Properties of IOTs Concrete Produced using Fly-ash Cement

ORITOLA Sikiru Folahan[1]

[1]Department of Civil Engineering, Federal University of Technology Minna

sfaoritola@futminna.edu.ng

Abstract. This work studied the effect of using iron ore tailings (IOTs) as partial replacement for sand, on some mechanical properties of concrete, using class F brand fly ash (FA) cement as the binder. The results obtained, were compared among the different concrete samples produced, varying the percentage of iron ore tailings content in the concrete. Basic properties of the focused material, iron ore tailings (waste material generated during the production of iron ore), were determined and compared with those of natural sand, which is conventionally used to produce normal strength concrete. Similarly, the field emission scanning electron microscopic image and the energy dispersive X-ray spectroscopy of sand and the iron ore tailings were evaluated. Five different types of concrete samples were produced. The percentage of IOTs as partial replacement for sand, used in producing the concrete samples was varied from 0% to 40% at 10% interval. Water/cement ratio of 0.54 with class F fly ash cement content of 463kg/m^3, was used in preparing fresh concrete samples. The concrete samples produced, recorded lower workability with increase in content of iron ore tailings, but concomitantly there was increase in cohesiveness. There was increase in strength of hardened concrete samples with increasing content of the IOTs up to the optimum at 30%. This trend is similar for the compressive strengths, splitting tensile strengths and the flexural strengths. The outcome of this study revealed that, IOTs can be used to partially replace sand, for the production of normal strength concrete, using class F fly ash cement.

Keywords: Fine aggregate, Iron ore tailings, Fly ash cement, Normal strength concrete, Properties of concrete.

Introduction

Iron ore tailings are industrial waste product obtained from the production process of iron ore. This industrial waste, generated on daily basis is generally piled up at the mining site, leaching the ground, thereby polluting the underground and surface water as well as contaminating farmland. Some of these wastes are dumped in the tailing pond causing nuisance to the mining environment. According to (Saidi, Ait-Medjber, Safi, & Samar, 2014), considering the industries on a global trend, there is universal need to conserve resources, protect the environment and make good use of energy with a resulting impact to be felt in the field of concrete technology. Emphasis on the use of waste and byproducts for the manufacture of cement and concrete is invariably of great importance in research and application in the industry. It is important to note that, there are environmental impacts associated with cement and concrete production, but we must not lose sight of the role concrete and cementitious materials play in our built environment and the value of this built environment in the quality of our life. This implies there is need to find means of utilizing this waste material so that it does not constitute nuisance to the environment. If economic benefit can be derived by using the tailings in concrete, huge financial investment incurred on the production process can be recovered. Also the greenness of the environment can be improved by reducing the demand for virgin material such as sand. Plant covers will also be saved from destruction.

Some related works have been done in the past by researchers. The properties of concrete containing iron tailings and manufactured sand as fine aggregate, with the addition of admixtures fly ash and slag was reported by (Zhang, Zhang, Zhou, & Cheng, 2014). Past studies also revealed the use of iron ore tailings as green engineered cementitious composites (Huang, Ranade, Ni, & Li, 2013) as fine aggregate in the production of mortar (Yu, Zhang, & Mu, 2012) and as siliceous materials in ceramics (Liu, Xu, Zhang, Hao, & Di, 2009).

The use of fly ash cement for construction works, is currently gaining wider applicability globally. Determination of the performance of concrete using IOTs with this cement, will therefore make applicability recommendations feasible. Thus, the basis of this study tends to find out the effect of iron ore tailings as partial replacement for sand on the properties of concrete produced using class F fly ash cement as binder. This will bring about reduction in cost of concrete production and will also reduce problems associated with waste disposal.

