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Experimental Studies on Flow Properties and Flexural Behaviour of Self Compacting Concrete with Synthetic Fibers and Manufactured Sand

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ABSTRACT
Concrete has become indispensible construction material worldwide because of its wide usage and its raw materials are available widely around the world and considered as the man made material. In the recent past, due to the advancements in research and innovations, various types of concretes like Self-compacting concrete, Lightweight concrete, Ready mix concrete and High performance concrete have gained importance in comparison with ordinary concrete. Among them, self compacting concrete has become increasingly popular because of its ability to fill empty spaces without the use of vibrators within the formwork. Self-compacting concrete flows under its own weight and will have no segregation. Segregation of concrete results in honeycombing in sections adjacent to the formwork. A well designed SCC mix has high deformability, excellent stability characteristics and greater workability. The present research work is mainly focused on the flexural behavior of self compacting concrete using macro synthetic fibers and manufactured sand. In this exploration work, cement was substituted with fly ash (FA), silica fume(SF) and ground granulated blast furnace slag (GGBS) in different proportions. Manufactured sand has been used in our work as fine aggregate owing to its eco friendly properties compared to river sand. Macro Synthetic fibers were incorporated in percentages 0f 0.5%, 1.0% and 1.5% in the SCC mix. Results obtained from this work showed that there was overall increase in the properties of SCC with the use of macro Synthetic fibers and M-Sand.
Keywords: Self compacting concrete, Cement, fly ash, silica fume, ground granulated blast furnace slag, manufactured Sand, macro synthetic fiber, workability, beams, Compressive strength and flexural strength.

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I. INTRODUCTION

In recent years due to increasing stipulations and requirements, the structures are becoming more complex leading to strenuous concreting conditions. Another major concern is that natural resources like sand and gravel are getting depleted because of their wide usage in construction field. There is a great necessity to save these natural resources and to make effortless concrete structures. These two major problems have compelled many researches and engineers to come up with new materials which can be used as substituting materials in place of natural resources and to develop new concrete construction methods. Major revolutionary innovations that took place in the domain of concrete technology in the recent three decades were development of freely flowing type of concrete called self compacting concrete (SCC), usage of manufactured sand (M Sand) as a substituting material to river sand or naturally occurring sand. Normal concrete will have honeycombed spaces left in the concrete mix due to improper vibrations and also strength will get reduced at the vital sections such as beam and column intersections due to the formation of void spaces. SCC eliminates all these major concerns that we have been facing in the past. SCC can be compacted by its own weight without use of vibrators. It has great passing capacity to fill the sides of the solids without using any compactors and vibrators. It requires less skilled workers in comparison with other types of concrete.

Dream of achieving highly durable type of concrete become possible with self compacting concrete. Fibers are normally added to concrete in low volume dosages (under 2.0%) and have been gave an impression of being fruitful in diminishing plastic shrinkage and cracks. Many types of fibers like steel fibers, synthetic fibers, and natural fibers were available in the market. In this work we have reinforced SCC mix with macro synthetic fibers because these fibers are more durable, less expensive and do not wrinkle easily. Inclusion of fibers increased the performance and strength characteristics of self compacting concrete mix.

II. LITERATURE REVIEW

K.V. ROOPCHAND [1] interrogated the effect of polypropylene fibers as reinforcing material and m sand as fine aggregate and concluded that compressive strength increases within the scope of 6% to 9%. This work had given the further scope to study the flexural behavior using above materials.

H.OKAMURA [2, 3] was the first person in 1995 to develop self compacting concrete in Japan in 1986 as a quality affirmation idea to address the issues like long creation times, undesirable workplace in cast in-situ solid innovation.

H.SHANKAR SANNI [4] explored the impact of fly ash on SCC and concluded that the flow properties increases with increase in the fly ash content and mechanical properties increases up to the optimal dosage of 30% of fly ash.

R. NATARAJAN [5] stated that usage of steel fibers in percentages of 0.3, 0.6, 0.9 & 1.2 increased the compressive strength of SCC mix but decreased the workability. Usage of steel fibers reduced the cracks and plastic shrinkage in concrete.

D. RAMA SESHU [6] researched the consequences of glass fiber reinforced SCC and concluded that addition of 0.03% of glass fiber increased the compressive strength by 5%, tensile strength by 7% and flexural strength by 18%.

V. RAJESH [7] in their investigation used steel fibers and reported that addition of steel fibers increased the compressive quality by minimizing the cracks and their by expanding the solidness of the concrete. He also stated that m sand can be used in place of river sand as it has given satisfactory results.

M. J. HASAN [8] investigated the impact of structural synthetic fibers on self compacting concrete and concluded that mechanical properties like compressive strength, tensile strength, flexural strength and ductility increased by the addition of fibers. Concrete with fibers have shown the ductile nature where as concrete without fibers have undergone brittle failure.

W. ZHU [9] carried experiments to study the bond strength between the concrete and steel reinforcement. Results obtained had shown the regression in the bond strength with the increase in the diameter of steel form 12 mm to 20 mm.

