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Self - Compacting Concrete Using Slag Sand as Fine Aggregate

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Abstract: ***Concrete is the most widely used material in the world in the construction industry. It may be for superstructures, substructures, dams, etc. The demand for raw materials used for concrete continues to grow unabated. Earlier, natural river sand was used as fine aggregate for concrete. Due to the scarcity, expense, and non - availability of natural river sand and also due to ecological imbalance, we are reducing the use of sand as fine aggregate. So crushed stone sand is being used as fine aggregate in place of natural river sand. Keeping in mind the available natural resources, we can reduce the usage of crusher sand by using industrial by - products as fine aggregate. Steel plant industries produce slag as an industrial byproduct. In addition to reducing the usage of natural materials, by using slag we can avoid the dumping of slag sand, which is accumulated in large quantities in the steel industries.***

Keywords: slag sand, ggbs, hardened and durability properties of concrete, natural resources, industrial by - products & self - compacting concrete

1. Introduction

Self - compacting concrete (SCC): This advanced concrete does not require vibration or compaction; it flows under its own weight, filling formwork and achieving full compaction even in the presence of congested reinforcement.

This project deals with self - compacting concrete where cement is replaced with ground - granulated blast furnace slag and natural sand with slag sand as fine aggregate.

A detailed study on the various properties of self - compacting concrete is carried out by using 50% GGBS and 50% OPC to achieve the desired target strength. Various properties of self - compacting concrete, such as filling ability, viscosity, and passing ability, are measured using a flow table, V - funnel, L - box, J - ring, and U - box test apparatus. In addition, the hardened properties of concrete, like compressive strength, flexural strength, and durability, are tested in this study.

2. Literature Survey

Effective Utilization of Slag Sand and Ground Granulated Blastfurnace Slag for the Production of Green and Sustainable Concrete.
Concrete can be made sustainable using alternatives to cement, fine aggregate, and coarse aggregate. In this study, slag sand is used as a complete replacement to natural sand and is physically characterized for its properties as per relevant IS codes of practices. Fresh concrete properties are determined by conducting compaction factor and slump tests, hardened properties namely compressive strength and split tensile strength at 7 days and 28 days are also determined. .

3. Methods and Materials

Before proceeding with the testing, the raw materials used for the analysis were subjected to basic tests in the laboratory, including studies on the properties of fresh concrete, hardening properties of concrete, and durability properties of concrete in relation to relevant codes. Sand's requirements with reference to a particular grade are studied, and the finer particles of the materials are proportioned before the arrival of the mix design.

4. Results/ Discussion

Laboratory Tests:
In this study, slag sand, GGBFS, cement, coarse aggregate, water, and superplasticizer are tested as per relevant IS codes.

1) Tests on Slag sand:

Chemical and physical tests were conducted on slag sand, and the results are as given in tables 1 and 2.

Table 1: Chemical percent content in slag

Constituents of current oxides	BFS Constituents in (%)
SiO_2	35.8
Al_2O_3	17.6
Cao	38.9
Mgo	8.2
S	<0.8
Mno	0.62

Table 2: Physical properties of fine aggregate (Slag sand)

1.	a) Loose bulk density	1239 kg/cu. m
	b) Dry rodded bulk density	1492 kg/cu. m
2.	Specific gravity	2.54
3.	Water absorption	4.5%
4.	**Sieve Analysis:**	

IS Sieve Designation	Cumulative Percentage Retained	Passing	Specification as per IS: 383 - 2016 (Percentage Passing) Zone I	Zone II	Zone III
4.75 mm	0	100	90 - 100	90 - 100	90 - 100
2.36 mm	16.5	83.5	60 - 95	75 - 100	85 - 100
1.18 mm	47.7	52.3	30 - 70	55 - 90	75 - 100
600 µm	64.2	35.8	15 - 34	35 - 59	60 - 79
300 µm	82.0	18.0	5 - 20	8 - 30	12 - 40
150 µm	97.6	2.4	0 - 10	0 - 10	0 - 10
REMARKS: 1). The sample supplied satisfies the requirements of grading Zone **II** as per IS: 383 - 2016.					

