Strength Characteristics of Iron ore tailing Concrete

Abd Latif Saleh[a1], Abd Rahman Mohd Sam[b1], Rozana Zakaria[c1], Mushairry Mustaffar[d1], Sikiru F. Oritola[e1,*]

[1]Faculty of Civil Engineering, Universiti Teknologi Malaysia, Skudai Malaysia
[a]alatif@utm.my, [b]abdulrahman@utm.my, [e]*sforitola2@live.utm.my

Keywords: Fine aggregate; iron ore tailings; normal strength concrete; compressive strength; splitting tensile strength; flexural strength; ultrasonic pulse velocity.

Abstract. Materials used in proportioning of concrete have significant impact on the properties of concrete produced. Iron ore tailings (IOTs) is a waste product generated from the production process of iron ore. In this study, IOTs is used as partial replacement for natural sand in the production of normal strength concrete. Samples of Iron ore tailings from two different mines in Kota Tinggi were collected. The Physical properties of natural sand and these Iron ore tailings were determined. The Energy Dispersive X-ray Spectroscopy (EDS) and the microscopic image of these materials were also studied. Normal strength concrete was designed based on water/cement ratio of 0.54 and cement content of 463Kg/m^3 was used in preparing the fresh concrete. For each kind of Iron ore tailings concrete, four different types of concrete samples were produced. The percentage of Iron ore tailings as partial replacement for sand in the sample was varied from 10% to 40% at 10% interval. For each concrete sample, the average of three cubes, three cylinders and three prism specimen results was used for the determination of the compressive strength, splitting tensile strength and the flexural strength respectively. Also studied are the water absorption, the ultrasonic pulse velocity and the mode of failure of the IOTs concrete compared with the normal strength concrete. The concrete sample CZT30 containing 30% IOTs recorded the highest 28days compressive strength of 43.7 N/mm^2.

Introduction

There are sixteen iron ore producing mines in the state of Johor in Malaysia, while we have a total of ninety-seven iron ore producing mines in the country. The other states that make up this figure are Perak, Pahang, Terengganu, Kelantan, Negeri Sembilan and Melaka. During the production process of iron ore, Iron ore tailings, a common industrial solid waste product is generated in enormous quantity. Presently, based on what was observed at the iron ore mines, these waste are stock piled on site or washed into the tailing pond. The stock piled tailings can leach into the ground and thereby contaminate farmland, flowing and underground water. In fact the Iron ore tailings can cause serious environmental problems.

Millions and millions of tons of Iron Ore Tailings have accumulated at different sites, and the fact that, it is increasing at an alarming rate has prompted researchers, technologists and entrepreneurs to investigate solutions with technological options. [1] conducted research on the particle size analysis of iron ore tailings obtained from iron ore mine in Malaysia.

The utilization of IOTs as partial replacement of sand in the production of normal strength concrete is the focus of this paper. Past studies have reported several ways to utilize IOTs as green engineered Cementitious Composites [2], as fine aggregate to produce ultra-high performance concrete [3], mechanochemical activation of iron ore tailings to produce high-strength construction materials [4], as replacement of sand in concrete [5], as fine aggregate in the production of mortar [6] as siliceous materials in ceramics [7, 8], as fine aggregate in the production of concrete [9] and in the production of autoclaved aerated concrete [10]. It is important to know 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 [11]. Iron ore tailings can be used as fine aggregate in concrete because they are relatively inert and the particle size of the tailings is significantly larger than that of cement.

Experimental investigations of this study focus on the characterization of the physical properties of the IOTs compared with sand and evaluation of the fresh and hardened properties of the concrete containing IOTs in terms of workability, compressive strength, splitting tensile strength, flexural strength, and the ultrasonic pulse velocity. Due to the wide applicability of normal strength concrete and the large abundance of iron ore tailings it is important to fully establish the use of iron ore tailings in normal strength concrete.

