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Experimental Study of Strength and Elastic Properties of Fibrous Self-Compacting Concrete

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ABSTRACT

Self-compacting concrete (SCC) speaks to a standout amongst the most extraordinary improvements in solid innovation since 1980s. At first created in Japan in the late 1980s, SCC in the mean time is spread everywhere throughout the world with a consistently expanding and shifted number of uses. Because of its particular improved properties, SCC may add to a noteworthy advancement of the nature of concrete structures and open up new fields for the use of cement.

Self-Compacting Concrete gets compacted and thick because of its self-weight. An exploratory research has been completed to decide diverse characters like quality and workability of Self-Compacting Concrete (SCC). Tests including different fiber extents for a specific blend of SCC were completed. Test techniques used to examine the properties of crisp cement were slump test, L-Box, U-Tube and V-Funnel. The properties like flexure, compressive and elasticity of SCC were additionally examined. Test outcomes demonstrate that the workability attributes of SCC are inside the restricting imperatives of SCC. The variety of various parameters of solidified cement (M30 and M40) concerning different level of steel fiber substance were analysed.

INTRODUCTION

GENERAL

Advancement of self-compacting concrete (SCC) is an alluring accomplishment in the construction industry so as to defeat issues related with cast set up concrete. Self-compacting concrete (SCC) is a creative concrete which does not require vibration for setting and compaction. The hardened cement is thick, homogeneous and has an indistinguishable building properties and durability from traditional vibrated concrete.

Self-compacting concrete is not affected by the skills of workers, the shape and amount of reinforcing bars or the arrangement of a structure and, due to its high-fluidity and resistance to segregation it can be pumped huge distances. The concept of self-compacting concrete was proposed in 1987 by Professor HajiHmeOkamudra, but the prototype was first developed in 1985 in Japan, by Professor Ozawsa at the University of Tokfyo. 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. Investigations for establishing a rational mix-design method and self-compatibility testing methods have been carried out from the view point of making it as standard concrete. Self-compacting concrete is cast so that no additional inner or outer vibration is necessary for the compaction.

It streams like "nectar" and has an extremely smooth surface level in the wake of setting. Concerning its structure, self-compacting concrete comprises of an indistinguishable segments from ordinarily vibrated solid, which are concrete, totals, and water, with the expansion of compound and mineral admixtures in various extents. Typically, the substance admixtures utilized are high-go water reducers (super plasticizers) and thickness altering operators, which change the rheological properties of cement. Mineral admixtures are utilized as an additional fine material, other than concrete, and at times, they supplant bond. In this examination, the concrete substance was incompletely supplanted with mineral admixture, e.g. flyash and silica fume, admixture that enhance the streaming and fortifying strength of the concrete.

PAST DEVELOPMENT OF SELF COMPACTING CONCRETE

Self-compacting concrete, in important, is not new. Uncommon applications, for example, submerged cementing have constantly required solid, which could be set without the requirement for compaction. In such conditions vibration was essentially outlandish. Early self-compacting concrete depended on high substance of bond glue and, once super plasticizers ended up noticeably accessible, they were included the solid blends. The blends required specific and particularly controlled submitting methodologies in demand to keep up a vital separation from seclusion, and the high substance of bond stick made them slanted to shrinkage. The general costs were high and applications remained uncommonly confined.

The introduction of "modern" self-leveling concrete or self-compacting concrete (SCC)is associated with the drive towards better quality concrete pursued in Japan around 1983, where the lack of uniform and complete compaction and been identified as the primary factor responsible for poor performance of concrete structures.

NECESSITY FOR DEVELOPMENT OF SELF-COMPACTING CONCRETE

Because of this reality, one answer for the accomplishment of sturdy solid structures autonomous of the nature of development work was simply the business compacting solid, which could be compacted into each edge of a formwork, absolutely by methods for its own weight. Concentrates to create Self-compacting concrete, including a crucial report on the workability of cement, were completed by scientists Ozawa and Maekawa at the University of Tokyo.

SPECIFICATIONS FOR S.C.C

Recommended specifications for SCC are the following:

Workability

A good SCC should regularly achieve a droop stream esteem surpassing 60 cm without isolation.

