An Experimental Investigation on Strength Characteristics of Hybrid Fiber Reinforced Concrete by Partial Replacement of Fine Aggregate with Bottom Ash

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Abstract— In the process of the growth of the industry large quantum of concrete is being utilized to cater the requirements of the industry, which requires huge raw materials in the production of the concrete for construction. Out of all the raw materials of concrete, lesser availability of the sand is a major concern in the construction industry. Day by day sand is getting costlier which directly increases cost of construction hence there is a need to evaluate the possible alternate materials that can be used as substitute in concrete without losing any of the properties of the concrete which are economically and easily available. The present work has been carried out with M25 grade concrete with w/c ratio 0.45. Bottom ash is replaced in 10%, 20%, and 30% by weight to the natural sand. Polypropylene fibers and WPE fibers are added as 0.75% and 0.25% by weight of cement respectively. The effect of bottom ash replaced with natural sand with addition of polypropylene fibers and WPE fibers is compared with that of the conventional concrete at different curing period, the optimum content of the bottom ash is found to be at 20% with Polypropylene fibers and WPE fibers are added as 0.75% and 0.25% by weight of cement.

Key words: Fine Aggregate with Bottom Ash, Hybrid Fiber Reinforced Concrete

I. INTRODUCTION

The highest consumed component in industry of construction today is that of concrete, use of which defines the rate of growth of the construction industry. Construction industry contributes a major part in development and it indicates rise in growth of any country in terms of infrastructure and modernization.

Concrete consists mainly of Coarse, Fine aggregates along with a binder material generally cement, which acts as solid once it attains its final setting time.

However compressive strength characterizes the concrete but Flexure strength is also a very important thing to be considered in many major locations thus the insertion of different fibers in concrete, increases Flexure strength of it to great extent.

Different type of fibers are used in the concrete such as natural fibers, steel fibers, polypropylene fibers, glass fibers, etc., Out of which few of them increase Flexure strength, few helps in other properties of the concrete.

II. MATERIALS USED

A. Cement

Chettinad of 53 grade confirming to IS 12269: (1987) been purchased locally and used in the project work. Physical property of Cement is shown.

Sl. No.	Properties	Values
1	Fineness	5%
2	Consistency	32%
3	Specific Gravity	3.14
4	Initial Setting Time	30 minutes
5	Final Setting Time	480 minutes

Table 1: Properties of the cement

B. Fine Aggregate

Locally available natural sand which was free from physical, biological impurities has been used in the project.

Sl. No.	Test carried out	Values
01	Specific Gravity	2.60
02	Bulk density	1633 kg/m^3
03	Fineness Modulus	3.10
04	Absorption of Water Content	2.0%

Table 2: Properties of Fine Aggregate

C. Coarse Aggregate

Crushed stone aggregates have been used as the Coarse aggregate in this experiment and they have been obtained from the local stone industries and maximum of the aggregate have been limited to 20mm size.

Sl. No.	Property	Values
01	Specific Gravity	2.72
02	Absorption of water	1.34%
03	Bulk density	1810 kg/m^3
04	Zone	I

Table 3: Properties of Coarse Aggregate

D. Bottom Ash

Bottom-ash is non-combustible waste obtained from burning in an incinerator. In an industrial condition, it refers to the coal burner that it includes traces of the fuels and the hot part of the coal combustion furnace attached to the walls during its combustion process.

Sl. No.	Property	Values
1	Specific gravity	1.70
2	Bulk density	831 kg/m^3
3	Water absorption	10.2%
4	Zone	II

Table 4: Physical Properties of Bottom Ash

Fig. 1: Bottom Ash

E. Polypropylene Fiber

Polypropylene is a 100% synthetic fiber that is transformed from 85% of propylene. The polypropylene monomer is propylene which is the byproduct of petroleum. The fibers used in this work were been manufactured by Reliance industries under the brand name of "Recron 3S".

Sl. No.	Property	Values
01	Length	12mm
02	Diameter	40 micron
03	Aspect ratio(L/D)	300
04	Density	1.36g/cm^3
05	Tensile strength	5000 kg/cm^2
06	Type of fiber	Monofilament

Table 5: Properties of Polypropylene Fibers

Fig. 2: Polypropylene Fiber

F. Waste Polyethylene (WPE) Fiber

Waste plastic fibers are obtained by cutting the waste plastic materials into the length of 5mm and least lateral dimension as 1mm has been used in the present experimental works.

Sl. No.	Description	Values
1	Length	50mm
2	Width	1mm
3	Aspect ratio	50
4	Density	1.34 g/cm^3

Table 6: Properties of WPE fiber

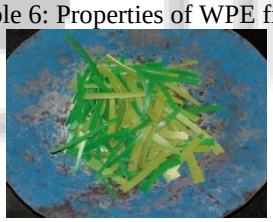

Fig. 3: WPE fibers

G. Water

Water required in mixing the concrete also for curing of specimens, it should not contain hazardous materials. In this investigation potable water is used.

