Recent Trends in Civil Engineering & Technology
ISSN: 2249-8753(online), ISSN: 2321-6476(print)
Volume 6, Issue 2
www.stmjournals.com

Partial Replacement of Sand and Cement by Iron Ore Slime for Concrete Building Material

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Abstract
Iron ore slime is a waste material generated after beneficiation of iron ores. It causes air, water and land pollution. From resource conservation point of view, the recovery of iron values is important and their use in different application. Researchers are also trying to find out value-added alternative application of iron ore slime rejects. In this paper, iron ore slime was used in concrete building material and evaluated the partial replacement of sand and cement in concrete. It was observed that the compressive strength of the concrete block was either equal or better with 15% partial replacement of cement and 20% partial replacement of sand with iron ore slime, respectively.

Keywords: *concrete, cement, sand, iron ore slime, compressive strength*

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INTRODUCTION
Iron ore slime is a waste material generated after beneficiation of iron ores. Due to limited iron ore resources and depleting iron ore, iron ore producers are emphasizing on recovery and value addition of iron ore slime. Generation of iron ore slimes in India is estimated to be 10–25% by weight of the total iron ore mined. The iron ore values are lost to the tune of 15–20 million tonnes every year. These slimes are readily available in finer size typically assaying 55–60% Fe [1]. These slimes were dumped in the tailing ponds in the mine area and are environmental hazard.

Value-added products from slime were developed by Shetty in 2014 [2]. He studied strength aspects of self compacting concrete (SCC) which has been prepared by partially replacing cementitious material by red mud (RM) and in the same mix, partially replacing sand by iron ore tailings (IOTs). Cementitious material in the SCC mixture was replaced with RM at 1%, 2%, 3%, and 4%. The compressive strength achieved for all the mix was more than the control mix. The maximum compressive strength and split tensile strength was achieved at 2% RM with 30% IOT. The flexural strength achieved for all the mix were more than the control mix and all these values were more than IS specified values. The maximum flexural strength was achieved at 2% RM with 30% IOT [2]. Zhao *et al*. found the possibility of using IOTs to replace natural aggregate to prepare ultra high performance concrete (UHPC) under two different curing regimes. It was found that 100% replacement of natural aggregate by the tailings significantly decreased the workability and compressive strength of the material. However, when the replacement level was no more than 40%, for 90 days standard cured specimens, the mechanical behavior of the tailings mixes was comparable to that of the control mix, and for specimens that were steam cured for 2 days, the compressive strengths of the tailings mixes decreased by less than 11% while the flexural strengths increased by up to 8% as compared to the control mix [3]. Huang *et al.* explored the feasibility of using IOTs as cheaper and more environmentally friendly alternative aggregates without sacrificing the ductile mechanical performance of standard engineered cementitous composites (ECC). Influences of the size of IOTs on plastic viscosity of fresh ECC mortar, and on tensile properties and fiber dispersion in composites were experimentally investigated. At two levels of fly ash/cement ratio, performance of ECC with IOTs under direct tension and compression was investigated. The results showed that ECC with IOTs as aggregates can attain tensile and compressive properties comparable to ECC with typically-used microsilica sand, provided that the size of IOTs used was in the appropriate range which facilitates good fiber dispersion. Thus, the feasibility of using industrial solid waste IOTs as aggregates in the development of highly ductile and green ECC was established [4]. Das *et al*. investigated the use of IOTs as replacement for sand. Da Silva *et al*. investigated the use of iron slime in production of ceramics. Their results indicated that the addition of tailings from concentration of iron ore for the production of red ceramics was highly feasible both technically and environmentally [5]. Cement concrete cubes and reinforced concrete beams are tested for compressive strength and flexural strength, respectively by varying percentages of sand replacement by IOTs. It is found that the cube compressive strength of cement concrete and flexural strength of reinforced cement concrete beams are in no way impaired by sand replacement. On the other hand, there is an enhancement in the strength for all percentages of sand replacement. The increase in strength is, however, not very substantial [6,7]. In the present investigation, an attempt was made to use the waste slime material in place of sand and cement partially in concrete making.