Methodology

In order to characterize the physical properties of the IOTs and to determine the fresh and hardened properties of the concrete containing IOTs, the following are the methodology of the study:

1. Collection of materials from iron ore producing mines, ZCM Minerals and Landas Seketa Mines both located in Kota Tinggi, Malaysia. Natural sand and granite used were obtained from a local quarry in Skudai and the ordinary Portland cement brand with strength class of 42.5 in accordance with the British standard [12] was used as binder for preparing the concrete samples. Particle size distribution, specific gravity, aggregate loose unit weight, aggregate compacted unit weight, X-Ray Florescence and energy dispersive spectroscopy tests were done for the fine aggregate.
2. Design of normal strength concrete using the current British method for the design of normal weight concrete made with Portland cement produced by the Building Research Establishment [12].
3. Production of normal strength concrete with water/cement ratio of 0.54 and cement content of 463[Kg/m^3] to serve as control mix.
4. Production of normal strength concrete for each of the IOTs. Four different types of concrete samples based on varying percentage of iron ore tailings (ranging from 10% to 40%) as partial replacement for sand.
5. Determination of slump and compacting factor for the fresh concrete samples for purpose of evaluating the workability.
6. Curing of concrete samples in water at an average temperature of 21^{O}C until the prescribed days of testing at 7, 14, 21 and 28 days.
7. Testing the hardened properties of the concrete samples.

Data Analysis

Properties of Sand and IOTs

The physical properties of sand and IOTs determined experimentally are recorded in Table 1.

Table 1. Physical properties of sand and IOTs

Physical properties	**Fine Aggregates**		
	Sand	ZIOTs	LIOTs
Size Passing 600µm %	44	95	96
Coefficient of uniformity	3.7	4.7	4.0
Coefficient of curvature	0.02	0.01	0.01
Porosity %	14	12.1	12.4
Specific gravity	2.65	2.91	2.74
Fineness Modulus	3.2	1.4	1.3
Loose unit weight kg/m^3	1459	1598	1554
Compacted unit weight kg/m^3	1696	1817	1774

The results of granulometric analysis (granularity) by sieving, for sand and the IOTs is shown in Fig. 1 by the cumulative granular curve. It represents the variation in the grains passing (or underflow) through a sieve. These accumulate according to the size of the sieve openings in a semi-logarithmic axes system.

