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Self compacting concrete with partial replacement of sand by waste foundry sand

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Abstract —*In the past few years use of Self Compacting Concrete (SCC) is growing tremendous and much research and modification has been done to produce self compacting concrete which has the desired characteristics. Generation of waste foundry sand as byproduct of metal casting industries causes environmental problems because of its improper disposal. The current area of research in self compacting concrete is introducing foundry sand in self compacting concrete. This project demonstrates the use of waste foundry sand as partial replacement by fine aggregate in self compacting concrete. An experimental investigation is carried out on a self compacting concrete containing waste foundry sand in the range of 0%, 10%, 20%, 30%, 40% by weight for M35 grade self compacting concrete. Material was produced, tested and compared with ordinary self compacting concrete in terms of strength. These tests are carried out on standard cube, cylinder and beam for 7 and 28 days to determine the mechanical properties of self compacting concrete. The aim of this research is to know the behavior and mechanical properties of self compacting concrete after addition of industrial waste in different proportion by tests like compressive strength, split tensile and flexural strength. The research is a resource for exploring the potential use of foundry sand as alternative to virgin raw materials.*

Keywords- *Self compacting concrete, Waste foundry sand, Flexural strength, Compressive strength, Non Destructive Test*

I. INTRODUCTION

Self compacting concrete was first development in 1988, to achieve durable concrete structures. One solution on the achievement of durable concrete structure independent of the quality of construction work is the employment of self compacting concrete which can be compacted in to every corner of the formwork purely by means of its own weight and without the need for vibrating compaction. The necessity of the type of concrete was proposed by Okamura in 1986.Studies to develop S.C.C including a fundamental study on the workability of concrete have been carried out by Ozawa in 1989.[1] Okamura defined, S.C.C is a highly flowable concrete that can spread in to place under its own weight and achieve good consolidation in the absence of vibration without exhibiting defect due to segregation and bleeding. S.C.C fill the congested section and area with restricted access to vibration besides reducing noise due to avoiding the use of vibrates, S.C.C consist of almost same ingredients as conventionally vibrated concrete (CVC) viz cement aggregate, water additives and admixture. However S.C.C has higher amount of super plasticizer and finer particle and also often viscosity modifying agent (VMA) results durability as traditional vibrated concrete. As environmental transportation and other constraints make the availability and use of river sand less attractive, a substitute or replacement product for concrete for industry need to be found river sand is most commonly used fine aggregate in the production of concrete posses the problems of acute shortage in many areas. Whose continued use has started posing serious problems with respect to its availability cost and environmental impact.

Foundry sand is high quality silica sand with uniform physical characteristics. It is a byproduct of ferrous and nonferrous metal casting industries, where sand has been used for centuries as a molding material because of its thermal conductivity. It is a byproduct from the production of both ferrous and nonferrous metal castings. The physical and chemical characteristics of foundry sand will depend in great part on the type of casting process and the industry sector from which it originates. In modern foundry practice, sand is typically recycled and reused through many production cycles. Industry estimates that approximately 100 million tons of sand is used in production annually of that 6 - 10 million tons are discarded annually and are available to recycle into other products and in industry. A schematic of the flow of sands through a typical foundry is shown in Fig.1.

Foundry sand is black. In some concretes, this may cause the finished concrete to have a grayish/black tint, which may not be desirable. Foundries produce Recycled Foundry Sand (RFS) generally in their overall production volume although there are different sand to metal ratios employed in different casting processes and products. These sands may be contaminated with metals or very large chunks of burnt cores and will need to undergo some type of segregation, crushing and screening before recycling.

