FLEXURAL BEHAVIOUR OF CONCRETE BEAMS INCOPORATING IRON ORE TAILINGS

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A THESIS SUBNITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY MINNA, NIGERIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF ENGINEERING IN CIVIL ENGINEERING (STRUCTURAL ENGINEERING)

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ABSTRACT

Aggregates make up 60-80% of the volume of concrete and 70-85% of the mass of concrete. The pressure on the river bed sourcing for river sand which is a major constituent in concrete making is causing a major ecological and environmental problem. Efforts are being carried out to conserve the environment by means of promoting the use of industrial wastes like iron ore tailings IOT which show physical properties similar to sand as replacement for sand in concrete making. This will not only conserve the river bed but also reduce the risk the tailings post to the environment. The scope of this research is to evaluates the flexural, compressive and split tensile behavior of concrete with IOT that was sourced from itakpe Kogi state in different proportions with respect to age of concrete. Test on the mechanical properties of concrete with 10%, 20%, 30%, and 40% sand replacement with IOTs were conducted, tests on workability, compressive strength, split tensile strength and flexural strength were also conducted. From the experimental results it was established that at up to 20% replacement of IOT, the compressive strength, split tensile strength and flexural strength values increased comparable with that of control concrete specimens. But there is a gradual decrease in the strengths above 20% replacement up to 40% of IOTs. Results of this investigation suggests that replacement of sand with 20% IOT can be used in concrete specimens as it shows good strength.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

As the world is becoming environmentally conscious, leaving the waste materials generated from mining activities to the environment directly may cause an immense environmental problem. The volume of tailings discharged worldwide from iron ore smelting processes (i.e., iron ore tailings) has increased dramatically in recent years, and the disposal of this waste poses a substantial ecological threat to soil, and surface and sub-surface water. Hence, there is need for an ample scope for waste utilization and management from the sustainability point of view. Waste can be used to produce new products; it can also be used as substitute for the natural resources both fine and coarse aggregate which the construction activities has put under a severe pressure so as to protect the environment from waste deposits.

Iron ore tailing is one of the waste materials that is being generated from the mining industry. These tailings are produced as the residue of the milling process that is used to extract metals of interest from mined ores. The particles of the tailings that is being generated during the process may result into air pollution, acid mine, and ground water contamination during the dry and raining season. Leaching of heavy metals is another major concern, this makes the disposal of mine tailing a serious environmental issue for any mining projects.

Aggregates make up about 70–80% of a concrete mix (Shetty *et al.*, 2014). As the natural granite quarries for aggregates are gradually decreasing, there would be the need for alternative materials to be used as natural aggregates in concrete. If mine tailings are considered as a partial or complete replacement of natural aggregates in concrete, majority of these tailings can be recycled and used sustainably by turning these mine tailings into useful resource and providing cheaper alternatives in concrete production (Ugama *et al.*, 2014). This will eliminate the need to mine virgin materials such as concrete aggregates. The scarce resources could be conserved while at the same time providing sustainable solution to the handling of the tailings. This could make it possible for the mining industries concerned to generate extra income to defray their cost of production to maximize profit margin.

Nigeria has about three billion metric tons of iron ore deposit, with about 182.5 million tone reserve in Itakpe Kogi state (Elinwa and Maichibi 2014), with this huge deposit and the government interest to develop the steel sector, private investors will come in and more processing plant will be built hence more iron ore tailing (IOTs) will be generated. If there is no proper way of handling these waste (IOTs), it could lead to adverse effect on the environment and adverse effect on human health.

The processing activities associated with the iron ore beneficiation is such that it results in the tailings with particle sizes within the fine range (Kuranchie *et al.*, 2014). If the federal government and the prospective iron ore mining companies in Nigeria could incorporate comprehensive utilization of the tailings in their operation, it could lead to cleaner production and sustainable development in their operation. This could have a potential of reducing both cost and environmental impacts created by these tailings (Haibin and Zhenling, 2010).

1.2 Statement of the Research Problem

As it is the desire of Nigeria government that Nigeria should be the industrial hub of Africa through mining and steel development, itakpe and environ which has the largest deposit of iron ore will experience a huge waste of mine tailings generation from the mining process. Mine tailings are characterized with environment pollution, ground water contamination due to leaching of heavy metals which can cause health hazards, dust erosion, destruction of vegetation through chemical reaction and oxidation that could result to acidic soil.

Due to large volume of waste that accompany the iron mining process a large volume of arable land that can be used for food production end up been used as dump tailing site also the cost of maintaining the tailing site is very huge to the extent that it can discourage any investor in the mining industry.

Due to high volume of construction activities, the demand for fine and coarse aggregate to meet up with construction need is very high, hence our river beds and quarries has been put under immense pressure to meet up to these demands. Research work has shown that iron ore tailings and sharp sand has some similar physical properties hence there is need to evaluate how these tailings can be used as an alternative material to fine aggregates in concrete making.

Hence, the problem to solve is how to convert these tailings into value added products for civil engineering applications and construction projects. This will reduce or eliminate the problems mine tailings bring to the environment and human health. It will also ensure economic and environmental sustainability of the mining industries and provide cheaper alternative materials for building and construction projects.

1.3 Aim and Objectives of the Study

The research tends to find out the Feasibility of Using Iron Ore Tailings (IOTs) obtained from Itakpe iron ore processing mill, in concrete.

The research aims to achieve this through the following objectives;

i. Material characterization

ii. Determination of Mix design of concrete with IIOTs

iii. Determination of compressive and split tensile strength of IIOTs concrete.

iv. Evaluation of flexural behaviour of IIOTs concrete beams.

1.4 Justification of the Study

The need for the production of iron ore from which locally available steel can be produced has generated a lot of interest from Nigeria government in the recent past. As a result of this itakpe and its environ which has the largest deposit of iron ore in Nigeria will experience a huge waste of mine tailings generation from the mining process. Research has shown that Mine tailings are characterized with environment pollution, ground water contamination due to leaching of heavy metals, dust erosion, destruction of vegetation through chemical reaction and oxidation that could result to acidic soil. Construction activities also has created a huge demand for fine and coarse aggregate to meet up with construction needs this has put a lot of pressure on our river beds and quarries. This study focuses on the feasibility of using iron ore tailings that is obtained from itakpe iron mine processing mill in concrete to solve the above-mentioned problems.

1.5 Scope of the Study

The scope of this research is limited to the use of iron ore tailings obtained from Itakpe iron ore processing company Kogi state Nigeria. The iron ore tailings are used directly (in its natural state) as obtained from source and no form of modifications made on the material. The study is limited to utilizing the iron ore tailings to partially replace sand in producing normal strength concrete.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Preamble

In order to produce a good outcome from this research there is a need to critically highlight what previous studies have reported relating to the topic of this research. In this chapter, previous studies that are closely related to the use of iron ore tailings in concrete are mentioned and the outcome of the studies are discussed. Topics relating to the study of concrete as a material are briefly explained. The production process of the focused material, iron ore tailings and its composition are also mentioned.

Concrete is a composite construction material made primarily with Cement, fine aggregates, water and coarse aggregates, and may contain chemical admixtures. It contains some amount of entrapped air and may also contain purposely entrained air obtained by use of an admixture or air entraining cement (ACI 211, 1997). The mixture of the materials results in a chemical reaction called hydration. Concrete is the basic engineering material used in most of the civil engineering structures.

Its popularity as basic building material in construction is because of its economy of use, good durability and ease with which it can be manufactured in a construction site. The ability to be moulded into any shape and size because of its plasticity in green stage and its subsequent hardening to achieve strength is particularly useful. Concrete is remarkably strong in compression but it is equally weak in tension. Hence the use of plain concrete as a structural material is limited to situations where significant tensile stresses and strain do not develop.

Concrete like other engineering materials needs to be designed for properties like strength, durability, workability and cohesion. Fresh concrete gains strength rapidly during the first few days and weeks, therefore structural design is generally based on the 28 days strength about 70% of which is reached at the end of first week after placing. During this initial period the strength of final concrete depend greatly on the condition of moisture and change in temperature. To maintain a constant temperature and moisture during this period curing is adopted. Arthur *et al.*, (2010) concluded that concrete lost up to 30% in strength due to the premature drying and up to 50% when a fresh concrete is frozen. Hence to prevent this loss of strength, concrete should be protected from loss of moisture for at least 7 days and in more sensitive work the curing should be extended to 14 days.

2.2 Previous Research on the use of Iron ore Tailings in Concrete

Mine tailings are the unwanted materials that are left over after separating the valuable minerals of economic interest from the gangue or wastes of an ore. Mine tailings are produced during ore processing stage which could include commutation, concentration, upgrading and leaching. Tailings are normally contaminated with heavy metals, solids, mill reagents and sulphur compounds and these could cause environmental pollution if they are not handled properly (Waldichuk, 1979). The chemical compositions of the itakpe iron ore tailings compared with others are shown in Table 1.1

Table 1.1 Chemical Compositions of Itakpe Iron Ore Tailings Compared with others Selected from Previous Researches Source: (Oritola *et.al.*, 2015)

Properties of IOTs Compositions from various Locations					*	*	*	
Chemical Xtics content (wt %)	K/Tinggi Malaysia	Miyun China	Itakpe Nigeria	Goa India	Rui China	Rui China	Rui China	Sujing China
Fe_2O_3	22.10	8.13	15	44.36	11.99	7.04	10.41	9.13
SiO_2	37.20	69.52	66	51.12	68.63	70.27	58.76	52.06
Al_2O_3	10.70	7.44	3.8	1.22	6.72	8.43	11.84	17.14
CaO	8.52	4.14	1.8	0.22	2.76	3.92	5.14	12.74
MgO	0.96	3.72	1.2	-	3.82	3.03	6.11	3.68
Mn_2O_3	1.04	-	1.0	-	-	-	-	0.25
Na_2O	0.46	1.38	-	-	1.6	1.66	2.71	0.97
K_2O	1.71	1.97	-	-	1.98	2.62	1.62	0.30
SO_3	0.26	0.03	-	-	1.91	2.02	0.10	-
TiO_2	0.43	0.016	-	-	-	-	-	0.45
L O I		2.5	-	2.95	-	-	-	3.23

In the earlier times in British Columbia, Cornwall, some parts of Britain and other parts of the world, mine tailings were thrown into the sea and rivers for a long time as means of disposal and it is still practiced in some mines. This was done to reduce the volumes and handling of mine tailings available. This practice was considered as damaging to the marine species and ecology in general as a result of the quantity of heavy metallic oxides that is involve and it is now strongly discouraged. This practice has the potential of causing water pollution because the tailings are normally contaminated with heavy metals, solids, mill reagents and Sulphur compounds (McKinnon, 2002)

Tailings are normally disposed as slurry of high-water content and could also contain coarse dry material (Wills, 1992). Low grade ores result in very large amounts of fine tailings. Therefore, the most acceptable and more sustainable way of dealing with mine tailings is to consider reuse options for them especially in construction and building where large volume could be used.

Tailings have other useful properties such as self-cementing characteristics which remove the necessity of adding cement when it is being used to fill mined-out areas and for other similar applications. The self-cementing characteristics of the tailings is due to its slimy nature and the large quantity of sulphides it contains which oxidizes on contact with the air to form hard cement-like crust. Hence there is a need for sustainable utilization of the iron ore tailings.

