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Experimental investigation on durability properties of concrete containing Waste Foundry Sand

Priya H. Surpur[1], R.B.Gadag [2]

[1]Research Scholar, Civil Engineering Department, KLE Dr.M.S.S.C.E.T, Belagavi, Karnataka, India

[2]Associate professor, Civil Engineering Department, KLE Dr.M.S.S.C.E.T, Belagavi, Karnataka, India

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Abstract – *Waste Foundry Sand [WFS] is a by-product of ferrous and nonferrous metal casting units. Foundries generate huge quantity of WFS; hence managing this solid waste material is a major issue. In the present study an attempt has been made to utilize the WFS in M20 concrete by replacing fine aggregate from 0% to 60% by weight of fine aggregate. In this study, WFS was obtained from Ashok iron works in Belagavi. Compressive strength of these concrete specimens was evaluated, showing highest strength of 34.96 MPa at 10% replacement of fine aggregate by WFS. Higher replacement levels decreased the compressive strength, indicating that increase in percentage replacement reduces the compressive strength properties. The samples with good results of 10% replacement were analyzed by X-ray diffraction. The experimentation work has shown that WFS can be effectively utilized in replacing fine aggregate up to 20%, hence sulphate attack study was restricted to replacement from 0% to 20%. After 28 days curing period, the concrete specimens were submerged in 5% & 10% sodium sulphate solution for a period of 30 and 45 days. The levels of sulphate attack were assessed by compressive strength reduction & weight loss of specimens along with visible examination of concrete specimens for development of crack.*

Key Words*: *Waste Foundry Sand, fine aggregate, Compressive strength, Sulphate attack, X-ray diffraction (XRD).

1. INTRODUCTION

Foundry sand is the left out sand after metal casting process and contains high percentage of silica. In foundries sand has been utilized for quite a long time as a shaping material due to its heat conductivity. Foundry sand can be generated from the automotive industries. Foundries effectively reuse the sand until the point when the sand can never again be reused and ultimately this expelled from the foundry industry. It is known as Waste Foundry Sand [WFS]. The chemical and physical features of foundry sand depends on the industrial area from which it originates and the types of casting process. In advanced foundry practice, sand is normally reused through numerous generation cycles. In United States of America foundry Industry evaluates that around 100 million tons of sand is utilized as a part of generation every year, of that 6–10 million tons are disposed off every year and are reutilized into different metal casting units [1]. The recycled WFS can be utilized in various applications as lining for landfill site, and other reuse alternatives are developed in Britain, Europe and North America. Cement manufacture, asphalt, concrete, bricks and for certain construction applications were used as the option for recycling of WFS. These options were beginning to be implemented in India, however is still in initial stage. External cases demonstrate that it is eco-friendly for environment as well as beneficial for the industries to utilize the normal sand on the other hand. These have essentially decreased the volume of waste sand going to landfill [2] [3].

Foundry sand categories depend upon the type of binder systems used in moulding and casting process. There are 2 types of foundry sand. Clay and chemically bounded sand. Clay bounded sand or green sand can be usually utilized for mould preparation process and 85–95% high composition of silica sand and 4–10% of bentonite clay as a binder with addition of 2–10% carbonaceous helps to develop the finishing of surface, and 2-5% of moisture. Due to presence of carbon and clay content, it is in black colour. And the chemically bounded sand can be developed for the preparation of core as well as mould making where it should resist heavy load of molten metal. Most chemical binder systems having organic and inorganic binders. These appear light in colour with smooth texture compared to green sand [1].

2. OBJECTIVES AND METHODOLOGY

1. To prepare the concrete by replacing natural sand (FA) by waste foundry sand (WFS) from 0% to 60%, at an interval of 10%. And check the compressive strength of specimen.
2. To determine the durability of concrete by keeping the specimens for sulphate attack when immersed in 5% & 10% concentration of sodium sulphate solution.
3. To determine the chemical composition of specimens by XRD analysis.

The cement, fine aggregates and coarse aggregates were taken as per mix design corresponding to M20 grade concrete and all the materials were dry mixed evenly in the concrete mixer. Fine aggregates were replaced with waste foundry sand in various proportions and properly mixed then known quantity of water was added. Clean and oiled moulds were used to prepare the specimen of dimension 150mm x 150mm x 150mm. The voids while preparation of moulds was avoided by 25 strokes of tamping. After 24 hours these specimens were de-moulded with care so that no edges were broken and were immersed in curing tank at atmospheric temperature.

