PROPERTIES OF ITAKPE IRON ORE TAILINGS COMPARED TO NATURAL SAND

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Abstract

Nowadays due to higher demand for concrete, mortar and some other products in the construction industry and the problem of climate change ravaging all parts of the world, particularly in areas prone to erosion, there is a need for alternative material for natural sand as fine aggregate in concrete, mortar and some other construction products. In the process of obtaining natural sand as fine aggregate for concrete, mortar and some other construction products, more and more plant covers and water course are damaged and the environment can be seriously destroyed, hence the need for study into the use of Itakpe iron ore tailings (IIOTs) as a construction material. In this work, the structure of Silica which constitute the major chemical oxide in Itakpe iron ore tailings is highlighted. The physical properties of Itakpe iron ore tailings compared to that of natural sand were analysed. Also, the oxide composition of Itakpe iron ore tailings are presented and related to that of natural sand. The particle size distribution of Itakpe iron ore tailings are depicted and compared to that of natural sand. The output of the physical properties, oxide composition and sieve analysis of Itakpe iron ore tailings reveals that it has similar properties which are close in comparison to that of natural sand. This suggest that Itakpe iron ore tailings can be used to partially or fully replace natural sand in concrete, mortar and some other construction products. The use of IIOTs material for construction purpose will also reduce the problem of depleted natural sand and solid waste disposal, thereby promoting the sustainability of the construction industry.

Keywords: Itakpe Iron ore tailings, Sustainability, Silicate Structure, Oxide Composition, Natural Sand.

1.0 Introduction

The major oxide in the chemical composition of Itakpe iron ore tailings (IIOTs) is Silicon dioxide (SiO_2) with the highest percentage of 66 %. Silicon dioxide (SiO_2), or silica, is the most abundant of all the oxide minerals in the Earth's crust, it is present in not only in combination with other oxide minerals but also in its isolated forms such as sand. Besides being the most abundant mineral on the Earth, it is also very important to life (Oritola *et al.,* 2019). Attempt has been made in the past to determine the oxide composition of Iron ore tailings. It is possible to have ten different types of Iron ore tailings and all the ten depicting different percentage of oxide composition. Table 1 depicts the oxide composition of Iron ore tailings obtained from some countries of the world as reported by Oritola *et al.,* (2015).

Vale et al., (2013), in their study of mineral composition of 19 Iron ore tailings pond, found out that, Iron ore tailings from different origins; do not have the same geotechnical behaviour. Iron ore tailings may even show similar grading, but the parameters cannot be generalized for mines in terms of mineralogy or beneficiation process, hence the need to carry out detailed study to determine the properties of Iron ore tailings {IOTs) for specific locations. Studies has also been carried out in the past to determine the similarities that exists between IOTs and Natural Sand in terms of the composition of their chemical elements. This is usually achieved through the application of Electron Dispersive Spectroscopy (EDS). A study carried out by Oritola *et al.,* (2019) in relation to this, is depicted in Table 2.

Natural sand is the conventional fine aggregate in concrete production. It is also the major material used in producing mortar and some other construction products. However, there has been extensive research into alternative materials suitable to replace sand in concrete and in the production of mortar and some other construction products. The need to find replacement for sand stems from the fact that in most parts of the world, there is growing concern about the depletion of sand deposits, environmental and socio-economic threats associated with extraction of sand from river banks, coastal areas and farm lands (Aditya and Lakshmayya, 2016).

Some alternative materials which have been studied for use as partial replacement for sand include slag limestone, silica stone and recycled fine aggregate (Siddique, 2003). Ugama *et al.* (2014); Uchechukwu and Ezekiel (2014) examined the feasibility of using Iron Ore Tailings (IOTs) as a substitute for sand, by determining the physical properties of IOTs. They also determine the compressive and tensile strengths of concrete produced using IOTs to partially replace sand.