Yellishetty *et al*. (2008) studied the use of iron ore mine tailings from Goa in India as an aggregate in concrete. They obtained the iron ore mine wastes from four different types of mine waste dumps in different companies in Goa India and mixed them together. They made two types of concrete, one with the mine aggregate and the other with normal granite quarry aggregate in concrete and compared the properties of the two different concrete with different aggregate. The composition of the concrete was in different proportions using mine aggregate (12.5mm – 20mm in size), sand and cement as the binder.

They concluded that the aggregate component of the mine wastes conforms to the Indian Standard Specifications for quality standards of aggregates. Their work is also an improvement for making concrete by adding some mine wastes to partially replace the coarse aggregate part. The use of mine wastes for 100% replacement for both fine and coarse aggregates will avoid the use of natural sand and natural granite quarry completely. Further study into this will bring much more improvement and economy in concrete production.

Yellishetty *et al*., (2008) also research into the suitability of using iron ore mine tailings from Goa in India as aggregates in making concrete and building material. 40% by weight of the mine wastes with size of 12.5 – 20 mm was used as aggregate in the concrete mix. The concrete mixture contained Mine wastes as coarse aggregates, siliceous sand as fine aggregates and portable water with neutral pH and ordinary Portland cement. Based on the mixture, concrete blocks were made and cured for 28 days.

Another concrete block was made with granite as the coarse aggregate instead of the mine wastes. The strength of the concrete with mine wastes aggregates was 225 kg/cm2 and that of granite aggregate was 200 kg/cm2. The ratio used was 1:2:4 cement, sand and aggregate respectively. They concluded that the compressive strength of concrete made of mine wastes as aggregate was more than that of the concrete made of granite as aggregate and the mine wastes aggregates of the concrete conforms to Indian Specification Standards.

Das *et al.*, (2000) also described a new development in managing iron ore tailings by converting them into value added products such as ceramic floor and wall tiles for building applications. They reported that iron ore particles below 150μm in size were discarded as waste tailings. They also tested constituents of the tailings from different locations and their mixture using standard techniques XRD (Siemens D 500) with Ni filter and Cu (Kα) radiation. The result of the test is indicating that the iron ore tailings were found to contain high percentage of silica.

The high silica content in the iron ore tailings is considered favourable in terms of the property and the raw material requirements for the production of ceramic tiles. The study concluded that iron ore tailings up to 40% by weight can be considered for use as a part of raw materials for ceramic floor and wall tiles due to its high silica content. The ceramic tiles from the iron ore tailing materials were found to be superior in terms of scratch hardness and strength. The new tiles from the iron ore tailings maintain most of the other essential properties as the conventional raw materials used for ceramic tiles. The application of iron ore tailings in the ceramic tiles production was also found to be cost effective in comparison with the usual traditional clay for ceramic tiles production.

Oritola *et al*., (2015) also work on the partial replacement of sand with iron ore tailing. They tested some samples of iron ore tailings whose particle size ranges from (850µm - 75µm), by using it to partially replace sand as fine aggregate in normal strength concrete. They studied the effect of iron ore tailings on the consistency of the fresh concrete as well as the density, compressive strength, flexural strength and splitting tensile strength, of the hardened concrete. The results of the consistency tests on concrete they obtained shows that the slump values range from 81 to 53 mm, while the compacting factor values ranges from 0.92 to 0.89. The density of the concrete cube samples they produced falls within the range 2350 to 2430 kg/m^3. They concluded by stating that the sand replacement up to 30% of iron ore tailings gave highest compressive strength value of 43.70 [N/mm^2 and highest flexural strength value of 4.79 [N/mm^2] after curing period of 28 [days].

Xiaoyan *et. al.,* (2013) used iron ore tailings powder as cement replacement for developing green ECC (Engineered Cementitious Composite) and concluded that the replacement of cement by less reactive IOTs in ECC reduces the matrix fracture toughness. Increasing the replacement of cement beyond 40% replacement ratio reduces the compressive strength of ECC. IOTs in powder form are used to partially replace cement to enhance the environmental sustainability of ECC. Mechanical properties and material greenness of ECC containing various proportions of IOTs are investigated. The newly developed versions of ECC in the study, with a cement content of 117.2–350.2 kg/m3, exhibit a tensile ductility of 2.3–3.3%, tensile strength of 5.1–6.0 MPa, and compressive strength of 46–57 MPa at 28 days. The replacement of cement with IOTs results in 10–32% reduction in energy consumption and 29–63% reduction in carbon dioxide emissions in green ECC compared with typical ECC.

Elinwa *et. al*., (2014) also evaluated the use of itakpe iron ore tailings in concrete production using the material to replace sand and cement, in proportions of 5 % up to 30 %, and curing period of 90 days in water. The mix they used in their research work had a total cement content of 380 kg/m3, fine aggregate content of 812 kg/m3, coarse aggregate of 1856 kg/m3 and a water content of 190 kg/m3. The Fine aggregate replacement levels they used were 5 %, 10 %, 20 %, and 30 %, by mass of IOT and cement replacement levels were 5 %, 10 %, and 20 % by mass of IOT. There concrete samples were tested in the fresh and hardened conditions. They also conduct a test on the IOT/OPC pastes to ascertain the setting time of the mixes.

The results show that there was increases in workability and slump height with increase in percentage of IOT. The hardened concrete was also tested for compressive strength. For this purpose, a total of 75cube specimens, 150 mm in size, were casted and cured in water for periods of up to 90 days. Sixty (60) cube specimens of the same size and days of curing were also prepared for the cement replacement levels. They also observed that the concrete exhibited improved workability and higher compressive strengths over the control strength with approximately 10 % and 38 % for sand and cement respectively.

Mehta and Monteiro (1993) agree that aggregate occupied about 70% to 80% of the volume of concrete in a concrete mix. It is inevitable that a constituent occupying such a large percentage of the mass should contribute important properties to both the fresh and hardened product. Aggregate is usually viewed as an inert dispersion in the cement paste. However, strictly speaking, aggregate is not truly inert because physical, thermal, and, sometimes, chemical properties can influence the performance of concrete.

To obtain consistent concrete strength, workability and durability, aggregate must be properly selected to be durable, blended for optimum efficiency and properly controlled. An aggregate is said to be of a good quality when it is clean, hard, strong, durable and be free of contaminated material that can affect hydration of cement or reduce the paste aggregate bond. When smooth and round aggregate is used instead of rough angular or elongated aggregate, it makes the concrete to be more workable. Angular and elongated aggregate are produced from crushed aggregate, which have a higher surface to volume ratio, it has a better bond characteristic but require more cement paste to produce a workable mixture.

When concrete is freshly mixed, the aggregates are suspended in the cement–water–air bubble paste. The behavior of fresh concrete, such as fluidity, cohesiveness, and rheological behavior, is largely influenced by the amount, type, surface texture, and size gradation of the aggregate. The selection of aggregate has to meet the requirement of the end use, i.e., what type of structure to be built. Although there is little chemical reaction between the aggregate and cement paste, the aggregate contributes many qualities to the hardened concrete. In addition to reducing the cost, aggregate in concrete can reduce the shrinkage and creep of cement paste. Moreover, aggregates have a big influence on stiffness, unit weight, strength, thermal properties, bond, and wear resistance of concrete.

2.3 Composition of Normal strength concrete

Concrete is a composite construction material made primarily with Cement, fine aggregates, water and coarse aggregates, and may contain chemical admixtures. It contains some amount of entrapped air and may also contain purposely entrained air obtained by use of an admixture or air entraining cement (ACI 211, 1997). The mixture of the materials results in a chemical reaction called hydration. Concrete is the basic engineering material used in most of the civil engineering structures.

Its popularity as basic building material in construction is because of its economy of use, good durability and ease with which it can be manufactured in a construction site. The ability to be moulded into any shape and size because of its plasticity in green stage and its subsequent hardening to achieve strength is particularly useful. Concrete is remarkably strong in compression but it is equally weak in tension. Hence the use of plain concrete as a structural material is limited to situations where significant tensile stresses and strain do not develop.

Concrete like other engineering materials needs to be designed for properties like strength, durability, workability and cohesion. Fresh concrete gains strength rapidly during the first few days and weeks, therefore structural design is generally based on the 28 days strength about 70% of which is reached at the end of first week after placing. During this initial period the strength of final concrete depend greatly on the condition of moisture and change in temperature. To maintain a constant temperature and moisture during this period curing is adopted. Arthur *et al.*, (2010) concluded that concrete lost up to 30% in strength due to the premature drying and up to 50% when a fresh concrete is frozen. Hence to prevent this loss of strength, concrete should be protected from loss of moisture for at least 7 days and in more sensitive work the curing should be extended to 14 days.

2.3.1 Aggregates

Aggregates can be divided into several categories according to different criteria, such as size, source, and unit weight as shown in Figure 2.1

(a) In accordance with size

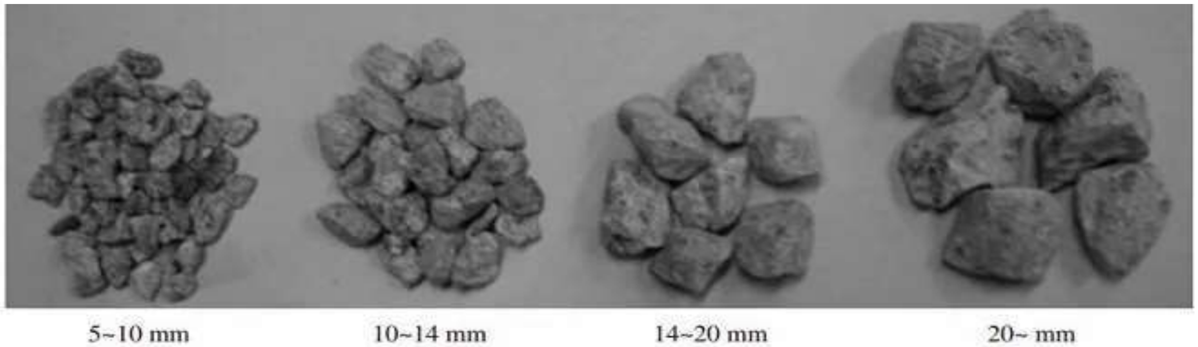

Figure 2.1: Aggregate sample used

Coarse aggregate: Aggregates predominately retained on a No. 4 (4.75-mm) sieve are classified as coarse aggregate. Generally, the size of coarse aggregate ranges from 5 to 150 mm. For normal concrete used for structural members such as beams and columns, the maximum size of coarse aggregate is about 25 mm. For mass concrete used for dams or deep foundations, the maximum size can be as large as 150 mm. as shown in Figure 2.1

Fine aggregate (sand): Aggregates passing through a No. 4 (4.75 mm) sieve and predominately retained on a No. 200 (75 μm) sieve are classified as fine aggregate. River sand is the most commonly used fine aggregate. In addition, crushed rock fines can be used as fine aggregate. However, the finish of concrete with crushed rock fines is not as good as that with river sand.

b) In accordance with source as shown in Figure 2.2

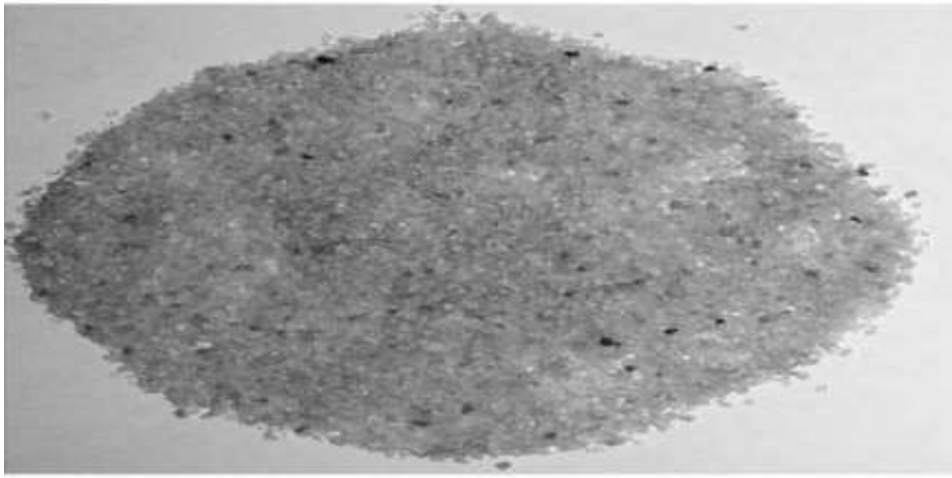

Figure 2.2: Profile of sand sample used.

