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Characteristics of Concrete Containing Waste Foundry Sand and Slag Sand

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Abstract: In metal casting process foundry industries dispose huge quantity of waste sand into landfills, causing harmful impact on environment. Therefore, its effective use in cement concrete needs to be investigated. In this research, an attempt was made to evaluate the properties of concrete containing waste foundry sand as a partial replacement to slag sand. Concrete mixtures with 0%, 15%, 30% & 45% waste foundry sand replaced partially by weight of slag sand, with mix proportion of M25 grade were produced in laboratory. An additional mix with 30% waste foundry sand replaced for the sieve sizes 300μm, 150μm & 75μm was also proportioned. Both fresh and hardened properties were investigated. Water/cement ratio of 0.45 was kept constant for all the mixes. Hardened properties included compressive strength, split tensile strength, modulus of elasticity, drying shrinkage and flexural strength at different curing periods. The test results showed that strength properties show a decreasing trend with the increase in waste foundry sand content in cement concrete. For 28 days, maximum decrease in compressive strength was 39% for concrete mixtures containing 45% WFS, when compared to reference mixture. The mixtures containing waste foundry sand replaced more than 30% showed very high shrinkage. Among all the strength properties, flexural strength was found to be least affected by WFS. From this limited study it can be concluded that concrete containing waste foundry sand up to 15% can be effectively used for structural applications. Higher replacements can be tried in non-structural applications like concrete pavements.

Keywords: *Waste foundry sand, cement concrete, slag sand, drying shrinkage*

1. Introduction

About 60% to 80% of concrete is composed of aggregate by volume. Both fine and coarse aggregate is used in concrete production. The utilization of sand as fine aggregate in the construction industry has increased by an alarming rate. To cater to this increasing demand the industry is facing difficulty in the supply of natural river sand. To overcome this situation, construction industries have identified alternatives like manufactured sand, robo sand, rock dust etc. Another alternative to this can be use of waste material in concrete.

Waste foundry sand is a waste material obtained from ferrous and non-ferrous metal casting industries. In foundry industries sand is recycled and reused many times for the purpose of casting. When the sand finds no advantage in this industry, it is disposed as a waste material, and termed as waste foundry sand (WFS). The incorporation of such material in concrete can help to reduce the disposal concerns of waste foundry sand, and also makes concrete production economical.

Partial replacement of fine aggregates with waste foundry sand will reduce the consumption of natural aggregates like river sand and crushed granite sand. It will also help to dispose the excess waste foundry sand effectively. This study primarily focuses on utilization of waste foundry sand as partial replacement to slag sand in cement concrete.

Research studies have already been conducted on the use of waste foundry sand in civil engineering applications. But studies carried on the reuse of waste foundry sand in concrete production with locally available materials are limited. With this aim, the main objective of this research is to study potential reuse of waste foundry sand obtained from various metal casting industries as a partial replacement to sand in cement concrete production.

B. J. Lee et al. [1] investigated the physical and chemical properties of concrete containing waste foundry sand as a partial replacement to natural sand. Strength and durability properties were evaluated in order to determine the influence of waste foundry sand on the behavior of concrete. From their study it was concluded that, control mix shows almost equal strength as that of the concrete mix with 30% of WFS. The durability properties of concrete mixtures containing waste foundry sand also showed a similar trend in their results as that of mechanical properties. From the entire test results it was concluded that, the concrete mixture containing 30% replacement of WFS can be effectively used in the construction industry without affecting the strength and durability properties of the concrete.

J. M. Khatib et al. [2, 3] investigated the properties of concrete incorporated with waste foundry sand. In their research fine aggregates were replaced with 0%, 30%, 60% and 100% WFS. Water content, water to cement ratio, cement content and coarse aggregate content were kept constant throughout the research. The properties like compressive strength, water absorption, ultra-sonic pulse velocity were studied at different curing periods (7, 28 and 90 days). The results showed that due to capillary action there was a systematic increase in water absorption. Compressive strength and ultrasonic pulse velocity indicated a decreasing trend in their values with the increase in waste foundry sand (WFS) content. They also concluded that sufficient strength can be attained by suitable replacement of WFS.

R. Siddique et al. [4, 5]. In this literature the investigators have shown that WFS can be effectively used in the production of low strength concrete. The study concludes that, with the increase in waste foundry sand the fluidity and the slump value of the fresh concrete decreases. It is due to the presence of clayey particles in foundry sand. Water absorption capacity showed a decreasing trend in their values with the increase in WFS content. Strength properties increased significantly when higher amount of WFS was used. The result of various studies indicates that WFS can be effectively used for the production of concrete and other materials of high quality.