- If required, SCC might remain stream capable and self-compacting for no less than a hour and a half.
- If required, SCC should have the capacity to withstand an incline of 3% in the event of free flat surface.
- If required, SCC should be pumpable for atleasta hour and a half and through channels with a length of atleast 100m.

Mechanical Characteristics

- Characteristics compressive quality at 28 days might be 25-60 Mpa.
- Early age compressive quality for lodging concrete might be 5-20 Mpa at 12-15 hours (identical age at 20°C).

CONSTRUCTION ISSUES

Since the improvement of the model of the self-compacting concrete in 1998, the utilization of self-compacting concrete in genuine structures. The fundamental purpose behind the work of self-compacting cement can be abridged as takes after:

- To abbreviate development period
- To guarantee compaction in the structure- particularly in bound zones where vibrating compaction is troublesome.
- To end commotion because of vibration-compelling particularly at solid items plants.

By using self-compacting concrete, the cost of engineered and mineral admixture is reimbursed before the finish of vibrating compaction and work done to level the surface of the common bond (Khaygat et al., 1998). In any case, the total cost for certain improvement can't for the most part be diminished, because common bond is used as a piece of a more significant rate than self-compacting concrete.

The creation of self-compacting concrete as a level of Japanese prepared blended solid, which represents 70% of aggregate solid generation in Japan, in just 0.1%. The present status of self-compacting concrete is "uncommon cement" as opposed to "standard cement".Other application of self-compacting concrete is summarized below:

- Bridge (anchorage, arch, beam, tower, pier, joint between beam & girder).
- Box culvert.
- Building
- Concrete filled steel column.
- Dam (concrete around structure).
- Diaphragm wall.
- Tank (side wall, joint between side wall and slab).
- Pipe proof.

EXPERIMENTAL INVESTIGATION

OBJECTIVES

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 use steel fibres at various percentages, not exceeding 0.4%.
- To employ steel fibres of various aspect ratios with a maximum of 25.
- To conduct tests for determination of Compressive Strength and Elastic Modulus.

MATERIALS USED

The following materials are employed in the present investigation

Cement 53 grade

Ordinary Portland cement of 53 grade of Zuaribrand was used and tested for physical and chemical properties as per IS: 4013-1988 and found to be confirming to various specifications of are 10269-1987.

The Cement used for this study is PortlandPozzolana Cement confirming to the Indian Standard IS: 10269-1987. Table 4.1 shows the properties of Cement used.

Table 4.1 Properties of cement

PROPERTY	RESULT
Specific gravity	2.8
Weight retained on 90μ sieve	7.66%
Initial setting time	35 min

Fine aggregate

In the present investigation, fine aggregate, Natural River sand 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.

The sand was collected from nearby area and the sand was sieved on 4.75mm sieve and Table 4.2 shows the properties of fine aggregate.

Table 4.4 gives the sieve analysis results of fine aggregates (30% robo sand + 70% fine sand)

Table 4.2 Properties of fine aggregate (River Sand)

PROPERTY	RESULT
Specific gravity	2.74
Fineness modulus	2.75
Water Absorption	1.62%
Bulk Dencity	1540 kg/m^3
Zone according to IS383-1970	Zone II

Table 4.3 Properties of fine aggregate (Rock Sand)

4.2.3 Coarse aggregate

The crushed coarse aggregate of 10-12mm 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.

The coarse aggregate chosen by shape as per IS: 2386 (part I) (1963), surface texture characteristics of the aggregate as classified in IS: 383-1970. Table 4.3 shows the properties of coarse aggregate obtained from tests.

Table 4.3 Properties of coarse aggregate

PROPERTY	RESULT
Specific gravity	2.8
Fineness modulus	7.7
Aggregate impact value	30.23%
Crushing value	18.80%
Bulk Density	1532 kg/m^3

Rock Sand

In the present investigation work, the TYPE-II fly ash was used as cement replacement material. It is obtained from Ramagundam 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.

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. Performance fluctuations due to variation in the material quality and the moisture in aggregate are attenuated by the VMA making quality control easy.