Natural aggregates: This kind of aggregate such as sand and gravel are taken from natural deposits without changing the nature during production. Natural aggregates can be obtained from variety of sources e.g. pits, river banks, beaches or other quarries that require minimum extra effort and cost in terms of granular material processing as shown in Figure 2.2. Utilizing natural aggregates in mix design leads to better performance of the concrete since they have smaller surface area (comparing to crushed aggregate of the same size) and also their relatively spherical shape facilitates the flow inside the aggregate structure. However, the negative environmental impact of using natural aggregate is of concern which includes and not limited to atmospheric pollution, water pollution, changes in water course, increase in settlement, changes in ecosystem, and so on. Therefore, in some other parts of the world there are regulations about the amount of natural aggregates that can be taken from the earth's crust. Hence the need for an alternative.

Manufactured (synthetic) aggregates as shown in Figure 2.3 These kinds of aggregate are manmade materials, resulting from products or by-products of industry. Some examples are blast furnace slag and lightweight aggregate.

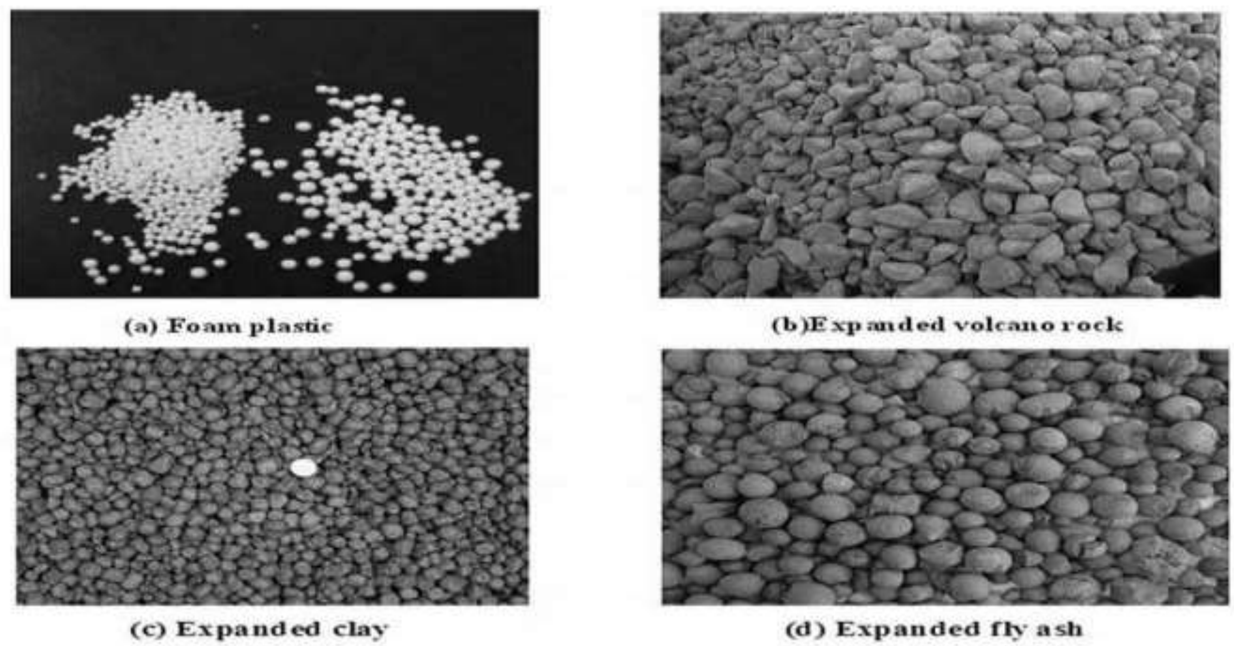

Figure 2.3: Synthetic Aggregate sample

c) In accordance with unit weight

Ultra-lightweight aggregate: The unit weight of such aggregates is less than 500 kg/m^3 including expanded perlite and foam plastic. The concrete made of ultra-lightweight aggregates has a bulk density from 800 to 1100 kg/ m^3, depending on the volume fraction of aggregate. Such a concrete can be used only as nonstructural members, like partition walls.

Lightweight aggregate: The unit weight of such aggregates is between 500 and 1120 kg/m^3. Examples of lightweight aggregates include cinder, blast-furnace slag, volcanic pumice, and expanded clay. The concrete made of lightweight aggregate has a bulk density between 1200 and 1800 kg/m^3. Such concrete can be either a structural member or nonstructural member, depending what type of aggregate is used.

Normal-weight aggregate: An aggregate with a unit weight of 1520–1680 kg/m^3 is classified as normal-weight aggregate. Sand, gravel, and crushed rock belong to this category and are most widely used. Concrete made with this type of aggregate has a bulk density of 2300–2400 kg/m^3. It is the main concrete used to produce important structural members.

Heavy-weight aggregate: If the unit weight of aggregate is greater than 2100 kg/m^3, it is classified as heavy-weight aggregate. Materials used as heavy-weight aggregate are iron ore, crashed steel pieces, and magnesite limonite. The bulk density of the corresponding concrete is greater than 3200 kg/m^3 and can reach 4000 kg/m^3. This kind of concrete has special usage, like radiation shields in nuclear power plants, hospitals, and laboratories. It can also be used as sound-shielding material.

2.4 Flexural Strength of Concrete

Flexural strength is an indirect measure of the tensile strength of concrete. It is a measure of the maximum stress on the tension face of an unreinforced concrete beam or slab at the point of failure in bending. It is measured by loading 150 x 150-mm (or (100 x 100-mm) concrete beams with a span length at least three times the depth. The flexural strength is expressed as Modulus of Rupture (MR) in MPa and is determined by standard test methods ASTM C78 (third-point loading) or ASTM C293 (center-point loading).

The specimen size and type of loading does impact the measured flexural strength and comparisons or requirements should be based on the same beam size and loading configuration. The MR measured by third-point loading (ASTM C78) is lower than that determined by center-point loading (ASTM C293), sometimes by as much as 15 percent. It is also observed that a lower flexural strength will be measured with larger beam specimens. Flexural strength is about 10 to 15 percent of compressive strength depending on the mixture proportions and type, size and volume of coarse aggregate used. For design of building members an estimate of the MR is obtained by:

$$F_r = 7.5\sqrt{f_c'} \tag{2.1}$$

where

Fr is the MR; F'c is the specified compressive strength. When MR is critical to design, the best estimate is established from laboratory tests for specific mixtures and materials used.

The flexural test on concrete can be conducted using either three-point load test (ASTM C78) or center point load test (ASTM C293). The configuration of each test is shown in Figure 2.4 and Figure 2.5 respectively. It should be noticed that, the modulus of rupture value obtained by center point load test arrangement is smaller than three-point load test configuration by around 15 percent. Moreover, it is observed that low modulus of rupture is achieved when larger size concrete specimen is considered.

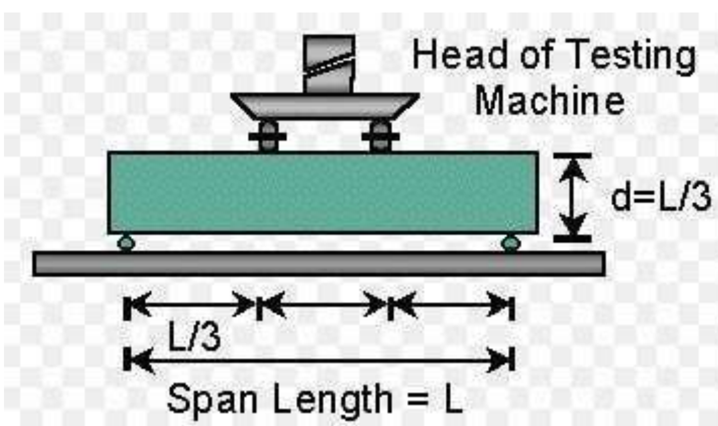

Figure 2.4: **Three-Point Load Test (ASTM C78)**

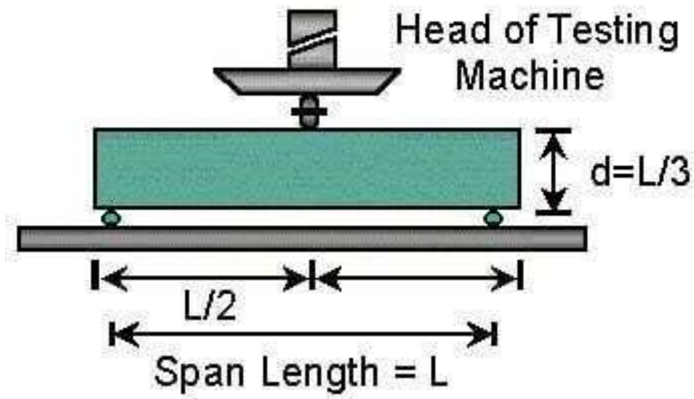

Figure 2.5: Centre Point Load Test (ASTM C293)

Finally, modulus of rupture is about 10 to 15 percent of compressive strength of concrete. It is influenced by mixture proportions, size and coarse aggregate volume used for specimen construction. Some of the application of flexural testing are to specify compliance with standard, it is essential requirement for concrete mix design and it is employed in testing concrete for slab and pavement construction.

2.5 Iron Ore

Iron ore are rocks and mineral from which metallic iron can be economically extracted. The ores in most cases are reach in iron oxides and it varies in colour from dark grey, bright yellow, or deep purple to rusty red. They are usually found in form of magnetite (Fe_3O_4) with 72.4% iron, hematite (Fe_2O_3) with 62.9% iron, goethite ($FeO(OH)$, 62.9% Fe), limonite ($FeO(OH)\cdot n(H_2O)$, 55% Fe) or siderite ($FeCO_3$, 48.2% Fe). The iron ores that containing very high quantities of hematite or magnetite (greater than about 60% iron) are known as "natural ore" or "direct shipping ore", meaning they can be fed directly into iron-making blast furnaces without any processing. Iron ore is the raw material used to make pig iron, which is one of the main raw materials to make steel 98% of the mined iron ore is used to make steel Indeed, it has been argued that iron ore is "more integral to the global economy than any other commodity, except perhaps oil.

