STRENGTH AND DURABILITY PROPERTIES OF CONCRETE WITH WASTE FOUNDRY SAND AS A PARTIAL SUBSTITUTE TO FINE AGGREGATE AND BANANA FIBER

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Abstract:

Concrete is the broadly utilized building material due to its increasing demand in construction industry. Reducing natural sand sources and the need to reduce the cost of concrete production has led to an increased need to identify substitute material to sand as fine aggregates in concrete production. The efforts has been carried out to minimize and optimum utilization of natural sand in concrete with the use of waste foundry sand (WFS) as a substitute to fine aggregate and to study its effect on strength and durability properties.. WFS was used in different replacement level of fine aggregate ranging from 0 to 60% with increment of 20% by weight. To study the influence of fiber in concrete, banana fibers were used in different percentages in weight fractions (0%, 2.5%, 5% and 7.5%) specimens such as cubes, cylinders and prisms were cast with an optimum waste foundry sand percentage of 60%. Tests were performed for strength properties viz. compressive strength, split tensile strength, flexural strength and durability characteristics such as sorptivity and resistance to acids (HCL and H_2SO_4). It was assessed from the results that, addition of foundry sand and banana fibers enhanced the strength and durability properties when compared with the control concrete mixes at all curing periods.

Keywords: **Waste foundry sand, Banana fibers, strength properties, durability properties**

1. INTRODUCTION

In recent developments of concrete various special concrete were developed to ensure the high strength. Nowadays the requirement of natural sand is increasing exponentially by availability of natural sand is gradually reducing. In order to overcome these demand there is a need to go for substitute material to conventional concrete ingredients. Also to overcome the brittleness of concrete, research community is developing mixes with discrete discontinuous fibers. Extensive research has done on concrete with WFS as fine aggregate but limited studies has published in concrete with waste foundry sand and banana fibers. WFS concrete had vast field applications in construction. Kleven et al. [1] performed research in used foundry sand (UFS) was partially replaced with fine aggregate on concrete mixtures and concluded that it can be effectively used in construction. Traeger [2] performed research in effective re-use of WFS in high-strength concrete production. Rafat Siddique et al. [3] replacement of fine aggregate with three types of foundry sand was studied. Khatib and Naik [4, 5, 6, 7] made several research on effective use of foundry sand in concrete and its applications. Bakis et. al [8] worked on asphalt concrete mixtures, indicated the strength enhancement of about 1.39 MPa with 0% WFS to 0.94 MPa with 20% WFS. Mathur [9] investigated the natural fiber composites and its immense importance in today's scenario in view of cost, alternate building materials and applications of natural fibers without compromising the various properties of concrete. Fernando et. al [10] demonstrates the review on concrete structures reinforced with vegetable fibers and concluded that structures with fibres are challenging tasks towards a effective sustainable construction. Large bamboo fibres needs improved durability when used in cement matrix, for enhanced engineering performance more research efforts are needed. Arsène et. al [11] made research on natural fibres (jute, sisal, coir, banana, etc. Elie et. al [12] investigated the effect of natural fiber ie. hemp fibers in concrete in different volume fractions (0.5, 0.75 and 1%) as partial substitute of coarse aggregate in volume of concrete. Various tests were performed and studied the effect of hemp fiber as replacement of coarse aggregate in concrete. From this research works authors concluded that 0.75 -1% addition of hemp fiber to concrete achieved 20-30% coarse aggregate reduction and hemp fiber mixes are applicable for various nonstructural applications. Merta et. al [13] investigated the fracture energy of reinforcing concrete with natural fibres such as hemp, wheat straw and elephant grass on wedge splitting test (WST) method and concluded that hemp fibers in concrete offers good bonding between fibers and concrete matrix and achieved sufficient stress transfer. The maximum fracture energy achieved for straw and elephant grass fibers are 2% and 5% respectively. Fiber mixes achieved reduction in splitting tensile strength of 4%, 7% and 8% compared to control concrete.

