Evaluation of FRC using Steel and PVA Fibers in Concrete

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Abstract— Concrete is the widely used construction materials. The conventional concrete is enhanced by the addition of fibers in it. The brittleness in concrete is reduced and the adequate ductility of concrete is ensured by the addition of fibers in concrete. Fibers used are polyvinyl alcohol and steel fibres in various volume combinations. The main reason for adding fibre to concrete matrix is to find its compressive strength, split tensile strength, and flexural strength. The base polyvinyl alcohol is highly resistant to the majority of aggressive agent and will never oxidize when exposed to the condition which causes the steel to rust. The hybrid fibres of various combinations in polyvinyl alcohol fibre is 0.1%, 0.25%, 0.5% and steel fibre 0.5%, 0.75%, 1.0% are decided to use in concrete mix. The workability of these fibre reinforced concrete mixes will be increased by addition of super plasticizer. It gives good impact strength, ductility, high load bearing capacity after being cracked, high resistance to corrosion. PVA and steel fiber got wide acceptance as a less hazardous and reasonable cost alternative. It is also suitable characteristic for reinforcing cementitious composites.

Keywords: Steel Fibre – Crimped, Polyvinyl alcohol fibre, optimum value, compressive strength, flexure strength, split tensile

I. INTRODUCTION

The concrete in which more than one fibre types are used as secondary reinforcement is called hybrid fibre reinforced concrete. A composite can be termed as hybrid, if two or more types of fibers are rationally combined in a common matrix to produce a composite that derives benefits from each of the individual fibre and exhibits a synergetic response. There are different types of fibers made from steel, glass, polypropylene, graphite, asbestos, Kevlar, different metal alloys and textiles are available these days for commercial and experimental use. Their physical properties and role in enhancing the mechanical properties of cementitious materials have been studied by many researchers over the past 50 years.

A. Steel Fibers

Steel fibres are filaments of wire, deformed and cut to lengths, for reinforcement of concrete, mortar and other composite materials. It is a cold drawn wire fibre with corrugated and flatted shape. Steel fibers intended for reinforcing concrete are defined as short, discrete lengths of steel having an aspect ratio in the range of 20-100, with any cross section and that are sufficiently small to be randomly dispersed in a fresh concrete mixture using usual mixing procedures. The recommend dosage of steel fiber is usually in between 20 and 40 kg/m3. The greater dosage rates the greater flexure strength of concrete. Make sure to add steel fibers into concrete mix as last ingredient, mix at highest speed at least one minute per cubic meter of concrete in order to prevent clumps formation into the concrete mixture.

B. Polyvinyl alcohol Fibers

Polyvinyl alcohol fibre (PVA) is an ideal environment-friendly cement reinforced material, which possesses alkali and weather resistance due to its unique molecular structure, taking on good affinity to cement, effectively prevent and suppress the crack formation and development, improve bending strength, impact strength and crack strength, improve permeability, impact and seismic resistance of concrete. This product can be widely used in industrial and civil buildings, walls, roofing, flooring and roads, bridges, tunnels, slope reinforcement.

II. OBJECTIVE OF THE INVESTIGATION

The objective of this present investigations is to investigate the workability, mechanical and flexural characteristics of concrete for various proportion of two different fibre and comparing the results with conventional concrete. The investigation is aimed in finding out the Compressive strength of cube, Split tensile strength of cylinder, Flexural strength of prism and Load Vs deflection of beam.

A. Scope of the Present Investigation

The scope of the investigation can be summarized as follows

1) To enhance the flexural strength and toughness by adding steel fibre.
2) To enhance the bridging of smaller micro cracks by addition of polyvinyl alcohol fibres.
3) To examine the effect of hybrid fibres on structural behaviour RC beams and
4) To investigate the hybrid fibres influence on strengthening of RC beams.

III. MATERIALS USED

A. Cement:

Portland Pozzolanic cement (PPC) of fly ash based is used for casting concrete and the specific gravity of cement was found to be 3.05.

B. Fine Aggregate:

The fine aggregate (sand) used was clean dry river sand conforming to IS 383:1970. The sand was sieved to remove all pebbles. The specific gravity was found to be 2.58.

C. Coarse Aggregate:

Hard granite broken stones of 20 mm size were used as coarse aggregate conforming to IS 383: 1970. The specific gravity is 2.64.

D. Steel fibre:

Steel fibres are filaments of wire, deformed and cut to lengths, for reinforcement of concrete, mortar and other

composite materials. It is a cold drawn wire fibre with corrugated and flatted shape. Crimped steel fibre is used in this study of the properties.

E. Polyvinyl Alcohol Fibres:

Polyvinyl alcohol fibres have attracted more attention for reinforcing cementitious materials in the recent years. In this part emphasis is given on polyvinyl alcohol fibres as they were used throughout the experimental program.