Nigeria has about three billion metric tons of iron ore deposit, with about 182.5 million tone reserve in itakpe Kogi state Nigeria (Elinwa and Maichibi 2014), with this huge deposit and the government interest to develop the steel sector, it is expected that there will be huge mining activities in this region in which private investors will come in and there will be an establishment of more processing plants with corresponding increase in mining waste. The disposal of the mine tailings continues to impose burden to the mining industries and the general public in terms of economic and environmental health. One potential problem of the tailings is that they can release toxic and heavy metals into the environment which can result into ground water contamination, erosion and the development of acid mine.

2.5.1 Mining processes and wastes generation

Mining processes commence with the collection of ores by exploration, blasting and excavation processes. These processes generate wastes which are usually in the form of top soil, mine overburden wastes and wastes rocks of variable sizes. The product that results from these processes are the ore which could be of variable types depending on the ore deposit in the area. The processes are shown in Figure 2.6. The ore then needs to be processed using favourable and efficient process for maximum liberation.

These processes could involve comminution, concentration, upgrading and leaching (Wills, 1992). During comminution solid ore materials are reduced in size through crushing and grinding. This exposes the mineral particles of interest and increases the surface area in order to be subjected to subsequent processes. The valuable minerals are embedded and are locked into the matrix or in strict combination with other materials. The comminution process helps to free the useful minerals of interest from the matrix. This process generates some other wastes as spoils or fines which the miner considers non-useful. This is done through concentration and upgrading of the ore by separating valuable minerals from the wastes. Concentration and upgrading are done by washing, froth flotation, magnetic and chemical separation depending on the type of ore being treated.

The processing of the ore stage, as elaborated below generates wastes such as tailings, process waste water, slurries, leached residues, hazardous chemicals and so on.as presented in Figure 2.6. The product from the ore processing stage is the bulk raw material. This needs to be processed further through smelting and refinery processes to arrive at the final marketable product. During melting and refinery processes wastes such as slags and ashes are produced.

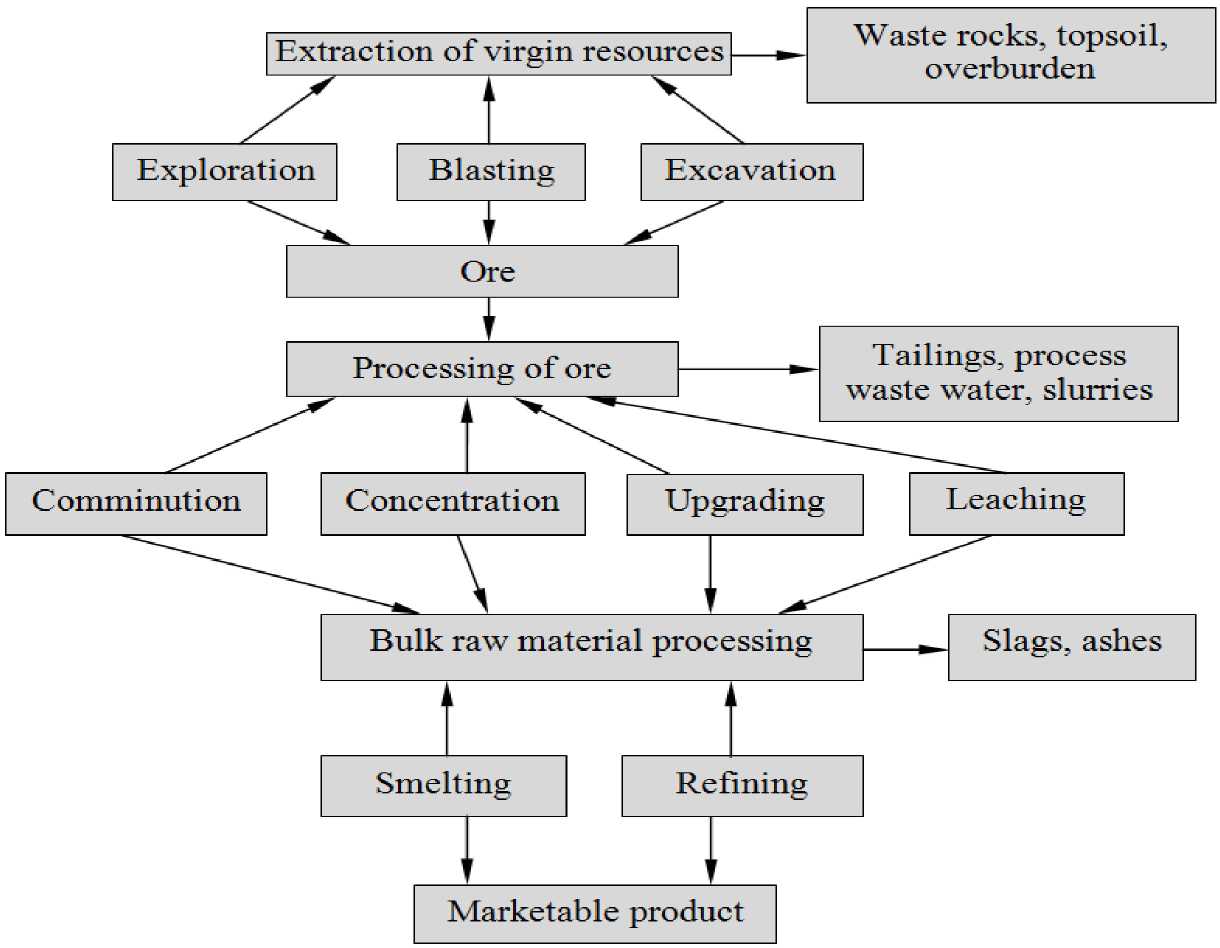

Figure 2.6: Mining processes and waste generation (Yellishetty *et al.*, 2008; Kuranchie *et al.*, 2012)

CHAPTER THREE

3.0 MATERIALS AND METHOD

3.1 General

This chapter presents the details of the materials used, details of specimens tested, test set up and testing procedure. The main objective of the present study is to arrive at an optimum percentage of replacement of cement with IIOT in concrete. Cubes, cylinders and concrete beams were casted with different replacement levels of IIOT varying between 10 to 40 percent. Tests on workability, water absorption, compressive strength, and flexural strength were conducted to study the mechanical properties of concrete with IIOT at 7th, 14th 21st and 28th day of curing.

3.2 Preliminary Investigation

Concrete which exhibits excellent behaviour in the fresh and hardened state for the purpose is meant for is refers to as good concrete. In the fresh state, good concrete offers consistence of mix such that it can be transported, placed and compacted in a good manner without segregation. In the hardened state it should offer satisfactory compressive strength. To make a concrete of desired strength, it is necessary to analyse the basic properties of the materials used for the study. Hence preliminary investigations were conducted on the raw materials used for the casting of specimens.

3.2.1 Material Description

For the normal concrete, conventional materials such as cement, fine aggregate (sand) and coarse aggregates (granite) were used. For the tailings concrete being studied, iron ore tailings were used as replacement for sand in certain percentage together with the cement to make the new concrete.

3.2.2 Cement

The cement which was used as a binder throughout this research work is ‘Dangote 3X cement’ grade 42.5 ordinary Portland cement conforming to BS EN 197-1 (2000) specifications. The cement which was produced and packaged in 50kg bags by Dangote group of company Nigeria Plc in Kogi and Ogun state was sourced in Bida, Niger State.

3.2.3 Iron Ore Tailings

The iron ore tailing used in this research was obtained from National iron ore mining company, Itakpe in Kogi State, Nigeria. A total of 5 different samples were collected from the tailing dump and the main objective of obtaining different sample from the site for the laboratory analysis is that its composition should be representative of the conditions that exists in the field. The procedure involves the random collection of material at the site over the designated area and combining them to form a composite sample for analysis as shown in Plate I.

Plate I: Heap of iron tailings

3.2.4 Fine aggregate

Fine aggregate used was properly graded to be free from deleterious materials like clay, silt content and chloride contamination and so on. For the present investigation, locally available river sand (coarse sand) at Bida conforming to Grading Zone II of ASTM D422 -63 (2007) was used as fine aggregate. The sand was washed and screened at site to remove deleterious materials and tested as per the procedure given in BS EN 12620 (2002) as shown in Plate II.

Plate II: Heaps of fine aggregate samples used (sand)

3.2.5 Coarse Aggregate

Hard crushed granite stone, coarse aggregates confirming to graded aggregate of size 20mm and 10mm as per ASTM D442(2003) was used in the study as shown in Plate III.

Plate III: Heap of coarse aggregate used (Granite)

3.2.6 Water

The mixing water which was used in this research was a portable water obtained from a borehole in the federal polytechnic Bida campus which conformed to BS EN 1008 (2002) requirements. Therefore, the water is fit for drinking, free from suspended particles, organic materials and soap which might affect hydration of cement

3.3 Mix design methods

3.3.1 The British method for the design of normal weight concrete made with Portland cement, produced by the Department of Environment (DOE), Building Research establishment (BRE) Laboratory was used for the Concrete mix design. This allows for proper 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. Based on the procedure of the concrete mix design and using the appropriate design tables and figures, a normal weight concrete with water content 190[kg/m3], cement content 380[kg/m3], fine aggregate content 732kg/m^3 and coarse aggregate content of 1098[kg/m^3] was designed using water-cement ratio of 0.5.

3.3.2 Proportioning of concrete materials

Five different types of concrete samples (CIT0, CIT10, CIT20, CIT30, and CIT40) were considered, with the percentage of tailings used to replace sand as fine aggregate ranging from 0 to 40%. The reference sample is taken as CIIT0 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 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 0.5, is shown in Table 3.1

Table 3.1 Concrete Samples and the Proportions of their Constituent Materials

Concrete Sample	Cement content (kg/m^3)	Water content (kg/m^3)	Fine aggregate content (kg/m^3)	Iron ore tailing content (kg/m^3)	Coarse aggregate content (kg/m^3)	% of iron ore tailings
$CIIT_0$	380	190	732	0	1098	0%
$CIIT_{10}$	380	190	658.8	73.2	1098	10%
$CIIT_{20}$	380	190	585.6	146.4	1098	20%
$CIIT_{30}$	380	190	512.4	219.6	1098	30%
$CIIT_{40}$	380	190	439.2	292.8	1098	40%

3.3.3 Concrete mix design procedure

The procedure of Concrete mix design in the British method as used is as stated below all the necessary charts and table as enunciated in the procedure was strictly adhere to.