Methodology

The methodology of this study, was done based on the following procedure:

- Materials collection.
- Determination of the physical properties of materials used for concrete production (BS812-103 & BS812-109) based on the British standard specifications. The chemical compositions of the iron ore tailings (based on the *X-ray florescence test)* was also determined. The result was compared with those obtained for some other mines as mentioned by (Rui, Wei, & Xiao, 2011). The *field emission scanning electron microscopic image* of sand compared to that of iron ore tailings were also studied. The e*nergy dispersive X-ray spectroscopy* of sand and the iron ore tailings were similarly evaluated.
- Design of normal strength concrete with water/cement ratio of 0.54 and cement content of 463kg/m^3 was used in preparing the fresh concrete. Five different types of concrete samples were produced. Each of the concrete sample contains fine aggregate content of 769kg/m^3, coarse aggregate of 868kg/m^3, and water content of 250kg/m^3. The description and proportioning of the concrete materials is shown in Table 1.
- Production of fresh concrete sample, the control and those containing iron ore tailings as partial replacement for sand based on varying percentage from 0 to 40%.
- Determination of fresh concrete properties.
- Curing of concrete samples until the prescribed date of testing.
- Determination of the properties of hardened concrete samples.

Table 1. Description and proportioning of concrete materials

Sample	Description	Constituents materials Kg/m^3				
		Water	Cement	Granite	Sand	IOTs
PCT0	Concrete with 0% IOTs	250	473	868	769	0
PCT10	Concrete with 10% IOTs	250	473	868	692	77
PCT20	Concrete with 20% IOTs	250	473	868	615	154
PCT30	Concrete with 30% IOTs	250	473	868	538	231
PCT40	Concrete with 40% IOTs	250	473	868	461	308

Results and Discussions

Fig. 1 shows the particle size distribution for sand, crushed granite and iron ore tailings. The chemical compositions of the Kota Tinggi iron ore tailings (based on the *X-Ray florescence test)* compared with some other mines as mentioned by (Rui, Wei, & Xiao, 2011) are indicated in Table 2. The *field emission scanning electron microscopic (FESEM) image* of sand compared to that of iron ore tailings is shown in Fig. 2, while Fig. 3 and Fig. 4 revealed the *energy dispersive X-ray spectroscopy* of sand and iron ore tailings respectively. Based on the FESEM image, it can be seen that within the same area, more particles of IOTs can be seen compared to sand. This indicate that the IOTs has larger particles per surface area, and is therefore more available to fill more void in concrete compared to sand.

The slump and the compacting factor tests were used in evaluating the workability of the fresh concrete produced, while samples of hardened concrete cubes, cylinder and prism were also tested for density, compressive strength, splitting tensile strength and flexural strength to describe the basic mechanical properties of the concrete. Tests results for consistency of the fresh concrete are presented in Table 3, while the results of density and compressive strength with age are presented in Fig. 5 and Fig. 6 correspondingly. The splitting tensile strength and flexural strength results are also shown in Fig. 7 and Fig. 8 respectively.

The slump of the concrete samples reduces with the increase in content of tailings. This result, tallies with the findings of (Zhao, Fan, & Sun, 2014). The rough surface and high specific surface area of the iron-ore tailings makes its affinity for water to be very high. The slump values obtained, lies within the range 105-153mm which can be regarded as high slump. Generally, based on result from previous studies, concrete produced with fly ash cement are usually characterized with high slump values.

The angular and rough texture of Iron ore tailings improves the compactness between the cement and aggregate interface, resulting in higher strength up to the optimum at 30%. The concrete sample PCT30 gave the highest compressive strength value of 28.1N/mm^2. The findings of (Zhang, Zhang, Zhou, & Cheng, 2014; Huang, Ranade, Ni, & Li, 2013; Yunfen, 2014) also show similar trend for the compressive strength of concrete containing iron ore tailings. The splitting tensile strength and flexural strength results also follows the trend of the compressive strength results. The concrete sample PCT30 recorded the highest splitting tensile strength value of 3.0 N/mm^2 while the highest flexural strength value of 5.0 N/mm^2 was also obtained through the same concrete sample.