F. Super Plasticizer:

Also known as high range water reducers, are chemicals used as admixtures where well-dispersed particle suspension is required. These polymers are used as dispersants to avoid particle aggregation, and to improve the flow characteristics (rheology) of suspensions such as in concrete applications. Polycarboxylate ether super plasticizer (PCE) was used which work differently from sulphonate based super plasticizer by giving cement dispersion by steric stabilization, instead of electronic repulsion that improves workability of concrete.

G. Water:

Potable tap water available in laboratory with pH value of 7.0±1 and confirming to the requirement of IS 456-2000 was used for mixing concrete and curing the specimen as well.

Properties	Steel fibre	Polyvinyl alcohol fibre
Length(mm)	30	15
Diameter(mm)	0.5	0.1
Shape	Crimped	Straight round
Aspect ratio	60	150
Density (g/cm3)	7.8	0.9
Elongation at break	3.2	8.1
Tensile strength (Mpa)	1500	800

Table 1: Properties of fibre

H. Inference:

- The properties of fiber are obtained from the supplier-SSV Fibre industries and supplier, Salem.
- The properties of steel fibre are obtained from the supplier Jeetmull jaychandhall Pvt (Ltd) Chennai.

IV. EXPERIMENTAL PROGRAM

The Mix Proportion for M25 Grade Concrete by Indian Standard Recommended Method of Concrete Mix Design as Per Design Code Is: 10262-2009. (Poly carboxylic ether) super plasticizer is used for high workability and help in uniform dispersion of cement particles and fibre and they can reduce mixing water requirement by up to 29%.

A. Casting of Specimen

Fresh concrete was cast in steel moulds and compacted on a vibrating table. The following specimens were prepared:

1) 150X150X150 mm cubes for compressive strength as per IS 516- 1999
2) 150X300 mm cylinders for split tensile strength as per IS 5816- 1999
3) 100X100X500 mm prism specimens for flexural tests as per IS 516- 1999
4) Polyvinyl alcohol fibre are added to controlled concrete from 0% to 0.5% PVA, the optimum level of PVA fibre in 0. 3%
   1) Steel fibre are added to controlled concrete from 0% to 1% steel fibre, the optimum level of steel fibre in 0. 8%
   2) Hybrid fibre reinforced concrete is casted according to the optimum level of two fibre i.e Steel fibre and Polyvinyl alcohol fibre.

V. TEST RESULTS AND DISCUSSION

Cubes, cylinder and prism specimen were casted, cured and tested on 7th and 28th day as per Indian standard. The values of PVA Fibre and steel fibre are used for casting and their compressive strength, split strength, & flexural strength according to time of curing are tabulated below.

Proportion		Slump value (mm)	
PVA fiber	Steel Fiber	PVA fiber	Steel Fiber
0	0	92	82
0.1	0.5	93	88
0.25	0.75	94	85
0.5	1.00	90	86

Table 2: Proportion & slump

A. Inference:

- It is found that workability of polyvinyl alcohol fibre is good when compared to steel fibre a higher volume fraction of steel fibre.
- Slump value of concrete increases by adding super plasticizer.

Proportion	compressive strength in N/mm^2	
PVA Fibre	After 7 days	After 28 days
0	31.11	35.42
0.1	32.44	36.53
0.25	33.33	46.13
0.5	24.44	31.55

Table 3: Test results of compressive strength for PVA Fibre

B. Inference:

- The compressive strength of concrete is improved by adding PVA fibre.
- Volume fraction of PVA fibre should be minimum, it should not exceed 0.25%.

Proportion	compressive strength in N/mm2	
PVA Fibre	After 7 days	After 28 days
0	31.11	35.42
0.1	32.44	36.53
0.25	33.33	46.13
0.5	24.44	31.55

Table 4: Test results of compressive strength for steel fiber.

C. Inference:

- In various volume fraction of fibre, the maximum compressive strength of concrete achieves at volume fraction of 0.25%.
- 0.5% steel fibre will lower the compressive strength.

Proportion	Split Tensile strength in N/mm^2	
PVA Fibre	After 7 days	After 28 days
0	2.12	3.25

0.1	1.55	2.94
0.25	2.4	3.64
0.5	1.83	2.82

Table 5: Test results of Split Tensile Strength for PVA Fibre

D. Inference:

- The volume fraction of PVA fibre is taken as 0.25% PVA and this value is optimum value.
- 0.5% steel fibre will lower the split tensile strength.

Proportion	Flexural strength in N/mm^2	
Steel Fibre	After 7 days	After 28 days
0	6.38	9.14
0.5	6.12	9.42
0.75	6.78	9.7
1.00	6.5	9.25

Table 6: Tests result of split tensile strength for steel fibre

E. Inference:

- The volume fraction should not exceed 0.75% of steel fibre.
- 1% steel fibre will lower the split tensile strength.

Proportion	Flexural strength in N/mm2	
PVA Fibre	After 7 days	After 28 days
0	6.38	9.14
0.1	6.12	9.32
0.25	6.78	9.81
0.5	6.5	9.5

Table 7: Test results of Flexural Strength for PVA fibre.

