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Durability Properties of Waste Foundry Sand Concrete with Carbon Fibres

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ABSTRACT: The project work covers to determine the durability properties of Waste foundry sand (WFS) concrete with carbon fibres of 0.5%, 0.75% and 1.0% to the volume of concrete. M40 grade of concrete was taken as the mix. Waste foundry sand from foundry industry was collected and it was take as the replacement of Fine aggregate in concrete. The optimum replacement of Waste foundry sand was found from various tests including compressive strength, split tensile and flexural test. 40% replacement of waste foundry sand shows the optimum results. Resistance of concrete against Alkali attack, Sulphate attack, Chloride attack, were determined for the optimum mix containing WFS with Carbon fibre of various percentages. It was found that, the minimum loss of weight and loss of compressive strength of concrete in all durability aspects due to the replacement of waste foundry sand and addition of carbon fibers. Some adverse effects was shown when the percentage of fibre addition increases. Hence suitable proportion of 0.5% carbon fibre with 30% WFS shows better resistance under durability tests.

KEYWORDS: Waste Foundry sand (WFS), carbon fibre, PAN, super plasticizer, Durability, sulphate attack.

I. INTRODUCTION

The construction industry identifies that considerable improvements are essential in productivity, product performance, energy efficiency and environmental performance. The industry needs to face and overcome a number of competitive and technical challenges. One of the major challenges to the environment is industrial wastes and thereby scarcity of space for disposal of such wastes. These wastes/by-products can be utilized as an alternative construction material in the construction industry. The usage of industrial by-products such as fly ash, foundry sand, bottom ash and slag can result in the improvements of overall industry energy efficiency and environmental performance. They are also needed in the construction sectors.

Fibres are used in concrete to control cracking due to plastic and drying shrinkage. One of the greatest benefits of carbon fibre is that, it can be applied to existing composite materials as reinforcement and it serves as the corrosion resistant material. The foundry sand used in the research work is spent foundry sand (SFS) and polyacrylonitrile (PAN) type carbon fibres was used. Different proportions of CF are 0.5%, 0.75% and 1.0% to the volume of concrete was taken. The objective of the research work involves to study the Durability properties of WFS concrete with and without addition of Carbon Fibres. Comparison is made on Control mix with and without WFS & CF.

II. EXPERIMENTAL WORK

A. MATERIALS USED:

1. Cement:

OPC 53 grade cement was used. The cement was tested as per the IS standard 4031-1996 and IS: 4032-1999.

2. Aggregates

Locally available natural sand with 4.75 mm maximum size was used as fine aggregate. From the local quarry the crushed stone aggregates were collected and it was used as coarse aggregate. The fine and coarse aggregates were tested as per the IS standard 383-1970.

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3. Waste Foundry Sand (WFS)

Waste Foundry Sand was collected from the local foundry industry. The WFS was used as a replacement of natural river sand in various proportions of 10 to 50% in concrete.

4. Carbon fibre

The Carbon fibres used in the experimental study were Panex® 35- based 50k tow fibres. It is manufactured from polyacrylonitrile (PAN) process. It has 50,000 filaments and 95% carbon content. The fibre length and diameter used was 12mm and 7.2microns

5. Water

Potable water was used for the research work.

6. Super plasticizer

Conplast SP-430 was used to improve the workability of concrete mixes and it satisfies with IS: 9103: 1999. The dosage of super plasticizer used in the experimental work was 1.2% by weight of cement.

B. CONCRETE MIX PROPORTIONS

The mix proportion for 30% optimum foundry sand concrete was 1:1.13:2.8:0.4. The proportions of M20 mix were given in Table 1.

Table 1

MIX PROPORTIONING	
MIX	WFS-30%
M40	1:1.13:2.8:0.4
C (kg/m ³)	394
FA (kg/m ³)	448.15
CA (kg/m ³)	1104.38
WFS (kg/m ³)	192.06
W (kg/m ³)	157.6
SP (%)	1.2
CF 1	0.5%
CF 2	0.75%
CF 3	1.0%

* WFS 30% - Waste Foundry Sand -30% replacement; C- Cement; FA- Fine Aggregate; CA- Coarse Aggregate; SP- Super plasticizer; W- Water; CF- Carbon fibre;

C. CONCRETE PROPERTIES

The effect of incorporating waste foundry sand of 30% replacement and carbon fibre (0.5%, 0.75% and 1.0%) in concrete on durability properties were evaluated.

1. Durability properties

- Alkali test
- Sulphate test
- Chloride test

Durability test was explained in this experimental study for control mix and optimum of 30% Foundry sand replacement with 0.5%, 0.75% and 1.0% CF.