3. EXPERIMENTAL RESULTS

After 28 days curing of specimens casted as per methodology, tests like compressive strength and sulphate resistance are carried out and results are mentioned below and also analyzed microstructural properties of concrete by XRD.

3.1 Compressive strength results

The cubes of dimensions 150mm x 150mm x 150mm were cast for determining the compressive strength in compressive testing machine at a constant loading rate as per IS: 516-1959 [6] .

Compressive strengths of cubes were evaluated by using following formula;

$$f = P/A$$

Where,
f = Compressive strength of cube (MPa),
P = Failure load of the cube (KN),
A= Cross sectional area of the cube (mm^2).

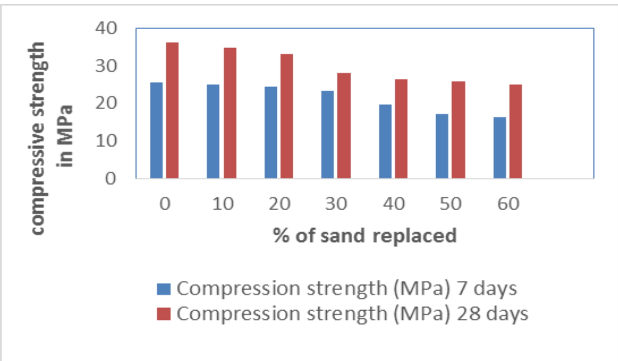

Fig-1: Compressive strength of concrete with varying percentage of waste foundry sand.

Fig 1 shows that the compressive strength of all the specimens was decreasing proportionally with increasing percentage replacement of waste foundry sand and curing period. At 28 days the highest strength of 34.90 MPa with 10% of WFS and a lowest strength of 24.89 MPa with 60% of WFS were obtained. The strength of other concrete specimens was found to decrease with increasing percentage replacement. The drastic decrease of 15.18% from 20 to 30% replacement was obtained. It is also evident that after 30% replacement there was no considerable difference in strengths, hence it was assumed that up to 20% replacement of fine aggregate with WFS could be effectively used to obtain later strengths.

3.2 XRD analysis

XRD analysis of specimens was done to know the chemical compounds present in cured specimens with good compressive strength. X- Ray Diffraction meter with scanning speed of 1°/min, 2Ɵ values ranging from 10 to 90° was used.

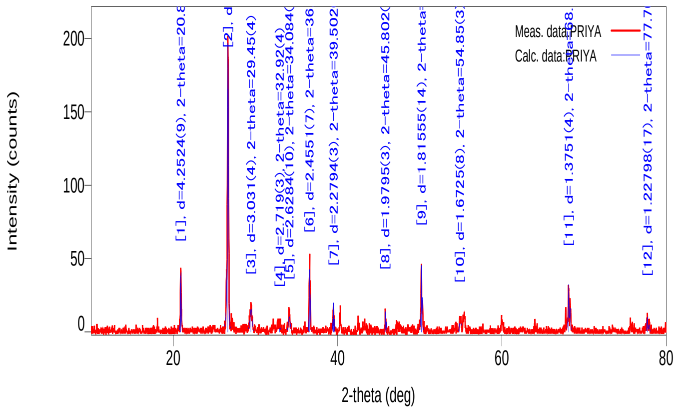

Fig-2: XRD analysis of specimen containing 10% of WFS.

The XRD pattern of specimen containing 10% WFS as fine aggregate is shown in fig-2. The 2θ values were checked to match with JCPDS cards. Most peaks obtained were of silicon dioxide at 2θ values 20.87, 26.62, 39.50, 50.20, 54.84 and 77.7 that were found to match with JCPDS card numbers 832299 and 872096. The peaks of copper iron (CuFe) were obtained at 34.083, 45.802 and 68.13 that matched with PDF numbers 491399 and 461058. The peaks of calcium silicate hydrate were obtained at 29.447 and 36.57 matching with cards 742413 and 491977. From the XRD analysis it was clear that the sample contained high amounts of silicon dioxide with trace amounts of C-S-H gel. The peaks of C_2S and C_3S were found to be missing. Therefore the reduction in calcium C_2S, C_3S and C-S-H quantities caused a decrease in the strength of concrete. On the other hand the high silicon contents does not contribute to the strength of concrete. The silica quantities in WFS was high because of use of sodium silicate in foundries as a binding material, neither this silica was not consumed in formation of C-S-H gel. All these reasons together contributed to the reduction in the strength of the concrete [2] [5].