S. Monosi et al. [6] investigated the fresh and hardened properties of mortars and concretes containing different dosages of waste foundry sand (WFS) as partial replacement of natural river sand. Mortars and concretes were evaluated with respect to the uniformity of fresh mix and compressive strength of the hardened concrete material. Dynamic elastic modulus was determined for different concrete mixtures at 28 days curing. The performance of mortar at lower percentage of waste foundry sand doesn't indicate much variation. The test results showed that with the addition of WFS the resultant mixture gives low slump values mainly due to the presence of fine clay binders. Therefore, higher dosage of super plasticizer is needed in order to maintain the workability as constant. Compressive strength of mortars containing WFS at water cement ratio 0.5, showed a decrease of 20-30% when compared to the control mix. Drying shrinkage increases with the increase in WFS content and this increase was systematic.

T. A. Naik et al. [7] investigated the fresh and hardened properties of concrete containing waste foundry sand as a replacement of fine aggregate. Regular concrete sand in the concrete mixes were replaced with 25% and 35% of waste foundry sand and clean foundry sand by weight. The results indicated that the concrete mixture containing 25% of WFS showed an increase in their values by 10% when compared to the concrete mixture containing 35% of WFS. Compressive strength of the control mix was about 20-30% higher than the mixes containing waste foundry sands. The test results also indicate that there was not much difference in the values of density for both hardened and fresh concrete.

2. Experimental Program

From literature study it was observed that concrete mixtures partially replaced with waste foundry sand up to 30% can provide satisfactory strength. The workability of fresh concrete decreased with higher replacement of waste foundry sand. However, limited information is available on the performance of concrete containing waste foundry sand, blended with materials like slag sand. Therefore, a conventional mix without WFS was proportioned as per IS 10262 procedure [8], and additional mixtures with WFS were proportioned as presented in Table 1. Table 2 presents the details of concrete proportions. To investigate the performance of waste foundry as a partial replacement to fine aggregate in concrete, various tests are performed on both fresh and hardened concrete as per Indian standard. The tests performed on cement concrete are presented in Table 5.

Table 1: *Details of concrete mixtures investigated*

Mix	Specification
A	100% slag sand & 0% WFS
B	85% slag sand & 15% WFS
C	70% slag sand & 30% WFS
D	55% slag sand & 45% WFS
E	70% slag sand & 30% WFS

From Mix A to Mix D, waste foundry sand is replaced randomly. For Mix E the specific sieve sizes (300μm, 150μm, 75μm) were replaced by 30% WFS to study the influence of WFS when replaced for the specific set of sieve sizes. The intention was to replace only the sieves that represent the size of WFS material.

Table 2: *Details of concrete proportions*

Mix	A	B	C	D	E
Cement (kg/m^3)	437	437	437	437	437
Coarse aggregate (kg/m^3)	1075	1075	1075	1075	1075
Water (kg/m^3)	190	190	190	190	190
Slag sand (kg/m^3)	687	584	481	378	481
WFS replacement (%)	0	15	30	45	30
WFS (kg/m^3)	0	103	206	309	206
Superplasticizer (kg/m^3)	1.31	1.96	2.62	3	2.62

3. Materials

3.1 Cement

Ordinary Portland cement of 53 grade conforming to standards of IS 12269-1987 [9] was used for all the concrete mixtures. The physical properties of cement was tested as per IS 4031-1999 [10]. Specific gravity was 3.15, with initial setting time of 40 minutes.

3.2 Aggregate

Slag sand conforming to grading zone-I as per IS 383-1970 [11], with specific gravity of 2.65 and water absorption of 1% was used as fine Aggregate. Crushed stone aggregate confining to IS 383-1970 [11], with specific gravity of 2.65, water absorption 0.5% and maximum nominal size of 20 mm was used as coarse aggregate. The chemical composition of slag sand is presented in Table 3.

Table 3: *Chemical composition of sand*

Material	Values in percentage (%)				
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO
Slag sand	30.73	16.32	0.56	38.47	6.41
WFS	60.21	5.96	6.37	2.22	1.43

3.3 Waste foundry sand

In this study, a mixture of four different waste foundry sand obtained from Belgaum foundry industry in Karnataka was used (figure1). The specific gravity of WFS was 2.35. Figure 2 shows the particle size distribution of WFS in comparison to slag sand. The chemical composition of waste foundry sand is presented in Table 3.

Figure 1 *Four different samples of waste foundry sand*

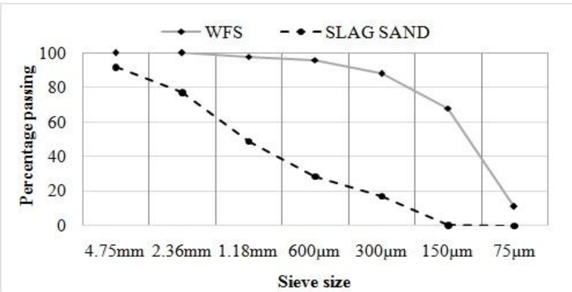

Figure 2 *Particle size distribution of WFS and slag sand*

3.4 Water

Clean potable water free from impurities was used as mixing water for production of concrete mixtures.