KHALLEL ET AL [10] stated that the size of the coarse aggregate and its proportion in the SCC mix had shown greater impact on the flow properties and strength parameters. Results had shown that the flowing ability of the SCC decreased with increase in the coarse aggregate size.

UYSAL & YILMA [11] in their research work used marble powder as an admixture in the SCC mix and stated that admixtures contributed certain properties for developing the high performance self compacting concrete.

MOUNIR N KAMAL [12] noticed that the fresh properties of the self compacting concrete were improved with use of steel and polypropylene fibers. Bleeding and segregation had not occurred with the fiber reinforced concrete. Polypropylene fiber of 1% by weight of cement showed an increase in compressive strength by 13% tested for 28 days of curing and steel fibers of 0.75% by weight of cement had a rise in compressive strength by 37%.

T SHANMUGA PRIYA [13] in their work replaced the cement with silica fume in percentages of 0, 2.5, 5, 10 and 20. Results obtained shown that the optimum dosage of silica fume that can be used as replacement to cement was 10% had shown a maximum increase in the compression strength.

A SIDDHARTH ANAND [14] used steel fibers in percentage ranges from 0 to 1.5 in his work to study the effect on compressive, tensile and flexural strength of fiber reinforced concrete and stated that mechanical properties increased as the percentage of fiber reinforcement increases but the soft properties had declined. He concluded that both the soft and hard properties had shown significant results at 0.75% and 1% of fiber reinforcement.

CHANDRAKANTH [15] investigated the effect of macro synthetic fibers and manufactured sand on the fresh and hardened properties of self compacting concrete and concluded that fresh properties decreases with increase in the fiber content and hardened properties increases with increase in fiber content

From the above literature reviews it was evident that in most of their research works self compacting concrete was reinforced with steel and polypropylene fibers but very less importance was given to the synthetic fibers. So in the present work flexural property of beams made of SCC in which m Sand and macro synthetic fibers incorporated were studied. This project is continuation of Chandrakanth [15] work in that investigation the flow characteristics, compressive strength and split tensile strength of SCC were evaluated.

III. OBJECTIVE

Main objective of this study is to evaluate the flexural properties of SCC. The cement content was limited to 65% and 35% of mineral admixtures namely Fly Ash, Silica Fume and GGBS were used in varying proportions. Macro Synthetic fibers (MSF) in percentages of 0, 0.5, 1.0 and 1.5 were used in SCC mix along with manufactured sand.

Research work was carried out in two phases. In the preliminary phase, flow characteristics of SCC like workability and flow tests were conducted by varying the percentages of cement, silica fume, fly ash and GGBS at various percentages of fiber content. In the secondary stage, tests were conducted to determine the strength parameters like compressive and flexural strengths of the mixes that have shown the characteristics of self compacting concrete in the primary phase.

IV. MATERIALS AND METHODOLOGY

The materials used in this research work are as follows

i. Cement: Maha Ordinary Portland cement of 53 grade is used.

ii. Fine aggregate: M sand passing through the 4.75 mm IS Sieve is used confining to grading Zone-II of [IS: 383-1970]

iii. Coarse aggregate: Locally available crushed coarse aggregate of size 12.5 mm was used. Aggregate passing through 12.5 mm and retaining on 10 mm IS Sieve which validates to [IS: 383-1970] free from organic matter, impurities such as dust and clay particles has been used.

iv. Fly ash: Fly ash obtained from Rayalaseema Thermal Power Plant (RTPP), Muddanur, AP, was used. It is obtained by burning of coal with fuel gases in the coal combustion plant.

v. Silica fume: Silica fume from Lankalapalem pharmaceutical company, AP, was used. It is a byproduct obtained in the burning of silicon alloy at high temperatures of about 2000°C in an electric arc furnace. Silicon dioxide vapors are formed which cools down at low temperatures to form silica fume.

vi. Ground Granulated Blast Furnace Slag: Obtained from the Vizag Steel Plant, AP. GGBS is obtained in the powder from when the byproduct of iron and steel slag obtained in the blast furnace was cooled in steam and water.

vii. Chemical Admixtures: Admixtures are added to the batch during mixing of the concrete to modify the freshly mixed, setting times and hardened properties of concrete. Supaflo PC is a high performance super plasticising admixture based on long chains polycarboxylic polymers specially made to increase the performance of concrete. Here in this research work we have used DCP Supaflow PC360 as chemical admixture.

Table 1. Properties of chemical admixture

S.no	Property	Value
1	Chemical	Supaflo PC360
2	Specific gravity	1.070
3	Ph	6.70
4	Solid content	22.95%
5	Colour	Pale yellow

viii. MSF: In this work, MSF made of nylon (as shown in figure 1) were used as reinforcement to self compacting concrete. These fibers are non biodegradable and need to be recycled to keep the environment safe so these fibers were used as low cost reinforcement in the construction field.

Figure 1. Macro Synthetic fibers

Table 2. Properties of MSF

S.No	Property	Result
1	Polymer	Nylon 6 polyfilament
2	Length	37-47 mm
3	Diameter	0.3 mm
4	Surface texture	Continuously dinted

ix. Water: Potable tap water free from toxic organic materials is used in this research work.
Properties of the constituent materials are shown in table 3.