H. Mix Design

The mix design forM25grade concrete is designed in accordance with IS 10262-2009.

Water	Cement	Fine Aggregate	Coarse Aggregate
197	437.77	638.38	1137.14
0.45	1	1.46	2.60

Table 7: Mix Proportion (kg/m^3), Mix Ratio of M25 Grade Concrete.

Sl. no	Mix ID	Cement	Polypropylene fibers	WPE fibers	Sand	Bottom ash	Coarse aggregate
1	M0	100%	0.75%	0.25%	100%	O%	100%
2	M1	100%	0.75%	0.25%	90%	10%	100%
3	M2	100%	0.75%	0.25%	80%	20%	100%
4	M3	100%	0.75%	0.25%	70%	30%	100%

Table 8: Different Mix Proportion

III. Results and Discussion

A. Tests on Fresh Concrete

1) Slump Cone Test

The slump values for different mix proportions are shows in the table below.

2) Compaction Factor Test

This test is used to find workability of fresh concrete as per *(IS¯1199–1959).*

Mix I.D	Slump (mm)	Compaction Factor
M0	72	0.93
M1	60	0.85
M2	54	0.82
M3	51	0.79

Table 9: Results of Slump Cone and Compaction Factor Test

B. Tests on Hardened Concrete

In this project work four tests is done for different mixes namely, Compressive Strength, Split Tensile, Flexural Strength &Sorptivity Test for various mixes.

1) Compressive Strength

This test is carried out to find the compressive strength of concrete which is the important properties of the concrete. to determine compressive strength of concrete, concrete cubes of dimension 150mmx150mmx150mm is casted and after 7 days &28 days curing the cubes was tested to get the compressive strength of various mixes. The formula to find Compressive strength is load at which specimen fail by area of the specimen and it is given by

$$Fc = \left\{\frac{P}{A} N/mm2\right\}$$

F_c = Compressive strength (N/mm$^{2)}$

P = force at which specimen break (N)

A = cube Cross sectional area in (mm^2)

MIX ID	Compressive strength(N/mm^2)	
	7days	28days
M0	20.54	32.80
M1	22.10	33.79
M2	24.95	34.82
M3	21.55	33.45

Table 10: Average Compressive Strength.

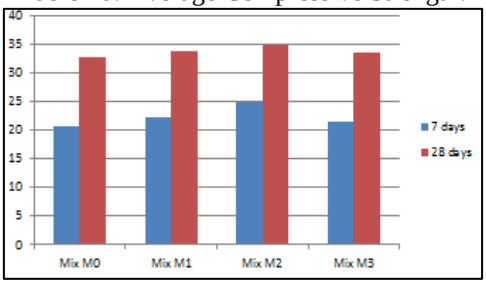

Fig. 4: Average Compressive Strength at 7&28 days

Fig. 5: Failure Pattern

2) Split Tensile Strength (IS-5816-1970)

Tensile strength test is carried out to find the tensile strength of concrete which is the important property of the concrete. The information of tensile value is very much needed for design the concrete structural member which is subjected to torsion, shrinkage, and temperature effects etc. The specimens of size 150mm diameter& 300mm height is tested after cured for 7 days and 28 days.

$$\text{Split. Tensile Strength} = \frac{2P}{\pi DL}$$

P = Applied force *N*.
L = Specimen Length mm.
D = Specimen diameter mm.

Mix ID	Split tensile strength(N/mm^2)	
	7days	28days
M0	2.16	4.10
M1	2.30	4.43
M2	2.54	5.14
M3	2.53	4.57

Table 11: Average Split tensile strength

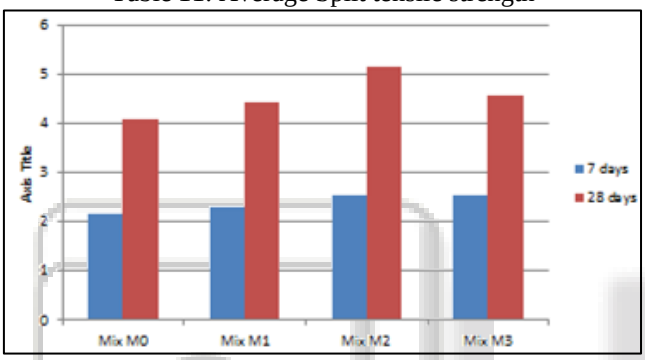

Fig. 6: Average Split Tensile Strength @ 7, 28 Days

Fig. 7: Failure Pattern of Cylinder

3) Flexural Strength Test (IS¯516-1959)

This test is used to find the flexural strength of concrete in accordance IS 516-1959.