Concrete grade (f m) = $25N/mm^2$

Cement type = Dangote Cement grades 42.5

Specific gravity of cement = 3.15

Aggregate size = 20mm

Specific gravity of fine Aggregate = 2.7

Specific gravity of coarse aggregate (20mm) = 2.65

Standard Deviation from (figure 1) = 8 N/mm^2

Proportion of defective = 5%

Risk factor for 5% defective = 1.64

Target mean strength = specified characteristic strength + Standard deviation x risk factor

Target means strength fm = 25 + (1.64 x 8) = 38.12 say 39N/m^2

Water cement ratio determination

From DOE table

W/C ratio of 0.5 for 28 days for crushes aggregate = 49N/mm^2

W/C ratio of 0.5 for 28 days for uncrushed aggregate = 42N/ mm^2

Mean target strength of concrete = 39N/m^2

Water cement ratio obtained from curve = 0.58

Since 0.58 is greater than 0.5 then adopt 0.50 as w/c ratio. (BS 8110 part 1 1985)

Adopted Water cement ratio W/C = 0.5

4. Calculation of water content

Slum height for 20mm aggregate = 30 – 60mm

From table 3 fine aggregate = 180

Coarse aggregate = 210

= $^{2}/_{3}$ x 180 + $^{1}/_{3}$ x 210

= 120 + 70 = 190kg/m^3

Cement content

Cement content = $\frac{Water\ content}{Water\ cement\ ratio}$ = $\frac{190}{0.5}$ = 380kg/m^3

Since 380kg/m^3 is more than 350kg/m^3 as required by BS 8110 part 1 1985 hence it is alright.

Weight of total aggregate

Density of wet concrete = 2400kg/m^3

Summation of water content and cement content = 190 + 380 = 570

Total weight of aggregate = 2400 – 570 = 1830 kg/m^3

Percentage of fine aggregate is 40% = 1830 x 0.4 = 732

Percentage of coarse aggregate = 1830 – 732 = 1098

Hence

Table 3.2: Concrete Samples and the Proportions of their Constituent Materials

	Cement content (kg/m^3)	**Water content (kg/m^3)**	**Sand content (kg/m^3)**	**IOT content (kg/m^3)**	**gravel content (kg/m^3)**	**% of IOT replacement**
$CIIT_0$	380	190	732	0	1098	0%
$CIIT_{10}$	380	190	658.8	73.2	1098	10%
$CIIT_{20}$	380	190	585.6	146.4	1098	20%
$CIIT_{30}$	380	190	512.4	219.6	1098	30%
$CIIT_{40}$	380	190	439.2	292.8	1098	40%

Table 3.3 Concrete Samples and the Proportions of their Constituent Materials in kg

Materials	**Cement**	**Fine aggregate**	**Coarse aggregate**	**Water**
Quantity kg/m^3	380.0	732.0	1098.0	190.0
Ratio	1.00	1.93	2.9	0.5
1 bag cement	50.0	96.5	145	25

3.3.4 <u>Batching for laboratory testing</u>

1. Total number of beams for one batch = 12

   Size of beam = 100 x 100 x 500

   Volume of beam = 0.1 x 0.1 x 0.5 = 0.005m^3

   Total volume of concrete in beam = 12 x 0.005m^3

   = 0.06m^3

   From the design mix

   Cement = 380kg/m^3 fine = 732 kg/m^3 coarse = 1098kg/m^3

   Cement = 380 x 0.06 = 22.8kg

   Fine = 732 x 0.06 = 43.92kg

   Coarse = 1098 x 0.06 = 65.88kg

   Water = 190 x 0.06 = 11.4kg

Table 3.4 Concrete batching and the Proportions of their Constituent Materials for beam

	Cement content (kg/m³)	Water content (kg/m³)	Sand content (kg/m³)	IOT content (kg/m³)	Gravel content (kg/m³)	% of IOT replacement
$CIIT_0$	22.8	11.4	43.92	0	65.88	0%
$CIIT_{10}$	22.8	11.4	39.528	4.392	65.88	10%
$CIIT_{20}$	22.8	11.4	35.136	8.784	65.88	20%
$CIIT_{30}$	22.8	11.4	30.744	13.176	65.88	30%
$CIIT_{40}$	22.8	11.4	26.352	17.568	65.88	40%
Total(kg)	114	57	175.68	44.46	329.4	

Hence
Assume 25% wastage for each

Cement	= 114kg	=	114 x 1.25	=	142.5kg
Water	= 57kg	=	57 x 1.25	=	71.25kg
Sand	= 175.68kg	=	175.68 x 1.25	=	219.6kg
Tailing	= 44.46kg	=	44.46 x 1.25	=	55.575kg
Coarse	= 329.4kg	=	329.4 x 1.25	=	411.75kg

<u>Batching for cylindrical cube</u>

Total number of cubes per set	=	4		
Size of cylinder	=	300 x 150		
Volume of cylinder	=	$\pi r^2 h$		
Volume of cylinder	=	$\pi \times 0.15^2 \times 0.3$	=	$0.0212m^3$
	=	4 x 0.0212	=	0.0848
Cement	=	$380kg/m^3$		
Fine aggregate	=	$732\ kg/m^3$		
Coarse	=	$1098\ kg/m^3$		
Cement	=	0.0848 x 380	=	32.234
Fine aggregate	=	0.0848 x 732	=	62.090
Coarse aggregate	=	0.0848 x 1098	=	93.136
Water	=	0.0848 x 190	=	16.12

Table 3.5: concrete batching and the Proportions of their Constituent Materials for cylindrical cube

	Cement content (kg/m^3)	Water content (kg/m^3)	Sand content (kg/m^3)	IOT content (kg/m^3)	Gravel content (kg/m^3)	% of IOT replacement
CIIT$_0$	32.23	16.12	62.09	0	93.136	0%
CIIT$_{10}$	32.23	16.12	55.881	6.209	93.136	10%
CIIT$_{20}$	32.23	16.12	49.672	12.418	93.136	20%
CIIT$_{30}$	32.23	16.12	43.463	18.627	93.136	30%
CIIT$_{40}$	32.23	16.12	37.254	24.836	93.136	40%
Total (kg)	161.15	80.6	248.36	62.09	465.68	

Assume 25% waste

Cement	= 161.15	= 161.15 x 1.25	=	201.44
Water	= 80.6	= 80.6 x 1.25	=	100.75
Fine aggregate	= 248.36 x 1.25		=	310.45
Coarse	= 465.68	= 465.68 x 1.25	=	582.1

3.4 Equipment

The equipment used to carry out this research work includes; slump cone, electric weighing balance, vibrating table, British standard sieves, density bottle, stop watch, hand trowel, tamping rod, head pan, compression machine, compacting factor machine, bucket and 100mm × 100mm × 500mm wooden mould, 100mm x 300mm cylindrical mould

3.5 Experiment and Methodology

In this research there are basically two parameters to be determines,

a) Determination of physical properties of aggregates (sand, gravel and IOTs)

b) Determination of properties of fresh and harden concretes

3.5.1 Determination of physical properties of aggregates

Aggregate is a granular material that is inert and is mixed with other binding materials to produce any building construction material such as concrete or mortar. Aggregate is used as a filler for increasing the volume of the building material because it is cheap as compared to cement thus decreasing the total construction expenses and most importantly increasing its strength, durability, and hardness. In this research work the physical properties of aggregates that was examined includes, particle size distribution, specific gravity, bulk density (aggregate loose unit weight, aggregate compacted unit weight), coefficient of uniformity, coefficient of curvature, porosity and fineness modulus.

Plate IV: Sieve Analysis test in Progress

3.5.1.1 ***Particle size distribution (sieve analysis) test***

Sieve analysis can simply be described as the process of separating a sample of aggregate into fraction of same particle size. Each fraction consists of particles within specific limit, these being the openings of the standard sieves. The sieves are mounted in frame so that they are placed in descending order with the largest at the top and the smallest at the bottom. The particle size analysis was carried out to determine the grading of the aggregates in accordance with BS 812: part 103 1985. This was achieved by plotting the grain size curve of the aggregates and the determination of the Uniformity coefficient (Cu) together with the Coefficient of curvature (Cc).

Thus,

$$C_U = \frac{D_{60}}{D_{10}} \tag{3.1}$$

$$C_C = \frac{(D_{30})^2}{(D_{10} \times D_{60})} \tag{3.2}$$

3.5.1.2 ***Specific gravity test***

The specific gravity is the fundamental physical characteristic of the material. Specific gravity is the ratio of mass of a unit volume of material to the mass of same volume of water at the same temperature. This test was carried out in accordance with BS EN 12620: (2002), a method of sampling and testing of mineral aggregate, sand and fillers.

Thus,

$$\text{specific gravity (Gs)} = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)} \tag{3.3}$$

Where,

W_1 = weight of the empty glass jar

W_2 = weight of glass jar + dry sample

W_3 = weight of glass jar + dry sample + water

W_4 = weight of glass jar + water

Plate V: Specific Gravity test in Progress

3.5.1.3 ***Bulk density test***

Bulk density is defined as the actual mass of the sample that would fill a container of unit volume and this density is use to convert quantities by mass to quantity by volume. The density depends on how densely the aggregate are packed and consequently on the size distribution of the particles. Thus, the degree of compaction has to be specified by 12620: (2002), which recognizes two degrees: loose (uncompacted) and compacted.

3.5.1.4 ***Aggregate crush value***

The aggregates crushing value gives a relative measure of resistance of an aggregate to crushing under gradually applied compressive load. The aggregate crushing strength value is a useful factor to know the behaviour of aggregates when subjected to compressive loads.

Thus,

Aggregate Crushing Value = $(W_B/W_A) \times 100$

Where,

Weight of Aggregate in the cylindrical steel cup = W_B

Weight of Aggregate passing through 2.36mm sieve = W_A

Plate VI: Aggregate crushing value test

Plate VII: Aggregate crushing value test in Progress

3.5.2 Determination of properties of fresh and hardened concrete

Concrete is the most commonly used man-made material on earth. It is an important construction material used extensively in buildings, bridges, roads and dams. Its uses range from structural applications, to paviors, kerbs, pipes and drains. It is also referred to as composite material, consisting mainly of Portland cement, water and aggregate (gravel, sand or rock).When these materials are mixed together, they form a workable paste which then gradually hardens over time. Concreter can be described in two sates fresh and hardened concrete. The properties of each state of the concrete and the test conducted on them is as stated below

***3.5.2.1* Properties of fresh concrete**

A concrete is said to be fresh when it is found in a plastic state. Plastic state in the sense that it can easily be moulded into a durable structural member of any shape and size. In this research the major properties of the fresh concrete that was examined was workability test which is measured through slump test and compacting factor test.

***3.5.2.2* Workabi1ity test (s1ump test)**

Workability is the relative ease or difficulty of placing and consolidating concrete. S1ump test was used to assess the workabi1ity of the concrete and average slum high of 75cm was obtained. The s1ump test measures the free unrestricted deformabi1ity in accordance to BS *BS* 1881: part 102

3.5.2.3 **P*roduction of concrete cubes***

A total of sixty (60) concrete cubes specimen of wooden mould size 150mm × 150mm × 500mm was produced for this study. Batching and casting of the concrete cubes was carried out in accordance with BS 1881: part 109 (1983) with mix ratio according to the design and a constant water cement ratio of 0.5. The mix design was used to select the required proportion of the constituent materials which include cement, iron ore tailings, water and aggregate to produce concrete that satisfies the requirements of strength, workability and durability. The test specimens are stored in stable room temperature for 3 days, protected against shock, vibration and dehydration at temperature of 25 °C ± 5 °C (hot c1imates). After this period the specimens are marked and removed from the moulds and kept submerged in c1ear fresh water at low temperature of 10 °C unti1 taken out prior to test. Twelve (12) cubes were cast as control, while the cement, water and gravel remain constant the sand is being replaced in percentage of 10%, 20% 30% and 40% with the tailings.