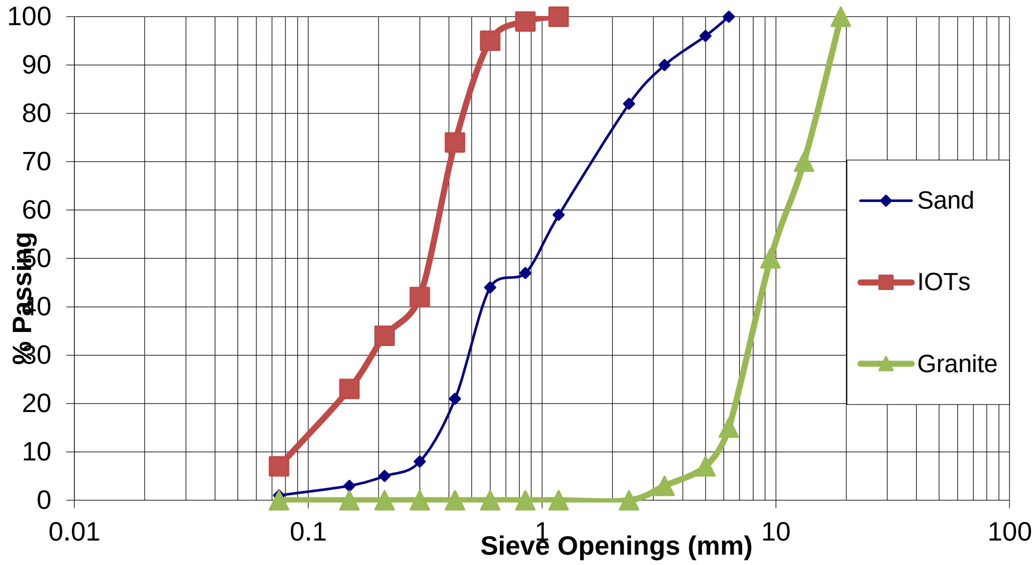

Fig. 1. Particle size distribution of aggregate

Table 2. Chemical composition of iron ore tailings

Chemical Content	Percentage compositions from various locations (%)					
	KTinggi Malaysia	Miyun China	Rui China	Sujing China	Itakpe Nigeria	Goa India
Fe_2O_3	22.1	8.1	10.4	9.1	15.0	44.4
SiO_2	37.2	69.5	58.8	52.1	66.0	51.1
Al_2O_3	10.7	7.4	11.8	17.1	3.8	1.2
CaO	8.5	4.1	5.1	12.7	1.8	0.2
MgO	1.0	3.7	6.1	3.7	1.2	-
Mn_2O_3	1.0	-	-	0.3	1.0	-
Na_2O	0.5	1.4	2.7	1.0	-	-
K_2O	1.7	2.0	1.6	0.3	-	-
SO_3	0.3	0.1	0.1	-	-	-
TiO_2	0.4	0.1	-	0.5	-	-
L O I		2.5	-	3.2	-	3.0