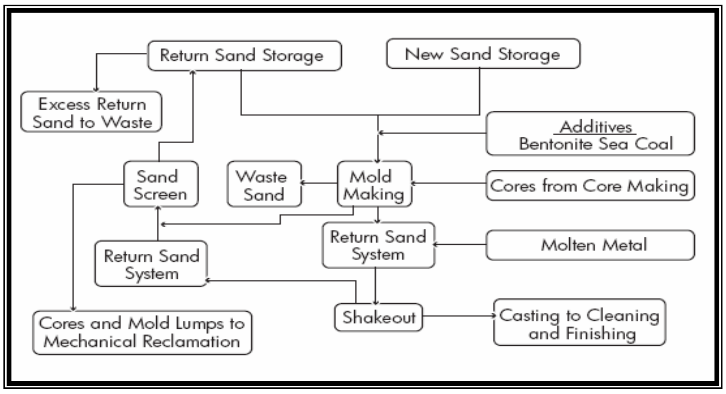

Fig. 1. Recycling of Foundry Sand

The necessity of the study is to optimize the self compacting concrete with foundry sand and natural sand, in the fresh and in harden state, but the literature indicates that some studies are available on plane S.C.C but sufficient literature is not available on S.C.C with foundry sand. Hence an attempt is made in this work to study the mechanical properties of S.C.C with foundry sand.

Keeping in mind the gap in the research area, the objective of this study is to determine the strength and durability properties of SCC containing waste foundry sand (WFS) as partial replacement of fine aggregate. Following are the objectives of this study:

- To produce Self compacting concrete by partial replacement of natural sand by waste foundry sand with 0%, 10%, 20%, 30% and 40% by weight.
- Characterization (Physical and Chemical Properties) of waste foundry
- Study of strength properties such as compressive strength, flexural strength by beam model and Splitting tensile Strength at the ages of 7 and 28 days.
- Comparative study of strength and durability properties of concrete containing waste foundry sand and ordinary sand.
- Statistical analysis of the results would be carried out

Fig .2 Foundry Sand

Fig. 3 Waste Foundry Sand

II. MATERIALS AND METHEDOLOGY

The ingredients of concrete i.e. cement, fine aggregate (River sand & Crushed sand), coarse aggregate are tested before use in concrete. Waste foundry sand is also tested before use in concrete. The relevant Indian Standard codes were followed for conducting various tests on the material.

- Cement: The cement used in this experimental work is “53 grades Ordinary Portland Cement”. Properties of cement are tested as per IS 12269 – 1987.
- Aggregates: Natural sand from Kopergaon (Godavari) river is taken for this experimental investigation. Various tests such as specific gravity, water absorption, moisture content, sieve analysis etc. have been

conducted on C.A. & F.A. Crushed black trap basalt rock of size 10mm down was used as coarse aggregate. The results of sieve analysis confirm the requirement of gradation as per I.S. 383-1970.

- Super plasticizer (SP): Poly-carboxylate ether based super plasticizer Sika ViscoCrete 10R, (supplied by Designer Concrete Pvt. Ltd. Nasik) is used as high range water reducing admixture in the experimental work. They satisfy the requirement of IS 9103- 1999 (Amended 2003).
- Viscosity Modifying Agent (VMA): Biopolymer based VMA Sika ViscoCrete 4R (supplied by Designer Concrete Pvt. Ltd. Nasik) is used as viscosity modifying admixture in the experimental work. They satisfy the requirement of IS 9103- 1999 (Amended 2003).
- Fly Ash: Ash (FLA) Pozzocrete 60” (process by Dirk India Pvt. Ltd., Nashik) is used in concrete in dry powder form. Color of Fly ash is light gray.
- Foundry Sand: Chemical properties of foundry sand are given in Table 1 and Physical properties of foundry sand are still remaining.
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TABLE 1: CHEMICAL PROPERTIES OF FOUNDRY SAND

Sr. No.	Constituent	Value (%)
1	SiO_2	83.93
2	Al_2O_3	0.021
3	Fe_2O_3	0.950
4	CaO	1.03
5	MgO	1.77
6	SO_3	0.057
7	LOI	2.19

1.1 Mix design procedure of SCC:

The following sequence is followed for self compacting concrete

- Determination of the desired air content.
- Determination of the coarse aggregate volume.
- Determination of sand content.
- Design of the paste composition.
- Determination of the optimum water to powder ratio and super plasticizer dosage in mortar.
- Finally the concrete properties are assessed by standard tests.

A flow-chart describing the procedure for design of SCC mix is shown in Fig. 4.

