



# STUDY ON THE STRUCTURAL PROPERTIES OF MIXED FIBROUS REINFORCED SELF COMPACTING CONCRETE WITH MINERAL ADMIXTURES

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**Abstract:** For the adoption of any new material or technology, it generally needs proven performance record over traditional materials. Considerable research is carried out in India, towards the technology development so that Self Compacting Concrete (SCC) could soon find a place in the Indian construction industry. In the present work, experimental investigation is carried out on the strength properties of fibrous SCC with triple blending. Fly ash and condensed silica fume (CSF) are both employed as replacement to cement at various percentages to give triple blending. By doing this kind of triple blending it is expected to derive the beneficial properties of both the mineral admixtures. Concrete mixture of grade M40 is designed and tried for the SCC. Steel fibres of different aspect ratios ranging from 10–20 are tried along with polypropylene fibres of 12 mm length. SCC mixtures with various combinations were tested for workability, compressive strength, split tensile strength and flexural strength. Comparisons are made. Based on the experimental investigation carried out in the present work, important and practically useful conclusions are drawn.

**Index Term:** Steel Fibre, Polypropylene fibre, Superplasticizer, Viscosity Modifying Agent, Mineral admixtures.

## I. INTRODUCTION

### A. General

Development of self-compacting concrete (SCC) is a desirable achievement in the construction industry in order to overcome problems associated with cast-in-place concrete. Self-Compacting Concrete (SCC) is an innovative concrete which does not require vibration for placing and compaction and it is able to flow under its own weight completely filling form work and achieving full compaction even in the presence of congested reinforcement. The hardened concrete is dense, homogeneous and has the same engineering properties and durability as traditional vibrated concrete.

Self compacting concrete is cast so that no additional inner or outer vibration is necessary for the compaction. It flows like “honey” and has a very smooth surface level after placing. With regard to its composition, self compacting concrete consists of the same components as conventionally vibrated concrete, which are cement, aggregates and water with the addition of chemical and mineral admixtures in different proportions. Usually, the chemical admixtures used are high range water reducers (super plasticizers) and viscosity-modifying agents, which change the rheological properties of concrete. Mineral admixtures are used as an extra fine material, besides cement and in some cases, they replace cement.

### B. Brief Review

The concept of self-compacting concrete was proposed in 1986 by Professor Hajime Okamura (1997) (3), but the prototype was first developed in 1988 in Japan. Self compacting concrete was developed at that time to improve the durability of concrete structures. Since then, various investigations have been carried out and mainly large construction companies have used SCC in practical structures in Japan.

### C. Objective of the Present Investigation

The present study deals with mixed fibrous self compacting concrete with triple blending. This triple blending includes the replacement of 20% of cement by fly ash and also replacement of 10% of cement by silica fume in every mix. Chemical admixtures like superplasticizer and viscosity modifying agent are also used for better flowability and workability. Workability tests like T50 and V-funnel tests are conducted as per EFNARC



standards to satisfy the SCC requirements. Percentage of fibre reinforcement is varied from 0.05–0.2 (in 5 stages). Aspect ratios of 10, 15 and 20 are adopted for each percentage. The results of compressive strength, split tensile strength and the flexural strength are compared.

## II. EXPERIMENTAL INVESTIGATION

### A. Experimental Programme

The objectives of experimental study are given below:

- Development of SCC mixes with the least amount of cement but with a target compressive strength.
- To use the lowest possible water/powder ratio in the development of the SCC mixes.
- To conduct tests on hardened SCC for strengths.

### B. Materials Used

The following materials are employed in the present investigation.

#### Cement 53 grade

Ordinary Portland cement of 53 grade from the local market was used and tested for physical and chemical properties as per IS: 4013–1988 and found to be confirming to various specifications of are 12269–1987.

#### Fine Aggregate

In the present investigation, fine aggregate is natural river sand which was obtained from local market. The physical properties of fine aggregate like specific gravity, bulk density, gradation and fineness modulus are tested in accordance with IS-2386.

#### Coarse Aggregate

The crushed coarse aggregate of 10 mm maximum size was obtained from the local crushing point. The physical properties of coarse aggregate like specific gravity, bulk density, gradation and fineness modulus are tested in accordance with IS-2386.

#### Fly ash

In the present investigation work, the TYPE-II fly ash was used as cement replacement material. It is obtained from Vijayawada thermal power station in Andhra Pradesh. The specific surface of fly ash is found to be 4750 cm<sup>2</sup>/gm by Blaine's permeability apparatus.

#### Condensed Silica Fume (CSF)

Condensed silica fume was obtained from M/s. V.B. Ferro Alloys Ltd., Rudraram near Hyderabad.

