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Flexural Behaviour of Steel Fiber Reinforced Concrete with Addition of Mineral Admixture

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ABSTRACT
Fibre Reinforced Concrete (FRC) is very useful in extreme climate where shrinkage of concrete causes cracks. The Fibre Reinforced Fly ash concrete (FRFAC) has been successfully used to minimize cavitations / damages in hydraulics structures. This experimental investigation is to study the effects of replacement of cement (by weight) with three percentage of fly ash and the effects of addition of steel fiber composite. A control mixture of proportions was designed. Cement was replaced with three percentages of Fly Ash. Three percentages of steel fibers having 20 mm length were used.
This study reports the feasibility of use of steel fibres and their effect due to variation in fibre length, fibre content on structural properties such as cube compressive strength, cylinder compressive strength, split tensile strength, modulus of rupture and modulus of elasticity of this composite. Tests will be conduct on beams with optimum fibre parameters, and the results compared with those of identical Reinforced Concrete beam.

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I. INTRODUCTION

1.1 GENERAL

- Fibre Reinforced Concrete (FRC) is very useful in extreme climate where shrinkage of concrete causes cracks
- The Fibre Reinforced Fly ash concrete (FRFAC) has been successfully used to minimize cavitations / damages in hydraulics structures

1.2 INTRODUCTION

Concrete is very strong in compression but weak in tension. As a Concrete is a relatively brittle material, when subjected to normal stresses and impact loads. The tensile strength of concrete is less due to widening of micro-cracks existing in concrete subjected to tensile stress. Due to presence of fiber, the micro-cracks are arrested. The introduction of fibers is generally taken as a solution to develop concrete in view of enhancing its flexural and tensile strength.

The fibers and fly ash are added for improving its performance against creep, wear, fracture and decrease in the permeability. The Fiber Reinforced Fly Ash Concrete (FRFAC) has been successfully used to minimize cavitation / erosion damages in hydraulic structures such as sluiceways; navigation docks and bridge piers where high velocity flows are encountered. It is also rapidly gaining acceptance as suitable material for repairing, rehabilitation and renovation of concrete structures. Topçu and Canbaz, demonstrated through experiments that the addition of fibers provides better performance for concrete, while fly ash in the mixture may adjust the workability and strength losses caused by fibers, and improve strength gain. The results are based on experimental investigations in which concrete was produced with three different replacement ratios of fly ash and three different types of steel and polypropylene fibers.

II. MATERIAL PROPERTIES

2.1 Cement

The cement used in this experimental work Portland Portland Cement. The specific gravity of the cement is 3.15. The initial and final setting times were found as 90minutes and 180 minutes respectively. Standard consistency of cement was 31.25%.
Physical and chemical characteristics of cement play a vital role in developing strength and controlling rheology of fresh concrete. Fineness affects water requirements for consistency. Finally, from strength point of view, this cement should be finally ground and contain a fair amount of C3S.

Table 2.1: Physical properties of cement

S. No.	Physical Properties	Experimental
1	Normal consistency	31.5
2	Initial setting time (min)	250
3	Final setting time (min)	315
4	Soundness of cement (autoclave %)	0.13
5	Fineness (retained on 90 µ IS sieve)	352
6	Specific Gravity	2.92
7	Compressive Strength (MPa)	25.3
8	3 days	24
9	7 days	34
10	28 days	45.5
11	Pozzolana used (Fly ash) %	32.1

2.2 Fine aggregate

Locally available sand passed through 4.75mm IS sieve is used. The specific gravity of 2.84 and fineness modulus of 3.895 are used as fine aggregate. The loose and compacted bulk density values of sand are 1094and 1162 kg/m3 respectively, the water absorption of 1.491%.

Both river sand and crushed stones may be used. Coarser sand may be preferred as finer sand increases the water demand of concrete and very fine sand may not be essential in Fibre Reinforced Fly ash Concrete as it usually has larger content of fine particles in the form of cement and mineral admixtures such as fly ash, etc. The sand particles should also pack to give minimum void ratio as the test results show that higher void content leads to requirement of more mixing water.

