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Assessment of Flexural Strength of fibre Based Concrete

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Abstract:
The aim of the present study is to investigate the effect of variation of polypropylene fibres ranging from 0.1% to 0.4% along with 0.8% steel fibres on the behaviour of fibrous concrete. The mechanical properties of the concrete such as compressive and tensile strength have been investigated. The result shows that addition of polypropylene fibre has a little effect on the compressive strength, but there was significant increase in the tensile strength with increase in fibre volume fraction. The present investigation shows an increase of 47% of split tensile strength and 50% of flexural strength. The result shows that ultimate load mainly depended on percentage volume fraction of fibre

Keywords: polypropylene fibres, steel fibres, split tensile strength , flexural strength, fibrous concrete ,fibre based concrete (FBC) ,Compressive strength analysis.

I. INTRODUCTION

Concrete is known to be a brittle material when subjected to tensile stresses and impact loads; tensile strength of the concrete is approximately one tenth of its compressive strength. As a result of this, concrete members are unable to withstand such loads and stress that are usually encountered by concrete structural members.

Usually, concrete members are reinforced with continuous reinforcing bars to withstand tensile stresses and to compensate for the lack of ductility and strength. The addition of steel reinforcement to concrete significantly increases its strength, but to produce a concrete with homogenous tensile properties and better micro cracking behaviour, fibres are advantageous.

The introduction of fibres in concrete has brought a solution to develop a concrete having enhanced flexural and tensile strength, which are a new form of composite material. At the micro-level, fibres inhibit the initiation and growth of cracks, and after the micro-cracks coalesce into macro-cracks, fibres provide mechanisms that abate their unstable propagation, provide effective bridging, and impart sources of strength gain, toughness and ductility. Fibres are mostly discontinuous, randomly distributed throughout the cement matrices.

The randomly distributed short fibres are generally introduced into concrete to enhance its control crack system and mechanical properties such as toughness, impact resistance, ductility (post cracking), tensile strength etc. of basic matrix.

There are many kinds of fibres, such as metallic, synthetic, natural etc. which are being used in normal concrete. The term fibre based concrete (FBC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibres that are uniformly distributed and randomly oriented. Different type of fibres in concrete changes the character of fibre based concrete. Further properties of fibre based concrete changes with varying concrete, fibre materials geometries, distribution, orientation and densities.

When fibre is added to a concrete mix, each and every individual fibre receives a coating of cement paste. Modification of synthetic fibre geometry includes monofilaments, fibrillated fibres, fibre mesh, wave cut fibre large end fibres etc. This increases bonding with cement matrices without increasing in its length and minimized chemical interaction between fibres and the cement matrices. In present study polypropylene and steel fibres have been used. Polypropylene fibre having low modulus, light density, small monofilament diameter and not susceptible to corrosion and steel fibre increases its ductility, toughness, and impact resistance.

Polypropylene and steel fibre is considered to be an effective method for improving the shrinkage, cracking characteristics, toughness and impact resistance of concrete material. Almost all FRCs used today commercially involve the use of a single fibre type. Clearly, a given type of fibre can only be effective in a limited range of crack opening and deflection.

The benefits of combining organic (polypropylene and nylon) and inorganic fibres (glass, asbestos and carbon) to achieve superior tensile strength and fracture toughness were recognized about 30 years back. Thereafter much research was not undertaken, recently again there is renewed interest in this field. In present study the structural behaviour of the fibre based concrete using hybrid fibres has been conducted.

II. MATERIALS USED

A. Cement

The cement is the main part of the concrete which imparts the strength to concrete. OPC-43 Grade cement was used in this study. It is important that cement shall be tested to get the chemical and physical properties. All the tests on cement were Carried out as per recommendations of IS: 12269-1989. The physical properties of the cement are presented and compared with the requirements of IS: 8112 in Table-1.