#### Superplasticizer

Superplasticizer (B233 of M/s. BASF INDIA LTD) was employed for the preparations of SCC.

#### Viscosity Modifying Agent (VMA)

The inclusion of VMA ensured the homogeneity and the reduction of the tendency of the highly fluid mix to segregate. Glenium-2 VMA of M/s. BASF India Ltd., is used for this work.

#### Steel Fibres

It has been shown that design recommendations for traditional vibrated steel fibre reinforced concrete (SFRC) can also be used for steel fibre reinforced self compacting concrete (SFRSCC).

#### Polypropylene Fibres

Addition of polypropylene fibres to concrete arrests cracking caused by volume change (expansion and contraction).

#### Water

Potable water which is fit for drinking is used for making concrete.

### C. Concrete Mix Design

Concrete mix of M40 grade was designed as per the guidelines of IS 10262–1909. The basic mix proportions are in table 1.



**Table 1.** Mix proportions for M-40

Cement	Fine Aggregate	Coarse Aggregate	Water/ Cement
1.0	1.3	2.20	0.45

**Mixed Fibres (Steel and Polypropylene)**

Steel fibres at 0.05, 0.10, 0.15 and 0.2 percentages with various aspect ratios from 0, 10, 15 and 20 were tried in the investigation. Polypropylene fibres of constant aspect ratio were tried at percentages of 0, 0.05, 0.10, 0.15 and 0.2 to obtain the mixed fibre. Details of the materials used are given in table 2.

**Table 2:** The final mix details for triple blended self compacting concrete

Cement	Fine Aggregate	Coarse Aggregate	W/c ratio	Mineral admixture		Optimum SP	Optimum VMA	Remarks
				Fly ash	CSF			
1.0	1.3	2.20	0.45	20.0	10.0	0.9	0.15	The percentage of mineral and chemical admixtures were arrived after several trials

**Table 3:**

Sl. No.	L.No.	% of Fibre	Aspect Ratio	T50 time	V-funnel	Remarks
1	V1	0.2	10	3	8	The workability results satisfy the EFNARC specifications
2	V2	0.15	10	4	8	
3	V3	0.1	10	3	9	
4	V4	0.05	10	4	10	
5	V5	0	10	3	10	
6	V6	0.2	20	3	13	
7	V7	0.15	20	4	12	
8	V8	0.1	20	3	12	
9	V9	0.05	20	4	13	
10	V10	0	20	4	14	
11	V11	0.2	15	4	10	
12	V12	0.15	15	5	12	
13	V13	0.1	15	3	10	
14	V14	0.05	15	3	11	
15	V15	0	15	3	11	
16	V00	0	0	2	7	

**D. Workability Tests**

Standard tests for S.C.C. like slump flow, V-funnel, U-box were conducted for the various combinations of triple blended fibrous SCC and the requirements as per EFNARC specifications are met. The results of workability tests are shown in table 3.

**E. Casting, Curing and Testing of Specimens**

Altogether 16 combinations of triple blended fibrous SCC including the reference mix were tried in the investigation. Required number of specimens of cubes, cylinders and prisms were cast, cured and tested at the age of 28 days. Standard procedures were followed in mixing with fibres, casting the specimens, curing and testing of the triple blended mixed fibre self compacting concrete specimens. The results are shown in table 5. Typical variations of flexural strength with mixed fibre (steel and polypropylene) are shown in figs. (1) to (3).



### III. DISCUSSION OF THE RESULTS

The results of the experimental investigation are discussed herein. All the strength results for various combinations tried are shown in table 4.

Sl. No.	I. No.	Fly ash percentage	CSF percentage	Super plasticizer Percentage	VMA percentage	Percentage of steel fibre	Aspect ratio	Percentage of Polypropylene fibre	Average compressive strength	Average Split tensile strength	Average Flexural strength	Remarks
		%	%	%	%	%		%	N/mm <sup>2</sup>	N/mm <sup>2</sup>	N/mm <sup>2</sup>	
1	V1	20	10	0.85	0.15	0.20	10	0.00	44.15	4.54	6.60	Reference Mix
2	V2	20	10	0.85	0.15	0.15	10	0.04	42.46	4.31	6.00	
3	V3	20	10	0.85	0.15	0.10	10	0.10	41.33	4.22	5.40	
4	V4	20	10	0.85	0.15	0.05	10	0.15	40.58	4.10	4.80	
5	V5	20	10	0.85	0.15	0.00	10	0.20	39.50	3.90	4.40	
6	V6	20	10	0.85	0.15	0.20	20	0.00	39.30	5.00	8.00	
7	V7	20	10	0.85	0.15	0.15	20	0.05	39.05	4.83	6.80	
8	V8	20	10	0.85	0.15	0.10	20	0.10	38.60	4.39	6.40	
9	V9	20	10	0.85	0.15	0.05	20	0.15	38.10	4.31	6.00	
10	V10	20	10	0.85	0.15	0.00	20	0.20	38.00	3.90	5.80	
11	V11	20	10	0.85	0.15	0.20	15	0.00	44.45	4.79	6.40	
12	V12	20	10	0.85	0.15	0.15	15	0.05	43.65	4.70	6.00	
13	V13	20	10	0.85	0.15	0.10	15	0.10	42.00	4.55	5.50	
14	V14	20	10	0.85	0.15	0.05	15	0.15	41.15	4.34	5.00	
15	V15	20	10	0.85	0.15	0.00	-	0.20	39.25	4.28	4.80	
16	V16	20	10	0.85	0.15	0.00	-	0.00	42.10	3.50	4.50	

