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An Experimental Investigation on Effect of Hybrid Fiber on High Strength Self Compacting Concrete and Vibrated Concrete

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Abstract: Hybrid Fiber Reinforced Concrete (HFRC) is formed from a combination of different types of fibres, which differ in material properties, remain bonded together when added in concrete and retain their identities and properties. The present experimental investigation focuses on hybrid fibre reinforced concrete (combination of hooked end steel fibre and glass fiber) for Self-Compacting concrete (SCC) and vibrated concrete (VC). This investigation is done for a M60 grade concrete with steel fiber dosage of 0.5% and glass fiber dosage of 0.034% for both SCC and VC. The fresh and hardened properties were studied for both concretes. Pulse velocity test and Rebound hammer tests were conducted to assess the quality of concrete. Test results showed that the addition of suitable fraction volume of glass and steel fiber can enhance the mechanical properties of the SCC and at the same time the flowing and passing abilities still within the accepted limits. Also incorporation of glass fibres had enhanced the ductility of self-compacting concrete. NDT tests revealed inclusion of fibers improve the surface hardness, homogeneity and quality of concrete.

Keywords: *Steel fibers, Glass fibers, Hybrid fibers, self-compacting concrete, Vibrated concrete, fiber reinforcement.*

1. Introduction

As a result of hybridization it has the ability to arrest cracks, increased extensibility and tensile strength, both at first crack and at ultimate, particular under flexural loading; and the fibres are able to hold the matrix together even after extensive cracking. The transformation from a brittle to a ductile type of material would increase substantially the energy absorption characteristics of the fibre composite and its ability to withstand repeatedly applied, shock or impact loading.

Earlier attempts were made to use different kind of fibers in concrete with various dosages, which has given a positive impact on its mechanical properties. By varying the percentage of glass fibers in vibrated concrete, the mechanical properties of concrete were studied by Deshmukh S.H [1]. It is observed that the mechanical properties of vibrated concrete increase with addition of percentage of glass fibers. Chandramouli K [2] have studied the effect of glass fibers on concrete of various grades. Only one amount of fiber content was used. They observed that the inclusion of fibers decreases the workability of fresh concrete and this effect is more pronounced for fibers with higher aspect ratios. The performance of steel fiber reinforced self-compacting concrete as plain self-compacting concrete is studied in depth by S.A. Balachandra [3]. Identification of combination of fibers is done by P.Muthu Priya [4].Mechanical properties of hybrid fiber-reinforced concrete at low fiber volume fraction by S.C.Patodi, Wu Yao [5-6].

2. Research Significance

In the literature review it is noticed that addition of fibers improves strength of concrete. Some of the researches have conducted experiments on concrete combining two fibers and reported that there is improvement in strength of concrete. In the present investigation it is postulated that the combination of glass and steel fiber may also contribute for improvement in strength of concrete. The experimental study aims at obtaining data on the effect of steel, glass fiber and its combination on workability, compressive strength, split tensile strength, flexural strength and Non-Destructive Tests (NDT) such as Rebound Hammer, Ultrasonic Pulse Velocity to evaluate the quality of concrete for SCC in comparison with VC. The present investigation include parametric variation in plain and fiber reinforced concrete, different types of fiber, type of concrete, with constant dosage and grade of concrete.

3. Experimental Investigation

The investigation consists of test results of vibrated concrete and SCC reinforced with steel fibers of aspect ratio 50 of hook end fiber with 0.5% dosage, glass fibers with 0.034% and the combination of steel and glass with same dosages to the volume of concrete is being cast. The grade of concrete considered for the study is M60. So, totally 24 cubes of size 150*150*150 mm, 24 cylinders of size 300 mm height and 150 mm and 24 prisms of size 100*100*500 mm [7]are being cast for 28 days of curing to determine mechanical properties for SCC and VC.

3.1 Materials Used

3.1.1 Cement

Ordinary Portland cement of mortar compressive strength (28 Days of curing) 53MPa, conforming to IS: 12269 – 1987 [8] has been is used in the present investigation. The specific gravity, standard consistency was 3.12 and 32% respectively.

3.1.2 Fine Aggregate

Local river sand conforming to IS: 383 – 1970 [9-10] has been used. The bulk density, specific gravity, and fineness modulus of the sand used were 1.41g/cc, 2.68, and 2.9.

3.1.3 Coarse Aggregate

Crushed granite aggregate of maximum 16 mm size conforming to IS: 383 – 1970 [9-10] has been used. The bulk density, specific gravity and fineness modulus of the coarse aggregate used were 1.46g/cc, 2.78 and 7.1.

3.1.4 Fly ash

Fly ash obtained from Thermal power plant, Ramagundam, India with specific gravity of 2.18 has been used as partial replacement of cement.