Flexural strength is calculated by,

$$\text{Flexural strength } F_b = \frac{pl}{bd2}$$

F_b = flexural strength N/mm^2
P = load N
L = prism length mm
B = prism width mm
D = depth in, mm

Mix ID	Flexural Strength(N/mm^2)	
	7days	28days
M0	2.66	4.70
M1	3.17	5.37
M2	3.34	6.03
M3	3.05	5.30

Table 12: Average Flexural Strength.

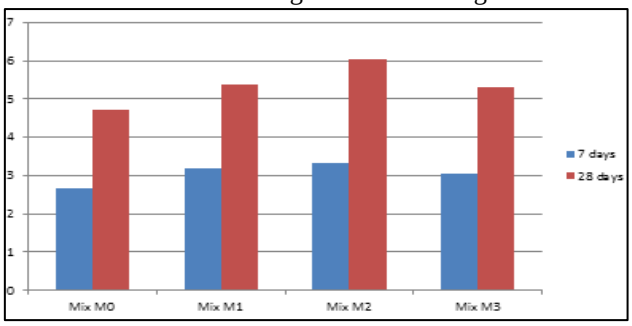

Fig. 8: Average Split Tensile Strength @ 7, 28 Days

Fig. 9: Failure Pattern of prism

4) Sorptivity Test

Sortivity test is used to determine the sorptivity, which is calculated by measuring the capillarity rise absorption rate on reasonable homogeneous material. In this test water was taken as Test fluid. The cylindrical disc of size 100mm diameter & 50mm ht. is casted and then after 24 hours demoulded and immersed in curing tank for 28days. After 28 days cylinders are kept in oven for drying @ a temperature of {100+10^{o}C} and it was submersed with level (not > 5mm) above the base of cylinder. Then flow by the peripheral Surface was sealed by Non-Absorbent coating. The amount of water which get absorb in 30 minutes was weighting on the weighing machine. The surface area of specimen was wiped off with a tissue paper and weight of the each specimens was taken within 30 sec.

Sorptivity (S) is a material property that is characterized by a tendency a porous material for absorption and transfer of water through capillaries. Cumulative water Absorption (Unit area at the entrance) increases as the square root of the flow Time (t).

$$S = I / t^{1/2}$$

S= Sorptivity
T= Time elapsed Minutes.

$$I = \Delta W / Ad$$

ΔW = changes in weight=W2-W1
W1=dry weight of cylinder in oven in mm
W2= cylinder Weight 30 minutes after capillary suction of water gm.
A= Surface area of the cylinder from where water is penetrated.
d= water density.

MIX ID	Dry weight in gm	Wet weight in gm	Sorptivity x 10^{-6} (m/s$^{1/2}$)
M0	969	980	15.00
M1	976	986	12.73
M2	979	988	11.82
M3	980	994	18.18

Table 13: Sorptivity Results

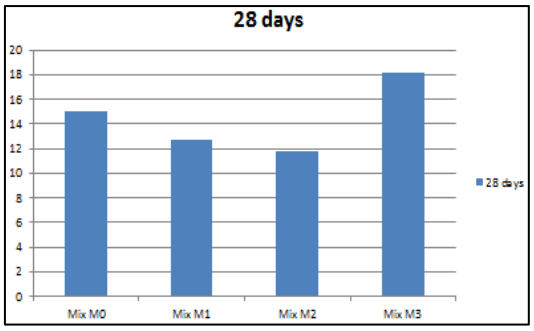

Fig. 10: Sorptivity Results

Fig. 11: Test Setup for Sorptivity test

IV. Conclusion

The basic idea is to study the strength parameters of the HFRC and its performance with addition of different fibers and various percentage of F.A replaced with bottom-ash, so that optimum value's are to be obtained by the investigations carried out on the M_{25} grade concrete.

- Experimental Investigations shows that comparisons made of 10%, 20%, 30% replacement of bottom ash, the 20% gives the optimum value with constant 1% of Hybrid fiber (0.75% PP +0.25% WPE) in terms of all the strength parameters.
- The addition of the bottom ash and fibers reduces the workability which is shown by the slump values, which can be overcome by using extra water content based on trial of mix proportions or by using admixtures.
- A nominal increase in compressive strength of about 10.2% is observed for the optimum value when compared to the normal concrete.
- An 30% increment is observed in tensile strength of concrete for the value of optimum replacement (20%) with constant 1% of Hybrid fiber (0.75% PP +0.25% WPE) compared to the 28 days of normal concrete as per IS:456-(2000), and that of flexural strength is 53%. The strength reduces as there is further increase in the replacement.
- Sorptivity values are reducing till 20.0% with constant 1% of Hybrid fiber (0.75% PP +0.25% WPE) and suddenly changed thereafter this happens due because the fibers induces the pores in concrete but Bottom-ash reduces pores thus the capillary absorption tends to fluctuate.

Thus, it is concluded that inclusion of fibers and 20% optimum replacement of fine aggregate with bottom-ash has a much improvement in mechanical properties of the concrete.

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