#### A. Workability Results

For the fibre reinforced triple blended self compacting concrete, the slump flow times (50 cm diameter) results are between 2–5 seconds. Similarly the V-funnel timings are between 8–15 seconds. The measured timings satisfy the EFNARC specifications for SCC mixes. It is observed that the timings are higher for higher aspect ratios of the fibre used. In the experimental investigations M-40 mix is designed and used. Superplasticizer used in percentages varying from 0.85 to 0.95 is giving the required workability. The viscosity modifying agent used in the investigation was maintained constant at 0.15%.

This shows that the optimum percentage of super plasticizer is between 0.8 percent to 1 percent and that of VMA is 0.15 percent. With these percentages, mixed fibre reinforced SCC satisfying the specifications can be produced.

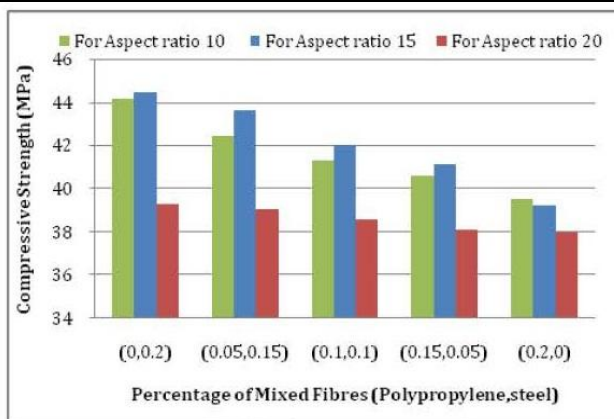


Fig. 1 Variation of compressive strength with fiber percentage for various aspect ratios

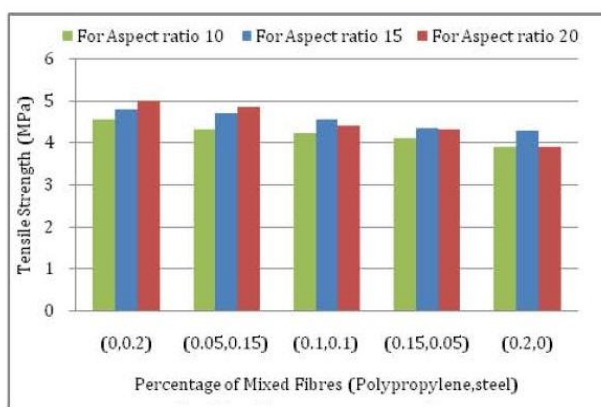


Fig. 2 Variation of split tensile strength with fiber percentage for various aspect ratios

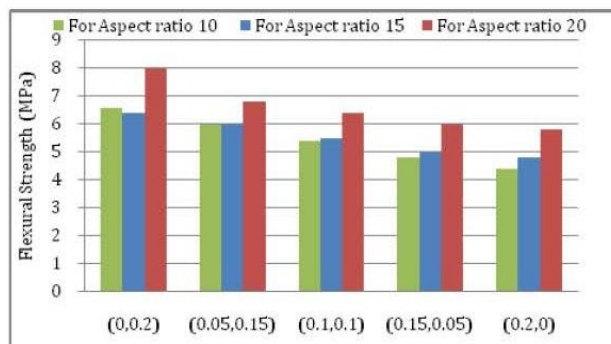


Fig. 3 Variation of Flexural strength with fiber percentage for various aspect ratios

**B. Compressive Strength Results**

The compressive strength of the reference concrete without blending and without fibres is 42.11 N/mm<sup>2</sup>, which satisfies the design requirements. The concrete mix with triple blending (fly ash-20%, CSF-10%) is showing higher strength than the reference mix. The admixture like CSF contributes towards additional strength in addition to giving beneficial properties. It can be seen from table. 4 there is an increase in the compressive strength with increase of aspect ratio initially but then finally decreases even after the increase of the aspect ratio. Hence, upto a certain aspect ratio it is clear that steel fibres contribute towards strength increase.

