© 2018 IJSRST | Volume 4 | Issue 5 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X
Themed Section: Science and Technology

Fiber Reinforced Self Compacting Concrete Admixtured with Fly Ash and Silica Fume

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ABSTRACT

SCC is generally defined as the "concrete that does not need compaction". It means SCC gets compacted without external efforts like vibration, floating, or poking. The mix therefore is required to have the ability of flowing, filling voids and being stable. The present experimental investigation deals with 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 mixtures of two grades M25 and M30 are designed and tried for the SCC. Steel fibres of different aspect ratios ranging from 15-25 are tried in the present investigation. 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 project, important and practically useful conclusions are drawn.

Keywords: Triple Blending, Self Compacting, Superplasticiser, VMA, Flowability.

I. INTRODUCTION

Preparation of Self Compacting Concrete

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. 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. 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. In this study, the cement content was partially replaced with mineral admixtures, like fly ash and silica fume. Admixtures improve the flowing and strengthening characteristics of the concrete.

Development of Self-Compacting Concrete for Modern Concrete Construction

Due to a gradual reduction in the number of skilled workers in Japan's construction industry, a similar reduction in the quality of construction work took place. As a result of this fact, one solution for the achievement of durable concrete structures independent of the quality of construction work was the employment of Self-compacting concrete, which could be compacted into every corner of a formwork, purely by means of its own weight.

Advantages of Self-Compacting Concrete

Self-compacting concrete (SCC) can be classified as an advanced construction material. The SCC as the name suggests, does not require to be vibrated to achieve full compaction. This offers many benefits and advantages over conventional concrete like Reduction in site manpower, Better surface finishes, Easier placing, Higher strength, Lower overall costs etc.

Applications of Self-Compacting Concrete

Applications of self-compacting concrete is summarized as Bridges (anchorage, arch, beam, tower, pier, joint between beam & girder), Box culvert, Buildings, Concrete filled steel columns, Tunnels (lining, immersed tunnel. Fill of survey tunnel), Dams (concrete around structure), Concrete products (block, culvert, wall, water tank, slab and segment), Diaphragm walls, Tanks (side wall, joint between side wall and slab).

Brief Review of Pioneering Work

Narayanan, R (6) studied the workability characteristics of steel fibres reinforced concrete (SFRC) and concluded that workability is decreased with increase in fibre reinforcement. Okamura and Ouchi [(8)] have developed new type of concrete, which can be compacted into every corner of a formwork purely by means of its own weight, was proposed by Okamura et al[(8)] in 1986. Ozawa[(10)] (1989) completed the first prototype of self-compacting concrete using materials already available in the market. By using different types of super plasticizers, he studied the workability of concrete and developed a concrete, which was very workable.

EFNARC-Proposals for Mix Composition

In designing the mix it is most useful to consider the relative proportions of the key components by Volume rather than by mass. The requirements are;

- ✓ Water/powder ratio by volume of 0.80 to 1.10
- ✓ Total powder content - 160 to 240 litres (400-600 kg) per cubic meter.
- ✓ Coarse aggregate content normally 28 to 35 per cent by volume of the mix.
- ✓ Water/cement ratio is selected based on requirements in EN 206. Typically water content does not exceed 210 litre/m3.
- ✓ The sand content balances the volume of the other constituents.

Details of the Present Investigation

The present study deals with fibrous self-compacting concrete with triple blending. This triple blending includes the replacement of 15% 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.

Strength properties of fibre reinforced self compacting concrete admixtured with fly ash and CSF are studied.

II. EXPERIMENTAL INVESTIGATION

The objectives of the present experimental study that was conducted are given below:

I. To design and try two basic concrete mixes of M-25 and M-30 grades.
II. Development of SCC mixes with the least amount of cement but with a target compressive strength
III. To use the lowest possible water/powder ratio in the development of the SCC mixes.
IV. To use triple blended cement by employing two mineral admixtures.
V. To use steel fibres at different percentages and different aspect ratios to produce fibrous triple blended SCC.

