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Test on Concrete after Adding Foundry Sand

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Abstract: Due to ever increasing quantities of waste materials and industrial by-products, solid waste management is the prime concern in the world. Scarcity of land-filling space and because of its ever increasing cost, recycling and utilization of industrial by-products and waste materials has become an attractive proposition to disposal. There are several types of industrial by-products and waste materials. The utilization of such materials in concrete not only makes it economical, but also helps in reducing disposal concerns. One such industrial by-product is Waste Foundry Sand (SFS). WFS is major byproduct of metal casting industry and successfully used as a land filling material for many years. But use of waste foundry sand (WFS) for land filling is becoming a problem due to rapid increase in disposal cost. In an effort to use the WFS in construction materials, research has being carried out for its possible utilization in making concrete as partial replacement of fine aggregate. In India, approximately 1.71 million tons of waste foundry sand and in Punjab region, approximately 0.17 million tons of waste foundry is produced yearly. This experimental investigation was performed to evaluate the strength and durability properties of M20 (30 MPa) and M30 (40 MPa) grades of concrete mixes, in which natural sand was partial replaced with waste foundry sand (WFS). Natural sand was replaced with five percentage (0%, 5%, 10%, 15%, 20%) of WFS by weight. A total of ten concrete mix proportions M-1, M-2, M- 3, M-4 and M-5 for M20 grade of concrete and M-6, M-7, M-8, M-9 and M-10 for M30 grade of concrete with and without WFS were developed. Compression test, splitting tensile strength test and modulus of elasticity were carried out to evaluate the strength properties of concrete at the age of 7, 28, 91 and 365 days. In non destructive testing, rebound hammer and ultrasonic pulse velocity test were conducted at the age of 28, 91 and 365 days. In case of durability property, abrasion resistance, rapid Chloride Permeability and deicing salt scaling resistance was evaluated at the age of 28, 91 and 365 days. Statistical analysis and comparative study between strength and durability properties of both grade of concrete (M20 and M30) were carried out at the age of 28, 91 and 365 days. XRD study was done to identify the presence of various compounds in M20 grade of concrete with foundry sand in varying percentages replacement of fine aggregate.

I. INTRODUCTION

The consumption of all type of aggregates has been increasing in recent years in most countries at a rate far exceeding that suggested by the growth rate of their economy or of their construction industries. Artificially manufactured aggregates are more expensive to produce, and the available source of natural aggregates may be at a considerable distance from the point of use, in which case, the cost of transporting is a disadvantage. The other factors to be considered are the continued and expanding extraction of natural aggregates accompanied by serious environmental problems. Often it leads to irremediable deterioration of the country side. Quarrying of aggregates leads to disturbed surface area etc., but the aggregates from industrial wastes are not only adding extra aggregate sources to the natural and artificial aggregate but also prevent environmental pollution. Foundry industry produces a large amount of by-product material during casting process. The ferrous metal casts in foundry are cast iron and steel, non ferrous metal are aluminium, copper, brass and bronze. Over 70% of the total by-product material consists of sand because moulds usually consist of moulding sand, which is easily available, inexpensive, resistance to heat damage, easily bonded with binder, and other organic material in mould. Foundry industry use high quality specific size silica sand for their moulding and casting process. This is high quality sand than the typical bank run or natural sand. Foundries successfully recycle and reuse the sand many times in foundry. When it can no longer be reused in the foundry, it is removed from the industry, and is termed as waste foundry sand (**WFS**). It is also known as spent foundry sand (SFS) and used-foundry sand (UFS). Waste foundry sand are by-products which appears to possess the potential to partially replace regular sand as a fine aggregate in concretes, providing a recycling opportunity for them. If such types of materials can be substituted partly/fully for natural sand (fine aggregates) in concrete mixtures without sacrificing or even improving strength and durability, there are clear economic and environmental gains. Currently, very limited literature is available on the use of these by-products in concrete. Waste foundry sand (WFS) is one of the major issues in the management of foundry waste. WFS are black in color and contain large amount of fines. The typical physical and chemical property of WFS is dependent upon the type of metal being poured, casting process, technology employed, type of furnaces (induction, electric arc and cupola) and type of finishing process (grinding, blast cleaning and coating).

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II. CONTENT

A. Cement

Ordinary Portland Cement was used. It was tested as per Indian standard specification (BIS-8112-1989). Test results are given in Table 1.