Table.1. Physical properties of OPC-43 grade

Parameter	Test value	IS 8112: 1989 Recommendation
Standard consistency (% of water by wt of cement)	28	-
Setting time(Minutes) a) Initial b) Final	 65 285	 30 (Min.) 600 (Max.)
Compressive strength 1) 3- day 2) 7 –day 3) 28- day	 24.4 34.2 49	 23 (Min.) 33 (Min.) 43 (Min.)
Soundness (mm)	1.4	10 (Max.)
Specific gravity	3.14	3.15
Comments : As per the test values, cement qualifies for 43 - Grade OPC		

Table.2. Chemical composition of cement

Chemical property	Results	Limits as per IS
Lime saturation Factor (%)	0.78	0.66 min - 1.02 max
Alumina Iron Ratio (%)	1.2	Min 0.665
Insoluble Residue (%)	0.8	Max 2%
Magnesia (%)	2.1	Max 6%
Sulphuric Anhydride (%)	1.1	2.5% to 35
Loss on ignition (%)	2.0	Max 5%

B. Fine aggregate

River sand was used as fine aggregate is natural and obtained from local market. The physical properties like specific Gravity, bulk density, gradation fineness modulus are tested in accordance with IS 2386 and their physical properties are in accordance with IS383: 1970as in Table 3:-

Table.3. Physical properties of fine aggregate

S.No	Characteristics	Requirement as per IS 383: 1970	Tested values
1.	Specific Gravity	2.6-2.7	2.64
2.	Fineness Modulus	2-3.5	3.022
3.	Water Absorption (%)	-	1.78
4.	Moisture Content (%)	-	0.50
5.	Grading	-	Zone II(IS 383-1970)

C. Coarse aggregate

The crushed angular granite metal of coarse aggregate of 20 mm maximum size as well as 12mm size are obtained from the local crushing plant, is used in the present study. The physical properties of the coarse aggregate like specific gravity, bulk density, gradation fineness modulus are tested in accordance with IS 2386 their physical properties are in accordance with IS383: 1970 as in Table 4:-

Table.4. Physical properties of coarse aggregate

S.No	Characteristics	Requirement as per IS 383: 1970	Tested values
1.	Specific Gravity	2.6-2.7	2.68
2.	Fineness Modulus	5.5-8	6.55
3.	Water Absorption (%)	-	0.50
4.	Moisture Content (%)	-	NIL
5.	Texture	-	Rough

D. Water

Tap water free from deleterious materials was used for casting as well as curing of the specimens. In curing tanks supply of fresh water was maintained and the curing tanks were cleaned from time to time.

E. Fibre

(a) Polypropylene fibre:-

Polypropylene fibres were used in present study which was provided by the FORTA Corporation. It offers good bonding power; enhance mechanical properties, long term durability, and true secondary temperature control. These are non-corrosive, chemically inert, and 100% alkali proof. The physical properties of polypropylene fibres are given in Table 5

Table.5. Properties of Polypropylene fibre

Properties	Forta Ferro multifilament fibre
Form	Twisted bundle multifilament Fibre
Specific gravity	0.90
Tensile strength (MPa)	680
Modulus of elasticity (GPa)	5.8
Length (mm)	54.0
Aspect ratio	158.8

(b) Steel fibre

Steel fibres were used in present study which was provided by the APEX Corporation. It improves structural strength, reduce steel reinforcement requirement, reduce crack width, and improve crack and abrasion resistance. The physical properties of steel fibres are given in Table 6

Table.6. Properties of Polypropylene fibre

Properties	Apex steel fibre
Form	Crimmped shape steel fibre
Diameter (mm)	0.51
Tensile strength (MPa)	680
Length (mm)	31
Aspect ratio	60.78

III. MIX PROPORTIONS

In the present investigation the existing method as per IS: 10262-1982 has been used for selecting the reference mix

(M30), however new information given in IS 456 -2000 have been incorporated, procedure is modified to the extent. In order to get the final mix proportion for the reference mix design, three trial mixes had been prepared earlier and tested at 28 days and was further modified by fine tuning the relative proportions of fine and coarse aggregate.

Table.7. Final mix design adopted

Mix	Water (kg/m3)	Cement (kg/m3)	Fine aggregate (kg/m3)	Coarse aggregate (kg/m3)
M30	191.58	425.733	574.51	1202.55
	0.45	1	1.34	2.82

Table.8. Mix proportion for one cubic meter of concrete for M30 concrete mix

S.No.	Constituent	Quantities
1	Cement (kg)	425.733
2	Fine aggregate (kg)	574.51
3	Coarse aggregate (kg)	1202.55
4	Water (Lit.)	191.58
5	w/c ratio	0.45
6	Proportion C : FA : CA	1 : 1.34 : 2.82

