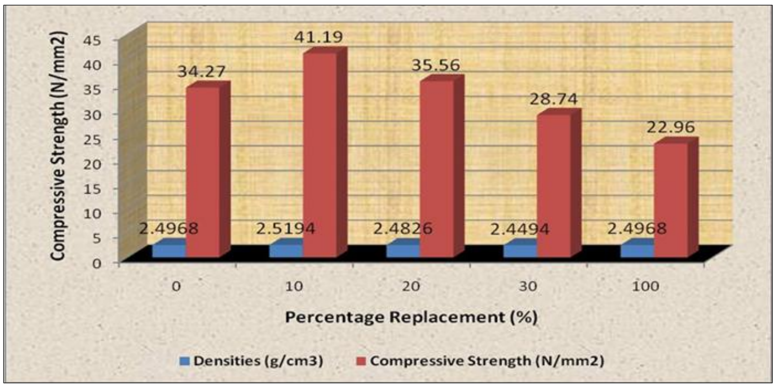

Figure 6 Comparison of Compressive strengths and densities against percentage replacement of fine aggregate with the iron-ore waste at 28days curing age

5. Appendix

5.1 A: Particle size distribution of sand and ire ore

Table 1 Particle size analysis of the waste sample

Sieve size	Weight retained (g)	% retained	% passing
10.0 mm	0.00	0.0	100
4.76 mm	12.00	4.0	96
2.36 mm	25.00	8.3	87.7
1.18 mm	30.00	10.0	77.7
600 u	76.00	25.3	52.4
300 u	32.00	10.6	41.8
150 u	22.00	7.3	34.5
75 u	14	4.7	29.8

Table 2 Particle size analysis of fine aggregate (sand)

Sieve size (mm)	Weight Retained (g)	% Retained	%Passing
9.50	0.00	0.0	100
4.76	10.00	3.3	96.7
2.36	17.00	5.7	91.0
1.18	46.00	15.3	75.7
600 u	85.00	28.3	47.4
426 u	40.00	13.3	34.1
300 u	27.00	9.0	25.1
150 u	31.00	10.3	15.1
75 u	12.00	4.0	11.1

Table 3 Particle size analysis of coarse aggregate (3/4)

Sieve size	Weight retained (g)	% retained	% passing	Envelope
25.4 mm	0	0.0	100	100
19.05 mm	425	14.0	86.0	85-100
12.5 mm	1025	34.2	51.8	50-75
9.52 mm	1356	45.2	6.6	0-25
4.76 mm	192	6.4	0.2	0-5

Table 4 Specific gravity of fine aggregate

Sample	A	B
Sample weight (P) (g)	500	500
Bottle + H_20 (B) (g)	1600	1600
Bottle + H_20 + sample (Ps) (g)	1848	1800
Specific Gravity, Gs	**2.14**	**2.29**
Average Gs		**2.22**

Table 5 Specific gravity of coarse aggregate

Sample	A	B
Sample weight (P) (g)	1000	1000
Bottle + H_20 (B) (g)	1510	1528
Bottle + H_20 + sample (Ps) (g)	2106	2170
Specific Gravity, Gs	2.48	2.79
Average Gs	2.64	

Table 6 Setting time of cement (Dangote Brand)

S/No.	Wt. of cement (g)	Wt. of water (g)	Depth of pen by plunger (mm)	Initial setting time	Final setting	w/c (%)
1	400	145	5.5	130 mins.	285 mins	36.25

5.2 Standard test results

Table 7 Soundness test on cement sample

S/no	w/c (%)	Dist. btw pointers before boiling, L1 (mm)	After boiling, L2 (mm)	Expansion, L2-L1 (mm)
1	36.25	14	16	2
2	36.25	14	15	1
3	36.25	13	14	1
4	36.25	13	15	2
5	36.25	14	14	0
6	36.25	13	14	1
			Average expansion	**1.17mm**