2. EXPERIMENTAL INVESTIGATIONS

2.1 Material properties

The materials and its properties used in the present study are mentioned in Table. 1

Table 1: Materials used and its properties

Materials used	Properties	Value
Cement (PPC 43 grade)	Specific Gravity	3.15
Fine Aggregate(FA)	Specific Gravity	2.62
	Fineness Modulus	3.39
Coarse Aggregate (20 mm size)	Specific Gravity	2.74
	Fineness Modulus	5.25
	Water Absorption (%)	1.56
Super Plasticizer (Conplast SP430(G))	Specific Gravity	1.20 to 1.22 at 30^0C
Waste Foundry sand (WFS)	Specific gravity	2.21
	Unit weight (kg/m^3)	1525
	Fineness modulus	1.6
	SiO_2	83.93
	Al_2O_3	0.021
	Fe_2O_3	0.950
	CaO	1.03
	MgO	1.77
	SO_3	0.057
Banana Fiber (Go Green Technologies, Chennai As per Manufacturer's Manual)	Tensile Strength (MPa)	650—780
	Elongation of Break (%)	2—4
	Diameter(mm)	1--3
	Density (g/cm^3)	1.3
	Aspect ratio	80

2.2 Mix design and methods

A mix proportion of 1:1.14:2.5 was arrived as per ACI [14] for M40 grade with 0.4 w/c ratio was adopted in this investigation. Following the mix, slump tests as per IS 1199 [15] were performed for plain concrete, waste foundry sand concrete and waste foundry sand based fibre-reinforced concrete. An effort was made to evaluate the workability, strength and durability properties of various parameters at different ages; and the results were compared with the control concrete. Cubes (100 mm x 100 mm x 100 mm), cylinders (100 mm diameter x 200 mm long) and prism specimens of 100 mm x 100 mm x 500 mm were cast and tested for strength properties. Durability test such as acid resistance, sulphate resistance, water absorption and sorptivity were studied.

3. RESULTS AND DISCUSSION

3.1 Slump test

The workability of concrete is mainly influenced by the water requirements at the time of mixing. For control concrete, it is decided mainly on the basis of the maximum size of aggregates used. The workability result of the control mix was 100 mm and WFS and banana fiber mixes was in the range of 100 to 120 mm. To maintain the workability in the specified range, water content considered constant for all the mixes, inclusion of superplasticizer makes the mix more plastic and workable permitting for ease of mixing and placement which does not significantly affect the workability of mixes with increased amount of WFS and fibers.

3.2 Effect of WFS and banana fiber on compressive strength

Compressive strength of concrete mixtures made with and without waste foundry sand (WFS) was determined at 7, 28 and 56 days of curing. At 28 days, control mix achieved a compressive strength of 43.64 MPa whereas mix with 20%, 40% and 60% WFS achieved a strength of 45.25 MPa, 48.36MPa and 50.5 MPa respectively; an improvement in compressive strength of 3.69%, 10.81% and 15.72% when compared with the control concrete strength (without WFS). The strength of concrete also increased with the age. The percentage increases in compressive strength at 56 days was 4.91%, 9.72% and 18.14%. Another mixtures were prepared with 60 % WFS (HSC) as partial replacement of fine aggregate with different percentage of banana fiber (0%, 2.5%, 5% and 7.5%) in weight fractions. The addition of fibers to control concrete mix (60% WFS and 0% fiber) enhanced the compressive strength compared to control concrete at all percentage of fiber content at all age. The percentage improvement in compressive strength compared to concrete without fiber was 4.23%, 11.07% and 13.01 % at 28 days and 4.48%, 9.66% and 10.02% at 56 days. The results are shown in figure 1 and figure 2.

