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Development of Concrete with Partial Replacement of Fine Aggregate by Waste Foundry Sand

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Abstract— In the last few years various research and modification has been done to produce concrete which has the desired properties. Concrete is one of the most common materials used in the construction field. The current area of research in the concrete was introducing foundry sand in the ordinary concrete. Generation of waste foundry sand as byproduct of metal casting industries causes environmental problems because of its improper disposal. Thus, its usage in building material, construction and in other fields is essential for reduction of environmental problems. This research was carried out to produce an eco-friendly concrete. This paper demonstrates the possible use of waste foundry sand as a partial replacement by fine aggregate in concrete of two groups. In which first group concrete contains natural sand as a fine aggregate and second group concrete contains artificial sand as a fine aggregate. Ingredients for group 1 concrete are cement, course aggregate, artificial sand (fine aggregate) and same for group 2 concrete are cement, course aggregate, natural sand (fine aggregate). An experimental investigation was carried out on a concrete containing waste foundry sand in the range of 0%, 5% 10%, 15%, and 20% by weight for M-30 grade concrete for both groups. Material was produced, tested and compared with conventional concrete in terms of strength. These tests were carried out on standard cube, cylinder and beam for 7 and 28 days to determine the properties of concrete. The aim of this research was to know the behavior and mechanical properties of concrete after addition of industrial waste in different proportion by tests like compressive strength by cube specimen, split tensile by cylindrical specimen and flexural strength by beam model. The research was a resource for exploring the potential use of foundry sand as an alternative to virgin raw materials.

Keywords- Industrial waste, Waste Foundry sand (WFS), OPC, Eco-friendly, Compressive strength, Split tensile strength, Flexural Strength.

I. INTRODUCTION

The current area of research in the concrete is introducing foundry sand in the ordinary concrete. 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. Indian foundries produce approximately 1.71 million tons of waste foundry sand each year (Metal World, 2006). The considerable disposal expense has made the current practice of WFS disposal in landfills less favorable. Besides the financial burden to the foundries, land-filling WFS also make them liable for future environmental costs, remediation problems and regulation restrictions. This issue is increasingly addressed by alternate options of reusing WFS beneficially. Beneficial reuses of WFS in variety of applications related to infrastructure engineering and rehabilitation works. Some of the researchers have reported the possible use of waste foundry sand in different civil engineering applications. These alternate applications offer cost savings for both foundries and user industries and environmental benefits at the local and national level.

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. Most foundries have two sand systems one feeding the external molding lines and the other feeding the internal core lines. After the metal is poured and the part is cooling, green sand is literally shaken off the castings, recovered and reconditioned for continual reuse. Used cores are also captured during this cooling and shake out process; these break down and are crushed and reintroduced into green sand systems to replace a portion of sand lost in the process. Broken cores are cores, which do not break down, are discarded. Depending on the projected end use, it may be important to segregate sand streams at the foundry as each stream can have different characteristics. Additionally some sand is typically unrecoverable during shake off and finishing processes. These sans 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.

II. MATERIAL USED AND PART ANALYSIS

2.1 Waste Foundry Sand

Waste foundry sand is made up of mostly natural sand material. Its properties are similar to the properties of natural or manufactured sand. Thus it can normally be used as a replacement of sand. Source of WFS for this research was from Aditya Foundry Ambad MIDC Nasik.

Table No. 1: Chemical Properties of Foundry Sand

Sr. No	Constituent	Value (%)
1	SiO2	83.93
2	Al2O3	0.021
3	Fe2O3	0.950
4	CaO	1.03
5	MgO	1.77
6	SO3	0.057
7	LOI	2.19

Source: R. Siddique, Waste Materials and By Products in Concrete, Springer-2008

Fig. 1 Waste Foundry Sand

2.2 Cement

Ordinary Portland cement 53 grade was used. It was tested as per Indian standard specification (BIS-1489 part 1:1991). Test results are given below.

Table No. 2: Physical Properties of ordinary Portland cement

Physical Properties		BIS-1489:1991	Test Result
Setting time (mm)	Initial	30 Min	92
	Final	600 Max	248
Specific gravity		----	3.15

2.3 Aggregate

The river sand and crushed sand was being used in two groups of concrete as fine aggregate conforming to the requirements of IS: 383. Crushed stone with maximum 20mm graded aggregates (nominal size) were used as coarse aggregate.

Table No. 3: Physical Properties of Aggregate

Sr. No.	Properties	Natural Sand	Artificial Sand	Coarse Aggregate
1.	Bulk Density (Loose), kg/m3	1.833	1.86	1.44
2.	Bulk Density (Compacted), kg/m3	1.87	1.91	1.55
3.	Specific Gravity	2.647	2.75	2.61
4.	Water Absorption (%)	1.0	4.67	2.04
5	Moisture content (%)	1.7	1.8	1.78

III. METHODOLOGY ADOPTED FOR CONCRETE MIX

Firstly Control mix proportion for M30 grade concrete was obtained for two group of concrete in which first group consist natural sand as fine aggregate and second group consist of artificial sand as fine aggregate. Remaining ingredients for both group concrete were same. Then mix proportion was modified by replacing fine aggregate from both groups by waste foundry sand in the range of 0%, 5% 10%, 15%, and 20% by weight. Mix design was carried out manually conforming to IS 10262:2009.