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III. RESULTS AND DISCUSSION

A. ALKALI TEST:

Alkali attack was carried out on control mix F-0 (0% WFS) and 30% WFS with 0.5%, 0.75%, 1.0% CF in concrete. The percentage increase in weight of conventional M40 specimen after immersion in Sodium hydroxide solution was 1.4% compared to the specimen before immersion. Similarly, for 30%WFS with 0.5%, 0.75% and 1.0% CF show relatively 1.5%, 1.63% and 1.7% increase in weight after 90days. Figure 1 shows the percentage increase in weight of different mixes.

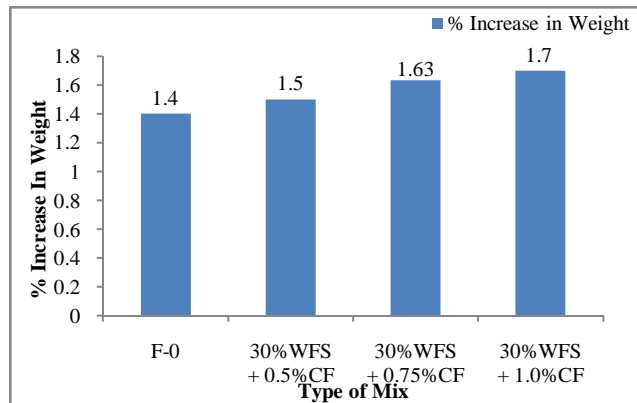


Figure 1 Weight of the specimen under Alkali test after 90days

The compressive strength of M40 conventional concrete is 48.58MPa after 28days. After 90days of alkaline attack, the compressive strength reduced to 46.25MP. The percentage loss of compressive strength of F-0 was 4.79% at 90days compared to the specimen before immersion in alkaline solution.

The compressive strength for various mixes is shown in Figure 2. The mix 30%WFS with 0.5%CF tend to be alkaline resistant compared to other mixes.

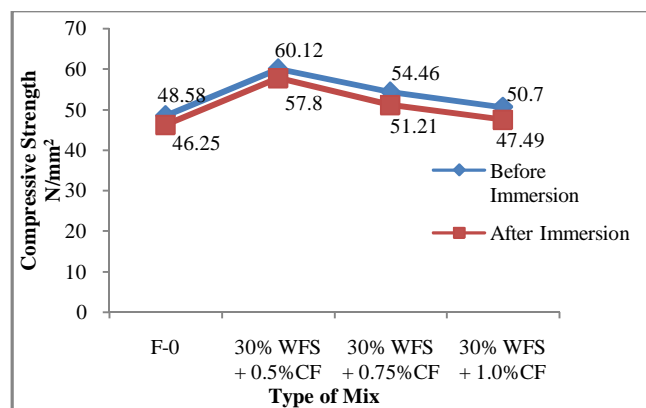


Figure 2 Compressive strength of the specimen under Alkali test after 90days

Alkali ions (Na⁺ and K⁺), primarily from the cement and WFS cause a reaction with reactive silica mineral present in aggregate in the presence of moisture. The increase in weight may be due to the alkaline solution attacks the siliceous aggregate, converting it to viscous alkali silicate gel. The penetrated alkaline solution converts the remaining siliceous minerals into bulky alkali silicate gel. Hence, the expansive pressure is stored in the aggregate and the accumulated pressure cracks the aggregate and the surrounding cement paste. Due to this reaction the increase in weight was influenced by the alkali attack.

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B. SULPHATE TEST:

Sulphate attack was carried out on control mix F-0 and 30% WFS with 0.5%, 0.75%, 1.0% CF in concrete. After the immersion of the concrete specimen in the sulphate solution for the entire test duration, a white patch was formed on the concrete specimen shown in Figure 3.



Figure 3 Sulphate attack of Specimen

Sulphate attack leads to loss of weight and loss of strength. The loss of weight due to sulphate attack of M40 grade of the conventional concrete is 0.59% after 90days. The loss of weight due to sulphate attack of the concrete prepared by 30% WFS with 0.5%, 0.75% and 1.0% CF was 0.35%, 0.46% and 0.47% respectively after 90days. Figure 4 shows the percentage loss in weight of different mixes