Plate VIII: Production of Concrete Beams Samples

Plate IX: Production of concrete beams samples

Plate X: Concrete beams samples

***3.5.2.4* Mixing of concrete**

The mixing of the concrete was done manually based on the volume to be used. The required quantities of samples, coarse aggregate, fine aggregate, water, cement, iron ore tailings were calculated and weighed with a pan on weighing balance. The whole samples were then mixed thoroughly to achieve the final uniformity. As soon as uniformity was achieved, slump test and compaction factor test were carried out on the fresh concrete.

P1ate XI: Mixing of concrete at Federal Poly Bida Civi1 Engineering Laboratory

3.5.2.5 **T*est on fresh concrete***

The following test was carried out on the prepared fresh concrete. They include: slump test and compacting factor test.

3.5.2.6 **S*lump test***

This test is utilized to determine the workability of fresh concrete that is normally embraced at the point of conveyance to guarantee that the concrete is in sufficient consistency for placement. The mould of slump test is a frustum of a cone 30.5mm in height and base 20.3mm in diameter. This test was carried out in accordance with BS 1881: part 102 (2013).

P1ate XII: S1ump testing in Federal Poly Bida Civi1 Engineering Laboratory

P1ate XIII: Slump test in Federal Poly Bida Civi1 Engineering Laboratory

P1ate XIV: Slump test in Federal Poly Bida Civi1 Engineering Laboratory

3.5.2.7 **C*ompacting factor test***

In compacting factor test, a standard amount of work was done on the concrete mix, the work done is the product of the weight of the concrete and the height through which it falls. This test measures the degree of compaction and is defined as the ratio of the weight of the partially compacted concrete to the weight of the same volume of fully compacted concrete. The test was carried out in accordance with BS 1881: Part 103. (2013)

Plate XVI: Compacting factor test in Federal Poly Bida Civi1 Engineering Laboratory

P1ate XVII: Compacting factor test at Federal Poly Bida Civi1 Engineering Laboratory

3.5.2.8 ***Curing of concrete cubes***

Curing is the name given to techniques utilized for advancing the hydration of concrete. It is also a procedure or a technique by which concrete element is kept from drying out too rapidly or quickly within a brief period of time. BS 8110 (2005) and Euro code comprehensively require a minimum but varying time period during which curing methods ought to be maintained. Curing of the concrete cubes was done by the method of ponding (immersion of the cubes into water) and was carried out for a period of 7, 14, 21 and 28 days only.

P1ate XVIII: Curing of concrete sample at Federal Poly Bida Civi1 Engineering Laboratory

P1ate XIX: Removal of formwork from the concrete beam

3.5.2.9 **T*ests on hardened concrete***

Hardened concrete considers essential properties, which are held for the life of the concrete. The essential properties of hardened concrete include density, strength, deformation under load and durability. In general, density and strength of hardened concrete were considered for this project work.

3.5.2.10 **D*ensity test***

Density is characterized as the mass of particles of the material divided by the total volume they possess. The total volume includes particle volume, inter-particle void volume and internal pore volume. For this project work, density of concrete was determined after the 7th 14th 21st and 28th days of curing. The concrete cubes were removed from the curing tank and allowed to dry for 3 minutes; weight and density of each cube will then be determined.

Thus,

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} \tag{3.6}$$

3.5.2.11 **C*ompressive strength test***

Compressive quality is the limit of a material or structure to withstand axially coordinated pushing force. It is additionally characterized as the maximum compressive load a concrete can take per unit area. It was carried out to determine maximum compressive strength of concrete cubes after 7th ^{14th} 21st and 28th days of curing. This test was carried out based on the specification in concrete cubes, BS EN 12390: Part 3(2009)

P1ate XX: Compressive testing in Federal Poly Bida Civi1 Engineering Laboratory

Thus,

$$\text{Compressive strength} = \frac{\text{Crushed load}}{\text{Surface area of concrete}} \tag{3.7}$$

3.5.2.12 ***Split tensile strength test***

This is an indirect test to determine the tensile strength of cylindrical specimens. Tensile strength tests were done on 300mm long and 150mm diameter cylinder concrete specimens at 7, 14, 21 and 28days of curing as per the procedure specified in BS EN 12390: Part 6 (2009). Figure 3.5 shows the experimental set up for tensile strength. Cylinder specimens were tested at 7, 14, 21 and 28days in a servo hydraulic 1000kN UTM and the maximum load applied to the specimen were then recorded. Average of three values was taken as the representative of batch.

P1ate XXI: Tensile strength testing in Federal Poly Bida Civi1 Engineering Laboratory

3.5.2.13* F*lexural strength

Flexural strength is defined as a materials ability to resist deformation under load. The determination of flexural strength is essential to estimate the load at which the concrete members may crack. The flexural strength was determined according to BS EN 12390: Part 5(2009) by testing standard test specimens (prisms) of size 100mm x 100mm x 500mm with various percentages of IOTS (0, 10, 20, 30, and 40%) and tested at 7,14,21and 26th day under symmetrical two-point loading. The flexural strength was `calculated using the formula,

$$f_{cr} = \frac{PL}{BD^2} \tag{3.8}$$

Where

f_{cr} = Flexural strength of the specimen in N/mm^2

P = Maximum load applied to the specimen

L = Span of the specimen

B = Width of the specimen, and

D = Depth of the specimen at the point of failure

The flexural behaviour of a specimen nearest to the average of the flexural strength (with the difference less than 10% through the mean and standard deviation less than 0.6 N/mm^2) was selected as a representative of that group.

P1ateXXII: Flexural testing in Bida Civi1 Engineering Laboratory

P1ate XXIII: Flexural testing in Bida Civi1 Engineering Laboratory

CHAPTER FOUR

4.0 RESULTS AND DISSCUSION

4.1 General

This investigation presents the experimental results on the partial replacement of sand with itakpe iron ore tailings (IIOT) on flexural strength of concrete beams with 0, 10, 20, 30 and 40% IIOT subjected to bending when tested at 7th, 14th, 21th and 28th day. The various parameters taken for the study are, material characterization, mix design of concrete with IIOT, properties of fresh and hardened concrete, and the flexural testing of concrete beams.

4.2 Aggregate Characterization Result

4.2.1 Particle size analysis for aggregates, sand,

The results of particle size analysis of fine and coarse aggregates used in this study are presented in Table 4.1, Table 4.2, Table 4.3 Figure 4.1, 4.2 and 4.3 respectively. Figure 4.1 and 4.2 shows the distribution curve of fine aggregate, while figure 4.2 shows distribution curve of the coarse aggregate. From the distribution curve it can be observed that the IOT curve has D10 turning to zero this shows that the iron ore are finer than the sand used which turns the coefficient of uniformity Cu and coefficient of curvature to zero. On the other hand, the sand and the granite show a positives coefficient of curvature and uniformity this indicates that the sample are well graded which corresponds with the Unified Soil Classification System (USCS).

Table 4.1: Particle size analysis of Sand

PARTICLE SIZE DISTRIBUTION OF FINE AGGREGATE (SHARP SAND)				
Sieve size (mm)	Mass Retained (g)	Cumm. Mass Retained (g)	% Retained	% Passing
4.75	2.20	2.20	0.44	99.56
2.36	4.50	6.70	1.34	98.66
1.18	36.30	43.00	8.62	91.38
0.6	155.30	198.30	39.76	60.24
0.3	221.10	419.40	84.08	15.92
0.15	74.30	493.70	98.98	1.02
0.075	4.00	497.70	99.78	0.22
Pan	1.10	498.80	100.00	0.00

Table 4.2: Particle size analysis of Iron ore Tailings (IOT)

PARTICLE SIZE DISTRIBUTION OF IRON ORE TAILLINGS (IOT)				
Sieve size	Mass Retained (g)	Cumm. Mass Retained (g)	% Retained	% Passing
4.75	0.00	0.00	0.00	100.00
2.36	0.90	0.90	0.20	99.80
1.18	28.70	29.60	6.53	93.47
0.6	69.90	99.50	21.96	78.04
0.3	105.90	205.40	45.34	54.66
0.15	117.30	322.70	71.24	28.76
0.075	68.60	391.30	86.38	13.62
Pan	61.70	453.00	100.00	0.00

Table 4.3: Particle size analysis of Sand

PARTICLE SIZE DISTRIBUTION COARSE AGGREGATE (GRANITE)				
Sieve size	Mass Retained (g)	Cumm. Mass Retained (g)	% Retained	% Passing
37.5mm	0.00	0.00	0.00	100.00
26.5mm	98.30	98.30	19.66	80.34
19.0mm	151.50	249.80	49.96	50.04
13.2mm	143.80	393.60	78.72	21.28
9.5mm	58.10	451.70	90.34	9.66
6.7mm	24.50	476.20	95.24	4.76
4.75mm	12.30	488.50	97.70	2.30
3.35mm	6.90	495.40	99.08	0.92
pan	4.60	500.00	100.00	0.00

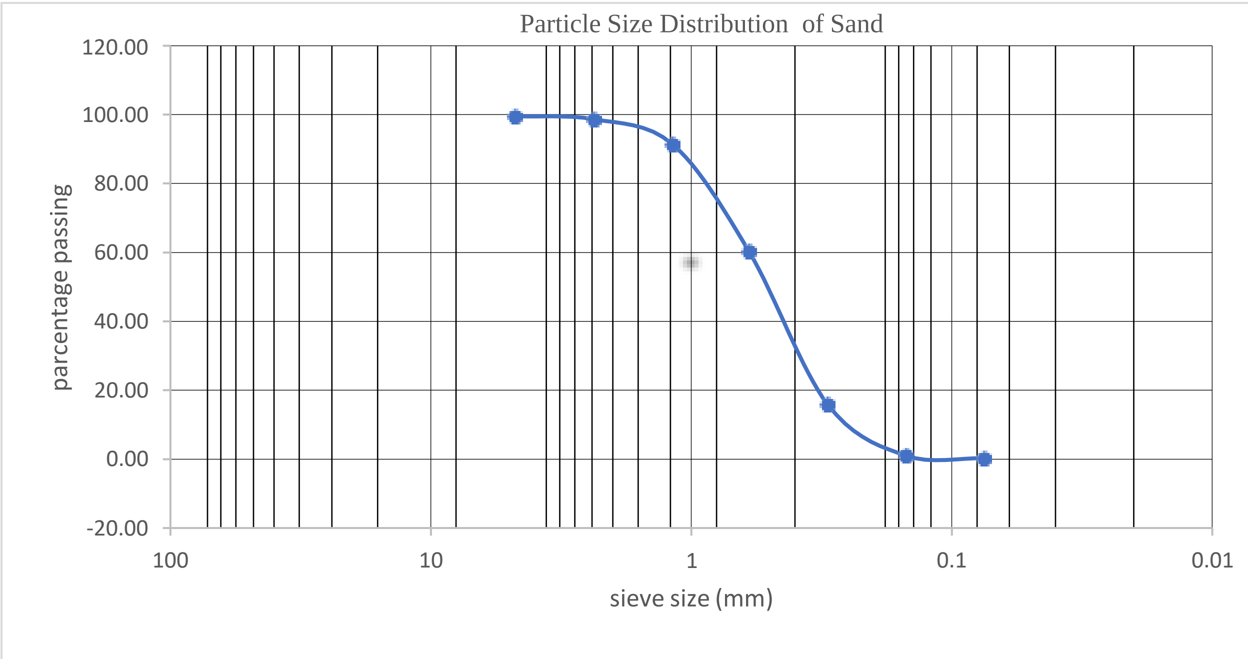

Figure 4.1: particle size distribution of fine aggregate (sand)