Table 8 Standard Flakiness test

Aggregate	3/4	
Total weight of aggregate, A (g)	2130	-
Weight of flaky aggregate, after passing gauge B (g)	131	-
B/A x 100 flakiness index (%)	**6.2**	-

Table 9 Standard Elongation test

Aggregate	3/4	
Total weight of aggregate, A (g)	2130	-
Weight of elongated aggregate after passing B (g)	833	-
Elongation index (%) B/A X 100	**39.1**	-

Table 10 Aggregate Crushing value test (ACV)

S/No.	Sample	A	B
1	Weight of material in mould (g)	3610	3690
2	Weight of material passing sieve 2.36mm (g)	808	841
3	ACV = 2/1 X 100	22.4%	22.8%
	Average	**22.6%**	

Table 11 Aggregate Impact value test (AIV)

S/No.	Sample	A	B
1	Weight of sample before test A (g)	610	660
2	Weight of sample passing 2.4mm sieve B (g)	52	61
	Impart value average B/A x 100	8.5%	9.2%
	Average	8.9%	

Table 12 Compressive strengths and densities of concrete cubes at 0% replacement of fine aggregate with the iron-ore waste (Control Test)

Cube No.	Curing Age (Days)	Date of cast	Crushing date	Weight of Concrete (Kg)	Volume of Concrete (cm³)	Density of Concrete (g/cm³)	Crushing Load (KN)	Area of Concrete (mm²)	Compressive Strength (N/mm²)
1	7	5/4/2013	12/4/2013	8200	3375	2.4296	600	22500	26.67
2	7			8150		2.4148	690		30.67
3	7			8275		2.4519	680		30.22
AVERAGE						2.4321			29.19
1	14	5/5/2013	19/4/2013	8310	3375	2.4622	720	22500	32.00
2	14			8390		2.4859	700		31.11
3	14			8285		2.4548	725		32.22
AVERAGE						2.4676			31.78
1	28	5/5/2013	3/5/2013	8380	3375	2.4830	770	22500	34.22
2	28			8500		2.5185	760		33.78
3	28			8400		2.4889	783		34.80
AVERAGE						2.4968			34.27

Table 13 Compressive strengths and densities of concrete cubes at 10% replacement of fine aggregate with the iron-ore waste

Cube No.	Curing Age (Days)	Date of cast	Crushing date	Weight of Concrete (Kg)	Volume of Concrete (cm³)	Density of Concrete (g/cm³)	Crushing Load (KN)	Area of Concrete (mm²)	Compressive Strength (N/mm²)
1	7	6/5/2013	13/5/2013	8150	3375	2.4148	540	22500	24.00
2	7			8300		2.4593	300		13.33
3	7			8210		2.4326	420		18.67
AVERAGE						2.4356			18.67
1	14	6/5/2013	20/5/2013	8600	3375	2.5481	610	22500	27.11
2	14			8250		2.4444	700		31.11
3	14			8320		2.4652	650		28.89
AVERAGE						2.4859			29.04
1	28	6/5/2013	03/6/2013	8510	3375	2.5215	860	22500	38.22
2	28			8490		2.5156	980		43.56
3	28			8509		2.5212	940		41.78
AVERAGE						2.5194			41.19

Table 14 Compressive strengths and densities of concrete cubes at 20% replacement of fine aggregate with the iron-ore waste

Cube No.	Curing Age (Days)	Date of cast	Crushing date	Weight of Concrete (Kg)	Volume of Concrete (cm³)	Density of Concrete (g/cm³)	Crushing Load (KN)	Area of Concrete (mm²)	Compressive Strength (N/mm²)
1	7	9/5/2013	16/5/2013	8350	3375	2.4741	600	22500	26.67
2	7			8100		2.4000	720		32.00
3	7			8250		2.4444	500		22.22
AVERAGE						2.4395			26.96
1	14	9/5/2013	23/5/2013	8120	3375	2.4059	590	22500	26.22
2	14			8650		2.5630	670		29.78
3	14			8200		2.4296	700		31.11
AVERAGE						2.4662			29.04
1	28	9/5/2013	06/6/2013	8280	3375	2.4533	820	22500	36.44
2	28			8471		2.5099	800		35.56
3	28			8386		2.4847	780		34.67
AVERAGE						2.4826			35.56