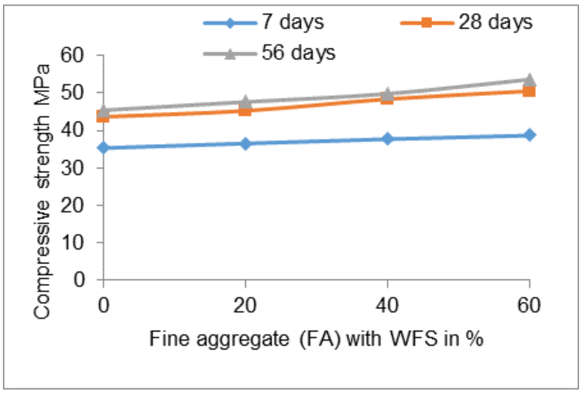

Figure 1: Compressive strength for the mixes with WFS

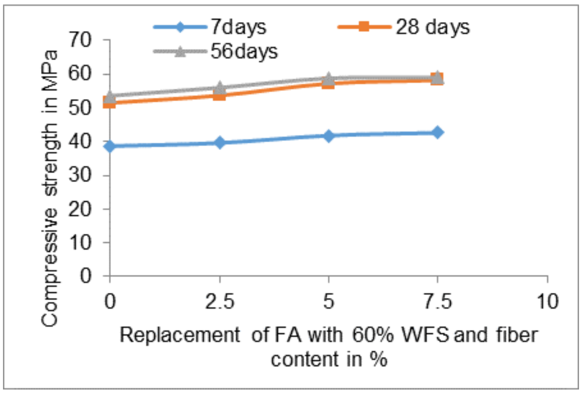

Figure 2: Compressive strength for 60% WFS and fiber

3.3 Effect of WFS and banana fiber on Split tensile strength

Split tensile strength of concrete mixtures made with and without waste foundry sand (WFS) was determined at 28 and 56 days of curing. Overall, age of testing, mix with WFS, fiber content was significantly influencing the split tensile strength of concrete. The results are shown in figure 3 and figure 4. The performance of concrete under tensile strength was similar to that of the compressive strength. There was an increase in split tensile strength for mixtures with WFS as partial replacement of fine aggregate. At 28 days, control mix achieved a split tensile strength of 3.98 MPa whereas mix with 20%, 40% and 60% WFS achieved a strength of 4.34, 4.89 and 5.46 MPa respectively; an improvement in tensile strength was 9.04%, 22.86%and 37.18% when compared with the control concrete strength (without WFS). At 56 days, control concrete achieved a split tensile strength of 4.54 MPa, whereas mix with 20%, 40% and 60% WFS achieved a strength of 5.17, 5.97 amd 6.59 MPa respectively. Another mixtures were prepared with 60 % WFS (HSC) as partial replacement of fine aggregate with different percentage of banana fiber (0%, 2.5%, 5% and 7.5%) in weight fractions. The addition of fibers to HSC (60% WFS and 0% fiber) enhanced the compressive strength compared to control concrete at all percentage of fiber content at 28 and 56 days. The percentage improvement in split tensile strength of WFS based fiber concrete when compared to control concrete (60% WFS, 0% fiber) were 3.11%, 10.07% and 16.67% at 28 days and 8.4%, 12.2% and 18.15% at 56 days.