MATERIALS AND METHODS

Materials

Ordinary Portland cement (OPC) of grade 53 confirming to IS: 12269-1987 was used in the present study. Normal consistency, initial and final settling time, specific gravity of the cement was studied and tabulated in Table 1.

Coarse Aggregates: Coarse aggregates are those retained in IS sieve size 4.75 mm. The nominal size of the aggregates was 20 mm.

Fine Aggregate: Fine aggregate are those less than 4.75 mm IS sieve size. The specific gravity of the sand was 2.62.

EXPERIMENTAL WORK

Possibilities of value addition of iron ore slime reject was evaluated, to make concrete blocks by partially replacing sand and cement with iron ore slime reject. Concrete blocks were made by replacing sand and cement with iron ore slime reject. Table 2 represents the properties and quantity of materials used for concrete block preparation.

Cement, sand, and coarse aggregate were mixed well using a showel and water was added slowly and mixed. The amount of materials used to make two blocks of one particular mix is given in Tables 3 and 4.

Table 1: *Characteristics of OPC 53 Grade Cement Used for Making Concrete.*

Sl. No	Characteristics	Values	As per IS 12269-1987
1	Normal consistency (%)	35	
2	Initial settling time (in min)	32	Not less than 30
3	Final settling time (in min)	248	Not more than 600
4	Specific gravity	3.10	3.15

Table 2: *Quantity and Standard of Materials for Construction of Concrete Blocks.*

Sl. No.	Grade designation	M30
1	Cement	OPC 53 grade confirming to IS 12269-1987
2	Maximum cement content	540 Kg/m^3
3	Minimum cement content	310 Kg/m^3
4	Maximum water–cement ratio	0.45
5	Degree of supervision	Good
6	Exposure condition	Normal
7	Mass of cement	380 Kg/m^3
8	Mass of water	180 L
9	Fine aggregate	711 Kg/m^3
10	Coarse aggregate	1283 Kg/m^3
11	Mass of water	180 L

Table 3: *Quantity of Materials taken to make Concrete in which Cement was Partially Replaced by Iron Ore Slime.*

Designation	Cement (Kg)	Fine aggregate (Kg)	Coarse aggregate (Kg)	Water (ml)	Iron ore slime (Kg)
Blank	0.76	1.422	2.566	360	0
C5 [5%]	0.722	1.422	2.566	360	0.038
C10 [10%]	0.684	1.422	2.566	360	0.076
C15 [15%]	0.646	1.422	2.566	360	0.114
C25 [25%]	0.57	1.422	2.566	360	0.19
C50 [50%]	0.38	1.422	2.566	360	0.38

Table 4: *Quantity of Materials taken to make Concrete in which Sand was Partially Replaced by Iron Ore Slime.*

Designation	Cement (Kg)	Fine aggregate (Kg)	Coarse aggregate (Kg)	Water (ml)	Iron ore slime (Kg)
Blank	0.76	1.422	2.566	360	0
S20	0.76	1.1376	2.566	360	0.2844
S40	0.76	0.8532	2.566	360	0.5688
S60	0.76	0.5688	2.566	360	0.8532
S80	0.76	0.2844	2.566	360	1.1376

Two blocks were made for each mix. The mould was filled 1/3rd and rammed well. The moulds were then vibrated and left to dry. These concrete blocks were then water cured for 28 days and compressive strength was measured.

RESULTS AND DISCUSSION

Physical and Chemical Characterization Studies

The size analysis of as received iron ore slime reject sample was carried out by wet sieving technique to know the distribution of Fe at various size fractions. The iron ore slime reject thus obtained were subjected to chemical analysis to ascertain the different quantitative elemental composition of the sample. The chemical analysis of slime reject is shown in Table 5 and wet size-wise chemical analysis of the same is shown in Table 6. The grain size distribution graph of iron ore slime is given in Figure 1.