2) Tests on cement

Tests on Physical properties of cement were carried out as per relevant IS codes the results are tabulated in table 3.

Table 3: Physical Properties of Cement

REFERENCE IS: 269 – 2015 Clause 7 for OPC 53				
Sl. No.	Test Conducted		Results	Requirements as per IS: 269 – 2015 Clause 7 for OPC 53
2.	Type of cement *		53 Grade, OPC	-
3.	Consistency		25.1 %	Not specified
4.	Initial setting time		195 Minutes	Shall not be less than 30 minutes
5.	Final setting time		410 Minutes	Shall not be more than 600 minutes
6.	Compressive strength: (Average of three results)	3 days	32.5 MPa	Shall not be less than 27.0 MPa
		7 days	43.0 MPa	Shall not be less than 37.0 MPa
		28days	58.0 MPa	Shall not be less than 53.0 MPa
7.	FINENESS (by Blaine's air permeability method)		316 m^2/kg	Shall not be less than 225 m^2/kg
8.	SOUNDNESS (by Le - Chatelier's method)		1.0 mm	Shall not be more than 10mm
REMARKS: Sample supplied was tested as per guidelines in IS 4031 (Part 3 to 6) 1988 (Reaffirmed 2014), IS 4031 (Part 2) - 1999 (Reaffirmed 2013).				

Tests on GGBFS (Ground Granulated Blast furnace Slag):

Tests on Chemical and Physical properties of GGBS were carried out as per relevant IS codes the results are tabulated in table 4 &5.

Table 4: Chemical test report on GGBFS

Test Conducted	Results	Requirements as per IS: 16714 - 2018
Manganese Oxide (MnO) (%)	0.41	Maximum 5.5
Magnesium Oxide (MgO) (%)	8.08	Maximum 17.0
Sulifide Sulphur (S) (%)	0.57	Maximum 2.0
Sulphate (as SO_3)	0.12	Maximum 3.0
Insoluble residue (Max.) (%)	2.35	Maximum 3.0
Chloride Conent	0.009	Maximum 0.1
Loss in Ignition	Nil	Maximum 3.0
$CaO + MgO + 1/3.\ Al_2O_3$ / $SiO_2 + 2/3\ Al_2O_3$	1.11	Minimum 1.0
$CaO + MgO + Al_2O_3$ / SiO_2	1.77	Minimum 1.0
Glass Content (%)	96	Minimum 85.0

Table 5: Physical test report on GGBFS

Test Conducted	Test Results	Requirements as per IS: 16714 - 2018
Specific Gravity	2.82	Not Specified
Fineness, m^2/kg, Min.	354	320
Slag Activity Index (%) $	69	
7 days	82	Not less than 60 perent of control OPC 43 Grade cement mortar cube
28 days		Not less than 75 perent of control OPC 43 Grade cement mortar cube

Tests on Coarse Aggregate:

Tests on Physical properties of coarse aggregate were carried out as per relevant IS codes Conforming to graded aggregate

The admixture is important in designing self - compacting concrete with high performance PCE - based admixture that meets IS 9103 - 1999 requirements.

Design of concrete mix:

A concrete mix design was carried out using the above mentioned materials as per IS 10262 - 1982. In this mix design, natural river sand and crushed stone sand are replaced by slag sand. OPC of 53 Grade, GGBFS, and high - range Poly carboxylic ether (PCE) admixture were used to carry out the mix design.

The mixing proportion plays a major role in conducting SCC. We have conducted a number of mix design trials with different proportions of materials and different water - cement ratios. When these trials are conducted, problems such as bleeding, segregation, ineffectual flow, etc. occur. Fresh concrete with a cohesive mix was achieved by using 56 percent of fine aggregate (slag sand) and 44 percent of coarse aggregate per cubic metre and a water - cement ratio of 0.35 for M35 grade concrete and similarly for M25 grade concrete.