Super plasticizer

Super plasticizer (B233 of M/S BASF INDIA LTD) was employed for the preparations of SCC.

Water

This is least expensive but most important ingredient of concrete. The water which is used for making concrete should be clean and free from harmful impurities such as oil, alkali, acid, etc.., in general the water which is fit for drinking should be used for making concrete.

STUDIES ON FRESH CONCRETE

There are three key aspects of workability, which should be carefully controlled to ensure satisfactory performance of SCC during its wet phase and for its successful classification as SCC (Ouchi et al 2003):

- **Filling ability:** The ability of the concrete to flow, maintaining homogeneity while undergoing the deformation necessary to fill the formwork completely, encasing the reinforcement and achieving consolidation through its own weight without vibration.
- **Resistance to segregation**: The ability of the particle suspension to maintain a cohesive state throughout the mixing, transportation and casting processes.
- **Passing facility:** The ability to pass through closely spaced reinforcement or enter narrow sections in form work, and to flow around other obstacles without blocking.

Table 4.4: Fineness modulus of River Sand

S. No.	Sieve	Weight	% Of Weight Retained	Cumulative % Weight Retained	% Weight
	Size (mm)	Retained (gms)			Passing
1	4.75	0	0	0	100

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2	2.36	0	0	0	100
3	1.18	30	3	3	97
4	600 µ	220	22	25	75
5	300 µ	550	55	80	20
6	150 µ	160	16	96	4
7	Pan	30	3	99	1

Cumulative percentage weight retained = 303

Fineness Modulus of Fine Aggregates = W/100 = 303/100

Fineness Modulus of Fine Aggregates = 3.03

Table 4.4: Fineness modulus of Rock Sand

S. No.	**Sieve Size (mm)**	**Weight Retained (gms)**	**% Of Weight Retained**	**Cumulative % Weight Retained**	**% Weight Passing**
1	4.75	0	0	0	100
2	2.36	50	5	5	95
3	1.18	300	30	35	65
4	600 µ	210	21	56	44
5	300 µ	230	23	79	21
6	150 µ	110	11	90	10
7	Pan	100	10	100	0

Cumulative percentage weight retained = 275

Fineness Modulus of Fine Aggregates = W/100 = 275/100

Fineness Modulus of Fine Aggregates = 2.75

Table 4.5: Fineness Modulus of Coarse Aggregates

S. No.	**Sieve Size (mm)**	**Weight Retained (kg)**	**% of Weight Retained**	**Cumulative % Weight Retained**	**% Weight passed**
1	80	0	0	0	100
2	40	0	0	0	100
3	20				
4	10				
5	4.75				
6	2.36				
7	1.18	0	0	100	0
8	600 µ	0	0	100	0
9	300 µ	0	0	100	0
10	150 µ	0	0	100	0

Cumulative percentage weight retained = 685.68

Fineness modulus of Coarse Aggregates = W/100 = 685.65/100

Fineness modulus of Coarse Aggregates = 6.85

MIXING OF VARIOUS COMBINATIONS

Various ingredients of concrete like PPC, fine aggregate (river sand and rock sand) and coarse aggregate (10-12mm) were weighed accurately.

All the materials were transferred to Pan Mixer. The machine was put on and dry mixing is carried out in the pan mixer for a minute. When the machine is operating water of calculated quantity with chemical admixtures (SP, VMA) is added in stages till we get a uniform, homogeneous, cohesive mix of wet concrete. Dry mix is shown in plate 5 and concrete mixing in Pan Mixer is shown in plate 6. Wet mix is shown in plate 7.

WORKABILITY AND TEST METHODS FOR SCC

Table 5.1 Provide a summary of the properties of SCC mixes in the fresh state. As it is evident the basic requirements of high flowability and segregation resistance, as specified by EFNARC guidelines on SCC are satisfied. The workability values are maintained by adding suitable quantities of super plasticizers. On the basis of the experiment study it was surface integrity of concrete, improve its homogeneity and reduce the probability of cracks occurring where there is some restraint settlement.