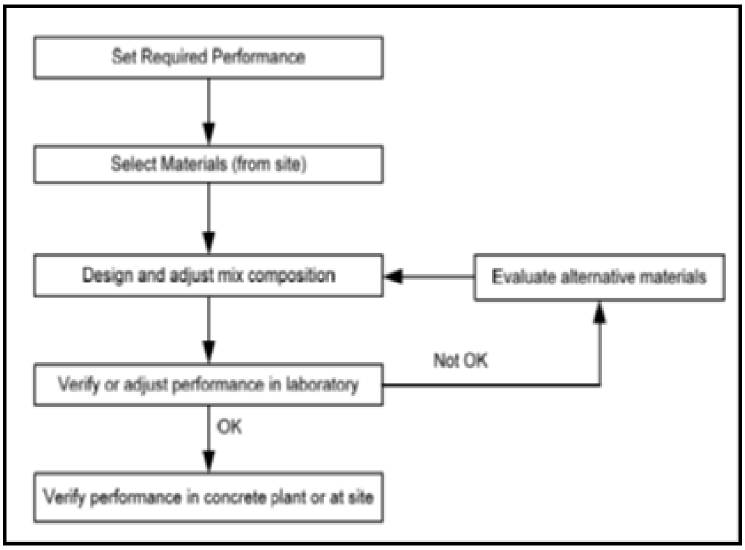


Fig .4 SSC Mix design (Europian code)

The quantity of ingredient materials and mix proportions as per procedures of European Federation of National Associations Representing for Concrete (EFNARC) guide lines is as under.

Table 2: Quantity Of Materials Per Cubic Meter Of Concrete For M35

Sr. No.	Materials	Proportion by weight	Weight in kg/m^3
1.	Cement	1	375
2.	F. A.	2.32	870
3.	Fly Ash	0.47	175
4.	C. A.	2.45	920
5.	W/C	0.32	176
6.	Super plasticizer	0.60%	3.3lit
7.	VMA	0.15%	0.83lit

III. PRELIMINARY TESTING ON MATERIALS

- Cement: Result obtained in preliminary testing of cement is obtained is shown in Table No. 3. The obtained results meet requirements as per IS.

Table No. 3 Physical Properties Of Cement

Sr. No.	Description	Requirement as per IS	Results
01	Fineness of cement	0- 10%	3 %
02	Specific gravity	--	3.15
03	Standard consistency	--	33 %
04	Initial setting time Final setting time	30 minute 600 minute	47 minute 420 minute
05	Soundness test	10.0 mm	3.0 mm
06	Compressive strength 7 days	40.0 N/mm^2	41.6 N/mm^2

- Fine Aggregate: Various tests conducted on fine aggregate is shown in Table IV. The obtained results meet requirements as per IS.

Table No. 4 Physical Properties Of Fine Aggregate

Sr. No.	Property	Results
01.	Particle Shape, Size	Round, 4.75 mm
02.	Fineness Modulus	2.683
03.	Silt Content	3.3 %
04.	Specific Gravity	2.72
05.	Bulk Density	1723 kg/m^3
06.	Surface Moisture	Nil

- Coarse Aggregate: Various tests conducted on coarse aggregate is shown in Table V. The obtained results meet requirements as per IS.

Table No. 5 Physical Properties Of Coarse Aggregate

Sr. No	Property	Results
01.	Particle Shape, Size	Angular, 20 mm
02.	Fineness Modulus	6.057
03.	Specific Gravity	2.74
04.	Water absorption	2.835 %
05.	Moisture content	Nil
06.	Bulk Density	1620 kg/m^3

- Fly Ash: Physical properties of fly ash are obtained from the supplier and are mentioned in Table VI

Table No. 6 Physical Properties Of Fly Ash

Sr. No	Physical properties	Values	Requirements as Per IS- 3821: 2003
01.	Fineness- Specific Surface, m^2 /kg	437	320 Minimum
02.	Retention in 45 microns,	2.1	34 Maximum
03.	Lime reactivity	4.8	4.5 Minimum
04.	Compressive strength	86	Not less than 80
05.	Soundness (%)	0.04	0.8 Maximum