Beyond an aspect ratio of 20–25 it can be understood that flow of SCC is affected and it may not satisfy EFNARC specifications and practical applications become difficult. Hence, the optimum aspect ratio is taken as 15 for good quality SCC of M-40 grade. As the percentage of steel fibres is increased, the compressive strength increases. But the increase in the polypropylene fibre percentage decreases the compressive strength. The



compressive strength of triple blended self compacting concrete at 28 days is higher by nearly 5% compared to the reference mix concrete. The strengths are further increased with use of steel fibres. The highest compressive strength was obtained at 0.2 percent steel fibre and an aspect ratio of 15.

### C. Split Tensile Strength

Compared to the reference mix (table 4), the split tensile strength has increased by around 10 percent in the case of M-40 grade triple blended concrete. Compared to the triple blended mix without fibre there is nearly 20 percent increase in the tensile strength for M-40 mix with fibre.

### D. Flexural Strength Results

The flexural strength of reference concrete mix (table 4) without blending and without fibres is 4.5 N/mm<sup>2</sup> which satisfies the design requirements. The concrete mix with triple blending (Fly ash 20% & CSF 10%) is showing higher strength than the reference mix.

### E. Influence of Mineral admixtures

In the present experimental investigation flyash at 20% and CSF 10% were used as replacement to OPC in the preparation of triple blended SCC. Flyash improves the flow properties of SCC. The flyash does not contribute towards strength increase, CSF when used at a small percentage of 10% contributes towards strength increases both the mineral admixtures contributes to several other beneficial properties also. Hence an optimum and economical triple blended SCC can be produced by employing flyash and CSF at appropriate dosages.

### F. Influence of Fibre Percentage and Aspect Ratio on Strength

As discussed earlier, it can be seen that as the fibre percentage is increased, the respective strengths are increasing. The strength increase is more in the case of split tensile strength and the flexural strength. In the case of self compacting concrete, higher percentages of steel fibre interferes with the flowability of SCC. Hence, the percentage of fibre is restricted at 0.20. Upto this optimum percentage, the strengths increase. With an aspect ratio of 15 for steel fibres, optimum compressive and split tensile strengths are obtained. But in the case of flexural strength, an aspect ratio of 20 has given the optimum value.

### G. Cracking and Ductility Characteristics

During the flexure test an SCC beam specimens, it was observed that the crack formation was gradual and the failure was smoother. The specimens exhibited more ductility. It shows that the addition of fibres to SCC has improved the cracking and ductility behaviour.

### H. Use of Mixed Fibres

Steel fibres contribute towards strength increase particularly in tension and flexure. Through the cracking behaviour is improved in general, addition of polypropylene fibres has contributed towards arresting micro cracks. This is the purpose of using dual fibres in the present investigation.

## IV. CONCLUSIONS

Based on the experimental investigation work conducted, the following conclusions are drawn.

1. The optimum percentage of super plasticizers is between 0.8 and 1 and the VMA is 0.1 to 0.15 respectively. With these percentages mixed fibre reinforced self compacting concrete upto M40 grade satisfying workability requirements. (as per EFNARC can be produced).
2. The concrete mix with triple blending (fly ash 20% and silica fume 10%) shows higher strength than the reference mix. In addition to assisting the flow of concrete.
3. The highest compressive strength was obtained with 0.2% steel fibre and an aspect ratio of 15 with triple blending. The comparative strength has increased by nearly 20% over that of the reference mix of M-40.
4. Similarly there are substantial increases in split tensile and flexural strengths also. Upto a certain optimum percentage and optimum aspect ratio, steel fibres contribute towards increase in the strengths.
5. Even in the case of SCC, addition of steel fibres improves the flexural strength as well as the deflection capacity.
6. In case of fibre reinforced SCC, cracking behaviour is gradual and it is more ductile by addition of polypropylene fibres. Micro cracks are minimised.
7. For practical modern concrete construction where SCC is employed, triple blending of cement using mineral admixtures is very much desirable.



8. In practical SCC constructions, use of fibres in concrete matrix helps in increasing the tensile, flexure, impact strength besides controlling the micro cracks and it is ideally suited for the construction of rigid pavement .

#### **ACKNOWLEDGEMENTS**

The authors gratefully acknowledge the authorities of Vasavi College of Engineering for the facilities and help extended during the research work carried out for the present investigation.

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