F. Inference:

- Flexural strength of prism for PVA fibre, which enhances at 0.25% PVA
- If increasing the proportion PVA Fibre beyond 0.25%, its flexural strength goes on decreasing.

Proportion	Split Tensile strength in N/mm^2	
Steel Fibre	After 7 days	After 28 days
0	2.12	3.25
0.5	2.97	3.46
0.75	3.12	3.8
1.00	3.06	3.75

Table 8: test results of flexural strength for steel fibre

G. Inference:

- Enhancement of flexural strength of concrete by adding fibre compare to controlled concrete.
- The maximum flexural strength at 0.75% SF.
- If increasing the proportion of steel Fibre beyond 0.75%, its flexural strength goes on decreasing.

Hybrid specimen is casted and these type of result is being obtained from it.

- Optimum value of PVA fibre is taken as 0.25% according to above result.
- Optimum value of steel fibre is taken as 0.75% according to above result.
- Concrete Mix Design as Per Design Code Is: 10262-2009. (Poly carboxylic ether) super plasticizer is used for high workability and help in uniform dispersion of cement particles and fibre and they can reduce mixing water requirement by up to 29%.
- Three specimen is casted of M 25, they are

1) 150X150X150 mm cubes for compressive strength as per IS 516- 1999
2) 150X300 mm cylinders for split tensile strength as per IS 5816- 1999
3) 100X100X500 mm prism specimens for flexural tests as per IS 516- 1999.

Proportion		compressive strength in N/mm2	
PVA Fibre	Steel fibre	After 7 days	After 28 days
0.25	0.75	36.35	49.80

Table 9: Test results of compressive strength for PVA Fibre & steel fibre

H. Inference:

- Enhancement of compressive strength of concrete by adding hybrid fibre with their optimum composition compare to controlled concrete.
- The hybrid fiber gives (3–4 %) more strength as compare to individual fibre composition.

Proportion		Split tensile strength in N/mm2	
PVA Fibre	Steel fibre	After 7 days	After 28 days
0.25	0.75	2.83	3.79

Table 10: Test results split tensile strength for PVA Fibre & steel fibre

I. Inference:

- split tensile strength increased by adding hybrid fibre with their optimum composition compare to controlled concrete.
- The hybrid fiber gives (2–3 %) more strength as compare to individual fibre composition.

Proportion		Flexural strength in N/mm2	
PVA Fibre	Steel fibre	After 7 days	After 28 days
0.25	0.75	6.88	9.89

Table No.11: Test results of flexural strength for PVA Fibre & steel fibre

J. Inference:

- flexural strength of concrete is increased with their optimum composition.
- The hybrid fiber gives (1.5–2 %) more strength as compare to individual fibre composition.

VI. ADVANTAGES

1) Greater resistance to crack formation.
2) Increase impact and abrasion resistance.
3) Improves toughness of concrete and less prone to corrosion resistance.
4) Flexural strength is improved up to 30% by decreasing the propagation of crack.

VII. DISADVANTAGES

1) High cost of materials
2) If proper techniques and proportions are not used the fibers may cause a finishing problem, with the fibers coming out of the concrete.

3) Required more precise configuration than plain concrete.

VIII. APPLICATION

1) Pre- cast application
2) Impact resistance structures
3) Highway and airfield pavements
4) Dams and hydraulic structures
5) Manholes, roof tiles, panels
6) Structural application
7) Tunnels
8) Slope stabilization

IX. CONCLUSION

From this Experimental Investigation it is concluded that,

1) Based on the compressive strength, split tensile strength, and flexural strength of cube, cylinder and prism respectively, the optimum level of polyvinyl alcohol fibre content was 0.25% and steel fibre content was 0.75%.
2) In addition of polyvinyl alcohol fiber, the crack formation had been arrested and mechanical and flexural properties of concrete achieve 30% higher than conventional concrete at lower volume fraction of fibre (0.25%).
3) In addition of Steel fiber, a mechanical and flexural property of concrete achieves 33% higher than conventional concrete at higher volume fraction of fibre (0.75%).
4) The hybrid fibre reinforced concrete at the volume fraction of 1% enhances compressive strength by 34%, split tensile strength by 15% and flexural strength by 10% compared to conventional concrete.
5) This type of concrete can be used as industrial ground floor slabs, roads, bridges, piling, shotcrete, tunnels, and dams and so on…
6) The elimination of conventional reinforcement and in some cases the reduction in section thickness can contribute to significant productivity improvement. Steel fibre plays a crucial role in improving the flexural performance of HFRC.
7) PVA fibre makes a complex contribution to the flexural performance of HFRC when the proportion of concrete is optimum value.
8) Both the hybrid ratio and the fibre volume content affect the flexural behaviour of HFRC
9) It provides high load bearing capacity after being cracked too.

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