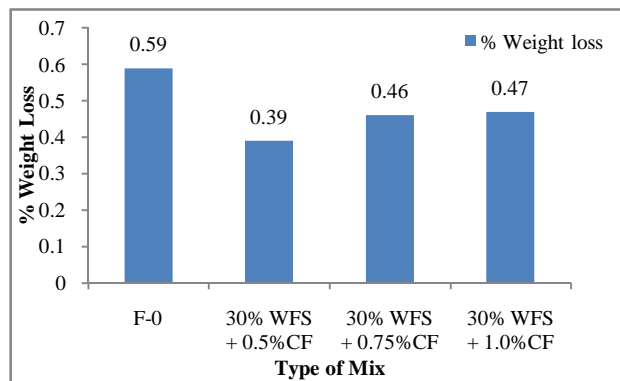


Figure 4 Weight of the specimen under Sulphate test after 90days

The compressive strength of M40 grade of the conventional concrete is 48.58 MPa after 28 days i.e., before immersing in Sodium sulphate solution. The compressive strength decreased by 46.41MPa after sulphate attack at 90days. It was observed that the compressive strength of the concrete before immersion in the sodium sulphate solution prepared by replacing 30% WFS with 0.5%, 0.75% and 1.0% CF addition was 3.69%, 4.29% and 4.90% respectively after 90days. The mix containing 30% WFS with 0.5% carbon fiber showed a maximum strength compared to the other mixes after immersing in acid solution. The loss of strength is shown in Figure 5.

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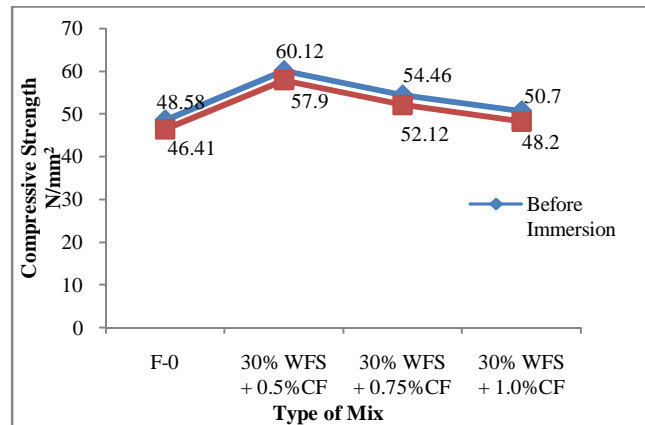


Figure 5 Compressive strength of the specimen under Sulphate test after 90days

Sulphate attack can take the form of a progressive loss of strength and loss of mass due to loss of cohesiveness in the cement hydration products. This was because due to the free movement of water which carried the calcium sulphate towards the surface of the concrete specimen. It was observed that the considerable strength and weight loss was found for 30% WFS with 0.5% addition of fibers in concrete compared to other mixes.

The decrease in sulphate resistance of WFS concrete may be due to the presence of traces of sulphur in the WFS, since it contains sulphur trioxide of 0.09% by weight. The presence of SO_3 may increase the strength of the Na_2SO_4 solution and enhances the ettringite formation ($3CaO \cdot Al_2O_3 \cdot 3CaSO_4 \cdot 32H_2O$), causing the deterioration of concrete. Also increase in fiber content leads to decrease in bonding between the aggregate and cement paste which causes voids in concrete may lead to sodium sulphate solution to penetrate the concrete. Hence, for higher percentages of 0.75% and 1.0% CF the sulphate resistance is decreased further. Not only due to sulphur content in WFS, sulphate attack occurs where a source of sulphate is incorporated into the concrete when mixed, includes the use of excess of added gypsum in the cement.

From the above results, it may be concluded that the presence of reactive material in WFS and higher percent of CF in concrete affects the durability properties of the concrete. Using suitable percentage upto 30% WFS with 0.5% CF addition resists the sulphate attack of concrete compared to other mixes.

C. CHLORIDE TEST:

The weight gain and compressive strength loss are shown in Figure 6 and 7. The percentage increase in weight of F-0 and 30% WFS with 0.5%, 0.75%, 1.0% CF were 0.469%, 0.46%, 0.47% and 0.48% respectively.