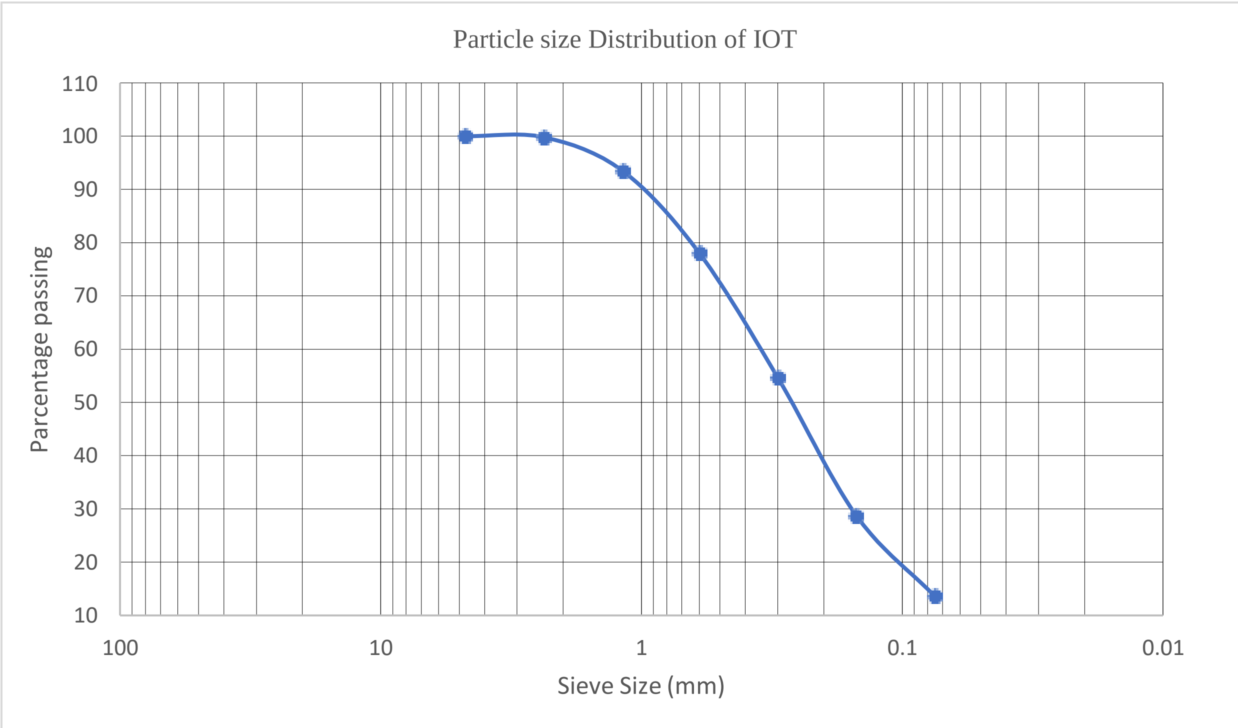

Figure 4.2: particle size distribution of fine aggregate (IOT)

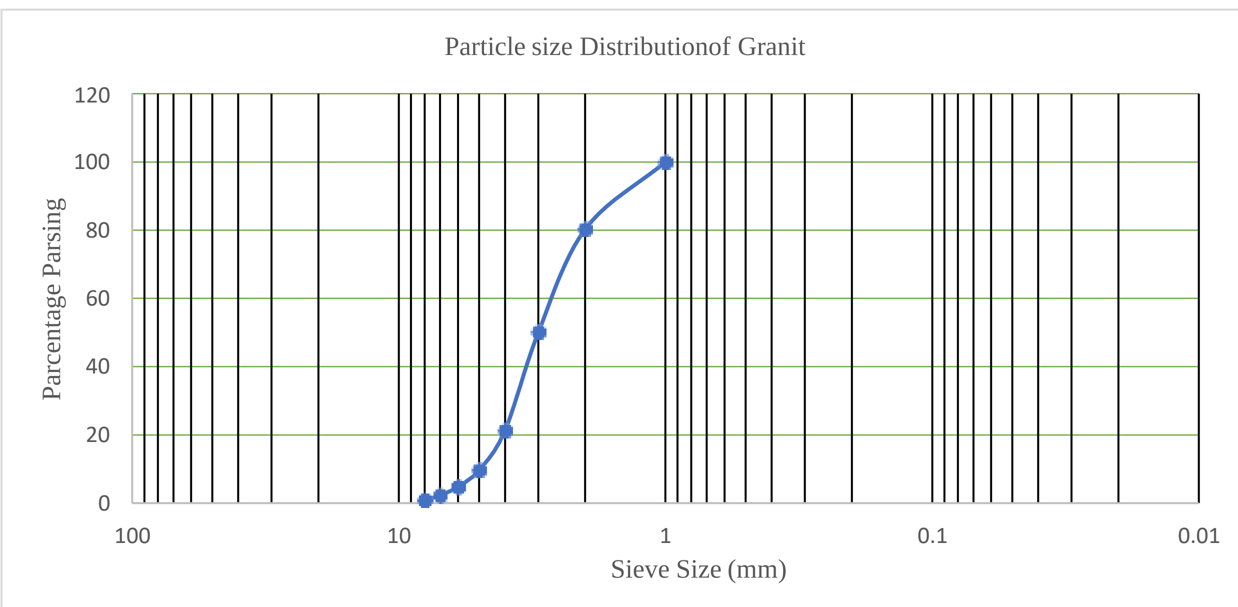

Figure 4.3: Particle size distribution of Coarse Aggregate

4.2.2 Specific gravity of aggregates, sand, granite and IOT

The result of specific gravity of the aggregates as shown in Table 4.4 shows that the specific gravity value of IOT was 2.55 over an average of three trials. The fine aggregate has a specific gravity value of 2.62 and that of coarse aggregate has a specific gravity value of 2.525 also over an average of three trials. These values are in accordance with the BS requirement of 2.6 to 3.0 for fine aggregate and 2.4 to 2.8 for coarse aggregate.

Table 4.4: Specific gravity of aggregates

NAME OFMATERIAL	SPECIFIC GRAVITY
SAND	2.506
IRON ORE TAILLINGS (IOT)	2.552
GRANITE	2.525

4.2.3 Bulk density of aggregates

The results of bulk density of aggregates, are as shown in Table 4.5. The value for compacted and un-compacted bulk density of IOT is 1680kg/m^3 and 1900kg/m^3. The results of bulk density depend on how the samples of materials are closely packed. IOTs are closely packed materials that are heavy in weight thereby leading to high coherent bulk density. The compacted and un-compacted bulk density of the fine aggregate (sand) is 1490kg/m^3 and 1580kg/m^3 while that of coarse aggregate (gravel) is 13104 kg/m^3 and 1490 kg/m^3. This correspond to the range of 1200-1800kg/m^3 specified by BS 812, part 2: 1995 for aggregates.

Table 4.5: Bulk density of aggregates

Name of materials used	Uncompacted value (Kg/m^3)	Compacted value (Kg/m^3)
Fine Aggregate (sand)	1490	1580
Coarse Aggregate (Gravel)	1310	1490
Iron Ore Tailings (IOT)	1680	1900

4.3 Properties of Fresh Concrete

4.2.1 Slump of concrete

The results of slump test for the concrete cubes containing IOT are shown in Table 4.7. The slump is a measure of workability of concrete, the difference in height between the standard cone and the height of concrete after slump gives the slump value. It was observed from the slump test result that the slump value reduces as the IOTS content increases upon inclusion in the mix from 0% to 40%, the difference in slump value when sand is partially replaced with IOTs shows the demand of water, hence giving rise to lower workability. Nevertheless, it can be decided that to achieve the required workability, mixes containing IOTs will require higher water content than the equivalent normal mixes

Table 4.6: Slump of fresh concrete

Percentage replacement (%)	IOT slump value (mm)
0	10
10	8
20	7
30	5
40	2

4.2.2 Compacting factor

The results of compacting factor test from Table 4.7 show that the compacting factor values increases with increase IOTs content up to 20%increases after which it declined. The compacting factor values increase from 0.83 to 0.85 at 20% replacement with IOT and declined as the replacement increased to 30% to 40%. Thus, indicating that the concrete becomes more workable up to 20% replacement and after which more water will be required as the percentage of IOT increase from 30% to 40%.

Table 4.7: Compacting factor of fresh concrete

Percentage replacement (%)	IOT Compacting Factor value (mm)
0	0.83
10	0.84
20	0.85
30	0.81
40	0.74

4.3.0 Compressive strength of concrete

The compressive strength of concrete cubes containing iron ore tailings (IOT) were investigated after a curing period of 7, 14, 21 and 28 days respectively. The summary of the results is as tabulated in table 4.8 and presented graphically in Figure 4.4.

Table 4.8: Compressive strength of concrete with partial replacement of sand with IOT

% OF IOT	7 DAYS	14 DAYS	21 DAYS	28 DAYS
0	16.38	21.22	22.4	25.06
10	17.65	21.75	22.71	25.29
20	21.71	22.68	23.11	26.80
30	21.34	22.49	23.05	25.63
40	21.21	21.84	22.98	25.14

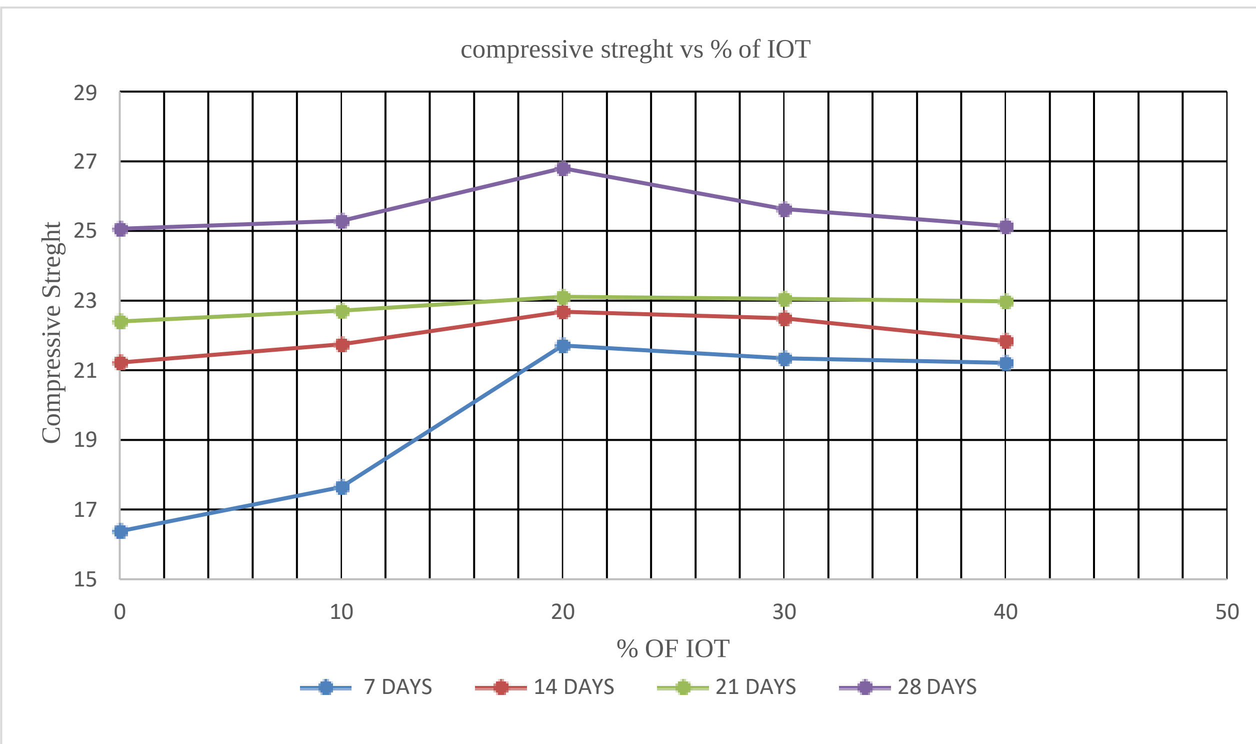

Figure 4.4: Compressive strength of concrete cubes with varying percentage of IOT