IV. FLEXURALSTRENGHT

Flexural tensile strength or modulus of rupture of concrete has been determined by applying the failure load on prismaticspecimen of size 100 mm x 100mm x 500 mm, using the beam testing machine of 5 tons capacity. The permissible error shall not be greater than ± 0.5 percent of the applied load where a high degree of accuracy is required and not greater than ± 1.5 percent of the applied load for commercial type of use. The bed of the testing machine was provided with two steel rollers, 38 mm in diameter, on which the specimen is to be supported, and these rollers were so mounted that the distance from center to center is 400 mm for 100 mm specimens. The load applied through two similar rollers mounted at the third points of the supporting span that is, spaced at 133 mm centre to centre. The load is divided equally between the two loading rollers and all rollers mounted in such a manner that the load was applied axially and without subjecting the specimen to any torsion stresses or restraints. The flexural strength of the specimen can be expressed as the modulus of rupture f_t.
Modulus of rupture is calculated from following expression:-
f_t = (pl/bd 2)
When „a" is greater than 133 mm for a 100 mm specimen, or
f_t = (3pa/bd 2)
When 'a' is less than 133 mm but greater than 110 mm for a 100 mm specimen.
Where,
b = measured width in cm of the specimen,
d = measured depth in cm of the specimen at the point of failure,
l = length in cm of the span on which the specimen was supported,
p = maximum load in kg applied to the specimen
If 'a' is less than 110 mm for a 100 mm specimen, the results of the test shall be discarded.

V. RESULTS AND DISCUSSIONSS

For studying the flexural behaviour beams of fibrous concrete were tested on flexural testing machine. The failure load was observed and the strength was calculated. The figures show the effects of volume variation of polypropylene fibre and flexural strength of concrete. It is observed that with the increase in polypropylene fibre, the flexural strength increases. However, it is noticed that threat of increase of flexural strength is more as compared to compressive strength. The results showthat optimum dosage for flexure is 0.3% of polypropylene fibre along with 0.8% of steel fibre. The below results shows flexural strength increases with increase in fibre volume fraction; this is due to the additional load taken by the fibres present in the matrix. However, after increasing the volume percentage ofpolypropylene fibre beyond the optimum value (0.3%) improper mixing of fibres with the matrix takes place due to balling effect of fibre, this increases the amount of vibrations required to remove air voids from the mix which in turn causes the problem of bleeding and decreases flexural strength of the mix. The failure pattern of plain and hybrid fibrous concrete in flexural strength test shows that fibrous concrete are more ductile as compared to plain concrete. This is because when the matrix cracked, the load was transferred from the composite to the fibres at the crack surfaces, which prevents the brittle failure of the composite. results of each cast have been mentioned in tables below:-

Table.9. Test results for split tensile strength at 7 days
Size of beams 100mm X 100mmX500mm
Concrete mix used M30 grade
Percentage of steel fibres 0.8% (with aspect ratio 60.78)

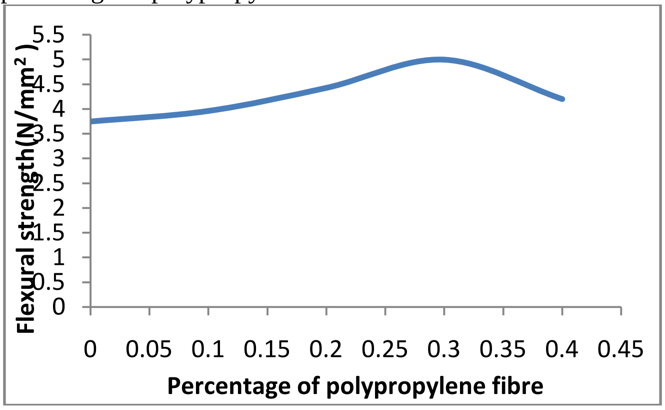
S.No.	Percentage of polypropylene fibre along with 0.8% steel fibre	Load at failure (KN)	Flexuralstrength(N/mm^2)
1	0%	9.00	3.65
2	0%+0.8%	9.35	3.75
3	0.1%+0.8%	9.85	3.96
4	0.2%+0.8%	11.10	4.43
5	0.3%+0.8%	12.56	5.00
6	0.4%+0.8%	10.40	4.20

Table.10. Test results forflexural strength at 28 days
Size of 150mm X 300mm
Concrete mix used M30 grade
Percentage of steel fibres 0.8% (with aspect ratio 60.78)