3.1.5 Super Plasticizer

Cryso Fluid optima S-815 based on modified polycarboxylate is used. Optimum dosage is confirmed by various trail mixes.

3.1.6 Steel Fibers

Plain galvanized steel fibers of Hook end type from 'Stewols India Private Limited' with aspect ratio 50 (0.6 mm diameter, 30 mm length) were used. Fibers of both aspect ratios have yield strength of 275 MPa.

3.1.7 Glass Fibers

Alkaline resistant (AR) glass fiber of length 6 mm, aspect ratio 428 with an Elastic Modulus of 73 GPa was used in present investigation.

3.1.8 Water

Potable water is used for mixing and curing.

For SCC Mix Design, Nanu-Su method [11] was adopted. For Vibrated concrete mix proportion is done as per IS :10262 – 2009 [12].

The details of quantities of ingredients and mix proportions along with corresponding split tensile strengths and cube compressive strengths are presented in Tables 1.

Table 1: *Quantities of ingredients (kg/m^3)*

Materials Used	VCC	SCC
Cement	450	430
Flyash	150	180
Fine Aggregate	732	847.1
Coarse Aggregate	844.4	782.6
Water	200	194
SP	0.6	5.16

4. Results and Discussions

4.1 Workability

Tests were conducted to verify the flow characteristics of fresh SCC. All the test results like slump flow, V-funnel and J-ring were confirming to EFNARC (European Federation of National Trade Associations) guidelines. The fresh properties of SCC are shown in Table-2 and slump of VC is shown in Table 3.

Table 2: *Fresh properties of Fibrous Self Compacting Concrete*

Test	EFNR AC Limits	Plain SCC	SCC Steel Fiber	SCC Glass Fiber	SCC(SF +GF)
Slump Flow(mm)	550-850	755	675	750	610
T_{500}(sec)	2-5	2.59	2.44	2.09	3.44
J-Ring(mm)	6-10	4	7	5	11
V-Funnel(sec)	6-10	8	11	9	11
V-Funnel at T_{5min}(sec)	6-12	10	11	10	12

Table 3: *Slump Values of Vibrated Concrete*

Designation	VC Plain	VC Steel Fiber	VC Glass Fiber	VC (SF+GF)
Slump (mm)	120	95	110	80

It is observed that workability of concrete is being slightly effected with the addition of fibers. Concrete becomes stiffer with the addition of fibers. Stiffness of concrete is more with steel fibers than with glass fibers. Combination of fibers has a significant effect on the workability of concrete.

4.2 Mechanical Properties

The mechanical tests were conducted as per IS: 516-1959[7].The cured specimens were tested using Tinius Olsen Testing machine of capacity 1810 KN for determining the compressive strength. The results of compressive strength of cubes tested were as shown in Table 4 and Figure 1.

Table 4: *Compressive strength (MPa) of the cube specimens*

Type of Fiber	Compressive Strength(MPa)			
	Plain	Glass Fiber	Steel Fiber	SF+GF
VC	68.56	72.25	73.76	74.75
SCC	69.94	72.51	74.36	75.02

It is observed from the above table that there is an increase in compressive strength with the addition of fibers. The combination of fibers has shown significant increase.

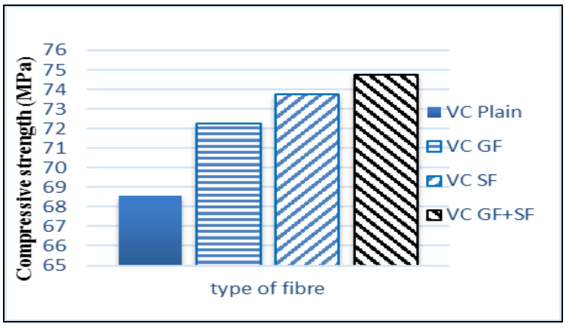

Figure 1(a): *Results of compressive strength of Vibrated Concrete*

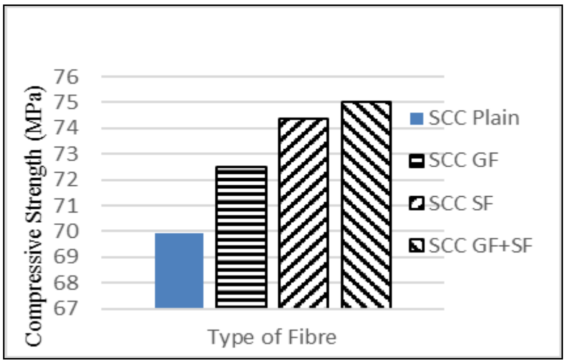

Figure 1(b): *Results of compressive strength of Self Compacting Concrete*

Concrete inherently possess micro cracks even without load and also micro pores, which acts as nucleolus for initiation, propagation and widening cracks, and resulting in failure with increase in load. The very purpose of adding fibers is to arrest the propagation and widening of cracks. The results of Split tensile strength are shown in Table 5, Figure 2 and flexural strength in Table 6.