IV. Experimental Investigation

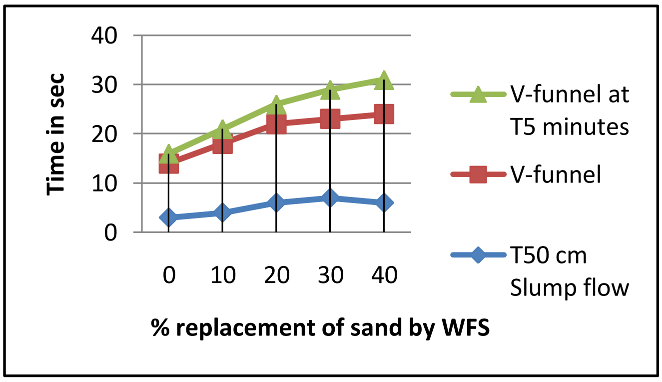
Experimental Investigation carried out for determination of Compressive strength, Flexural strength and Split tensile strength of SCC with varying percentage of waste foundry sand. The test results of 7 days compressive strength are determined with compression testing machine. The details of test on fresh concrete and test on harden concrete are described below:

- Test on fresh concrete: Workability of the self compacting concrete is major governing criteria for the design. Hence workability of the SCC with waste foundry sand is determined with various tests like Slump flow, V Funnel, L Box and J Ring test. The result obtained for SCC with waste foundry sand is shown in Table VII.

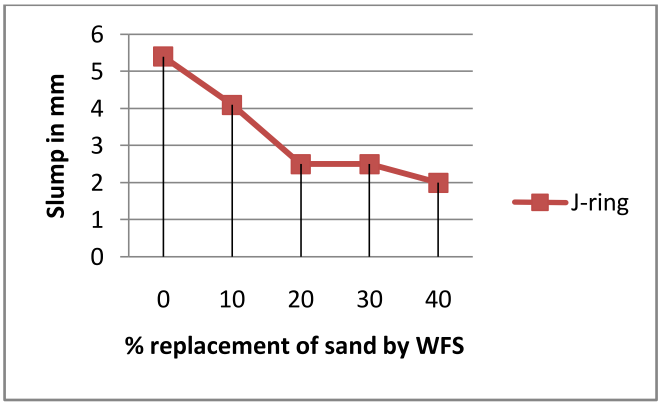
Table No. 7 Results For Workability Of Scc With WFS

Sr. No.	Workability of SCC by	Percentage replacement of WFS in NS				
		0%	10%	20%	30%	40%
1	Slump flow mm	695	680	672	655	640
2	$T_{50\ cm}$ Slump flow sec	3	3	5	6	6
3	J-ring mm	5.0	6.5	8.0	10.5	12.0
4	V-funnel sec	11	12	15	15	17
5	V-funnel at T_5 minutes sec	15	14	17	18	20
6	L-box H_2/H_1	0.9	0.75	0.6	0.55	0.55

Graph 1: Results for Workability of SCC with WFS by various tests



Graph 2: Results for Workability of SCC with WFS by J-ring



- Test on hard concrete: The tests on hard concrete were conducted for 7 days and 28 days for compressive strength using concrete cube specimens. The flexure strength of SCC with WFS is going to determined by using beam specimens for 28 days and Split tensile strength of concrete is to determine taking concrete cylinder specimens. Till date the 7 days strength of the concrete cube specimens were conducted for SSC control specimens and for varying percentage of waste foundry sand. The density of SCC with WFS is also studied for consideration of weigh of SCC with WFS. The Table 8 and Table 9 given below shows the results of 7 days compressive strength of SCC control specimens and SCC with WFS.