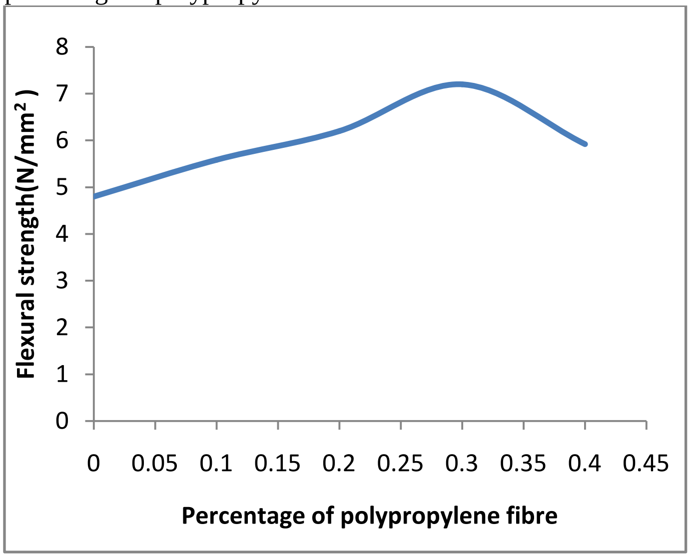
S.No.	Percentage of polypropylene fibre along with 0.8% steel fibre	Load at failure (KN)	Flexuralstrength(N/mm^2)
1	0%	11.70	4.70
2	0%+0.8%	12.00	4.80
3	0.1%+0.8%	13.93	5.59
4	0.2%+0.8%	15.50	6.20
5	0.3%+0.8%	18.00	7.20
6	0.4%+0.8%	14.80	5.92

Variation of Flexural strength

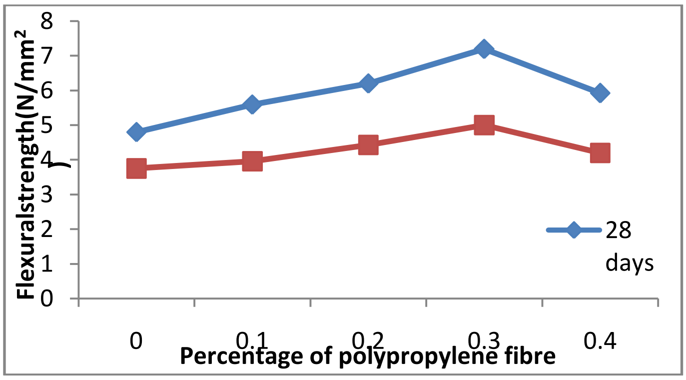
a) Variation ofFlexuralstrength at 7 days v/s percentage of polypropylene fibre



b) Variation of Flexuralstrength at 28 days v/s percentage of polypropylene fibre



c)Flexuralstrength at 7 and 28 days v/s percentage of polypropylene fibre



For studying the flexural behaviour, cylinders of fibrous concrete were tested on universal testing machine in structures lab. The failure load was observed and the strength was calculated which is presented in Table 9 and 10and is graphically shown in Fig. (a) to (c). From the above results it observed that the addition of the polypropylene fibre in the control mix has effect on the flexural strength. The effects are as follows:-

a) It is observed that with the increase in polypropylene fibre, the flexural strength increases.

b) It is noticed that the rate of increase of flexural strength is more as compared to compressive strength.

c) The results show that optimum dosage for flexure is 0.3% of polypropylene fibre along with 0.8% of steel fibre.

d) The above results show that flexural strength increases with increase in fibre volume fraction; this is due to the additional load taken by the fibres present in the matrix.

e) After increasing the volume percentage of polypropylene fibre beyond the optimum value (0.3%) improper mixing of fibres with the matrix takes place due to balling effect of fibre,

f) This increases the amount of vibrations required to remove air voids from the mix which in turn causes the problem of bleeding and decreases flexural strength of the mix.

g) The failure pattern of plain and hybrid fibrous concrete in flexural strength test shows that fibrous concrete are more ductile as compared to plain concrete. This is because when the matrix cracked, the load was transferred from the composite to the fibres at the crack surfaces, which prevents the brittle failure of the composite.

VI. CONCLUSION

Based on experimental investigation and analysis of results obtained, the following conclusions may be drawn broadly:-

1) Steel-polypropylene fibre reinforced concrete showed increase in flexural strength when compared with steel fibre reinforced concrete.

2) The maximum gain in flexural strength was achieved for 0.3% polypropylene fibre. Thereafter increase in fibre content has marginally reduced the flexural strength.

3) From the present study it is observed that the optimum dosage of polypropylene fibre fraction is 0.3%.

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