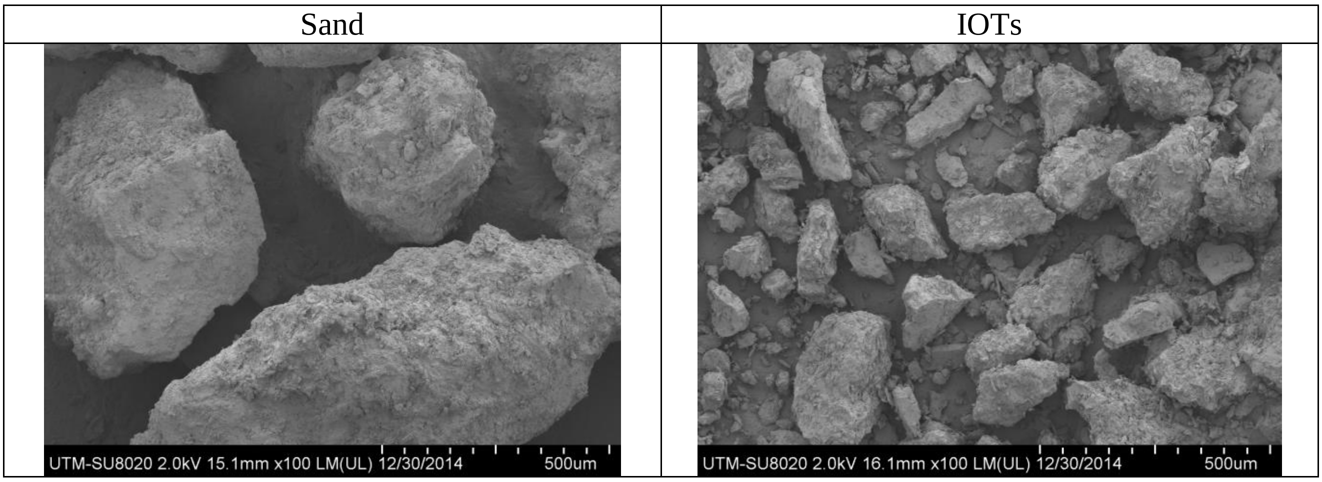

Fig. 2 FESEM morphology of sand compared with the IOTs at 500µm

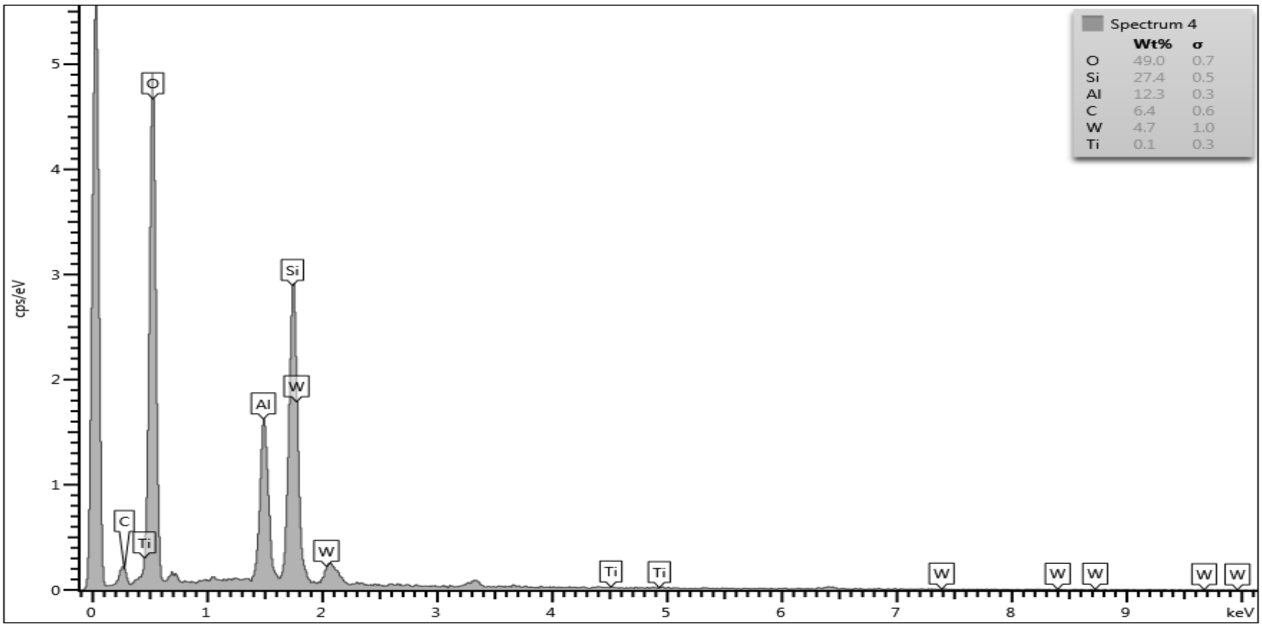

Fig. 3 Energy dispersive X-ray spectroscopy of sand

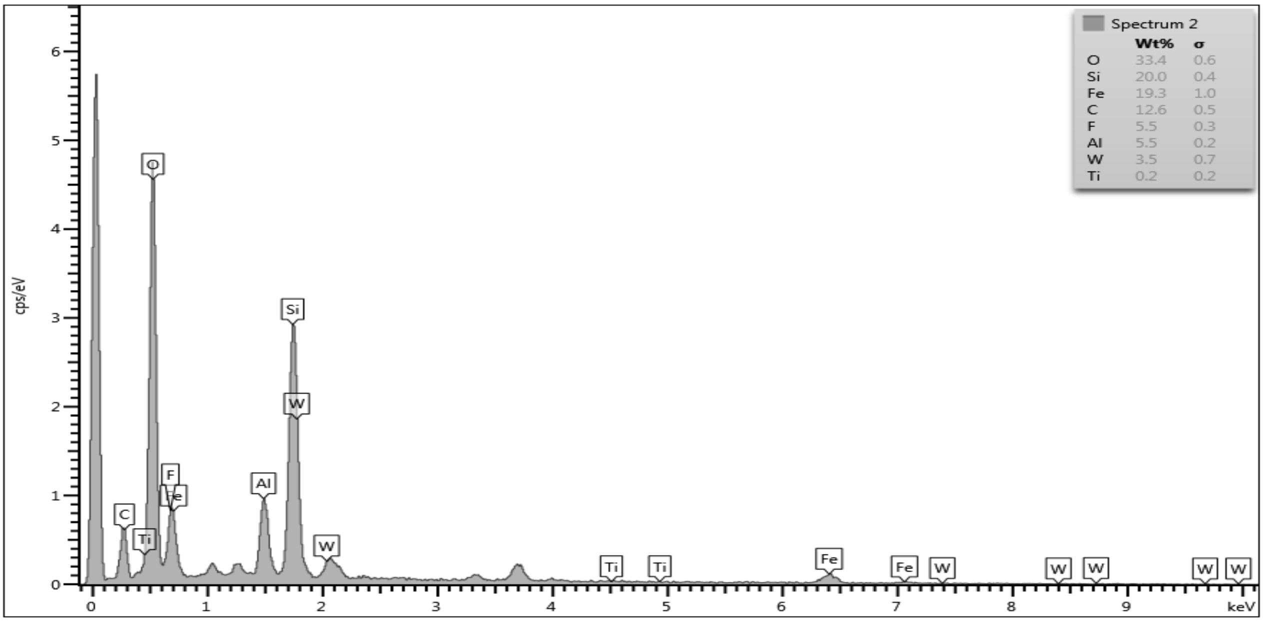

Fig. 4 Energy dispersive X-ray spectroscopy of IOTs

Table 3. Workability of concrete

Workability	Concrete samples				