Materials Used

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 IS 10269-1987.

Fine Aggregate

In the present investigation, fine aggregate is natural river sand 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 10mm maximum size is obtained from the local crushing point. The physical properties like specific gravity, bulk density, gradation and fineness modulus were tested in accordance with IS-2386.

Fly Ash

In the present investigation work, the TYPE-II fly ash used as cement replacement material was obtained from Ramagundam Thermal Power Station in Andhra Pradesh. The specific surface of fly ash is found to be 4750cm^2/gm by Blaine's permeability apparatus.

Viscosity Modifying Agent (VMA)

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

Superplasticizer

Superplasticizer B233of M/S. BASF India Ltd., was employed in the present investigation.

Steel Fibres

Mild steel fibres of 0.9mm diameter with three aspect ratios were employed.

Water

Potable water is used for mixing and curing.

Designed Concrete Mix Proportions for M-25 and M-30 Grades

Concrete mixes of M-25 and M-30 grades are designed as per IS: 10262-2009. In the present experimental investigation mineral admixtures of fly ash and CSF are empl oyed at 15% and 10% respectively as replacements to OPC towards triple blending.

Wrkability and Test Methods for SCC

The following tests were conducted on the fibrous triple blended SCC mixes for workability.

1. Slump flow: The slump flow is used to assess the horizontal free and the filling ability of SCC in the absence of obstructions. It is recommended to maintain slump flow value as 650 to 800mm.
2. V-funnel: This test is used along with slump flow test to assess the flowability of SCC.

The Above Tests were Conducted as Per Efnarc Specifications and the Results are Found to be Satisfactory.

Testing for Compression, Split Tension and Flexure

Required number of cube, cylinder and prism specimens were cast for various combinations of S.C.C., cured for 28 days and tested for compressive strength, split tensile strength and flexural strength. Casting, curing and testing were carried out as per standard specifications. The strength results are given in table.2.

III. DISCUSSION OF THE RESULTS

The strength results are given in table.2. The load-deflection plots are given in figs. 1 and 2.

Workability Results

For the fibre reinforced triple blended SCC, the results of workability tests are shown in table.1. For the various mixes considered both for M-25 and M-30 mixes, the slump flow times (50cms diameter) results are between 2 to 5 seconds. Similarly the V-Funnel timings are in between 8 to 12 seconds. The measured timings satisfy the EFNARC specifications for SCC mixes. It is generally observed that the timings are on the higher side for higher percentages of steel fibre and higher aspect ratios.

This shows that the optimum percentage of super plasticizers is between 0.8 and 1.2 and the VMA is 0.1 respectively. With these percentages, fibre reinforced triple blended self compacting concrete satisfying the requirements can be produced.

Compressive Strength

The compressive strength results are shown in the table.2 for both M-25 and M-30 mixes. The concrete mix with triple blending (Fly ash 15% & 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. It can be seen from table.2, that the compressive strength of SCC of M-25 and M-30 grades is increasing with increase in fibre percentage. There is increase in the compressive strength with aspect ratio also but in the present investigation the maximum percentage of fibre is kept at 1 and the maximum aspect ratio was 25. Hence, it is clear that upto certain optimum percentage and optimum aspect ratio, steel fibres contribute towards strength increase. Beyond 1% fibre percent and beyond an aspect ratio of 25, it can be understood that the flow of SCC will be adversely affected and it may not satisfy EFNARC specifications. Practical applications become difficult. Hence, the optimum values may be taken as fibre percent 1% and aspect ratio of 25.

Split Tensile Strength

It can be seen from table.2 the tensile strength of SCC of M-25 and M-30 grades is increasing with increase in fibre percentage. There is increase in the tensile strength with aspect ratio also. But in the present investigation the maximum percentage of fibre is kept at 1 and the maximum aspect ratio is 25. Hence, it is clear that upto certain optimum percentage and optimum aspect ratio, steel fibre contributes towards strength increase.