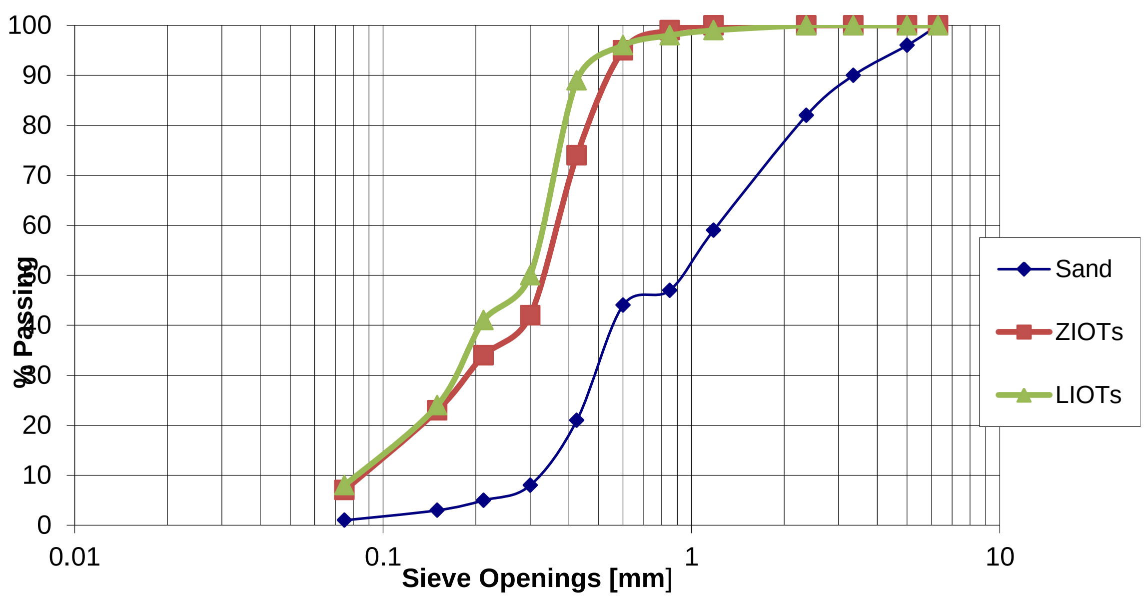

Fig. 1 Particle size distribution for sand and IOTs

The Field emission scanning electron microscopy (FESEM) provides topographical and elemental information at useful magnifications with virtually unlimited depth of field. FESEM provides ultrahigh resolution imaging and very useful in terms of materials evaluation. The microscopic image of sand compared with the IOTs at magnification of 500µm is reflected in Fig. 2.

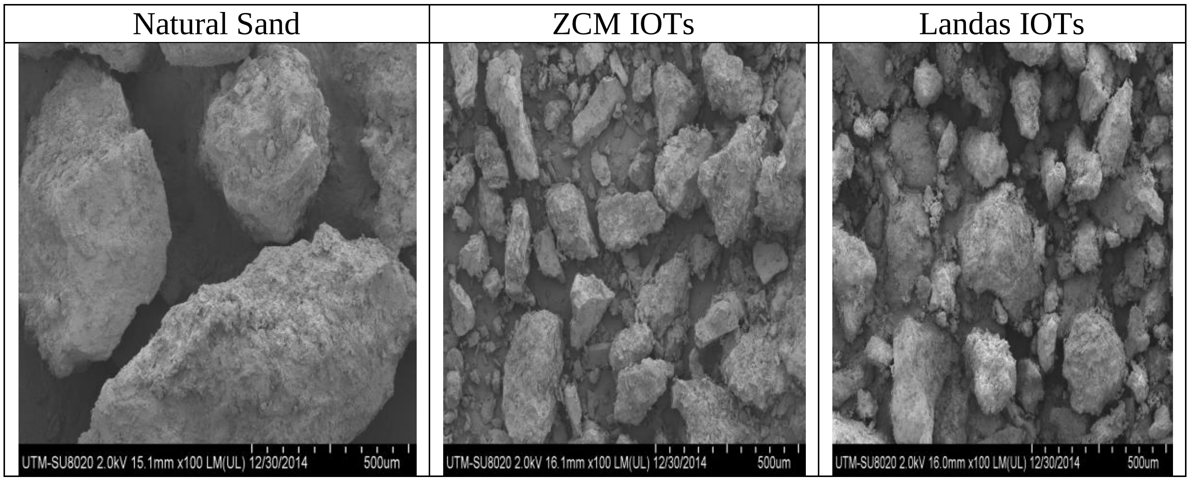

Fig. 2 Microscopic image of sand compared with the IOTs at 500µm

Design of Normal Strength Concrete

Normal strength concrete was designed based on water-cement ratio of 0.54 and cement content of 463[Kg/m^3]. The description of the different types of concrete samples produced and the proportioning of materials are shown in Table 2.

Table 2 Description and composition of concrete samples

Sample	*Description*	*Constituents Materials Kg/m^3*				
		Water	Cement	Granite	Sand	IOTs
CTO	Concrete with no IOTs	250	473	868	769	0
CZT10	Concrete with 10% ZCM IOTs	250	473	868	692	77
CZT20	Concrete with 20% ZCM IOTs	250	473	868	615	154
CZT30	Concrete with 30% ZCM IOTs	250	473	868	538	231
CZT40	Concrete with 40% ZCM IOTs	250	473	868	461	308

Workability of Fresh Concrete

The summary of test results for slump and compacting factor are shown in Table 3.

Table 3 Slump and Compacting factor of Concrete Samples

Workability	*Concrete Sample*								
	CT0	CZT10	CZT20	CZT30	CZT40	CLT10	CLT20	CLT30	CLT40
Slump [mm]	81	79	67	59	53	71	63	57	55
C. Factor	0.92	0.91	0.90	0.90	0.89	0.92	0.91	0.90	0.89

Strength of Concrete Samples

The compressive strength of concrete cube samples at 7, 14, 21, and 28days of curing for concrete containing ZIOTs and LIOTs are represented with Fig. 3 and Fig. 4 respectively. The 7days and 28days Splitting tensile strength and Flexural strength for ZIOTs and LIOTs are shown in Figs. 5, 6, 7 and 8.