3.3 Sulphate resistance test

The experimentation of compressive strength achieved the good results for up to 20% replacement of fine aggregate were near to the control mix. Hence, WFS restricted up to 20% replacement and these specimens were kept for sulphate attack with varying percentages 0, 5, 10, 15 and 20% of WFS. Immersed in 5% and 10% solution of sodium sulphate at 30days and 45 days.

Table-1: Compressive strength variation due to sulphate attack

Percentage replacement of WFS	Before sulphate attack compressive strength (28 day)	Compressive strength after sulphate attack			
		5% of $NaSO_4$ solution of 30 days		10% of $NaSO_4$ solution of 45 days	
		For 30 days	For 45 days	For 30 days	For 45 days
0%	36.14	35.20	34.22	35.07	33.14
5%	35.11	34.62	33.40	34.23	32.86
10%	34.51	34.51	33.90	34.31	33.20
15%	33.48	33.13	32.54	33.03	32.40
20%	33.18	32.85	32.49	32.77	32.15

Table-2: Weight loss due to sulphate attack

Percentage Replacement of WFS	Before sulphate attack compressive strength (28 day)	Weight loss due to sulphate attack			
		5% of $NaSO_4$ solution of 30 days	10% of $NaSO_4$ solution of 45 days	5% of $NaSO_4$ solution of 30 days	10% of $NaSO_4$ solution of 45 days
0%	8.75	8.64	8.60	8.47	8.44
5%	8.92	8.84	8.79	8.75	8.71
10%	8.56	8.49	8.44	8.4	8.37
15%	8.53	8.49	88.4	8.29	8.32
20%	8.50	8.47	8.40	8.37	8.35

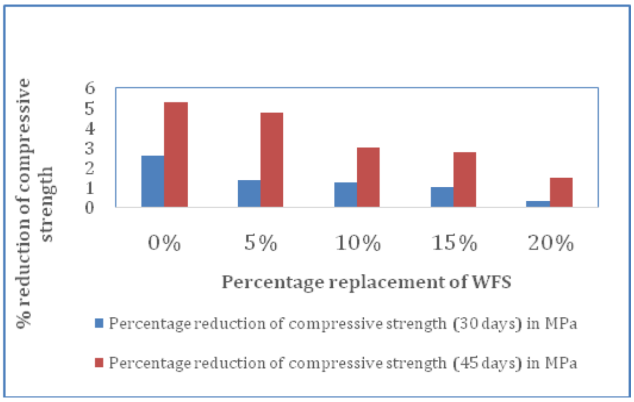

Fig-3: variation of compressive strength after sulphate attack immersed in 5% solution of sodium sulphate

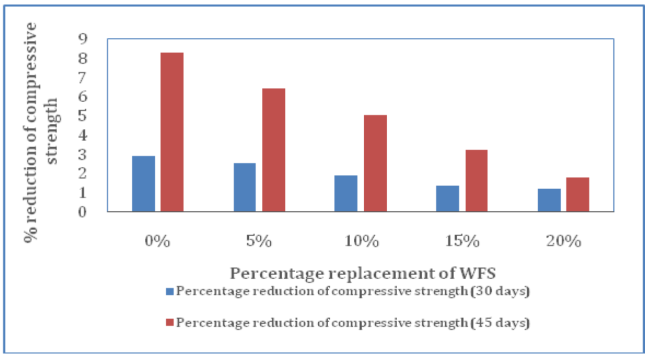

Fig-4: variation of compressive strength after sulphate attack immersed in 10% solution of sodium sulphate.

Due to sulphate attack the compressive strength of concrete containing WFS decreases with increase in percentage of replacement. From the table 1, the maximum and minimum compressive strength reduction of 5.3%, 2.07% and 8.3%, 3.10% were obtained when specimen placed in 5% and 10% of sodium sulphate solution for 45days respectively.

