EFFECT OF MIXED FIBERS (Steel and Polypropylene) ON STRENGTH PROPERTIES OF FIBROUS SELF COMPACTING CONCRETE

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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.*

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

1. INTRODUCTION

1.1 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.

1.2 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.

1.3 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.

2. EXPERIMENTAL INVESTIGATION

2.1 Objectives of investigation

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.

2.2 Materials used

The following materials are employed in the present investigation.

2.2.1 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.

2.2.2 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.

2.2.3 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.

2.2.4 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^2/gm by Blaine's permeability apparatus.

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

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

2.2.7 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.

2.2.8 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).

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

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

2.3 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

2.4 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.

2.5 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.

2.6 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 4.

3. 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 and they are also illustrated by bar charts in fig 1 to 3.

3.1 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. It can be said that superplasticizer was used in percentages varying from 0.85 to 0.95. The viscosity modifying agent used in the investigation was maintained constant at 0.15%. The observations are shown in table. 3. 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 can be produced.

3.2 Compressive Strength Results

The compressive strength of the reference concrete without blending and without fibres is 42.11 N/mm^2, 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.

3.3 Split Tensile Strength

The admixture like condensed silica fume contributes towards additional strength in addition to giving beneficial properties. It can be seen from table. 4 that there is an increase in the tensile strength with increase of aspect ratio initially but then finally decreases even after the increase of the aspect ratio. Hence, up to a certain aspect ratio it is clear that steel fibres contribute towards increase in strength.
Compared to the reference mix, 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.

3.4 Flexural Strength Results

The flexural strength of reference concrete mix without blending and without fibres is 4.5 N/mm^2 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 mineral admixtures like CSF contribute towards increase in the strength in addition to giving additional beneficial properties. Beyond an aspect ratio of 15 it can be understood that the flow of self compacting concrete will be adversely affected and it may not satisfy EFNARC specifications. 0.2 percent steel fibre with an aspect ratio of 20 has given optimum flexural strength.

3.5 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.

3.6 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.

3.7 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 sting micro cracks. This is the purpose of using dual fibres in the present investigation.

Table 2. The Final Mix Details for Triple Blended Self Compacting Concrete

Cement	Fine Aggregate	Coarse Aggregate	Water / Cement Ratio	Mineral Admixtures percentages		Optimum S.P.	Optimum VMA
				Fly ash	CSF		
1.0	1.3	2.20	0.45	20.0	10.0	0.9	0.15

Table 3. Workability Tests on Mixes of M40 Grade Triple Blended Mixed Fibre Reinforced SCC

Sl. No.	I. No.	% of Fibre	Aspect Ratio	T50 time	V-funnel
1	V1	0.2	10	3	8
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

Note: The percentages of mineral admixtures and chemical admixtures were arrived after several trials. The workability results satisfy the EFNARC specifications

Table 4. 28d Strength Results of Compressive, Split Tension and Flexure (M40 Reference Mix)

Sl. No.	I. No.	% of steel fibre	Aspect ratio	% of Polypropylene fibre	Average compressive strength	Average Split tensile strength	Average Flexural strength
		%		%	N/mm²	N/mm²	N/mm²
1	V_1	0.20	10	0.00	44.15	4.54	6.60
2	V_2	0.15	10	0.04	42.46	4.31	6.00
3	V_3	0.10	10	0.10	41.33	4.22	5.40
4	V_4	0.05	10	0.15	40.58	4.10	4.80
5	V_5	0.00	10	0.20	39.50	3.90	4.40
6	V_6	0.20	20	0.00	39.30	5.00	8.00
7	V_7	0.15	20	0.05	39.05	4.83	6.80
8	V_8	0.10	20	0.10	38.60	4.39	6.40
9	V_9	0.05	20	0.15	38.10	4.31	6.00
10	V_{10}	0.00	20	0.20	38.00	3.90	5.80
11	V_{11}	0.20	15	0.00	44.45	4.79	6.40
12	V_{12}	0.15	15	0.05	43.65	4.70	6.00
13	V_{13}	0.10	15	0.10	42.00	4.55	5.50
14	V_{14}	0.05	15	0.15	41.15	4.34	5.00
15	V_{15}	0.00	15	0.20	39.25	4.28	4.80
16	V_{16}	0.00	15	0.00	42.10	3.50	4.50

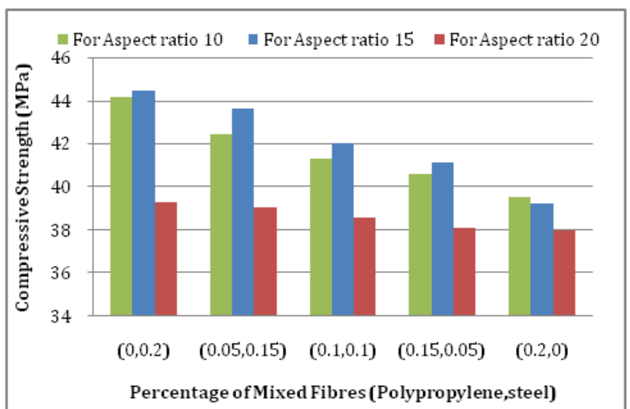

Fig 1: Variations of Compressive strength (MPa) for various percentages of mixed fibres and aspect ratioes of steel fibres(aspect ratio of polypropylene is constant)

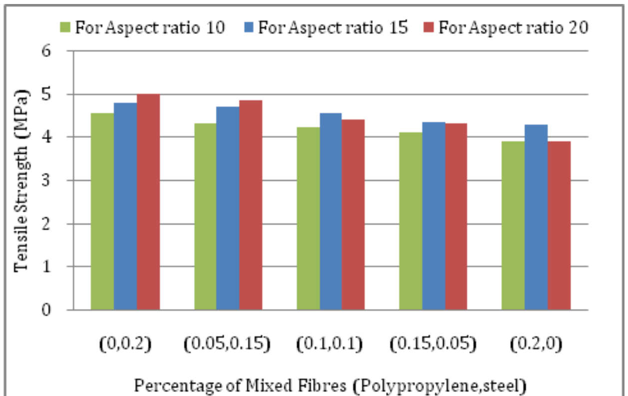

Fig 2:Variations of Tensile strength (MPa) for various percentages of mixed fibres and aspect ratioes of steel fibres(aspect ratio of polypropylene is constant)

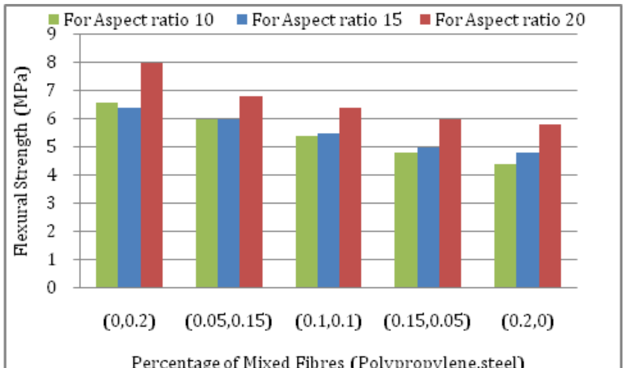

Fig 3:Variations of Flexural strength (MPa) for various percentages of mixed fibres and aspect ratioes of steel fibres(aspect ratio of polypropylene is constant)

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 the requirements can be produced.
2. The concrete mix with triple blending (fly ash 20% and silica fume 10%) shows higher strength than the reference mix.
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 concretes.

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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