T50cm Slump flow: This test is used along with slump flow test to assess the flowability.

a) **V-funnel:** This test is used along with slump flow test to assess the flowability of SCC.
b) **L-Box:** This test is used to assess the flowability of SCC
c) **U-Box:** This test is used along with slump flow test to assess the flowability.

The values of workability are given in table5.1. Plates8 to 11 gives workability tests apparatus respectively.

CASTING AND CURING OF SPECIMENS

For each combination of SCC, 6 no's of cube specimens each of size 150mm X 150mm X 150mm were cast for conducting the compressive strength test. Similarly 3 no's of standard cylinders each of size 150mm diameter and 300mm height were cast for determination of elastic properties. All the moulds were cleaned; nuts and bolts were fixed and well oiled inside. The wet concrete was poured into the moulds layer by layer to avoid any gaps. The moulds were left in the laboratory for air drying for about 24 hours as normal practice. At the end of this period demoulding was carried out and the marked specimens were immediately transferred to curing tank. Continuous curing was carried out till the age of 7 days and 14 days in clean water in the curing tank. At the age of 7 days and 14 days the specimens were removed from the curing tank, the water was wiped out and the dry specimens were tested.

TESTS CONDUCTED

Compressive Strength Test

The compression strength testing was conducted by using the Standard Digital Compression Testing Machine (CTM) of 3000 KN capacity in the concrete lab. The dry specimen was kept on the bottom platen of the machine and the top platen was adjusted to be in contact with the specimen. The machine was put on with uniform rate of loading as per the specifications of IS 516. The load reading was shown on the digital scale. At some load level first crack was developed and the load further increased to the ultimate level at which the specimen has completely failed. The first crack load and ultimate load were noted.The specimens during compression were shown in plates 15 to 17. The crushed specimens were shown in plate 18.

Determination of Elastic Properties

For the determination of elastic properties of concrete like Young's Modulus and Poisson's Ratio the setup consisting of longitudinal and lateral extensometers were used on the standard cylinders of 14 days age. The arrangement was fixed on the cylinder as shown in plate 19 and 20. For the longitudinal extensometer the gauge length is 200mm and least count of the gauge is 0.025mm. For the lateral extensometer the gauge is fixed at the end of the diameter and its least count is 0.025mm. After ensuring that all the screws are fixed properly the cylinder with the setup is kept on the bottom platen of CTM. Compressive load is applied at uniform rate of loading. Load and extensometer readings were taken at regular intervals of 10 KN and they were noted instantly. Loading was continued even after few cracks have occurred on the cylinder till the ultimate load where, the cylinder was completely crushed. The crushed specimens were shown in plate 21.

Plate5: Photograph of dry constituents of SCC with River sand

Plate 6:Photograph of Slump Cone Test

Plate 7:Photograph of V-Funnel Test on SCC

Plate 8: Photograph of U-Box Test on SCC

Plate 9: Photograph of L-Box Test on SCC

Plate 10: Photograph of casted specimens

Plate 11: Photograph of dry specimens after curing in curing tank

Plate 12: Photograph of Compression Testing Machine Panel

Plate 13: Photograph of Loading Unit of CTM

Plate 14: Photograph of Specimen during Compression

Plate 15: Photograph of specimen after crushing

Plate 16: Photograph of Testing of Elastic Modulus by using Extensometer

Plate 17: Photograph of Setting of Extensometer

RESULTS AND DISCUSSIONS

PRESENTATION OF RESULTS

The results obtained from the experimental investigation are given as follows

Table 5.1gives the Workability results of different mixes of Self Compacting Concrete.

Table 5.2 gives the results of Compressive Strength of various mixes of Self Compacting Concrete.

Table 5.3 gives the results of Elastic Properties like Young's Modulus and Poisson's Ratio of Self Compacting Concrete for various mixes.

The variation of compressive strength for various fibre percentages and aspect ratios is plotted in fig 1 to 4

The variation of Young's Modulus with fibre percentage and aspect ratios is plotted in fig 5 to 8

- The results of experimental investigation are discussed below.