Table 5: *Chemical Analysis of the Iron Ore Slime Reject.*

%Fe	%SiO_2	%Al_2O_3	%LOI
42.7	13.68	12.5	12.53

Table 5 reveals that the iron ore slime contains 42.7% Fe with high silica and alumina, i.e., 13.68% & 12.5 %, respectively.

d_{90}=72 µm

90% of the particles are passing through 72 µm. Table 6 depicts that most of the particles are in the range below 30 micron size. Also more than 72% of the material is of grade ~40 % Fe.

Table 6: *Size-wise Chemical Analysis of the Iron Ore Slime Reject.*

Size (µm)	%Weight	%Fe
100	5.5	51.3
75	4.8	47.4
60	3.1	49.8
44	2.5	54.3
37	7.4	50.9
30	4.7	50.3
-30	72.1	39.7

VALUE ADDITION OF IRON ORE SLIME

Compressive Strength of Concrete Cubes Made by Replacing Cement by Iron Ore Slime

Concrete cubes of size 100 x100 x100 mm were cast by replacing 0%, 5%, 10%, 15%, 25%, and 50% of iron ore slime with cement. The cubes were cured in water for 28 days. The compressive strengths of the cubes are given in Figure 2.

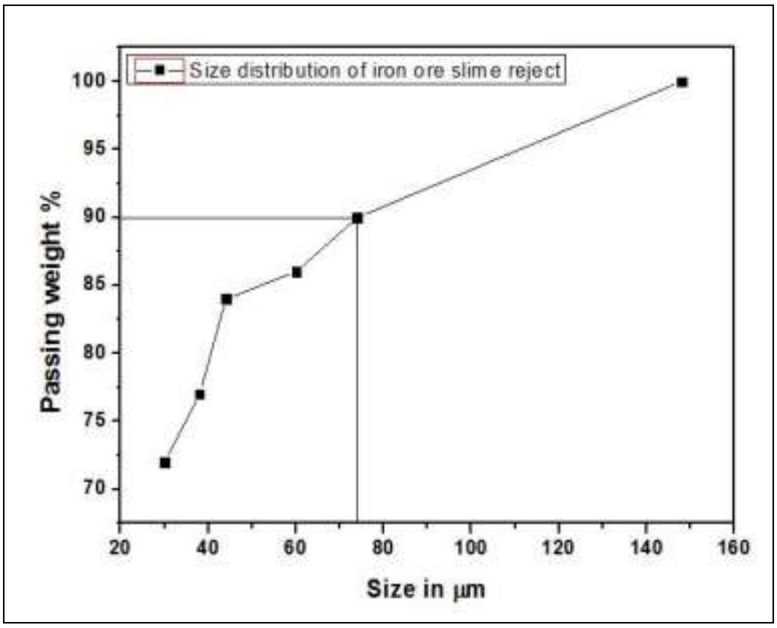

Fig. 1: *Size Distribution of Iron Ore Slime.*

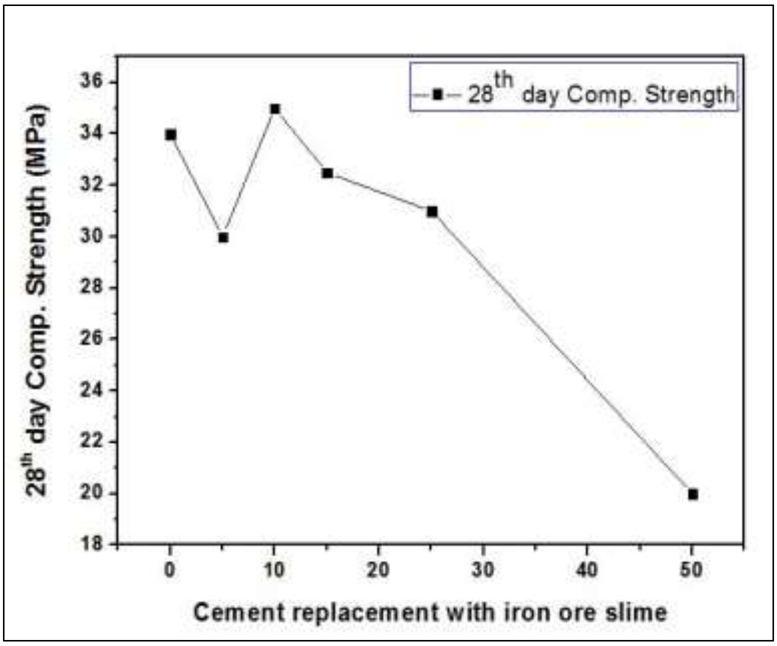

Fig. 2: *Compressive Strength of 28 Days Cured Concrete Made by Replacing Cement by Iron Slime.*

There is not much difference in compressive strength of cubes by normal concrete mix and the others which are replaced with cement. The concrete blocks were observed to have compressive strength of nearby 30 MPa, but the concrete cube block made by replacing cement 50% showed inferior quality.

Compressive Strength of Concrete Cubes Made by Replacing Sand by Iron Ore Slime

Concrete cubes of size 100 x100 x100 mm were cast by replacing 0%, 20%, 40%, 60%, and 80% of iron ore slime in concrete. The cubes were cured in water for 28 days. The compressive strengths of the cubes replacing sand by iron ore slime are given in Figure 3.

The concrete blocks made by replacing 20% sand with iron ore slime was showing slightly higher compressive strength than blank. Replacing more than 40% of sand resulted in inferior quality blocks. Hence even though it doesn't increase any strength characteristics significantly, iron ore slime could be used to replace sand and cement to an extent of 20%.

INITIAL AND FINAL SETTLING TIME

The initial and final settling time of cement replaced by iron ore slime is presented in Figure 4. The iron ore slime was observed to decrease the settling time. It acted as an admixture to reduce the time of setting.