Table No. 4: Mix Proportion for Group-I Concrete (M30)

Water (Lit.)	Cement (kg/m3)	Natural Sand (kg/m3)	Coarse Aggregate (kg/m3)
180	418.60	744.92	1076.15
0.43	1	1.78	2.57

Table No. 5: Replacement of Natural Sand in Group-I by WFS

Sr. no.	Coding	Natural Sand replaced by WFS	Concrete mix design proportion				
			w/c ratio	C	NS	CA	WFS
1	NC	0% replacement	0.43	1	1.78	2.57	-------
2	FS1	5% replacement	0.43	1	1.691	2.99	0.089
3	FS2	10% replacement	0.43	1	1.602	2.99	0.178
4	FS3	15% replacement	0.43	1	1.513	2.99	0.267

5	FS4	20% replacement	0.43	1	1.424	2.99	0.356

C=Cement, NS=Natural Sand, CA=Coarse Aggregate, WFS=Waste Foundry Sand

Table No. 6: Mix Proportion for Group-II Concrete (M30)

Water (Lit.)	Cement (kg/m3)	Artificial Sand (kg/m3)	Coarse Aggregate (kg/m3)
181	420.92	620.42	1181.70
0.43	1	1.47	2.80

Table No. 7: Replacement of Artificial Sand in Group-II by WFS

Sr. no.	Coding	Natural Sand replaced by WFS	Concrete mix design proportion				
			w/c ratio	C	AS	CA	WFS
1	CM	0% replacement	0.43	1	1.47	2.80	-------
2	F1	5% replacement	0.43	1	1.396	2.80	0.0735
3	F2	10% replacement	0.43	1	1.323	2.80	0.147
4	F3	15% replacement	0.43	1	1.25	2.80	0.221
5	F4	20% replacement	0.43	1	1.176	2.80	0.294

IV. EXPERIMENTAL SETUP AND RESULTS

Keeping in mind the gap in the research area, the objective of this study was to determine the strength of concrete containing waste foundry sand (WFS) as partial replacement of fine aggregate. For this purpose different test on harden concrete were conducted at the age of 7 and 28 days like compressive strength on 150 x 150 x 150 mm size cube, splitting tensile strength on 150 mm X 300 mm cylinder, flexural strength on beam of size 100 x100 x 500 mm. As per IS 516 Total 180 number of specimen were tested for both group of concrete. Results are tabulated as below:

4.1. Compressive strength

Compressive strength tests were performed on cube samples using compression testing machine. Three samples per batch were tested with the average strength values reported in table no. 8

Table No. 8: Compressive Strength Test Results

Group Designation	Concrete Type	Average Ultimate Compressive Strength At 7 Days (N/mm2)	Average Ultimate Compressive Strength At 28 Days (N/mm2)
Group-I	NC	23.48	30.28
	FS1	24.04	34.40
	FS2	30.82	36.70
	FS3	33.40	39.83

	FS4	31.24	35.98
Group-II	CM	24.22	29.98
	F1	30.63	33.53
	F2	31.28	34.41
	F3	34.67	38.12
	F4	33.05	36.36

4.2. Splitting Tensile strength

Splitting tensile strength tests were performed on compression testing machine using cylindrical samples. Three samples per batch were tested with the average strength values reported in table no. 9

4.3. Flexural strength

Flexural strength tests were performed on flexural testing machine having 100KN capacity using beam specimen. Three samples per batch were tested with the average strength values reported in table no.10

Table No. 9: Splitting Tensile Strength Test Results

Group Designation	Concrete Type	Average Tensile Strength At 7 Days (N/mm2)	Average Tensile Strength At 28 Days (N/mm2)
Group-I	NC	2.20	3.30
	FS1	2.22	3.51
	FS2	2.58	3.87
	FS3	2.53	3.77
	FS4	2.16	2.93
Group-II	CM	1.91	3.21
	F1	2.27	3.41
	F2	2.72	4.03
	F3	2.98	4.11
	F4	2.119	3.25

Table No. 10: Flexural Strength Test Results

Group Designation	Concrete Type	Average Tensile Strength At 7 Days (N/mm2)	Average Tensile Strength At 28 Days (N/mm2)
Group-I	NC	5.2	7.02
	FS1	4.6	6.21
	FS2	4.0	5.40
	FS3	4.67	6.31
	FS4	4.93	6.66
Group-II	CM	5.3	7.16
	F1	4.21	5.68
	F2	3.97	5.36
	F3	4.8	6.48
	F4	5.1	6.88

V. CONCLUSIONS

Based on above results following conclusion were made regarding properties of concrete incorporating waste foundry sand.

- Compressive strength of concrete increases with increase in percentage of waste foundry sand as compare to regular concrete in both group of concrete. It was maximum for 15 % replacement.
- Split tensile strength increases with increase in percentage of waste foundry sand up to 15 % replacement after that it decreases.
- There was adverse effect on flexural strength of beam model but which was also within the limit as compare to ordinary concrete.
- Among both group concrete results, second group concrete i.e. concrete containing artificial sand and WFS shows more positive results.
- Use of waste foundry sand in concrete reduces the production of waste through metal industries i.e. it's an eco-friendly building material.
- The problems of disposal and maintenance cost of land filling is reduced.
- Application of this study leads to develop in construction sector and innovative building material.
- The result of percentage cost change reduces up to 3.5 for 15% replacement of waste foundry sand. This shows that the concrete produced is economical.

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