Flexural Strength

The flexural strength results are shown in the table.2. It can be seen that the flexural strength of SCC of M-25 and M-30 grades is increasing with increase in fibre percentage. There is increase in the flexural strength with aspect ratio also but in the present investigation the maximum percentage of fibre is kept at 1 and the maximum aspect ratio was 25. Hence, it is clear that upto certain optimum percentage and optimum aspect ratio, steel fibre contribute towards strength increase.

Load Deflection Characteristics

The load deflection characteristics are plotted and shown in figs. 1 and 2 for typical percentages. It can be seen that there is a smooth increase of deflection with the increase in the total load and the behaviour is ductile. The specimens have failed after reaching the ultimate load and only a few readings could be taken after failure. The ultimate load is observed to be more with increase in fibre percentage as well as increase in aspect ratio.

The highest ultimate load recorded for the fibre percent of 1 and aspect ratio of 25 is 12.8 kN. Maximum deflection reached corresponding to ultimate load is 18mm for 1% fibre and aspect ratio of 25.

Cracking Characteristics

In the case of plane SCC specimens, the specimens crack and fail simultaneously. In the case of fibre reinforced SCC, the specimens have undergone gradual and ductile failure. Fibres have helped SCC to possess better cracking behaviour and made it more ductile.

Table 1. Workability results for fibrous, triple blended SCC with basic concrete mixes of M-25 and M-30

S.No.	% of Fiber	Aspect Ratio	T50 time (sec)	V-funnel (Sec)	T50 time (sec)	V-funnel (Sec)	Remarks
1	-	-	3	8	3	7	The workability results satisfy the EFNARC specifications. Min. values are 2 & 6 seconds respectively.
2	-	-	4	8	4	8	
3	0.50	15	3	9	4	9	
4	0.75	15	4	10	4	9	
5	1.00	15	3	10	4	10	
6	0.50	20	3	10	3	10	
7	0.75	20	4	11	3	11	
8	1.00	20	4	12	4	12	
9	0.50	25	5	12	4	12	
10	0.75	25	5	12	5	12	
11	1.00	25	5	12	5	12	

Table 5. Strength Results of Fibrous Triple Blended SCC with Different Combinations

Sl. No.	Compressive Strength		Split Tensile Strength		Flexure Strength	
	M-25	M-30	M-25	M-30	M-25	M-30
1	27.20	31.20	2.46	2.60	3.65	4.40
2	28.80	33.30	2.75	2.79	3.84	4.47
3	32.50	34.40	2.80	2.82	3.95	4.52
4	33.90	35.20	2.84	2.85	4.05	4.65
5	35.10	36.00	2.90	2.92	4.20	4.70
6	35.75	37.14	2.95	2.98	4.30	4.25
7	36.20	38.50	2.99	3.10	4.50	4.85
8	37.30	40.60	3.00	3.21	4.65	5.00
9	37.60	41.20	3.12	3.31	4.75	5.15
10	37.90	42.32	3.15	3.42	4.88	5.22
11	39.20	43.50	3.30	3.50	5.12	5.36

Use of Triple Blending

Triple blending of cement using mineral admixtures like fly ash and silica fume, renders the concrete mix to flow smoothly and contributes towards strength increase. Besides use of mineral admixtures in certain proportions in concrete matrix, improves the durability property.

In the case of high strength concrete mixes and high performance concrete, triple blending really helps in strength gaining and durability. Hence, for practical modern concrete constructions where SCC is employed, triple blending of cement using mineral admixtures in SCC is very much desirable.

Use of Fibres

In the present investigation, steel fibres have been employed to develop fibre reinforced triple blended SCC. As it is self compacting mix where the flow of concrete is important, the percentage of steel fibre and aspect ratios are restricted. However, the introduction of the steel fibres has improved the strength properties, flexural behaviour, cracking characteristics and ductility. Hence, it may be stated that in practical SCC construction, use of fibre in concrete matrix helps to increase the tensile and flexural strengths, impact strength besides controlling the micro cracks.