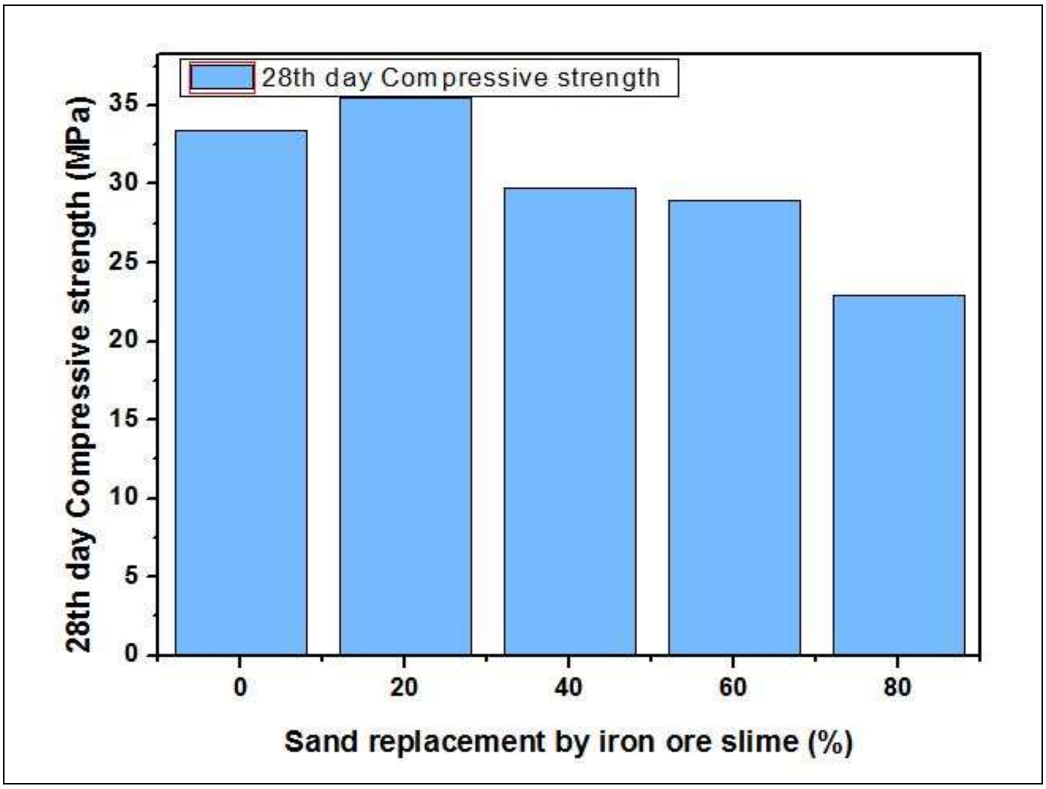

Fig. 3: *Compressive Strength of 28 Days Cured Concrete Blocks Made by Replacing Sand by Iron Ore Slime.*

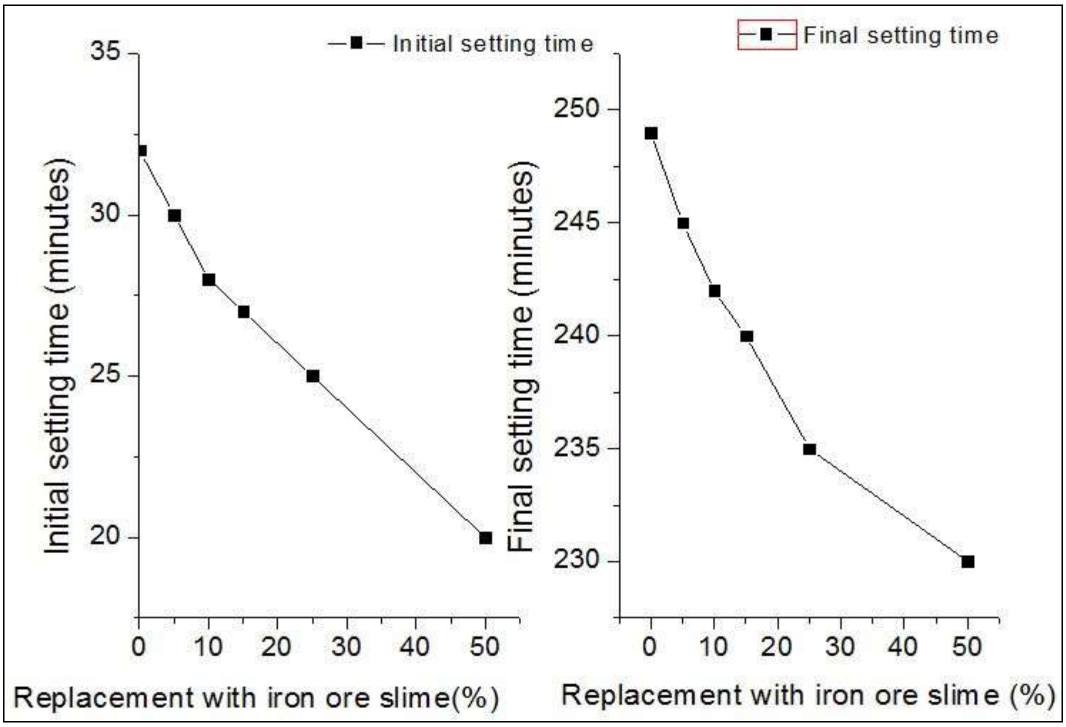

Fig. 4: *Initial and Final Setting Time of Mortar Partially Replaced by Iron Ore Slime.*

CONCLUSION

Value addition of iron ore slime reject in concrete was evaluated by replacing sand and cement with iron ore slime separately. The 28th day compressive strength of the concrete blocks up to 15% replacement of cement with iron ore slime showed satisfactory strength. But beyond that it produced inferior quality concrete. Also replacing more than 20% of iron ore slime with sand reduced the strength properties. Hence even though it doesn't increase any strength characteristics, it can be used to replace sand and cement to an extent of 20%.

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Cite this Article
Jerin J, Rath RK, Kumar A. Partial replacement of sand and cement by iron ore slime for concrete building material. *Recent Trends in Civil Engineering & Technology*. 2016; 3(2): 37–42p.