4.3.1 Effect of IOTs on the compressive strength of the concrete

The result of the effect of IOT on the compressive strength of concrete is shown in Table 4.10 and Figure 4.3. It can be seen from Table 4.10 that for the control concrete cubes (0%) the compressive strength increased from 16.38N/mm^2 at 7 days to 25.06N/mm^2 at 28 days, thus indicating the strength developed at 28 days falls under grade 25 concrete as stated by BS 8110, 1997. It can also be observed that concrete cubes containing the IOTs yielded a compressive strength value range from 10% to 20 % replacement level to be (17.65 N/mm^2 – 21.71N/mm^2) at 7 days to (25.29N/mm^2 – 26.80N/mm^2) at 28 days of curing. While It was also observed that an increment in the quantity of IOT resulted in decrease in compressive strength of the concrete cubes thus indicating that the compressive strength reduces as the percentage IOT goes above 20% replacement. The result also reveals that concrete cube containing OIT higher than 20% reduce the strength, of the concrete from 21.71 N/mm^2 – 21.21N/mm^2) at 7 days to 26.80 N/mm^2 – 25.14N/mm^2) at 28 days. This shows that the percentage decrease in strength between 20% IOT and 40% IOT replacement is just 4%. hence the strength value developed at 28 days still fall under grade 25 concrete as specified by BS 8110, 1997, thus indicating that it can still be used for reinforced concrete with lightweight aggregate.

4.3.1 Effect of IOTs on the Tensile strength of the concrete

Tensile strength tests were carried out on 300mm long and 150mm diameter cylinder concrete specimens at 7th, 14th, 21th and 28th days of curing. The experiment for tensile strength cylinder specimens were tested using servo hydraulic 1000kN Universal Testing Machine and the maximum load applied to the specimen were then recorded. Average of three values was taken as the representative of the batch as shown in table 4.11 and Figure 4.5. From the Table 4.11 and Figure 4.5, it is found that the split tensile strength of concrete with 20% of IOT is more than the control concrete specimens when tested at 7th, 14th, 21th and 28th days. But there is a gradual decrease in split tensile strength in concrete specimens beyond 20% replacement of IOT.

Table 4.9: Split Tensile strength of concrete with partial replacement of sand with IOT

% OF IOT	7 DAYS	14 DAYS	21 DAYS	28 DAYS
0	1.8018	2.122	2.016	2.2554
10	1.9415	2.175	2.0439	2.2761
20	2.3881	2.268	2.0799	2.412
30	2.3474	2.249	2.0745	2.3067
40	2.3331	2.184	2.0682	2.2626

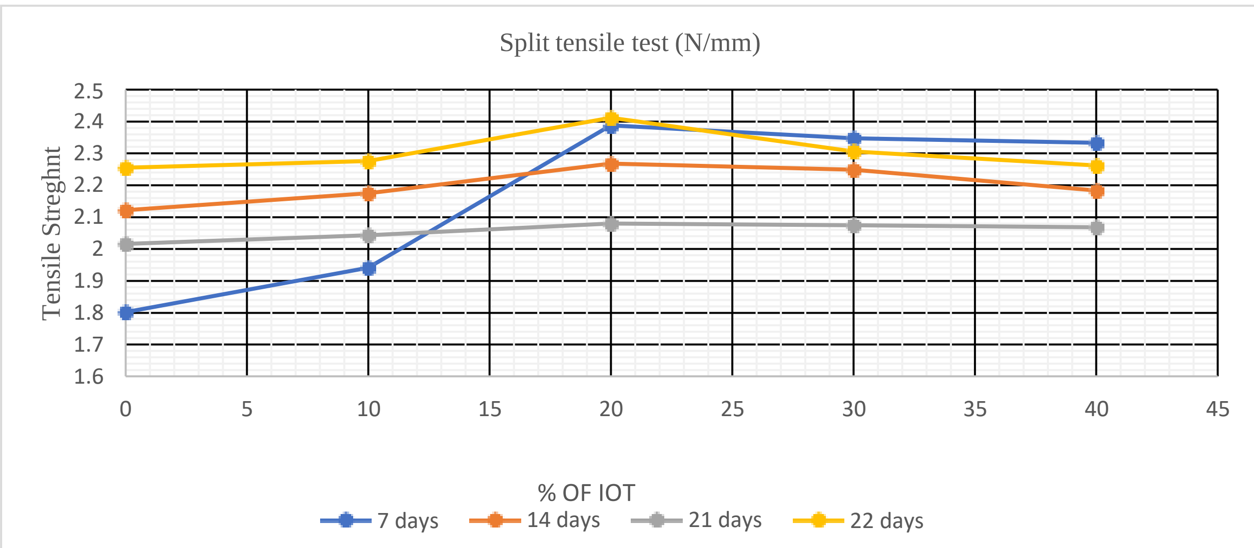

Figure 4.5: Split tensile strength of concrete cubes with varying percentage of IOT

4.4.0 Flexural strength of concrete

Flexural strength is defined as a materials ability to resist deformation under load. The determination of flexural strength is essential to estimate the load at which the concrete members may crack. The flexural strength was determined by testing standard test specimens (prisms) of size 100mm x 100mm x 500mm with various percentages of IOT (10%, 20%, 30%, and 40%) and tested at 7th, 14th, 21th and 28th days under symmetrical single-point loading. Average of three values was taken as the representative of the batch as shown in Table 4.10 and Figure 4.6.

Table 4.10: Flexural strength of concrete with partial replacement of sand with IOT

% OF IOT	7 DAYS	14 DAYS	21 DAYS	28 DAYS
0	1.79	2.23	2.35	2.59
10	1.91	2.29	2.37	2.61
20	2.28	2.37	2.41	2.75
30	2.25	2.35	2.4	2.63
40	2.24	2.29	2.39	2.59

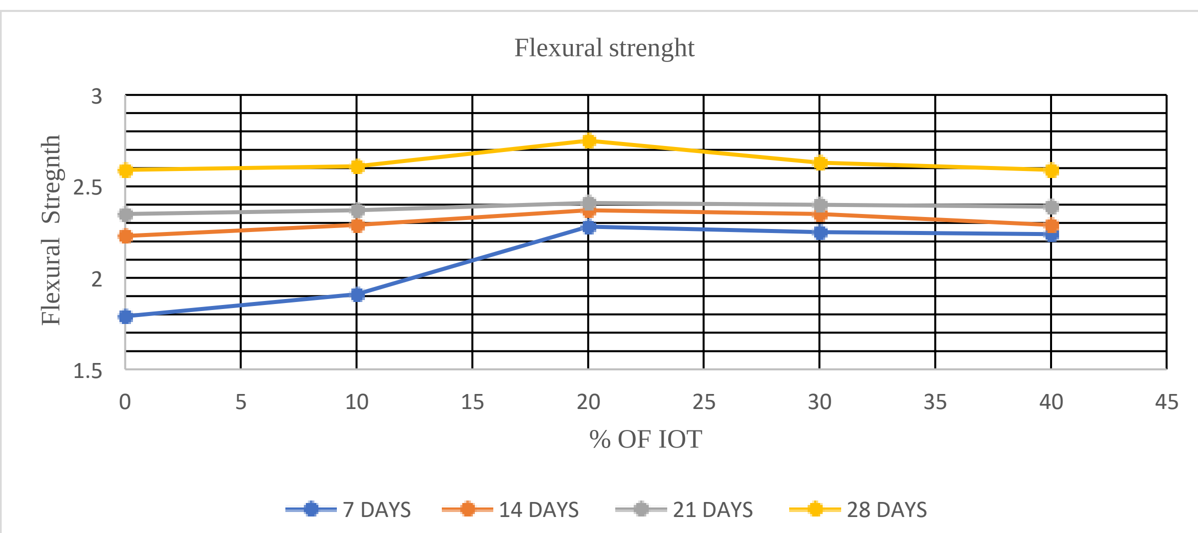

Figure 4.6: Flexural strength of concrete cubes with varying percentage of IOT

The result of the effect of IOT on the flexural strength of concrete as shown in Table 4.12 and Figure 4.6. Indicates that for the control concrete prism (0%) the flexural strength increased from 1.79N/mm^2 at 7 days to 2.59N/mm^2 at 28 days. It can also be observed that the maximum flexural strength was observe at percentage replacement of 20% in the range of 2.28N/mm^2 at 7 days to 2.75N/mm^2 at 28 days. A gradual decrease in flexural strength was also observed when the quantity of the iron ore tailings (IOT) was increase to 30% and 40%

CHAPTER FIVE

5.0 CONLUSION AND RECOMMENDATIONS

5.1 Conclusion

The following conclusions are made from the various experiments conducted on the flexural behaviour of concrete made with varying percentage replacement of sand with iron ore tailings (IOT) tested at 7, 14, 21 and 28 days intervals.

Increase in percentage replacement of sand with iron ore tailings resulted in decrease in slump value of the fresh concrete. This reveals that the iron ore tailings have higher affinity for water compared to the natural sand. The compacting factor test result for the fresh concrete also shows similar trend.

It was also observed that from the compressive strength, flexural strength and split tensile strength results that optimum level of percentage replacement of sand with IOT in concrete was attained at 20%.

5.2 Recommendations

The following recommendations were drawn from the experimental work:

i. It is recommended that further studies should be carried out on the flexural behavior of concrete beams incorporating iron ore tailings (IOT) by increasing the percentage replacement of IOT from 40% to 100% as the difference in strength for 0 to 40 % is just 4% which is very small

ii. Investigation may also be carried out to study the flexural behaviour of IOTs on pre-stressed concrete, fiber reinforced concrete and in precast elements.

iii. Similar studies can be conducted by varying the grade of concrete mix used.

5.3 Contribution to Knowledge

The study established that at up to 20% replacement of sand with IOT, compressive strength, spilt tensile strength and flexural strength values increase by 20% over the control.

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