WORKABILITY

The workability results (table 5.1) show that the mixes of all combinations are satisfying EFFNARC specifications after comparing with the acceptance criteria shown in table A-3 of Annexure-1.

COMPRESSIVE STRENGTH

Compressive strength of concrete is defined as the load, which causes the failure of a standard specimen divided by the area of cross section in uniaxial compression under a given rate of loading.

MODULUS OF ELASTICITY

The modulus of Elasticity is determined by subjecting a cylinder specimen to uniaxial compression and measuring the deformations by means of dial gauge. The modulus of elasticity of concrete is a function of the modulus of elasticity of the aggregates and the cement matrix and their relative proportions. The modulus of elasticity of concrete is relatively constant at low stress levels but start decreasing at higher stress levels as cracking of matrix develops. The elastic modulus of the hardened paste may be in the order of 10-30 GPA and aggregates about 45-85 GPA.

POISSON'S RATIO

In the present study the Poisson's ratio is decreasing with increasing fibre percentage. Table 5.3 shows Poisson's ratio values. The concrete mix with triple blending and with fibre is showing lower values than the reference mix. It can be seen that Poisson's ratio of triple blended fibrous SCC of M50 grade is decreasing with increase in fibre percentage and the increase in aspect ratio.

INFLUENCE OF FIBRE PERCENTAGE ON STRENGTH

As discussed earlier it can be seen that as the fibre percentage is increased, the respective strengths are increasing. In the case of SCC higher percentages of steel fibre interferes with the flowability of SCC. Hence the percentage of fibre is restricted at 0.4. Up to this optimum percentage, the strength increases.

INFLUENCE OF ASPECT RATIO OF STEEL FIBRE

As the aspect ratio of the fibre increase it can be seen that there is increase in the strength. When

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the aspect ratio is high it interferes with the flow of concrete because its weight is more. With higher aspect ratios there may be balling effect also.

Table 5.1 Workability for different mixes of SCC

Sl.NO	MIX NO.	Flyash %	CSF %	Fibre Percentage	Aspect Ratio	T 50cm slump flow	V-funnel	L-box	U-box	Remarks
Limits as per EFFNARC SPECIFICATIONS – 2002						2-5 (sec)	6-12 (sec)	0.8-1.0	0-30 mm	
1	S1	0	0	0	0	3	8	0.8	28	The SCC mix satisfies the EFNARC Specifications.
2	S2	20	10	0	0	3.2	7	0.82	25	
3	C1	20	10	0.1	10	4	7	0.8	20	
4	C2	20	10	0.1	15	4.6	10	0.84	25	
5	C3	20	10	0.1	20	3.34	6.2	0.86	28	
6	C4	20	10	0.1	25	4.2	7	0.8	30	
7	C5	20	10	0.2	10	3	6.5	0.82	24	
8	C6	20	10	0.2	15	3.6	7	0.83	26	
9	C7	20	10	0.2	20	4.2	10	0.82	28	
10	C8	20	10	0.2	25	5	10.8	0.8	30	
11	C9	20	10	0.3	10	3.56	8	0.85	25	
12	C10	20	10	0.3	15	4.1	8.4	0.86	27	
13	C11	20	10	0.3	20	4.5	9.2	0.84	30	
14	C12	20	10	0.3	25	4.8	11.1	0.82	30	
15	C13	20	10	0.4	10	4.1	8.2	0.86	28	
16	C14	20	10	0.4	15	4.3	9.6	0.84	27	
17	C15	20	10	0.4	20	4.6	10.9	0.82	29	
18	C16	20	10	0.4	25	4.9	11.5	0.8	30	