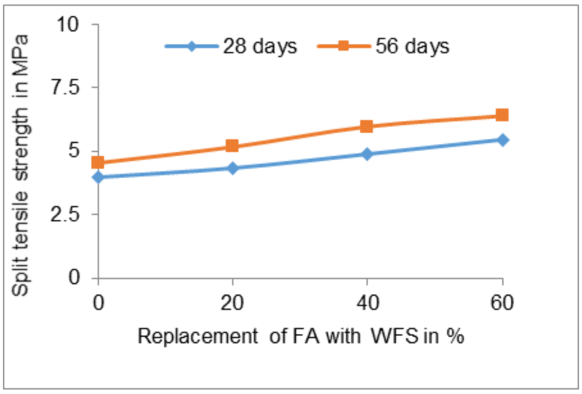

Figure 3: Split tensile strength for the mixes with WFS

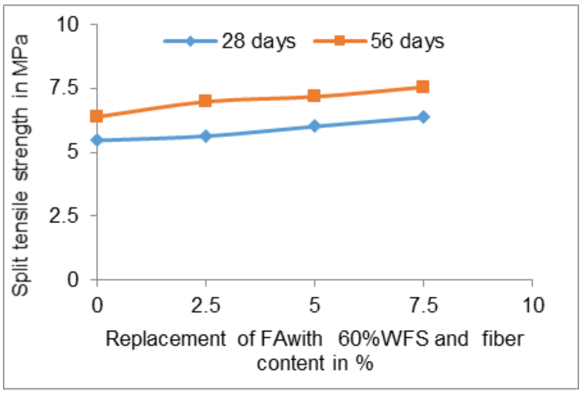

Figure 4: Split tensile strength for 60% WFS and fiber

3.4 Effect of WFS and banana fiber on Flexural strength

Between 28 and 56 days of curing, the flexural strength test of the mixtures made with and without waste foundry sand (WFS) was carried out on the prism specimens. The tests of blends without and without WFS were observed to be in the range of 28 days between 4.28 MPa and 5.96 MPa and 56 days between 4.84 MPa and 6.79 MPa. At 28 days, the percentage improvement in flexural strength of mixes with 20%, 40% and 60% WFS was 10.74%, 28.04% and 39.25% compared to control concrete. At 56 days, the percentage improvement in flexural strength of mixes with 20%, 40% and 60% WFS was 15.08%, 30.58%and 40.29% respectively when compared to control concrete. Based on the test results, another mixes were prepared with 60% WFS and different percentage of banana fiber (0%, 2.5%, 5% and 7.5%) and flexural strength was determined after 28 and 56 days of curing. Mix with 60% WFS, 0% fiber was considered as control mix. The percentage increase in flexural strength with the addition of fibers was 4.53%, 14.14%, 20.30% and 4.63%, 14.26%, 20.48% at 28 and 56 days respectively. The results are shown in figure 5 and figure 6.

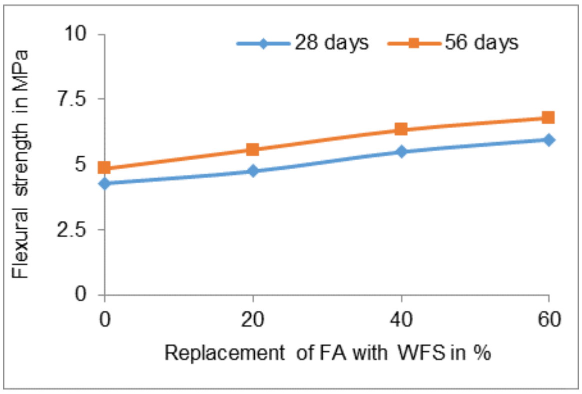

Figure 5: Flexural strength for the mixes with WFS

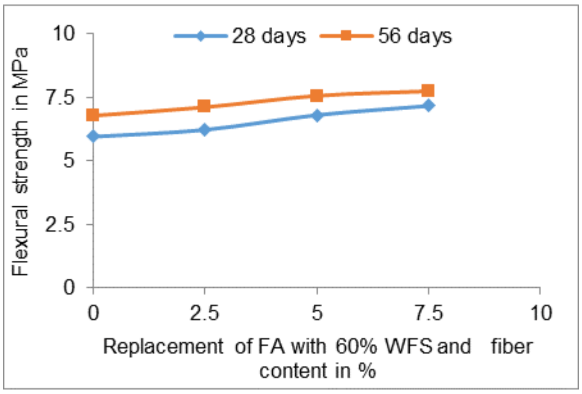

Figure 6: Flexural strength for 60% WFS and fiber

3.5 Sorptivity

Figures 7 and 8 show the sorptivity curves attained for the mixes at the age of 28 days of curing. The graph findings suggest that the absorption rate has reduced. This is largely because of the superior matrix. It was also observed that higher amounts of WFS content result in significantly lower absorption, which is consistent with the superior porous structure with reduced porosity and contrasts with the control concrete in which the increase in the absorption rate results in micro-cracking due to a high amount of heat release at a higher cement content. Coefficient of sorption was obtained based on linear fit in the table. Figure 7 and Figure 8 show the absorption rate for mixes with different WFS percentage and WFS (optimum) 60% with banana fiber respectively. The graph concluded that the 60% WFS sorption coefficient gives the best value than other blends. This is due to small WFS particles covering the vacuum spaces with air bubbles to decrease the permeability of concrete by sealing the air gaps and thus, as these air bubbles are filled, concrete permeability becomes significantly diminished and mixing with WFS is extremely impermeable. Mixing of 60% WFS and 2.5% fiber content offers higher values than other mixtures. The absorption rate improves with an improvement in mixes of 60% WFS and all fiber material relative to concrete mix (60% WFS as partial substitution of fine aggregate without fibre). While water infiltration is mostly of fibres, it does not impact concrete's strength characteristics.