Table 1 Test Results of Cement Sample

S.No.	Characteristics	Experimental value	Requirements as per IS: 8112-1989
1.	Consistency (%)	28	-
2.	Specific gravity	3.15	3.15
3.	Initial setting time (min)	95	>30
4.	Final setting time (min)	215	<600
5.	Fineness (%)	5	10
6.	Soundness (mm)	2.55	<10
7.	Compressive strength		
(i)	3 days (MPa)	26.10	≥23
(ii)	7 days (MPa)	36.69	≥33
(iii)	28 days (MPa)	46.56	≥43

B. Fine Aggregates

Locally available natural river sand was used as the fine aggregate. Its sieve analysis and physical properties are shown in Tables 2 and 3.

Table 2 Sieve analysis of fine aggregate
Weight of sample taken = 2.0 kg

IS sieve size (mm)	Retained weight (kg)	% weight retained	Cumulative %wt retained	% Passing
10.0	0.00	0.00	0.00	100
4.75	0.068	3.40	3.40	96.6
2.36	0.080	4.00	7.40	92.6
1.18	0.147	7.35	14.75	85.25
600 µ	0.162	8.10	22.85	77.15
300 µ	1.095	54.75	77.60	22.4
150 µ	0.335	16.75	94.35	5.65
Pan	0.113	-	-	-
Total	∑=2.0		∑=220.35	

Fineness modulus = 220.35/100 = 2.2035. **Sand conforms to Grading Zone III as per IS: 383-1970.**

Table 3 Physical properties of fine aggregate

Particulars	Properties
Specific gravity	2.67
Fineness modulus	2.20
Bulk density (loose), Kg/m³	1590
Bulk density (compacted), Kg/m³	1780

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C. Coarse Aggregates

Crushed stone conforming to IS: 383-1970 was used as coarse aggregate. Its sieve analysis and physical properties are shown in Tables 4 and 5, respectively.

Table 4 Sieve analysis of coarse aggregate
Weight of sample taken = 5.0 kg

IS sieve size (mm)	Retained weight (kg)	% weight retained	Cumulative %wt retained	% Passing
20	0.00	0.00	0.0	100
16	0.00	0.00	0.0	100
12.5	0.125	2.5	2.50	97.5
10	2.393	47.86	50.36	49.64
4.75	2.455	49.1	99.46	0.54
2.36	0.027	0.54	100	0.0
1.18	-	-	100	0.0
600 µ	-	-	100	0.0
300 µ	-	-	100	0.0
150 µ	-	-	100	0.0
Total	∑=5.0		∑=652.32	

Fineness modulus = 652.32/100 = 6.5232
Coarse aggregate conforms to IS: 383-1970.

Table 5 Physical properties of coarse aggregate

Particulars	Properties
Specific gravity	2.67
Fineness modulus	6.52
Bulk density(Loose),kg/m³	1460
Bulk density(compacted),kg/m³	1650
Maximum size, mm	10

D. Foundry Sand

Foundry sand obtained from Jagadhari foundry was used. The physical, chemical properties and sieve analysis of foundry sand are given in the Tables 6, 7 and .8 respectively.

Table. 6: Physical Properties of Foundry Sand

Sr. No.	Properties	Observed Values
1.	Color	Grey (Blackish)
2.	Bulk Density (Loose), kg/m3	1336
3.	Bulk Density (Compacted), kg/m3	1638
4.	Specific Gravity	2.18
5	Fineness Modulus	1.89
6	Water absorption (%)	0.42
7	Moisture Content (%)	0.11
8	Material Finer than 75µ (%)	8

Table. 7: Chemical Properties of Foundry Sand

Constituents	% by Weight (Used in present study)
Silica (SiO2)	83.8
Iron Oxide (Fe2 O3)	5.39
Alumina (Al2O3)	0.81
Calcium Oxide (CaO)	1.42
Magnesium oxide (MgO)	0.86
Titanium Dioxide (TiO2)	0.22
Sodium Oxide (Na2O)	0.87
Potassium Oxide (K2O)	1.14
Sulphur Trioxide (SO3)	0.21
Manganese Oxide (Mn3O4)	0.047
Strontium Oxide (SrO)	Nil

Table. 8: Sieve Analysis of Waste Foundry Sand
Weight of the sample taken = 1.0 kg

I.S. Sieve Size	Weight retained in grams	Percentage weight retained in grams	Cumulative percentage of weight retained	Percentage passing
4.75mm	00	00	00	100
2.36mm	11	1.1	1.1	98.9
1.18mm	15	1.5	2.6	97.4
600µm	25	2.5	5.1	94.9
300µm	791	79.1	84.2	15.8
150µm	122	12.2	96.4	3.6
Pan	36	3.6	100	00