Table 15 Compressive strengths and densities of concrete cubes at 30% replacement of fine aggregate with the iron-ore waste

Cube No.	Curing Age (Days)	Date of cast	Crushing date	Weight of Concrete (Kg)	Volume of Concrete (cm³)	Density of Concrete (g/cm³)	Crushing Load (KN)	Area of Concrete (mm²)	Compressive Strength (N/mm²)
1	7	14/5/2013	21/5/2013	8380	3375	2.4830	410	22500	18.22
2	7			8245		2.4430	370		16.44
3	7			8310		2.4622	400		17.78
AVERAGE						2.4627			17.48
1	14	14/5/2013	28/5/2013	8370	3375	2.4800	560	22500	24.89
2	14			8310		2.4622	740		32.89
3	14			8345		2.4726	620		27.56
AVERAGE						2.4716			28.45
1	28	14/5/2013	11/6/2013	8350	3375	2.4741	510	22500	22.67
2	28			8200		2.4296	700		31.11
3	28			8250		2.4444	730		32.44
AVERAGE						2.4494			28.74

Table 16 Compressive strengths and densities of concrete cubes at 100% replacement of fine aggregate with the iron-ore waste

Cube No.	Curing Age (Days)	Date of cast	Crushing date	Weight of Concrete (Kg)	Volume of Concrete (cm^3)	Density of Concrete (g/cm^3)	Crushing Load (KN)	Area of Concrete (mm^2)	Compressive Strength (N/mm^2)
1	7	5/6/2013	12/6/2013	8450	3375	2.5037	440	22500	19.56
2	7			8200		2.4296	440		19.56
3	7			8230		2.4385	455		20.22
AVERAGE						2.4573			19.78
1	14	5/6/2013	19/6/2013	8300	3375	2.4593	490	22500	21.78
2	14			8350		2.4741	475		21.11
3	14			8345		2.4726	420		18.67
AVERAGE						2.4687			20.52
1	28	5/6/2013	03/7/2013	8550	3375	2.5333	510	22500	22.67
2	28			8350		2.4741	520		23.11
3	28			8380		2.4830	520		23.11
AVERAGE						2.4968			22.96

6. Conclusion

All results obtained in terms of densities and compressive strengths for the control test reveals consistency, satisfying the standard requirements for grade 30 (G30) concrete as specified in BS 1881, 1978 method of testing concrete. Other results relating to percentage replacements of fine aggregate with the ore waste at 10%, 20%, 30% and 100% were also established at various curing ages. Studying these results, there are variations in the compressive strengths of all concrete cubes produced under these replacement conditions indicating an increase in strengths at 10% and 20% when compared with the control test results at 28days curing age. Generally, densities of concrete cubes remain consistent but increases slightly, notably at 10% and 20% of waste replacement, this increment is proportional to the curing ages. At 30% waste replacement, there was reduction in compressive strengths at 28days curing age and this reduction remains proportional as the percentage was increased towards 100%. The percentage increment of compressive strengths at 10% replacement is 20%. The percentage reduction of compressive strengths from 30% towards 100% replacement is 16%, this represents 2.3% decrease in strength for every 10% increment in the waste replacement from 30% and above. Percentage increment for 100% replacement is 33%.

It is however recommended that concrete produced under this condition (10% and 20% replacement) can be utilized for all construction purposes where concrete is required. More so, since road construction requires enormous earthwork, sometimes borrow pits are not readily available or accessible, it is therefore recommended that this waste material be investigated to ascertain its suitability as sub base and base material for road work projects. Finally, it is recommended that further study of the waste material be conducted to find ways of attaining higher concrete strength at higher percentage replacements, say 70%, 80% and 90%.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest.

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