Table 2.2 Tests on Fine Aggregate

S.NO	TESTS	VALUES
1	Specific gravity of fine aggregate	2.60
2	Fineness modulus of fine aggregate	2.53
3	Bulk density of fine aggregate	1580 kg/m3

2.3 Coarse Aggregate

The coarse aggregate is the strongest and least porous component of concrete. Coarse aggregate in cement concrete contributes to the heterogeneity of the cement concrete and there is weak interface between cement matrix and aggregate surface in cement concrete. This results in lower strength of cement concrete by restricting the maximum size of aggregate and by making the transition zone stronger. By usage of mineral admixtures, the cement concrete becomes more homogeneous and there is marked enhancement in the strength properties as well as durability characteristics of concrete. The strength of Fibre Reinforced Fly ash Concrete may be controlled by the strength of the coarse aggregate, which is not normally the case with the conventional cement concrete 20MSA:-Crushed aggregate available from local sources has been used. The coarse aggregates with a maximum size of 20mm having the specific gravity value of 2.958and fineness modulus of 7.136 are used as coarse aggregate.

The loose and compacted bulk density values of coarse aggregates are 1467 and 1629kg/m3 respectively, the water absorption of 1.30%. 10MSA:- Crushed aggregate available from local sources has been used. The coarse aggregates with a maximum size of 10mm having the specific gravity value of 3.016and fineness modulus of 5.829 are used as coarse aggregate.

The loose and compacted bulk density values of coarse aggregates are 1531 and 1726kg/m3 respectively, the water absorption of 1.835%.

Table 2.3 Tests on coarse aggregate

S.NO	TESTS	VALUES
1	Specific gravity of coarse aggregate	2.60
2	Bulk density of coarse aggregate	1652.89 kg/m3
3	Impact value on coarse aggregate	11.48%
4	Fineness modulus in 10mm,20mm	6.4, 7.6 resp.,

2.4 Water

Water is an important ingredient of concrete as it actively participates in the chemical reactions with cement. The strength of cement concrete comes mainly from the binding action of the hydrated cement gel. The requirement of water should be reduced to that required for chemical reaction of unhydrated cement as the excess water would end up in only formation of undesirable voids in the hardened cement paste in concrete. From Fibre Reinforced Fly ash Concrete mix design considerations, it is important to have the compatibility between the given cement and the chemical/mineral admixtures along with the water used for mixing.

2.5 Fibers

The steel fibre is procured from precision Drawell Pvt. Ltd., Nagpur. The steel fiber used in the study is the hook ended type HK0750 having aspect ratios 71. The constant dosages of 0.5 % fibers up to 1.5% are used by total volume of concrete. The length of dividing fiber is 50mm and the diameter of fiber is 0.7.

Table 2.4 Tests on steel fibre

Property	Value
Density of steel fibre (kg/m3)	7850
Length (mm)	25
Diameter (mm)	0.6
Aspect ratio (L/D)	41.7
Grade of steel fibre	I
Type of steel fibre	Carbon

2.6 Fly Ash

Fly Ash is available in dry powder form and is procured from Dirk India Pvt. Ltd., Nasik. The light grey, fly ash under the product name “Pozzocrete 60” is available in 30kg bags. The Fly ash produced by the company satisfies all the requirements of the IS 3812: 1981, BS 3892: Part I: 1997.

Table 2.5 Tests on Flyash

Chemical composition (%)	
Silicon dioxide (SiO2)	60.5
Aluminium oxide (Al2O3	22.80
Iron oxide (Fe2O3)	8.80
Calcium oxide (CaO)	2.38
Magnesium oxide (MgO)	0.6
Loss on ignition	1.1
Chlorides (Cl)	0.01
Sodium oxide (Na2O)	0.