	PCT0	PCT10	PCT20	PCT30	PCT40
Slump	147	142	131	119	105
Compacting factor	0.92	0.91	0.89	0.87	0.85

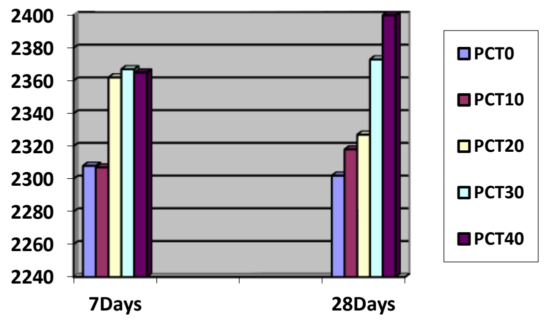

Fig. 5 Density of concrete Samples (kg/m^3)

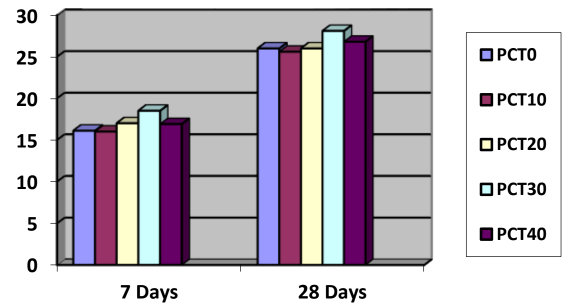

Fig. 6 Compressive strength of concrete samples (N/mm^2)

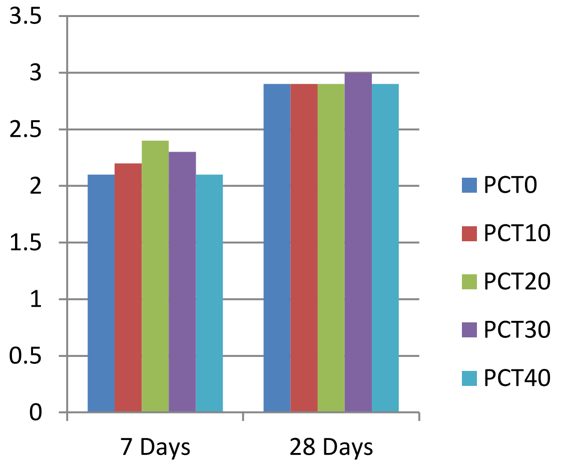

Fig. 7 Splitting tensile strength of concrete samples (N/mm^2)