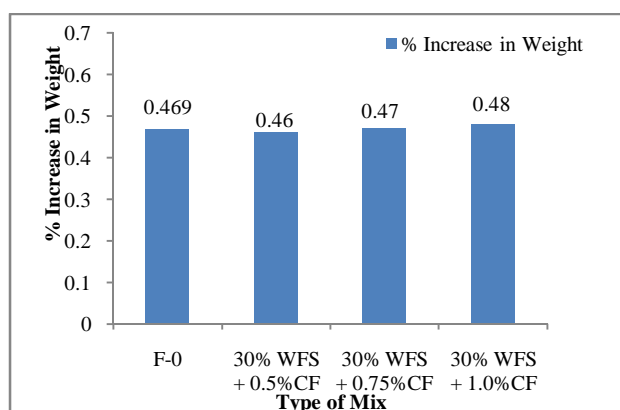


Figure 6. Weight of the specimen under Chloride test after 90days

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The loss in compressive strength was 4.89% for M40 specimen after 90days chloride test. The percentage loss in strength was 4.15%, 4.35% and 5.83% for WFS with CF concrete mixes. Considerable weight gain and strength loss was observed for 30%WFS with 0.5% CF mix compared to other mixes. Because of fineness of WFS, not much chloride ions are penetrated into the concrete.

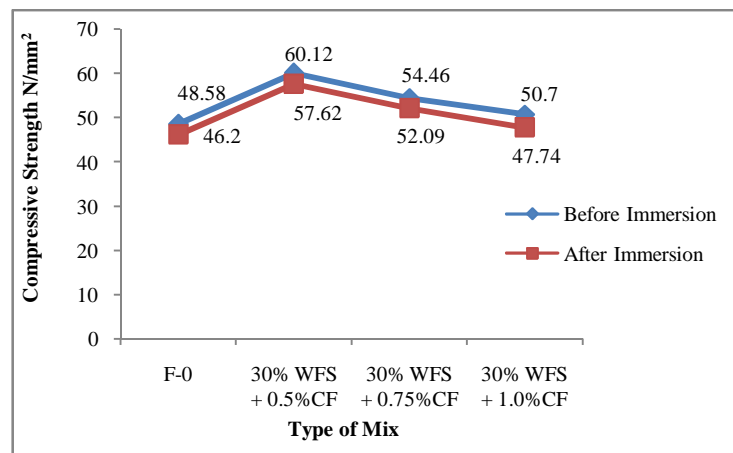


Figure 7 Compressive strength of the specimen under Chloride test after 90days

The weight gain and strength loss increased for 0.75% and 1.0% CF addition leads to weak interlocking between the cement pastes.

The presence of chlorides is responsible for increase in weight and strength loss. Chloride enters the concrete from cement, water and aggregate and also by diffusion from environment. OPC 53 grade cement used in this experiment contains 0.01-0.1% chloride content. The allowable chloride content in cement is 0.1 per cent as per IS 456: 2000. Sodium chloride used in this test has been shown to leach calcium hydroxide and cause chemical changes in Portland cement, leading to loss of strength. The chlorides attack mainly the reinforcement present in the concrete. Since, no reinforcements present in the specimens tested, the predictions under the chloride test are not much significant. Hence, there is no significant increase in weight and strength loss can be predicted.

IV. CONCLUSIONS

The test result shows the following conclusions:

- The maximum compressive strength of 37.43MPa (7 days) and 60.12 MPa (28 days) were obtained at 30% replacement of sand by WFS. Further replacement reduces the strength.
- The compressive strength increased by 8.05% (at 7days) and 4.13% (28days) for the mix (30% WFS & 0.5%CF) compared to control mix of (30% WFS & 0%CF). Beyond 0.5% fibre addition, the strength reduces gradually due to fibre clusters balls are formed during the mixing process.
- In alkali attack, considerable weight loss and compressive strength was observed for 30%WFS with 0.5% carbon fibre. The percentage increase in weight for 30% WFS with 0.5%, 0.75% and 1.0% CF show relatively 1.5%, 1.63% and 1.7% increase in weight after 90days. The mix 30%WFS with 0.5%CF tend to be alkaline resistant compared to other mixes.
- The loss of weight due to sulphate attack of the concrete prepared by 30% WFS with 0.5%, 0.75% and 1.0% CF was 0.35%, 0.46% and 0.47% respectively after 90days. The mix containing 30% WFS with 0.5% carbon fiber showed a maximum strength compared to the other mixes after immersing in acid solution.
- The decrease in sulphate resistance of WFS concrete may be due to the presence of traces of sulphur in the WFS. Hence, for higher percentages of 0.75% and 1.0%CF the sulphate resistance is decreased further. Sulphate attack occurs

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where a source of sulphate is incorporated into the concrete when mixed, includes the use of excess of added gypsum in the cement.

f.) The presence of chlorides is responsible for increase in weight and strength loss. The chlorides attack mainly the reinforcement present in the concrete. Since, no reinforcements present in the specimens tested, the predictions under the chloride test are not much significant. Hence, there is no significant increase in weight and strength loss can be predicted.

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