3.5 Super Plasticizer

Master-Glenium SKY 8233 is used as a superplasticizer or water reducing admixture (WRA) in this study. It is an admixture based on modified polycarboxylic ether. This admixture is certificated by IS 9103:1999[12]. Performance test data for Master-Glenium SKY 8233 is presented in Table 4.

Table 4: *Performance test data for MasterGlenium SKY 8233*

Aspect	Light brown liquid
Relative Density	1.08 +/- 0.001 at 25°C
pH	>6
Chloride ion Content	<0.2%

4. Specimen Preparation and Testing

The current study is carried out to examine mechanical properties of concrete mixes of grade M25 in which slag sand (fine aggregate) is partially replaced with waste foundry sand. Water/cement ratio of 0.45 is kept constant for all the mixes. Required quantity of cement, coarse aggregate, fine aggregate, waste foundry sand and admixture are mixed thoroughly in a pan mixer until uniform mix is obtained. Steel moulds are used for the casting purpose. The prepared mix is poured into steel moulds in three layers by compacting with tamping rod, followed by vibration with table vibrator for almost 30 seconds. Specimens are demoulded after 24 hours of air curing and then they are immersed in water tank for different curing periods. After curing the specimens, it was taken out of the tank and kept dry for 30 minutes before testing. Different types of specimens casted for various tests are presented in Table 5. Tests are conducted as per the Indian standard codes. Compressive strength, flexural strength, and modulus of elasticity are determined in accordance with IS: 516-1959[13]. Split tensile strength test is conducted as per IS: 5816-1999[14]. Drying shrinkage test is performed in accordance with ASTM C490 [15].

Table 5: *Tests performed on fresh and hardened concrete*

Test Type	Specimen Type	Dimension (mm)	Curing Time (days)
Slump	-	-	-
Compressive strength	Cube	150×150×150	7, 28
Modulus of elasticity	Cylinder	150×300	28
Split tensile strength	Cylinder	150×300	7, 28
Flexural strength	Beam	100 × 100 × 500	28
Drying shrinkage	Prism	285×75×75	3,7,14, 28

5. Results and Discussions

5.1 Fresh concrete properties

Workability of fresh concrete was determined using standard slump test. The fresh properties obtained for normal concrete and concrete containing different quantities of waste foundry sand is given in the Table 6.

Table 6: *Slump and unit weight of concrete*

Mix	Slump without WRA(mm)	Slump with WRA(mm)	Unit weight (kg/m^3)
A	80	120	2320
B	30	78	2343
C	0	35	2396
D	0	15	2423
E	0	42	2378

Maximum slump value of 120 mm was obtained for control mix. The slump drops significantly from 120 mm for the reference mix to 15 mm for mix containing 45% WFS . This indicates that workability of concrete reduces with inclusion of waste foundry sand. Excessive addition of waste foundry sand into concrete affects its workability due to the presence of very fine binders in waste foundry sand. Therefore, high amount of super plasticizer is necessary to preserve excellent workability. Clayey particles present in the waste foundry sand reduce the fluidity of concrete. The unit weight of concrete increases with higher replacement of WFS content in the mix. This behavior can be explained by filling ability of WFS, causing the density to be slightly higher than the conventional mix.

5.2 Hardened concrete properties

Table 7 presents the mechanical properties of hardened concrete. Tests were performed on one conventional concrete mixture and four mixtures containing different quantities of waste foundry sand. Compressive strength and split tensile strength was determined for 7 and 28 days curing time. Flexural strength and modulus of elasticity was determined for 28 days curing time.

Table 7: *Hardened concrete properties containing WFS*

Test	Mix				
	A	B	C	D	E
7 days curing					
Compressive strength (N/mm^2)	33	27	22	21	27
Split tensile strength (N/mm^2)	2.60	2.37	2.16	2.00	2.32
28 days curing					
Compressive strength (N/mm^2)	42	37	27	26	30
Split tensile strength (N/mm^2)	3.41	3.07	2.39	2.22	2.78
Modulus of elasticity (N/mm^2)	31438	27705	22941	21382	23824
Flexural strength (N/mm^2)	6.18	5.66	5.33	5.23	5.54

There is a significant decrease in compressive strength of concrete with increase in WFS content. At 28 days curing time a maximum decrease of 39% was observed for concrete mixture containing 45% WFS, when compared to control mix. The decrease in strength observed was systematic with increase in WFS. This decrease can be attributed to the presence of binders such as clay in waste foundry sand, which causes weak bond between aggregate and cement paste. There is also considerable decrease in split tensile strength with increase in percentage of WFS at 28 days curing time. Figure 3 shows the failure surface of concrete with and without waste foundry sand.