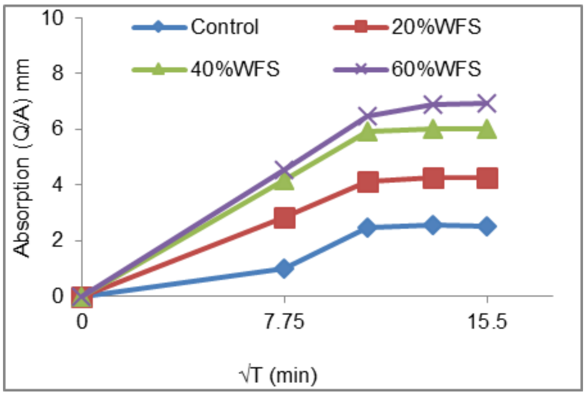

Figure 7: Sorptivity results of the Mixes with WFS

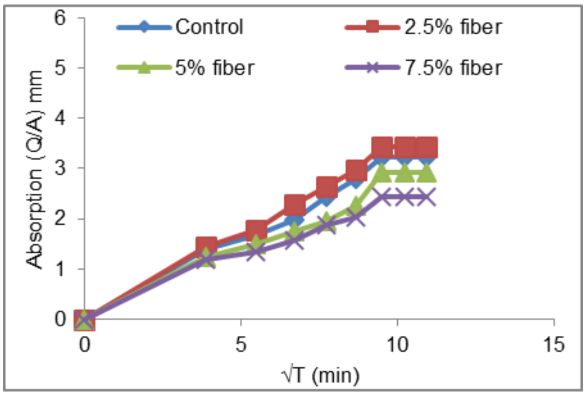

Figure 8: Sorptivity results for 60% WFS and fiber

3.6 Acid resistance test

Waste foundry sand (WFS) as partial replacement of fine aggregate in concrete being used as innovative material, has to be tested for its durability characteristics. Exposure to acid attack was chosen to study its durability characteristics as the acids are normally considered to be highly aggressive to concretes. The Hydrochloric acid and sulphuric acid were taken into account as this combines both acidic and sulphate environment simultaneously. The percentage variations in weight and compressive strength of the various concrete mixes after exposure to 2% Hydrochloric and sulphuric acid over a period of 56 days were assessed. The percentage reductions in weight and compressive strength for the mix with WFS are shown in Figure 9 and figure 11 respectively. The percentage variation in weight loss and strength after exposure to acids for the mix with 60% WFS and fiber content are shown in figure 10 and 12 respectively. It was observed that the percentage reduction in weight decreased with the increase of WFS and WFS based fiber concrete. The percentage reduction in weight for mixes with WFS (0%, 20%, 40% and 60%) was found to be in the range of 3.6 -4.5% and 3.3- 4.2% for Sulphuric and Hydrochloric acid respectively. Mix with fiber content of 0%, 2.5%, 5% and 7.5% was found be in the range of 2.3 - 3.6% and 2-3.3% for Sulphuric and Hydrochloric acid respectively. The maximum increase in strength for Sulphuric and Hydrochloric acid were found to be 7.07 % for control mix (0% WFS) and 3.76% respectively and 6.26% and 3.9% for 60% WFS with 5% fiber content with respect to control mix.