Itakpe iron-ore deposit has an ore reserve of about 200 million tonnes with an average of 36% iron content, a conservative mine life of 25 years, with an average production rate of 8 million tonnes per year (Audu *et al.*, 2003; Oladeji *et al.*, 2015). The Itakpe iron ore deposit in Nigeria which has a total estimated reserve of about 182.5 million metric tonnes consists mainly of quartzite with magnetite and hematite (Soframines, 1987; Ajaka, 2009). The Itakpe project was designed to treat a minimum of 24,000 tons of ore per day and operate 300 days per year. The main aim of this study is to highlight the potential of Iron ore tailings, generated at National ore smelting company, Itakpe. Rather than this tailings being discarded, it can be utilized as a construction material, thereby saving cost and promoting the sustainability of the construction industry.

Table 1. Composition of Oxides in Iron ore tailings from Selected Countries (Oritola *et al.*, 2015)

Oxides in IOTs	**Composition from various countries (%)**				
	Itakpe Nigeria	K/Tinggi Malaysia	Goa India	Miyum China	Rui China
Fe_2O_3	15	22.1	44.4	8.1	7.0
SiO_2	66	37.2	51.1	69.5	70.3
Al_2O_3	3.8	10.7	1.2	7.4	8.4
CaO	1.8	8.5	0.2	4.1	3.9
MgO	1.2	1.0		3.7	3.0
Mn_2O_3	1.0	1.0		-	-
Na_2O		0.5		1.4	1.7
K_2O		1.7		2.0	2.6
SO_3		0.3		0.1	2.0
TiO_2		0.4		0.1	-
LOI		-		2.5	-

Table 2. Composition of Chemical Elements in Iron ore tailings and Natural Sand

(Oritola *et al.*, 2019)

Chemical Elements	**Composition by Weight (%)**	
	Natural Sand	Iron ore tailings
Oxygen	49.0	33.4
Silicon	27.4	20.0
Iron	-	19.3
Aluminum	12.3	5.5
Carbon	6.4	12.6
Fluorine	-	5.3
Titanium	0.1	0.2
Moixture	4.7	3.5

2.0 Structure of Silicate

The structural unit for the simplest silicate, SiO_2, also known as silica, is the tetrahedron with the silicon atom at the centre surrounded by large open circles of oxygen. The SiO_4 tetrahedron has a formal charge of −4, which must be neutralized with cat-ions, such as other Si atoms, in real compounds. Pauling's second rules indicate that the bond strength in silicon is 1, and the third and fourth rules shows that, the corners of the tetrahedral are generally shared. This is not always the case, and different macroscopic silicate structures results, depending on how the tetrahedral are combined. Corners, edges, or faces of tetrahedral can be shared.

As the nature of combination of the tetrahedral changes, so must the O/Si ratio, and the charge neutrality is maintained through the addition of cat-ions. These structures are summarized in Table 3. Crystalline Silicate Network, when all four corners of the SiO_4 tetrahedral are shared, it results in a highly ordered array of networked tetrahedral such as the structure of quartz, one of the crystalline forms of SiO_2. From Table 3, even though the O/Si ratio is exactly 2.0, the structure is still composed of isolated $(SiO_4)_4$− tetrahedral.

Each oxygen on a corner is shared with one other tetrahedron, however, there are in reality only two full oxygen atoms per tetrahedron. There are actually several structures, or polymorphs, of crystalline silica, depending on the temperature. Quartz, with a density of 2.655 g/cm^3, is stable up to about 870◦C, at which point it transforms into tridymite, with a density of 2.27 g/cm^3. At 1470◦C, tridymite transforms to cristobalite with density of 2.30 g/cm^3), which melts at around 1710◦C. There are high and low forms of each of these structures, which result from slight, albeit rapid, rotation of the silicon tetrahedral relative to one another.