Table No. 8 Results For 7 Days Compressive Strength Of Scc With WFS

Sr. No.	Designation	Compressive strength at 7 days	Avg. Compressive Strength at 7 days
1	SCC-0%1	29.14	27.83
	SCC-0%2	28.69	
	SCC-0%3	25.67	
2	SCC-10%1	22.33	21.68
	SCC-10%2	19.25	
	SCC-10%3	23.47	
3	SCC-20%1	16.52	15.77
	SCC-20%2	15.87	
	SCC-20%3	14.93	
4	SCC-30%1	15.96	14.56
	SCC-30%2	12.58	
	SCC-30%3	15.16	
5	SCC-40%1	14.22	13.05
	SCC-40%2	12.67	
	SCC-40%5	12.27	

Graph 3: Results for 7 days Compressive strength of SCC with WFS

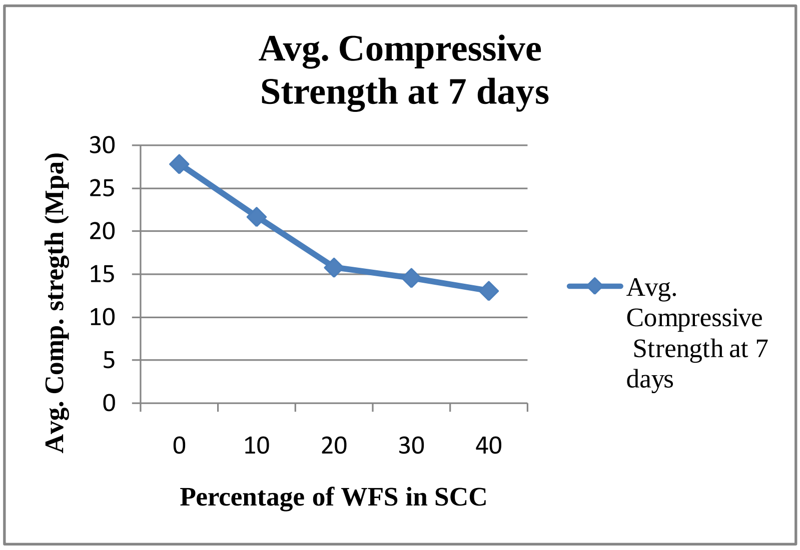
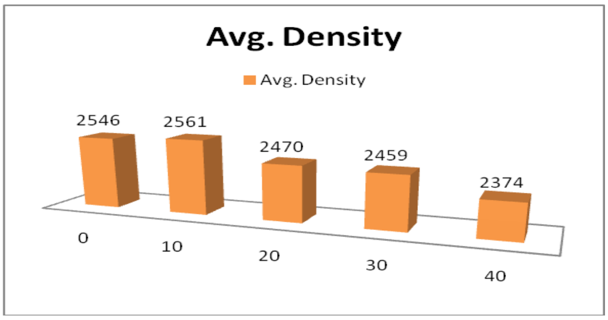


Table No 9 Results For Density In Kg/M^3 Of Scc With WFS

Sr. No.	Designation	Density in kg/m^3	Avg. Density in kg/m^3
1	SCC-0%1	2467	2546
	SCC-0%2	2590	
	SCC-0%3	2581	
2	SCC-10%1	2432	2561
	SCC-10%2	2615	
	SCC-10%3	2636	
3	SCC-20%1	2447	2459
	SCC-20%2	2434	
	SCC-20%3	2495	
4	SCC-30%1	2371	2470
	SCC-30%2	2381	
	SCC-30%3	2657	
5	SCC-40%1	2376	2374
	SCC-40%2	2376	
	SCC-40%5	2370	

Graph 4: Results for Density in Kg/m^3 of SCC with WFS



V. Conclusions

- It is clearly seen from the results obtained for various tests of workability of SCC control specimen and SCC with WFS that for control specimen workability observed is within the permissible range specified by European Code. Hence it approves the mix design of SCC.
- Form Graph 1, it may be concluded that workability obtained by Abram cone test decreases as the percentage of waste foundry sand increases , whereas for 20% replacement of WFS in SCC shows maximum decrease in workability of concrete.
- The same behavior of workability was observed in other methods of workability determination. Hence it can be said that the SCC is less workable with WFS.
- The average compressive strength of concrete at 7 days was determined on compression testing machine. The result obtained for average compressive strength is shown in graph above.
- Graph 4 shows the behavior of density for SCC control specimen and SCC with WFS. It is observed from result that density of SCC with WFS decreases as percentage of WFS increases. This is because less weight of WFS as compared to Natural Sand.

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