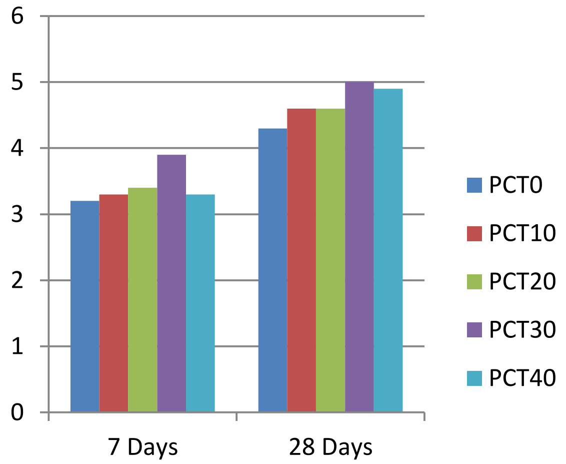

Fig. 8. Flexural strength of concrete samples (N/mm^2)

Conclusion

The outcome of this study revealed that, iron ore tailings has similar trend of grading with sand. It is possible to use the material as fine aggregate in concrete to partially replace sand.

The microscopic analysis shows that iron ore tailings is finer than sand. The fly ash cement, also has large specific surface area, the combination of which resulted in producing concrete with less void than those produced using only sand. The concrete samples which contains iron ore tailings are denser than those with only sand as fine aggregate.

The iron ore tailings, can be used to partially replace sand to improve the compressive strength, splitting tensile strength and flexural strength of concrete.

The waste material iron ore tailings, can be utilized as fine aggregate in concrete, for the construction of structural elements, where it is desired to have less permeable concrete.

Utilization of fly ash cement and iron ore tailings in concrete production, will bring about, reduction in cost of construction, thereby improving the sustainability of the construction industry.

References

British Standard Institutions, (1985). Methods for Determination of Particle Size Distribution, *BS 812*: part 103, London.

British Standard Institutions, (1990). Testing aggregates. Methods for determination of moisture content. *BS 812*: part 109, London.

Huang, X. Ranade, R. Ni, W. & Li, V. (2013). Development of green engineered cementitious composites using iron ore tailings as aggregates. *Construction and Building Materials,* 44, 757-764.

Liu, M., Xu, L. H., Zhang, X. M., Hao, H. S., & Di, Y. P. (2009). Preparation of eco-friendly composite ceramic from iron ore tailings. *Mater. Sci. Forum*, 803 (610), 281-284.

Rui, B., Wei, J., & Xiao, F. (2011). Study on Reducing ASR Expansion in Concrete Prepared with Iron Ore Tailings Sand. *Advanced Materials Research*, 295-297, 594-597.

Saidi, M., Ait-Medjber, F., Safi, B., & Samar, M. (4014). Recycling of Aggregates from Construction Demolition Waste in Concrete: Study of Physical and Mechanical Properties. *International Journal of Civil, Structural, Construction and Architectural Engineering*, Vol. 8 No: 12.

Yu, L. Zhang, J. & Mu, K. (2012). Relationships between Compressive Strength and Microstructure in Mortars with Iron Ore Tailings as Fine Aggregate. *Applied Mechanics and Materials,* 188, 211-218.

Yunfen, H. (2014). Comparison of Effect of Iron Tailing Sand and Natural Sand on Concrete Properties. *Key Engineering Materials*, 599, 11-14.

Zhang, G., Zhang, X., Zhou, Z., & Cheng, X. (2014). Preparation and properties of concrete containing iron tailings /manufactured sand as fine aggregate, *Advanced Materials Research*, 838-841, 152-155.

Zhao, Z., Fan, J., & Sun, W. (2012). Utilization of Iron ore Tailings as Fine Aggregate in Ultra-High Performance Concrete, *Construction and Building Materials*, 50, 540–548.