Fineness modulus of waste foundry sand = 1.89

E. Superplasticizer

It was observed that increase in waste foundry sand content in concrete mixes lead to decrease the slump value of concrete. It could be due to the increase in fine particle of WFS in concrete mixes lead to increase the surface area of the fine aggregate with constant water cement ratio. To maintain the slump value, a polycarboxylic ether based superplasticizer (Sika viscocrete-10R) of SIKA brand complying with BIS: 9103–1999 was used. Specifications of superplasticizer are given in Table 9

Table .9: Specifications of Superplasticizer

Basis	Aqueous solution of modified polycarboxylate
Appearance	Brown liquid
Density	1080g/l at 30°C
pH	Approx. 5.0

F. Water

Water used for casting specimens conformed to the requirements of BIS: 456-2000. Test results are given in Table 10

Table 10: Properties of Water

Properties	Observed value
pH	8.0
Dissolved Solids (mg/l)	290
Suspended Solids	Nil
Chlorides (mg/l)	20
Sulphates (mg/l)	74
MPN Value/100 ml.	Nil

III. MIX DESIGN

Mix design is a process of selecting suitable ingredients for concrete and determining their proportions which would produce, as economically as possible, a concrete that satisfies the job requirements. The proportioning of the ingredients of concrete is an important phase of concrete technology as it ensures quality and economy. In pursuit of the goal of obtaining concrete with desired performance characteristics, the selection of component materials is the first step, the next step is a process called mix design by which one arrives at the right combination of the ingredients. There are many methods of designing concrete mixes.

A. Design of Concrete Mix

The compressive strength of concrete is considered as the index of its quality. Therefore the mix design is generally carried out for a particular compressive strength of concrete with adequate workability so that the fresh concrete can be properly mixed, placed and compacted. The proportions for the mix were calculated adopting the requirements of water as specified in BIS: 10262-1982.

The proportioning of concrete mixes consists of three interrelated steps.

1) Selection of suitable ingredients-cement, supplementary cementing materials, aggregates water and chemical admixtures.
2) Determination of the relative quantities of these materials in order to produce as economically as possible a concrete, that has desired rheological properties i.e. strength and durability.
3) Careful quality control of every phase of the concrete making process.

In the present study Mix Design for M20 (Design value at the age of 28 days) and M30 (Design value at the age of 28 days) grade concrete is done according to BIS: 10262-1982.

B. M20 Design Mix: Data

Characteristic strength at 28 days = 20 N/mm2
Degree of quality control expected at site = Good
Maximum size of aggregate = 12.5mm
Degree of workability desired (C.F.) = 0.9 (Medium)
Type of exposure = Mild, no sulfate attack
Concrete use = Concrete structure
Target mean strength = 30 N/mm2
Ingredients of M20 concrete mix are given in Table 3.11

Table 11: Mix Proportion M-20

Unit of Batch	Water (Liters)	Cement (Kg)	F.A (Kg)	C.A. (Kg)
Cubic meter content	195	390	569	1165
Ratio of ingredients	0.5	1	1.45	2.98

C. M30 design mix: Data

Characteristic strength at 28 days = 30 N/mm2
Degree of quality control expected at site = Good
Maximum size of aggregate = 12.5mm
Degree of workability desired (C.F.) = 0.9 (Medium)
Type of exposure = Mild, No sulphate attack
Concrete use = Concrete structure

Target mean strength: = 40 N/mm2

Ingredients of M30 concrete mix are given in Table 3.12

Table 12: Mix Proportion M-30

Unit of Batch	Water (Liters)	Cement (Kg)	F.A (Kg)	C.A. (Kg)
Cubic meter content	189	450	554	1139
Ratio of ingredients	0.42	1	1.23	2.53

D. Mix Composition

Initially, two series of control mixes were designed to have 28-day compressive strength of 30 MPa (M20 grade of concrete) and 40 MPa (M30 grade of concrete). The concrete mixes were designed with constant cement, fine aggregate, coarse aggregate and superplasticizer.