Table 5: *Split tensile strength (MPa) of the cylindrical specimens*

Type of Fiber	Split Tensile Strength(MPa)			
	Plain	**Glass Fiber**	**Steel Fiber**	**SF+GF**
VC	4.05	4.36	4.55	4.63
SCC	4.24	4.8	5.1	5.22

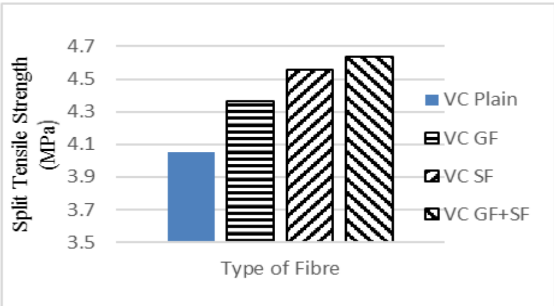

Figure 2(a): *Results of split tensile strength of Vibrated Concrete*

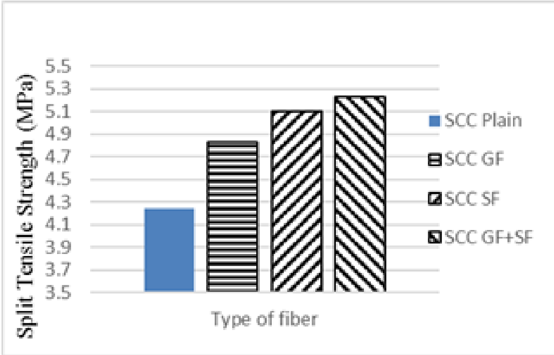

Figure 2(b): *Results of split tensile strength of Self Compacting Concrete*

Table 6: *Flexural strength (MPa) of the Prisms*

Type of Fiber	Flexural Strength			
	Plain	**Glass Fiber**	**Steel Fiber**	**SF+GF**
VC	5.83	6.3	6.58	6.7
SCC	5.89	6.70	7.12	7.30

The flexural test was studied using two point load testing [10]. The effect fibers are more significant in split tensile and flexural strength than in compressive strength. The percentage of increase of these properties in SCC is pronounced than in VC. This effect may be due to flowable nature of SCC which made the fibers to distribute uniformly in concrete leading to more homogeneity and integrity of fibers. Inclusion of fibre has enhanced the ductility nature of both concrete. Addition of hybrid fibres has contributed towards the energy absorbing mechanism (bridging action) whereas; the non-metallic fibres resulted in delaying the formation of cracks. In the volume of concrete, different sizes of cracks will be present at a point of time. As the load is applied, some of the cracks widen. Combined fiber have addressed to arrest and propagate cracks concrete in better than individual steel and glass powder.

5. Non-Destructive Testing

5.1 Rebound Hammer test and Ultrasonic Pulse Velocity (UPV)

Rebound Hammer test is performed on specimens after 28 days of curing to quantify the effect of fibers on surface hardness of concrete.

Table 7: *Rebound Number of all the specimens*

Type of Fiber	Rebound Number			
	Plain	**Glass Fiber**	**Steel Fiber**	**SF+GF**
VC	34	37	37	39
SCC	35	38	40	41

Table 8: *UPV values of all the specimens for 28 days*

Type of Fiber	Ultrasonic Pulse Velocity (km/sec)			
	Plain	**Glass Fiber**	**Steel Fiber**	**SF+GF**

VC	4.16	4.26	4.4	4.44
SCC	4.29	4.35	4.42	4.6

From Table 7 and 8 it is observed that with inclusion of fibers increases the rebound number of concrete compared to plain specimens. The specimens with combination of fibers have more rebound number and more velocity than plain specimens and specimens with single fiber. It shows that the inclusion of fibers enhances the surface hardness and uniformity of concrete. This effect is seen more in SCC than VC may be due to uniform distribution of fibers because flowable property of SCC which increases the homogeneity and integrity of concrete.

6. Conclusions

1) Inclusion of steel and glass fibers in suitable dosages marginally decreases the slump cone values and flow properties of VC and SCC respectively.
2) The compressive strength of both concrete increased marginally with inclusion of fibers.
3) Inclusion of both fibers separately, in both the concretes enhances the split and flexural properties. Combination of fibers in both concretes will also increase the split and flexural properties but the hybrid effect of fibers in SCC is more predominant than VC.
4) It can be observed that the crack density is more in both the concretes when the fibers are added in suitable proportions.
5) The surface hardness of concrete increases with the inclusion of both steel and glass fibers.
6) The homogeneity, integrity and quality of concrete increases with fibres. This effect is more significant in combination of fibers, in turn which is more in SCC than VC.

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