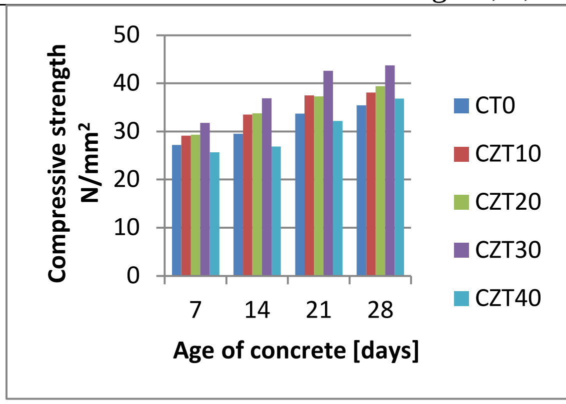

Fig. 3 Compressive strength of ZIOTs Concrete

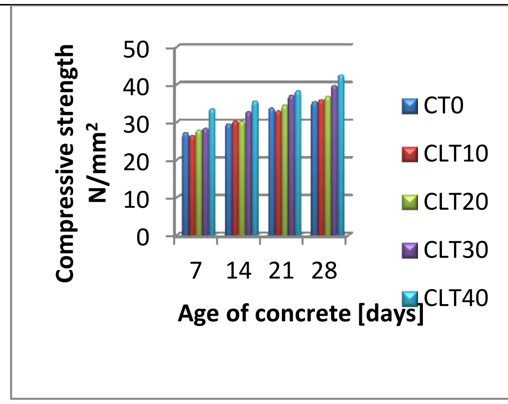

Fig. 4 Compressive strength of LIOTs Concrete

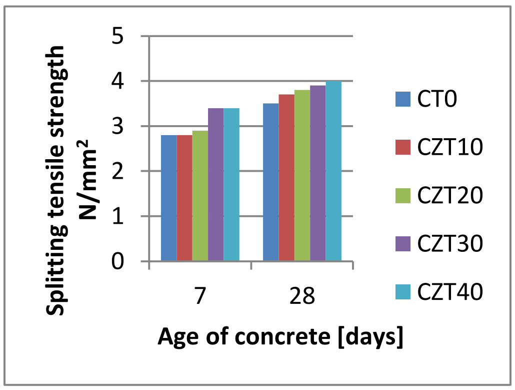

Fig. 5 Splitting tensile strength of ZIOTs Concrete

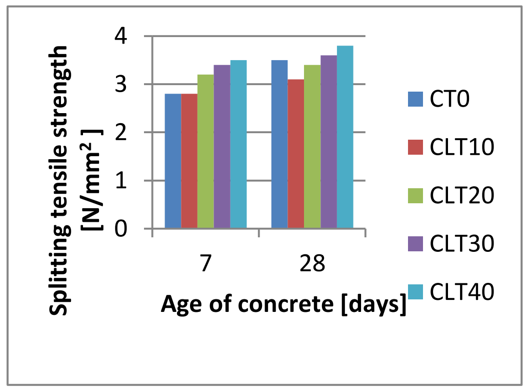

Fig. 6 Splitting tensile strength of LIOTs Concrete

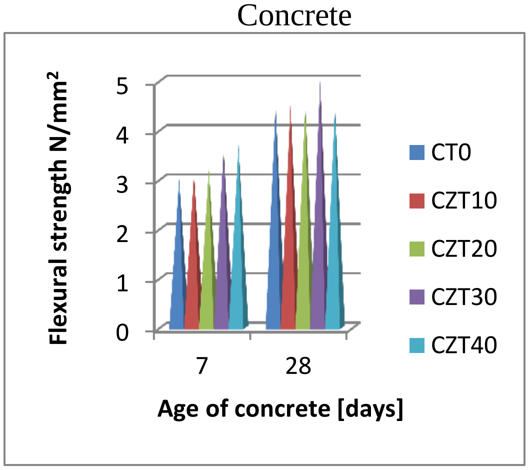

Fig. 7 Flexural strength of ZIOTs Concrete

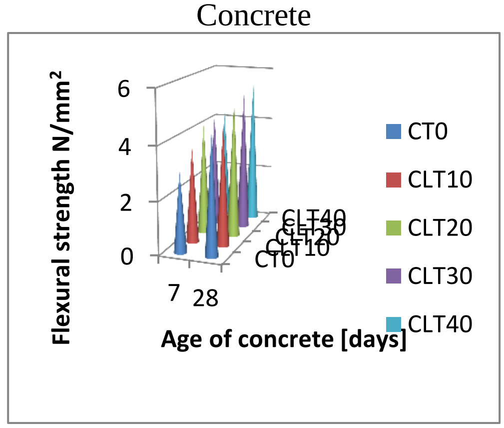

Fig. 8 Flexural strength of LIOTs Concrete

Conclusion

There is need for alternative material for sand in production of concrete, in this manner, plant covers can be saved. The consumption of IOTs in concrete will bring about lesser demand for natural sand, hence promoting the greenness of the environment. This paper has identified that concrete samples produced using IOTs partially as fine aggregate in concrete, satisfy the guidelines requirements and specifications for normal strength concrete based on the British standard. The IOTs concrete samples gave better performance than the reference sample in terms of compressive strength, splitting tensile strength, and the flexural strength. Results show that the concrete sample CZT30 gave the highest compressive strength value of 43.7 N/mm^2, while CZT40 gave the highest splitting tensile strength of 3.9 N/mm^2 and CLT40 gave the highest flexural strength of 5.2 N/mm^2. IOTs is inert and the particle size is relative to that of the sand hence, the material can be recommended as cheaper and more environmentally friendly alternative aggregates in concrete.

References

[1] Samayamutthirian P, Beneficiation of Iron Ore Slime. Nova Publishers (2011), 205-216.