Table 5.2: Compressive Strength of different mixes of SCC

Sl.No	MIX NO	Flyash Percentage	CSF Percentage	Fibre percentage	Aspect ratio	Ultimate load in KN	Average cube compressive strength at 28 days in N/m

							m²
1	S1	0.0	0.0	0.0	0	403	40.30
2	S2	20	10	0.0	0	404.7	40.47
3	C1	20	10	0.1	10	406.65	40.67
4	C2	20	10	0.1	15	410.75	41.07
5	C3	20	10	0.1	20	421.8	42.18
6	C4	20	10	0.1	25	439.1	43.91
7	C5	20	10	0.2	10	429.2	42.92
8	C6	20	10	0.2	15	444.55	44.45
9	C7	20	10	0.2	20	461.85	46.19
10	C8	20	10	0.2	25	497.2	49.72
11	C9	20	10	0.3	10	430.45	43.05
12	C10	20	10	0.3	15	459.2	45.92
13	C11	20	10	0.3	20	467.25	46.72
14	C12	20	10	0.3	25	502.7	50.27
15	C13	20	10	0.4	10	432.4	43.24
16	C14	20	10	0.4	15	465.05	46.51
17	C15	20	10	0.4	20	481.2	48.12
18	C16	20	10	0.4	25	515.3	51.53

Table 5.3: Young's Modulus and Poisson's ratio of different mixes of SCC

S.N	MIX	FLY AS	CS	FIBRE	ASPECT RAT	YOUNG'S MODU	POISSON'S
1	S1	0.0	0.0	0	0	25284.19	0.156
2	S2	20	10	0	0	25868.99	0.152
3	C1	20	10	0.1	10	26629.84	0.150
4	C2	20	10	0.1	15	27976.30	0.142
5	C3	20	10	0.1	20	28973.27	0.133
6	C4	20	10	0.1	25	31092.54	0.125
7	C5	20	10	0.2	10	27400.71	0.147
8	C6	20	10	0.2	15	28652.36	0.135
9	C7	20	10	0.2	20	29396.58	0.130

10	C8	20	10	0.2	25	32336.24	0.121
11	C9	20	10	0.3	10	29580.31	0.129
12	C10	20	10	0.3	15	30111.27	0.128
13	C11	20	10	0.3	20	32669.60	0.117
14	C12	20	10	0.3	25	33062.90	0.112
15	C13	20	10	0.4	10	31689.52	0.124
16	C14	20	10	0.4	15	34618.80	0.110
17	C15	20	10	0.4	20	34931.12	0.107
18	C16	20	10	0.4	25	35740.05	0.105