Table 13: Detailed Description of Concrete Mixes

M20 Grade of concrete	
M-1	0% WFS
M-2	5% WFS
M-3	10% WFS
M-4	15% WFS
M-5	20% WFS
M30 Grade of concrete	
M-6	0% WFS
M-7	5% WFS
M-8	10% WFS
M-9	15% WFS
M-10	20% WFS

Table 14: M20 Grade Mixes

Mixture No.	M-1	M-2	M-3	M-4	M-5
Cement(Kg/m3)	390	390	390	390	390
Natural sand (Kg/m3)	569	541	513	484	456
WFS (%)	0	5	10	15	20
WFS (Kg/m3)	0	28	56	85	113
Coarse aggregate (12.5mm) (Kg/m3)	1165	1165	1165	1165	1165
W/C ratio	0.5	0.5	0.5	0.5	0.5
Water (Kg/m3)	195	195	195	195	195
Super plasticizer(L/m3)	0.59	0.59	0.59	0.59	0.59
Slump (mm)	90	85	85	80	80
Air temperature (°c)	27	27	28	27	27
Concrete temperature (°c)	26	27	27	26	26

Table 15: M30 Grade Mixes

Mixture No.	M-6	M-7	M-8	M-9	M-10
Cement(Kg/m3)	450	450	450	450	450
Natural Sand (Kg/m3)	554	527	500	471	443
WFS (%)	0	5	10	15	20
WFS (Kg/m3)	0	27	54	83	111
Coarse Aggregate (12.5mm)(Kg/m3)	1139	1139	1139	1139	1139
W/C ratio	0.42	0.42	0.42	0.42	0.42
Water (Kg/m3)	189	189	189	189	189
Super Plasticizer(L/m3)	1.65	1.65	1.65	1.65	1.65
Slump (mm)	90	80	80	80	75
Air Temperature (°c)	27	27	28	27	27
Concrete Temperature (°c)	27	27	26	26	26

The fine aggregates were replaced with waste foundry sand varying from 0% to 20% at the equal interval of 5%, to study the effect of replacement of fine aggregates with waste foundry sand on the strength and durability properties of concrete. Control mix (0%WFS) having 30 MPa strength was designated as M-1 and mixes made with WFS were designated with M-2, M-3, M-4 and M-5. Similarly control mix (0% WFS), having compressive strength 40 MPa was designated as M-6 and mixes with WFS were designated as M-7, M-8, M-9 and M-10.

The detailed descriptions of all mixes are given in Table 3.13. The details of mix proportions of M20 and M30 grade of concrete mixes are given in Tables 3.14 and 3.15.

IV. CASTING OF SPECIMENS

All the specimens were cast having mix proportions as given in Tables 3.14 and 3.15. For these mix proportions, required quantities of materials were weighed. The mixing procedure adopted was as follows:

1) The cement and foundry sand were dry mixed in a tray for about 5 minutes. A uniform color was obtained without any clusters of cement, foundry sand.
2) Weighed quantities of coarse aggregates and sand were then mixed in dry state.
3) The mix of cement and foundry sand was added to the mix of coarse aggregates and sand and these were mixed thoroughly until a homogeneous mix was obtained.
4) Water was then added in three stages as given below:
   a) 50% of total water to the dry mix of concrete in first stage.
   b) 40% of water and superplasticizer to the wet mix.
   c) Remaining 10% of water was sprinkled on the above mix and it was thoroughly mixed in the mixer.

All the moulds were properly oiled before casting the specimens. The casting immediately followed mixing, after carrying out the tests for fresh properties. The top surface of the specimens was scraped to remove excess material and achieve smooth finish. The specimens were removed from moulds after 24 hours and cured in water till testing or as per requirement of the test.

V. TESTING PROCEDURE

After required period of curing, the specimens were taken out of the curing tank and their surfaces were wiped off. Besides measuring the fresh properties (workability, air content and concrete temperature), following tests were performed on hardened concrete.

A. *Strength Properties*

1) Compressive strength (BIS: 516 – 1959)
2) Splitting tensile strength (BIS: 5816 – 1999)

These properties were determined at the age of 7, 28, 90 days

B. *Fresh Properties*

The workability of fresh concrete is a composite property which includes the diverse requirements of stability, mobility, compactability, placeability and finishability. There are different methods for measuring the workability. Each of them measures only a particular aspect of it and there is really no unique test which measures workability of concrete in its totality. The fresh properties were studied in the following tests with the order of testing as mentioned below:

1) Slump test
2) Compaction factor

For determining the fresh properties, slump flow and Compaction factor tests were performed as envisaged by BIS: 1199-1959. All fresh test measurements were duplicated and the average of measurements was given.

C. *Slump Test*

The vertical settlement of unsupported fresh concrete, flowing to the sides and sinking in height is known as slump. Slump is a measure indicating the consistency or workability of cement concrete. It gives an idea of water content needed for concrete to be used for different works. A concrete is said to be workable if it can be easily mixed, placed, compacted and finished. A workable concrete should not show any segregation or bleeding. The setup of the slump test is shown in Fig. 3.1.