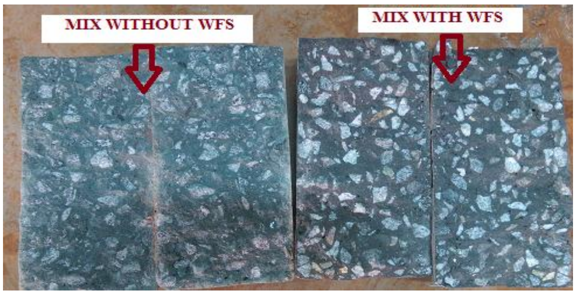

Figure 3 *Failure surface of concrete with and without WFS*

Figure 4 shows the percentage decrease in strength of concrete containing waste foundry sand with respect to control mixture. At 28 days curing time, a decrease of 13% in compressive strength is observed for Mix B (15%WFS), 36% for Mix C (30% WFS), and 39% for Mix D (45% WFS), compared to Mix A (Control mix). Mix E showed better strength than Mix C. At 7 days curing time, split tensile strength doesn't vary significantly when compared to control mix. Mix E shows higher split tensile strength than Mix C. At 28 days curing time, a decrease of 10% in split tensile strength is observed for Mix B (15%WFS), 30% for Mix C (30% WFS), and 35% for Mix D (45% WFS) compared to Mix A (Control mix). Compressive strength and splitting tensile strength showed almost similar trends in concrete strength decrease. Among all the strength properties, flexural strength was found to be least affected by WFS.

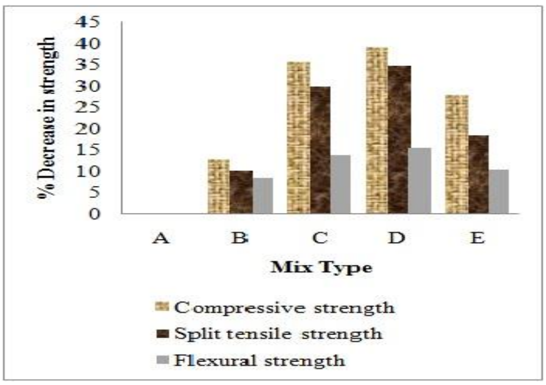

Figure 4.*Percent decrease in concrete strength at 28 days with respect to control mix*

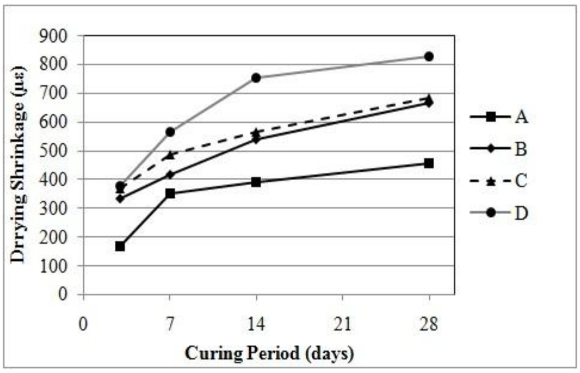

Figure 5 *Drying shrinkage of concrete containing WFS*

Figure 5 shows the drying shrinkage of concrete containing waste foundry sand. From the results it was observed that there is a significant increase in drying shrinkage of concrete with increase in percentage of WFS. Drying shrinkage of concrete also increased with curing time. The magnitude of 3 days shrinkage is more than 7, 14 and 28 days shrinkage. The presence of clay as a binder in WFS lowers the restraining effect on shrinkage. Since, clay by itself is subject to shrink considerably, clay coating on the aggregates can increase shrinkage by up to 70 percent [16]. The mixtures containing WFS above 30% shows very high shrinkage. Figure 6 shows the specimens and length comparator used in this study to measure drying shrinkage of concrete.

Figure 6 *Drying shrinkage test setup. A) Length comparator B) Prism specimens*

6. Conclusion

Excessive addition of waste foundry sand in concrete affects its workability due to the presence of very fine binders in waste foundry sand. Therefore, high amount of super plasticizer is necessary to preserve excellent workability. Compressive strength, split tensile strength, modulus of elasticity and flexural strength of concrete decreased with the increase in waste foundry sand. The replacement of slag sand with waste foundry sand up to 15% is desirable, as it doesn't adversely affect the strength properties of concrete. There is significant increase in shrinkage of concrete with increase in percentage of WFS and also with the age of concrete. Mixtures containing waste foundry sand above 30% showed very high shrinkage. From the obtained results it can be concluded that concrete containing waste foundry sand up to 15% can be efficiently used for structural applications. Higher replacements can be tried in non-structural applications like concrete pavements.

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