Table 3. Structural units observed in crystalline silicates

O/Si Ratio	Silicon–Oxygen groups	Structural units	Examples
2	SiO_2	Three-dimensional network	Quartz
2.5	Si_4O_{10}	Sheets	Talc
2.75	Si_4O_{11}	Chains	Amphiboles
3.0	SiO_3	Chains, rings	Pyroxenes beryl
3.5	Si_2O_7	Tetrahedra sharing one oxygen ion	Pyrosilicates
4.0	SiO_4	Isolated orthosilicate tetrahedra	Orthosilicates

3.0 Composition of Oxides in Itakpe Iron ore tailings

X-ray fluorescence (XRF) microscopic method was used to determine oxides composition of Itakpe Iron ore tailings and the result is presented in Figure 1. The emission of characteristic secondary (fluorescent) X-rays from the IIOTs was excited by bombarding it with high-energy X-rays which resulted in the chemical analysis of the material. The outcome of the oxides composition of Itakpe Iron ore tailings shows that the material has strong similarity with natural sand with regards to their oxides content. The dominant oxides in most natural sand (arranged in decreasing order of percentage by weight) are Silicon dioxide, Iron tri-oxide, Aluminum tri-oxide and Calcium oxide. This trend is also displayed by Itakpe Iron ore tailings.

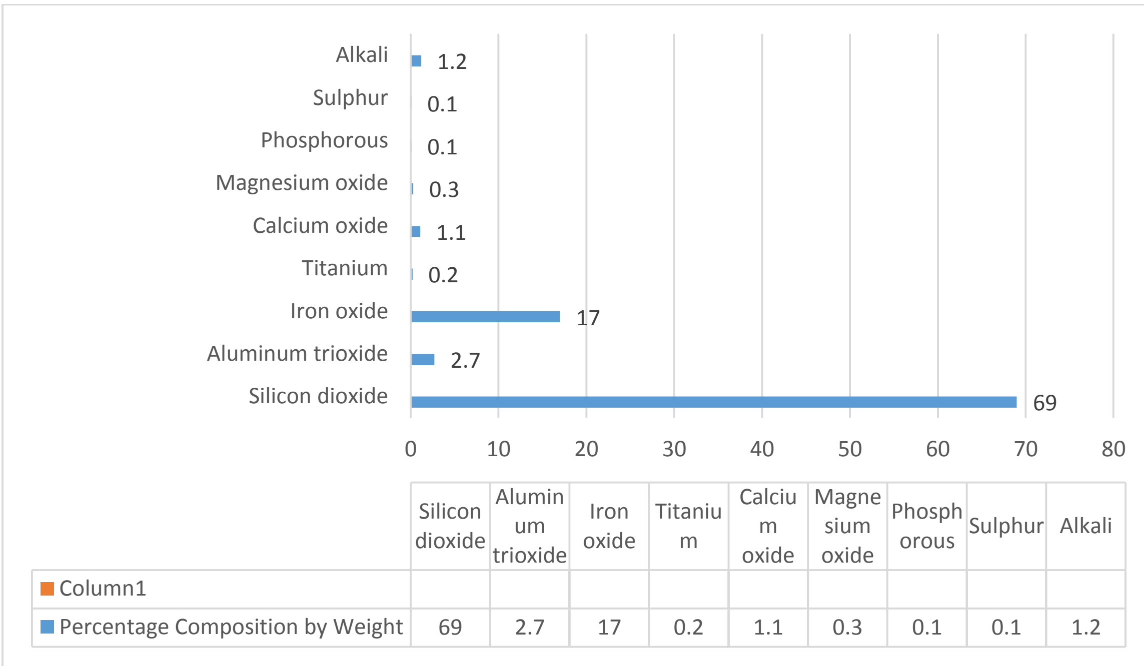

Figure 1. Chemical Composition of Oxides contained in Itakpe Iron ore tailings

4.0 Physical Properties of Itakpe Iron ore tailings

The photographic images of Itakpe Iron ore tailings and Natural sand as shown in Figure 2 reflects resemblance in texture of the two materials. The particle size distribution of Natural Sand and Itakpe Iron ore tailings as shown in Figure 3 reveals that the percentage passing the 600 µm sieve is 43% for Natural sand and that of Itakpe Iron ore tailings is 92% . This indicate availability of finer particles in IIOTs compared to Natural sand. The sieve analysis outcome indicates that the the particle size distribution of Itakpe Iron ore tailings and Natural sand, falls within the British Standard (BS) upper and lower limits.