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Fig. 1 Slump Test

D. Compaction Factor Test

Compaction factor test is based on the definition, that workability is that property of the concrete that determines the amount of work required to produce full compaction. The test consists essentially of applying a standard amount of work to standard quantity of concrete and measuring the resulting compaction as shown in Fig.3.2.

E. Strength Properties

1) *Compressive Strength Test:* Compressive strength test is initial step of testing concrete because the concrete is primarily meant to withstand compressive stresses. Compressive strength tests were carried out on 150 mm x 150 mm x 150 mm cubes with compression testing machine of 3000 KN capacity. The specimens after removal from the curing tank were cleaned and properly dried. The surface of the testing machine was cleaned. The cube was then placed with the cast faces in the contact with the platens of the testing machine. Cubes were tested at 7 and 28 days of casting.

Fig. 2 Compaction Factor

2) *Split Tensile Strength Test:* Split-tensile strength test is an indirect method to determine tensile strength of concrete. The test consists of applying compressive line loads along the opposite generators of concrete cylinder placed with its axis horizontal between the platens. Cylinders of size 150mm diameter and 300mm height were cast to check the splitting tensile strength of the concrete. Specimens were tested at 7 and 28 days of casting.

Fig 3 Compression Testing

F. Rebound Hammer

Rebound hammer test is also called surface hardness method. The rebound hammer test measure the elastic rebound of concrete and primarily for compressive integration. The test was conducted on 150mm cube at the age of 28, 91 and 365 days. SCHMIDT rebound hammer (digital) was used for testing as shown in Fig. 3.10. In this method a test hammer hits the concrete at a definite energy 2.2Nm and compressive strength is directly obtained from rebound hammer. The equipment was operated vertically downward. The plunger was pressed strongly and steadily against the concrete surface to be tested at right angle. Normally grid was used to locate impact points not less than 20mm apart from each other. BIS 13311(part 2) recommended 12 reading taken over an area mean of compressive strength values was calculated. According to BIS 13311 (part 2), the estimation of strength of concrete by rebound hammer method cannot be held to be very accurate and probable accuracy of prediction of concrete strength in structure is ± 25 percent.


Fig 4 Split Tensile Testing

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VI. CONCLUSION

A. Compressive strength of both grades of concrete mixes (M20 and M30) increased due to replacement of fine aggregate with waste foundry sand. However, compressive strength observed for both grades of concrete mixes were appropriate for structural uses.

B. M20 grade concrete mix obtained increase in 28-day compressive strength from 25.0MPa to 30.20MPa on 15% replacement of fine aggregate with WFS, whereas it increase was from 36.6MPa to 42.8MPa for M30 grade of concrete mix. Maximum strength was achieved with 15% replacement of fine aggregate with WFS. Beyond 15% replacement it goes to decrease for both grades of concrete, but was still higher than control concretes

C. At 15% replacement of fine sand with WFS, M20 Grade of concrete showed better percentage increase than M30 Grade of concrete by 9% at 28 days, 19.5% at 90 days

D. Effect of inclusion of WFS was better effect on M20 grade of concrete mixes rather than M30 grade of concrete mixes. The rate of gain of strength for M20 grade of concrete mixes observed to be more than M30 grade of concrete mixes at all percentage replacement.

E. Compressive strength also increased with increase in age for both grades of concrete. The rate of compressive development of waste foundry sand concrete mixes were higher compared to no waste foundry sand concrete mixes.

F. Concrete mixes obtained linear increase in 28-day splitting tensile strength from 2.62MPa to 2.96MPa for M20 grade of concrete mix (M-1) and 3.95MPa to 4.36MPa for M30 grade of concrete mix (M-6) on replacement of 15% of fine aggregate with waste foundry sand.

G. Splitting tensile strength of all concrete mixes for both grades of concrete (M20 and M30) was found to increase with increase in with varying percentage of waste foundry sand.

H. At the age of 28 days, splitting tensile strength of M20 grade of concrete mix (M-1) increased by 12.8% whereas increase was 10.4% for M30 grade of concrete mix (M-6) at same age. Development of splitting tensile strength was more in M20 grade mixes than M30 grade mixes.

I. At 15% replacement, M20 Grade of concrete mix (M-4) achieved higher percentage increase. It means that, particle size distribution of M20 Grade of concrete mixes with 15% WFS has more adherence than M30 Grade concrete mixes

J. Maximum increase in splitting tensile strength was observed at 15% replacement of fine aggregate with waste foundry sand at all age for both grades of concrete mixes (M20 and M30).

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