2.7 Chemical Admixtures

Chemical admixtures are the essential ingredients in the concrete mix, as they increase the efficiency of cement paste by improving workability of the mix and there by resulting in considerable decrease of water requirement. Different types of chemical admixtures are

- Plasticizers
- Super plasticizers
- Retarders

- Air entraining agents

Placticizers and super placticizers help to disperse the cement particles in the mix and promote mobility of the concrete mix. Retarders help in reduction of initial rate of hydration of cement, so that fresh concrete retains its workability for a longer time. Air entraining agents artificially introduce air bubbles that increase workability of the mix and enhance the resistance to deterioration due to freezing and thawing actions.

2.8 Mineral admixtures

The major difference between conventional cement concrete and High-Performance Concrete is essentially the use of mineral admixtures in the latter. Some of the mineral admixtures are

- Fly ash
- Silica fumes
- Carbon black powder
- Anhydrous gypsum based mineral additives

Mineral admixtures like fly ash and silica fume act as puzzolonic materials as well as fine fillers, thereby the microstructure of the hardened cement matrix becomes denser and stronger. The use of silica fume fills the space between cement particles and between aggregate and cement particles. It is worth while noting that addition of silica fume to the concrete mix does not impart any strength to it but acts as a rapid catalyst to gain the early age strength.

III. EXPERIMENTAL METHODOLOGY

3.1 Workability Test

Workability is carried out by conducting the slump test and compaction factor test as shown in Fig. As per I.S. 1199-1959 on ordinary concrete and fibre reinforced concrete.

3.2 Compressive strength test

The compressive strength of concrete is one of most important properties of concrete in most structural applications. For compressive strength test, cube specimens of dimensions 150 x 150 x 150 mm were cast for M20 grade of concrete. After curing, these cubes were tested on Compression Testing machine as shown in Fig.3. As per I.S. 516-1959. The failure load was noted. In each category two cubes were tested, and their average value is reported. The compressive strength was calculated as follows,

Compressive strength (MPa) = Failure load / cross sectional area.

The aim of this experimental test is to determine the maximum load carrying capacity of test specimens. The compression test specimens were tested on a compression testing machine (CTM) of capacity 1000 KN. The specimen was placed on machine in such a way that its position is at right angles to its own position which it had at the time of casting.

Table 4.1 Compressive strength

Compressive strength in N/mm2			
Replacement in Concrete	7 Days Test	14 Days Test	28days Test
Conventional concrete	17.80	20.40	23.40
10 % Flyash (0.3% fibre)	19.00	22.20	24.60
10 % (0.45% fibre)	18.64	21.20	24.00
10 % (0.6% fibre)	18.20	21.00	23.40
20 % (0.3% fibre)	20.40	24.60	26.20
20 % (0.45% fibre)	19.20	23.20	25.00
20 % (0.6% fibre)	19.40	23.00	25.00
30 % (0.3% fibre)	19.20	23.00	24.40
30 % (0.45% fibre)	19.40	22.10	22.80
30 % (0.6% fibre)	18.80	22.40	23.10

3.3 Flexural strength test

For flexural strength test beam specimens of dimension 150x150x700 mm were cast. The specimens were demoulded after 24 hours of casting and were transferred to curing tank where in they were allowed to cure for 7 days. These flexural strength specimens were tested under two point loading as per I.S. 516-1959, over an effective span of 600 mm divide into three equal parts and rest on Flexural testing machine as shown in Fig. 4. The load is normally increased & failure load is noted at cracking of beam specimen. In each category two beams were tested, and their average value is reported. The flexural strength was calculated as follows.
Flexural strength (MPa) = (P x L) / (b x d2),

Where, P = Failure load, L = Centre to centre distance between the support = 600 mm, b = width of specimen=150 mm, d = depth of specimen= 150 mm.
The specimen is subjected to two points loading and the load at the failure of the specimen is noted down.Prisms of size 100 x 100 x 500 mm were cast. Two numbers of specimens for each set were tested for 28days. These specimens were tested in universal Testing Machine (UTM) of capacity 400 kN