The fig 3 and 4 shows percentage reduction of compressive strength of concrete specimens when immersed in 5% and 10% solution for duration of 30 days and 45 days respectively. For 30 days, the sulphate attack was very less as compared to 45 days hence it is concluded that the increase in curing period increases the reduction of compressive strength.

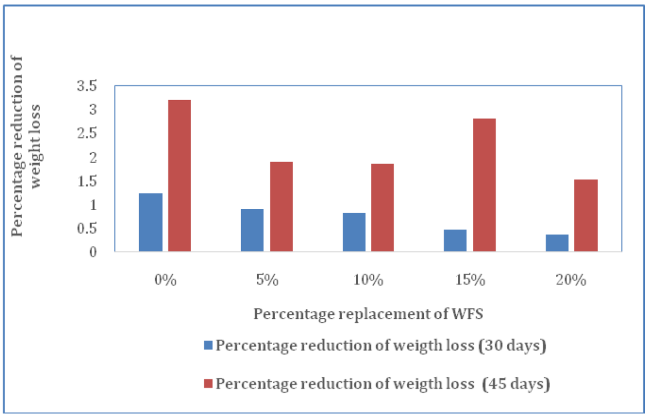

Fig-5: Weight loss due to sulphate attack when immersed in 5% solution of sodium sulphate.

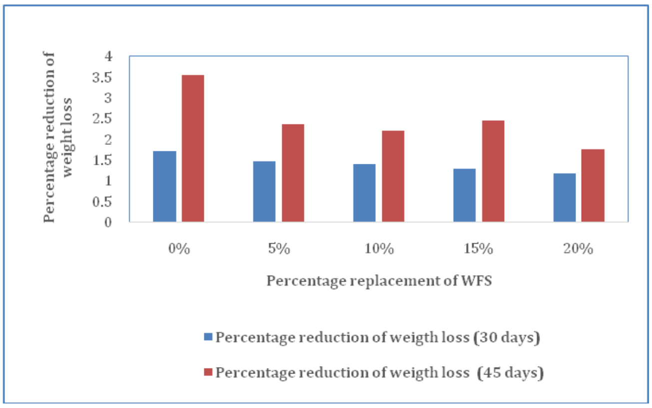

Fig-6: weight loss due to sulphate attack when immersed in 10% solution of sodium sulphate.

Table-2 represents the weight loss of concrete specimens. When immersed in different concentration of sodium sulphate solution for curing period of 30 days and 45 days. The highest and lowest reduction of weight was obtained as 3.2% and 1.53% for 30 days, 3.54% and 1.76% for 45 days. Fig 5 and 6 shows the less reduction in weight with increase in curing period and percentage replacement of fine aggregate.

4. CONCLUSIONS

1. From the compressive strength investigation of M20 grade it was evident that replacement of WFS for fine aggregate does not provide considerable strength when compared to control mix specimen.
2. Highest strength of 34.96 MPa was obtained for 10% replacement and lowest strength of 24.89 MPa was obtained for 60% replacement of natural sand by WFS at curing period of 28 days.
3. The compressive strength was comparable with control only up to 20% replacement so the concrete with 0%, 5%, 10%, 15% and 20% of WFS were chosen for sulphate resistance test.
4. It was found that as the duration of sulphate attack and concentration of sodium sulphate increases the compressive strength and weight decreases but the compressive strength and weight reduction was less with increase in percentage replacement of WFS.
5. After sulphate attack the maximum compressive strength reduction of 8.3% was obtained for 5% replacement and minimum reduction of 3.1% was achieved for 20% replacement.
6. It was found that the concrete containing WFS effective in improving the resistance of concrete to sulphate attack. The sulphate resistance of concrete increased with increasing replacement levels of WFS. 20% replacement of natural sand by WFS showed excellent durability to sulphate attack.
7. From XRD analysis for 10% replacement concrete it was found that silicon dioxide was higher compared to C-S-H gel and C_2S as well as C_3S were not found which causes decrease in the compressive strength.
8. Replacement of WFS in concrete helps to reduce the solid waste disposed problem; hence, it is eco-friendly construction material.

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