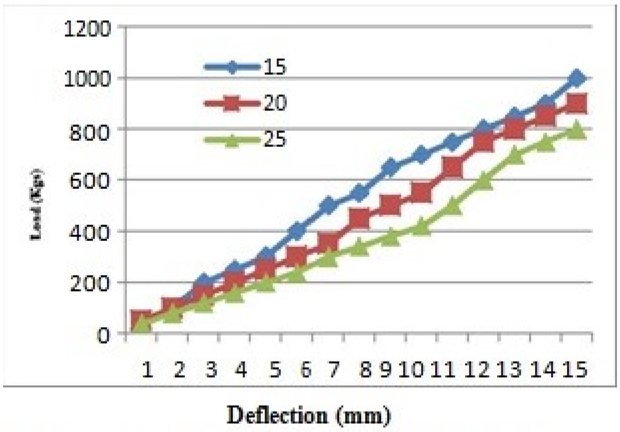

Fig. 1: Load-Deflection Relationship of M25 for a Typical Fiber Percentage of 0.50 for Different Aspect Ratio

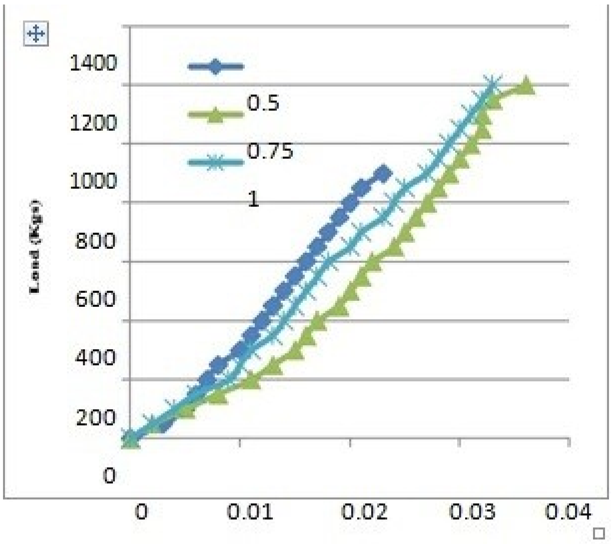

Fig. 2: Load-Deflection Reltionship of M30 for a Typical Fibre Percentage of 1.0 for Different Aspect Ratio

IV. CONCLUSIONS

1. The optimum percentage of super plasticizers is between 0.8 and 1.2 and the VMA is 0.1 respectively. With these percentages, fibre reinforced self compacting concrete satisfying the requirements can be produced with basic concrete mixes of M-25 and M-30.
2. The concrete mix with triple blending (fly ash 15% and silica fume 10%) shows higher strength (compressive, split tensile and flexure) than the reference mix.
3. Upto a certain optimum percentage and optimum aspect ratio, steel fibres contribute towards increase in the strengths.
4. Beyond 1% fibre percent and beyond an aspect ratio of 25, the flow of SCC will be adversely affected.
5. Even in the case of SCC, addition of steel fibres improve the flexural strength as well as the deflection capacity besides improving the cracking behaviour.
6. For practical modern concrete constructions where SCC is employed, triple blending of cement using mineral admixtures with fibres is very much desirable.
7. It is concluded that by employing mineral admixtures economical and environmental friendly concrete mixed can be produced with several other beneficial properties. By employing steel fibre without affecting the flow ability, the tensile and flexural strengths are considerably increased. On the overall admixtures, fibre reinforced self compacting concrete possesses optimum properties all round.

V. ACKNOWLEDGEMENTS

The authors sincerely thank the authorities of Vasavi College of Engineering, Hyderabad, for extending the laboratory facilities in conducting the present experimental investigation.

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