The Itakpe iron ore tailings recorded specific gravity value of 3.12 while 2.65 was obtained for the Natural Sand as indicated in Table 4. The higher the specific gravity of any material the finer is the material, implying that the Itakpe Iron ore tailings has finer particles than Natural sand. The fineness modulus of IIOTs is 2.43 while that of natural sand is 3.49. For fine aggregate materials, the lower the value of fineness modulus, the finer is the material. The results of specific gravity and the particle size distribution tallies and confirmed the availability of more fines particles in Itakpe Iron ore tailings compared with Natural Sand.

Figure 2. Photographic images of Itakpe Iron ore tailings and Natural Sand

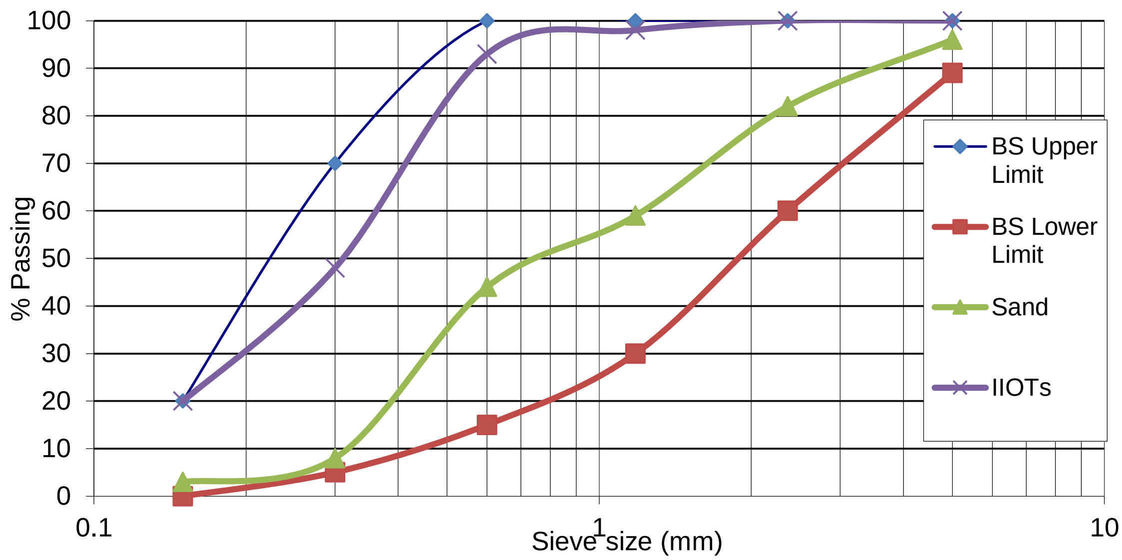

Figure 3. Particle size distribution of Itakpe Iron ore tailings and Natural sand

Table 4. Physical Properties of Itakpe Iron ore tailings and Natural sand

Materials	Physical Properties				
	Un-compacted Bulk Density (kg/m^3)	Compacted Bulk Density (kg/m^3)	Fineness Modulus	Moisture Content (%)	Specific Gravity
Natural Sand	1537.4	1688.7	3.29	2.41	2.65
Itakpe Iron ore tailings	1660.1	1924.5	2.43	5.74	3.12

5.0 Conclusion

Based on the outcome of this study, the following conclusion are deduced.

- The composition of chemical oxides in Itakpe Iron ore tailings is similar to that of Natural sand. The amount of each of these oxides by weight in percentage, is also comparable to that of Natural sand. This suggest that the Itakpe Iron ore tailings can be used to replace Natural sand for construction purpose.
- Due to the high content of Silica in Itakpe Iron ore tailings, it can be regarded as a pozolan, therefore it can contribute positively to the strength of concrete, mortar and other construction artifact it may be used to produce.
- The texture of Itakpe Iron ore tailings and the outcome of its particle size distribution, reveals that the material can serve effectively as fine aggregate, just like Natural sand.
- The fineness modulus and specific gravity of Itakpe Iron ore tailings suggest that, the material can be used to produce more dense concrete, mortar or any other construction products compared to Natural sand.
- The Itakpe Iron ore tailings is presently discarded as a waste material, instead of being a nuisance to the environment, it can be turned to an economic gain. This will promote the sustainability of the construction industry.

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