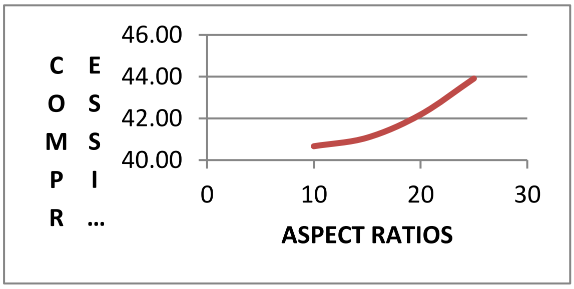

Fig 1: Graph showing Compression Strength (N/mm²) and Aspect Ratio of 0.1% fibre

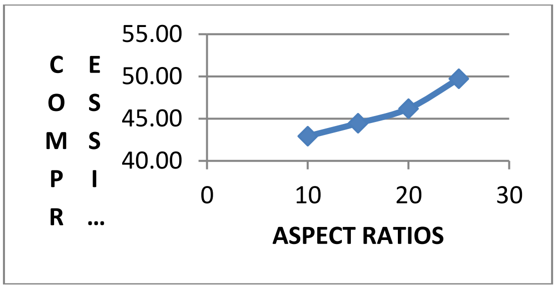

Fig 2: Graph showing Compression Strength (N/mm²) and Aspect Ratio of 0.2% fibre

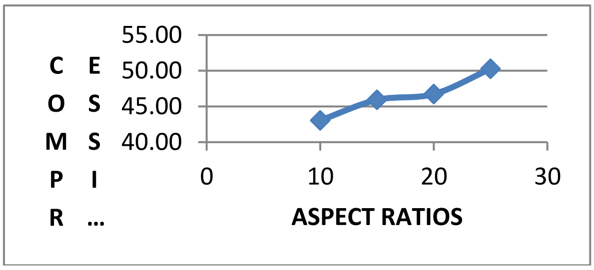

Fig 3: Graph showing Compression Strength (N/mm²) and Aspect Ratio of 0.3% fibre

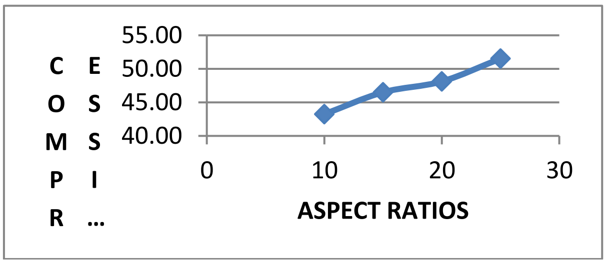

Fig 4: Graph showing Compression Strength (N/mm²) and Aspect Ratio of 0.4% fibre

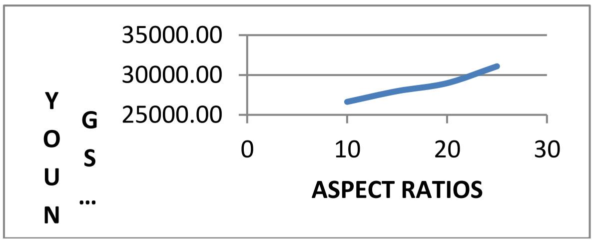

Fig 5: Graph showing Young's Modulus (N/mm²) and Aspect Ratio of 0.1% fibre

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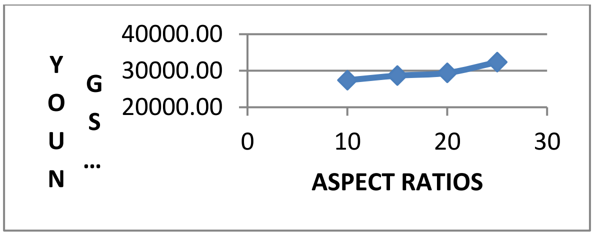

Fig 6: Graph showing Young's Modulus (N/mm^2) and Aspect Ratio of 0.2% fibre

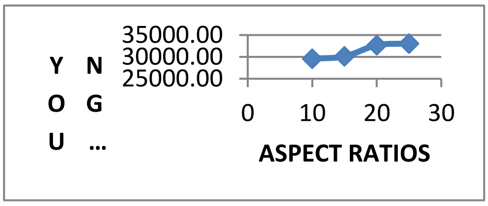

Fig 7: Graph showing Young's Modulus (N/mm^2) and Aspect Ratio of 0.3% fibre

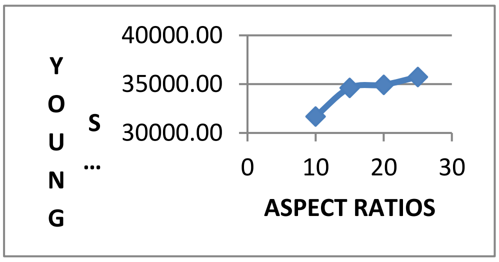

Fig 8: Graph showing Young's Modulus (N/mm^2) and Aspect Ratio of 0.4% fibre

CONCLUSIONS

Based on experimental investigation conducted in present project, the following conclusions are drawn.

1. The Triple Blended Fibrous Self Compacting Concrete can be prepared by using steel fibres upto 0.4% and with aspect ratios varying upto 25.
2. Up to certain optimum percentage and optimum aspect ratio, steel fibres contribute towards strength increase.
3. Young's Modulus of triple blended fibrous SCC of M50 grade increases with increase in fibre percentage and also with aspect ratio.
4. Poisson's ratio of triple blended fibrous SCC of M50 grade is decreasing with increase in fibre percentage and the increase in aspect ratio.
5. The optimum fibre percentage and aspect ratios are 0.4 and 25 respectively in the present investigation. Higher values than these would adversely affect the flowability of SCC.
6. By triple blending SCC with 20% flyash and 10% condensed silica fume(CSF), strength increase is marginal but the triple blending as given better flowability.
7. In general, by resorting to triple blending with flyash and condensed silica fume, strength loss due to flyash can be compensated by condensed silica fume. The optimum mix obtained is economical.

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