Table 6: Quantities per cubic meter of concrete in (SSD condition) in kgs

Mix Ingradients	M35	M 25
Cement	250	200
Ggbs	250	200
Slag sand (Fine aggregate)	902.6	1018
12.5 mm aggregate	779.7	784.0
Free water	175.0	172.0
Admixture	3.5	2.4

Test on fresh concrete:

Obtaining the final mix proportion, to check the fresh concrete properties like flow test, V funnel, L box & U box test were carried out in the laboratory.

The test results and requirements of properties of SCC are as given in the table below.

Table 7: Test Results and acceptance criteria for fresh concrete

Test	Property	Range Value	Obtained test results
T50 slump flow	Filling ability	2 - 5 sec	3 sec
Flow	Filling ability	600 - 800 mm	650 mm
V - funnel	Viscosity	6 - 12 sec	10 sec
Lbox (h2/h1)	Passing ability	0.8 - 1.0	0.9
Seive Segregation	Filling ability	1.3%	1.5%

Test on Hardened concrete:

The compressive strength, flexural strength, and durability properties of hardened concrete were carried out, and the results are as given in tables 9 and 10.

Table 8: Test results on hardened concrete

Test conducted	Test age (Water Curing)	Obtained results (Avg. of 3 sample) (N/mm2)		Test method
		M35	M25	
Compressive Strength	7 days	26.9	21.2	IS 516: 1959
	28 days	43.7	33.9	
Flexural Strength	7 days	3.3	3.0	
	28 days	4.8	4.1	

Table 9: Durability properties of concrete:
Water Permeability Test:

Test CONDUCTED	Depth of penetration (mm) Test results				Requirement as per MORT&H 5 th revision 2013 clause 1717.75 & DIN 1048 part 4
	M35		M25		
	individual	Average	individual	Average	
Water Permeability at 5 bar at. . hours, Test method as per DIN 1048 part 1	9.22	9.20	12.36	13.51	Max 25 mm
	8.12		14.08		
	10.26		14.10		

Rapid Chloride penetration Test:

Technical reference: ASTM C 1202 - 03

S. No.	Identification* (Average of three results)	Total Charge passed* (Average of three test results) (Coulombs)
1	M35	1887
2	M25	1978

Requirement as per ASTM C - 1202 - 03, Table I, Chloride ion penetrability based on charge passed.

Charge passed (Coulombs)	Chloride Ion penetrability
> 4000	High
2000 – 4000	Moderate
1000 – 2000	Low
100 – 1000	Very low
< 100	Negligible

5. Conclusion

When there is congested reinforcement and no vibration, Self - Compacting Concrete can be used.

Slag sand, which is available as an industrial byproduct from the steel manufacturing industry, can be used for concrete purposes; it may be conventional concrete or SCC.

Slag sand can be used in place of river sand and crushed stone sand in any grade of concrete.

The target strength is achieved for M35 and M25 grade concrete by using slag sand as a replacement, and it’s showing good results in flexural strength.

A result of the penetration of water in concrete cubes is a plus, since they meet the standards.

Chloride penetration in concrete is lower when slag sand is used in place of natural materials.

6. Future Scope

Sand is a major component of plastering, so how slag sand can be used for plastering should be investigated.

Long - term strength and its durability parameters should be included in the future scope.

Typical Photographs of fresh concrete properties of concrete

L-BOX TEST

FLOW TEST

U-BOX TEST

V-FUNNEL TEST

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Praveen Nayak S, B. E, Civil Engineering, M. Tech, Computer Aided Design of Structures, working as a quality manager in Bureau Veritas India Pvt Ltd, Bengaluru I have 12 years of research experience in the field of concrete technology and mix design for major projects like BMRCL, L& T, JSW etc., and my research focuses on HPC, FRC, HSC, and HFRC.