Table 4.3 Flexural strength

Replacement in Concrete	7 Days Test	14 Days Test	28days Test
Conventional concrete	2.56	3.22	3.57
10 % Flyash (0.3% fibre)	2.94	3.57	4.68
10 % Flyash (0.45% fibre)	3.14	3.98	5.30
10 % Flyash (0.6% fibre)	3.07	3.95	5.27
20 % Flyash (0.3% fibre)	4.16	4.78	5.88
20 % Flyash (0.45% fibre)	4.03	4.53	5.57
20 % Flyash (0.6% fibre)	3.97	4.72	5.67
30 % Flyash (0.3% fibre)	3.84	4.46	5.05
30 % Flyash (0.45% fibre)	3.97	4.53	4.99
30 % Flyash (0.6% fibre)	3.78	4.46	4.87

3.4 Split tensile strength test

Tensile strength is one of the basic and important properties of concrete. Size of test sample of 15cm diameter, 30cm height and 0.3cm thick cylindrical mould is used. The cylinder is placed left and right between the two plates of the compressive testing machine and the load is applied. The load at which the sample in the end fails is noted and split tensile strength is calculated.

The cracking is a form a tensile failure. The main of this experimental test is to determine the maximum load carrying capacity of test specimens. Cylinders of size 150 mm in diameter and 300 mm height were cast for split tensile test. Two numbers of specimens were tested 28days. The splitting tests are well known as indirect tests used for determining the tensile strength of concrete.

Table 4.2 Split Tensile Strength

Split Tensile strength in N/mm2			
Replacement in Concrete	7 Days Test	14 Days Test	28days Test
Conventional concrete	2.11	2.43	3.39
10 % Flyash (0.3% fibre)	2.23	2.61	3.53
10 % Flyash (0.45% fibre)	2.17	2.61	3.46
10 % Flyash (0.6% fibre)	2.35	2.74	3.53
20 % Flyash (0.3% fibre)	2.70	2.99	3.72
20 % Flyash (0.45% fibre)	3.07	3.55	4.00
20 % Flyash (0.6% fibre)	3.07	3.30	3.79
30 % Flyash (0.3% fibre)	3.01	3.24	3.72
30 % Flyash (0.45% fibre)	3.01	3.24	3.72
30 % Flyash (0.6% fibre)	2.95	3.12	3.39

3.5 Modulus of Rupture

The variation of flexural strength values with respect to fly ash percentage, fibre length and fibre content is needed to analyse. The maximum Flexural strength obtained for Steel Fibre Reinforced Concrete and that for Plain Cement Concrete are determine. The corresponding strength improvement will be calculated. It is observed during testing that the plain concrete specimens failed without any warning, whereas Fibre Reinforced Concrete specimens showed a ductile failure, giving ample warning.

3.6 Dynamic modulus of elasticity (Ed)

Ed of cylindrical concrete specimens was determined using Non-Destructive testing equipment (NDT). Cylinders of dimensions 300 mm (height) and 150 mm (diameter) were used. Two transducers on either side of the specimen were placed to get the frequency of the specimen. Concrete members were subjected to longitudinal vibration at their natural frequency to find dynamic modulus.
Dynamic modulus can be calculated by using the relationship: Ed = Kn2L2ρ
Where, K is a constant, n is the resonant frequency, L is the length of the specimen, and ρ is the density of concrete.

3.7 Impact Resistance

The impact resistance of the specimen was determined at 28 days, 60 days and 90 days. The failure patterns of the Impact specimens after ultimate failure are note down. The first visible crack (N1) and then cause ultimate failure (N2) were noted for all the specimens. The impact energy delivered to the specimen are calculated by each impact is calculated as follows:
EI = Nmgh

where EI is impact energy (N m), N is the number of blows, m is mass of the drop hammer (kg), g is gravity acceleration (N/kg), and h is height of drop hammer (m).

IV. CONCLUSION

The fly ash can serve as a good substitute for cement. Properties of the resulting composites show better performance than plain concrete both in terms of mechanical and structural strengths.

- Increase in workability
- Decrease in water content requirement
- Decrease in ultimate load carrying capacity
- Decrease in heat evolution during hydration
- Increased use of fly ash
- High resistant to acid attack
- High resistant to sulphate attack
- Environment friendly concrete
- Increased workability and strength

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