[2] Huang X, Ranade R, Ni W, Li V.C. Development of green engineered cementitious composites using iron ore tailings as aggregates Construction and Building Materials, Volume 44, July 2013, Pages 757-764.

[3] Zhao S, Fan J, Sun W. Utilization of Iron ore tailings as fine aggregate in ultra-high performance concrete, Construction and Building Materials, Volume 50, 15 January 2014, Pages 540-548.

[4] Zheng Y.C., Ni W. Xu L., Li D.Z., and Yang J. H.. Mechanochemical activation of iron ore tailings and preparation of high-strength construction materials J. Univ. Sci. Technol. Beijing, 32(4), (2010), pp. 504-507.

[5] Cai J. W., Zhang S.B., Hou G. X., and Wang C.M. Effects of ferrous mill tailings as aggreagtes on workability and strength of concrete, J.Wuhan Univ. Technol., 31(7), (2009), pp.104-107.

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

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

[8] Das, S. K., Kumar, S., and Ramachandrarao, P. Exploitation of iron ore tailing for the development of ceramic tiles. Waste Management, 20(8), (2000), pp. 725-729

[9] Zhang G, Zhang X, Zhou Z, Cheng X, Preparation and properties of concrete containing iron tailings /manufactured sand as fine aggregate, Advanced Materials Research Vols. 838-841 (2014) pp 152-155, www.scientific.net Trans Tech Publications, Switzerland.

[10] Li D.Z, Ni W, Zhang J.W, Wu H, and Zhang Y.Y, Phase transformation of iron ore tailings during autoclaved curing J. Chin. Ceramic Soc. 39(4), (2011), pp. 708-804.

[11] Vale S.A, Mendes M.B, Milonas JG, Pirete W. and Souza W.J, Geotechnical Parameters of Iron Ore Tailings from the Quadrilátero Ferrífero after Different Treatments and Ore Processing, J.P.S. Silva University of São Paulo, Brazil, (2013).

[12] Building Research Establishment laboratory, Note on Mix Design method, Department of Environment (DOE), London, UK, 1988