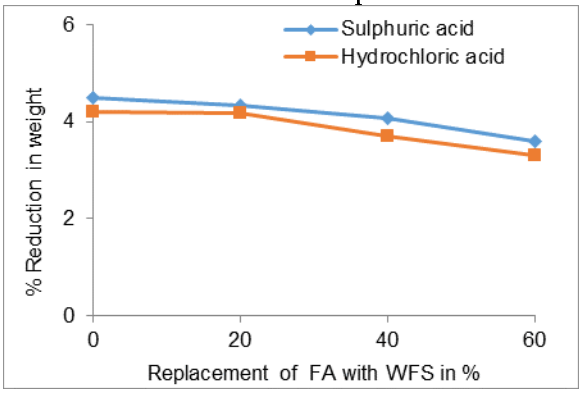

Figure 9: Weight loss in % for WFS

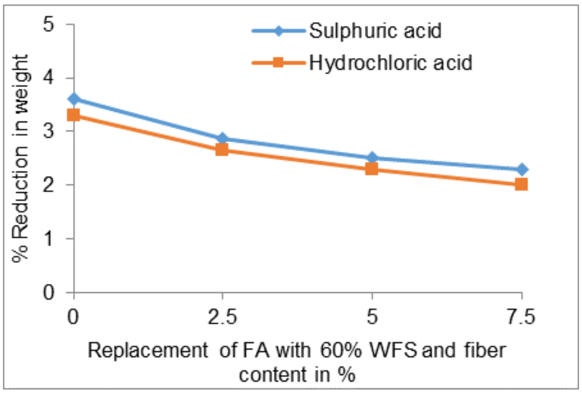

Figure 10: Weight loss in % for WFS and fiber

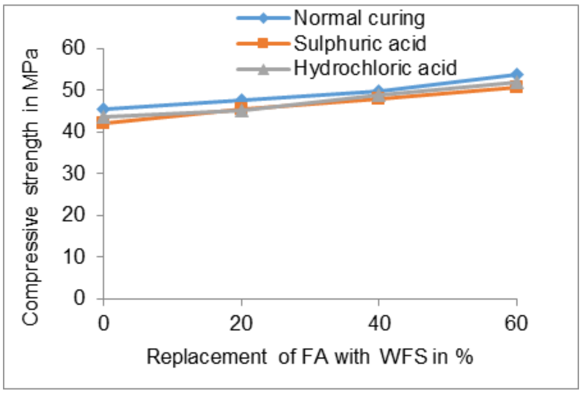

Figure 11: Compressive strength when exposed to acids

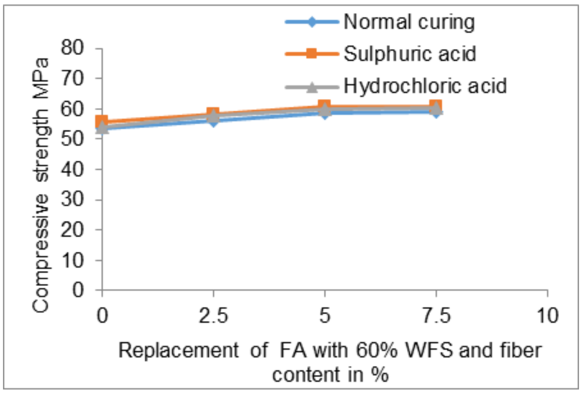

Figure 12: Compressive strength when exposed to acids

4. CONCLUSIONS

From the above experimental investigations carried out, the following conclusions can be drawn

1. Based on the slump test, the workability for all the mixes were observed to be comparative with the control mix.
2. The mechanical properties of WFS based banana fiber concrete increases with the increase in the replacement of fine aggregate by WFS and 60% replacement level at all fiber content produces maximum strength.
3. The compressive strength increases with the increase in WFS compared with control concrete. The maximum increase in compressive strength was 9.55%, 15.72% and 18.14% at 7 days, 28 days and 56 days of curing for 60% of WFS replacement by fine aggregate.
4. The compressive strength of concrete increases with the addition of banana fiber was 20.67%, 29.97% and 33.36% at 7 days, 28 days and 56 days of curing when compared to control concrete.
5. The percentage increase in split tensile strength of mix with 60% WFS was 37.18% and 40.75% at 28 days and 56 days of curing when compared to the control mix.
6. The percentage increase in split tensile strength for 7.5% fiber content was 60% and 66.30% at 28 days and 56 days when compared with the control mix.
7. The percentage increase in flexural strength of mix with 60% WFS was 39.25% and 40.3% at 28 days and 56 days of curing and mix with 7.5% fiber content was 60.12% and 67.52% at 28 days and 56 days when compared with the control mix.
8. The strength improvement was calculated for different curing periods, at all WFS and fiber content exhibited superior strength improvement for flexural strength than split tensile strength and compressive strength.
9. After 28 days curing in Sulphuric acid and Hydrochloric acids, mix with WFS for different percentage of replacement with fine aggregate and 60% WFS with banana fiber was found to be more than 7% increase in strength.
10. Durability characteristics of concrete have shown good performance for different percentage of replacement of WFS and banana fiber.
11. Based on the experimental results obtained, maximum of 60% WFS can be used as an alternative material for fine aggregate.
12. The addition of banana fibers significantly improved the properties of the concrete and ability to resist cracking and sudden failure.

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