Table 3: Properties of Materials used in Self compacting concrete mix

S. No	Name of the Material	Physical Properties of the substantial	
1	OPC – 53 GRADE	Specific gravity	3.10
		Setting time (Initial)	29 minutes
		Setting time (Final)	240 minutes
		Fineness	5.4%
		Normal consistency	29%
2	Fine aggregate passing through 4.75 mm IS sieve (M sand)	Specific gravity	2.58
		Fineness modulus	2.60
		Water absorption	2.31%
3	Coarse aggregate passing through 12.5 mm IS sieve	Specific gravity	2.62
		Water absorption	0.35%
		Moisture content	0.25%
		Bulk density	1600kg/m^3
4	Class F Fly ash	Specific gravity	2.5
5	Silica Fume	Specific gravity	2.31
6	GGBS	Specific gravity	2.80

V. EXPERIMENTAL PROCEDURE

An exploratory examination has been administered on SCC with different substitutions i.e., mineral admixture flyash is replaced with silica fume and ground granulated blast furnace slag blended together by varying the fiber in percentages of 0, 0.5, 1.0 and 1.5.

5.1. Mix design

Initially several trails were made to find the suitable proportions for SCC mix. R1 mix (65% cement and 35% flyash) was taken as the reference mix and in the remaining mixes cement was kept constant at 65% and fly ash 35% was replaced with 5% of silica fume, 5% of GGBS and MSF in percentages of (0.5, 1, 1.5) were used. The mix proportions which satisfied the filling and passing ability properties as recommended by the EFNARC guidelines are shown in table 4.

Table 4. Mix proportions of SCC mix

Mix name	CEMENT (Kg/m3)	FLY ASH (Kg/m^3)	FA (Kg/m^3)	CA (Kg/m^3)	FIBERS (%)	SILICA FUME (Kg/m^3)	GGBS (Kg/m^3)	WATER (Kg/m^3)	ADMIXTURE (Kg/m^3)
R1	345	186	891	810	0	0	0	186	4.77
R2	345	133	891	810	0	27	26	186	4.77
R3	345	186	891	810	0.5	0	0	186	4.77
R4	345	133	891	810	0.5	27	26	186	4.77
R5	345	186	891	810	1.0	0	0	186	4.77

R6	345	133	891	810	1.0	27	26	186	4.77
R7	345	186	891	810	1.5	0	0	186	4.77
R8	345	133	891	810	1.5	27	26	186	4.77

5.2 Mixing procedure

The main principles that have been followed in our research work for producing self compacting concrete are by restricting the coarse aggregate content diminished the internal stresses between the aggregates, to lessen the water content of the flowable concrete super plasticizer is used and to modify the soft and hard properties of concrete admixtures were used. The following mixing sequences are performed to produce high quality Self compacting concrete.

1. Initially aggregates and fibers were blended together and mixed in the machine for about two minutes for uniform distribution of fibers limiting the formation of solid lumps.
2. Powder materials were added to above mix and dry blended for about one minute.
3. Super plasticizer and 75% of water are stirred together and poured in to the dry mix and mixed for one minute.
4. Later remaining 25% of water is added and mixed for some time.
5. The machine was stopped after proper mixing.

Concrete mix was taken out from the mixer and placed in the moulds in two layers. Top surfaces of the moulds were kept smooth with the help of the trowel. Samples were put away for 24 hours under a temperature of 15°C to 27°C for the setting of concrete. After setting of concrete the samples were demoulded and kept in the water tank for 28 days of curing and the samples were kept ready for testing.

VI. FRESH PROPERTIES

The workability performance criteria of synthetic fiber reinforced SCC mix need to be known before testing the hardened properties. Fresh properties like filling ability and passing ability are determined using slump flow, V funnel, L box and U box tests. Permissible limits of SCC mix as per EFNARC guidelines are shown in Table 5 and test results are shown in Table 6.

Table 5. EFNARC Acceptance criteria for SCC

Property	Test Method	Units	MIX RANGES
Filling Ability	Slump Flow T_{50cm} Flow V-Funnel	mm sec sec	650 - 800 3 - 5 6 - 12
Passing Ability	L-Box U-Box	h2/h1 ratio mm	0.8 - 1.00 0 - 30

Table 6. Fresh Properties of Fiber reinforced SCC Mix

S.no	Mixes	Slump Flow	T50 Flow	V-Funnel	L-Box	U-Box
1	R1	755	3.166	7.12	0.976	6.7
2	R2	748	3.322	7.55	0.967	10.2
3	R3	734	3.284	7.75	0.952	9.6
4	R4	728	3.544	8.24	0.942	12.6
5	R5	712	3.424	8.15	0.912	13.5
6	R6	704	3.712	8.62	0.896	15.7
7	R7	684	3.592	8.68	0.886	15.6
8	R8	676	3.845	9.18	0.871	17.3

The results shown in the Table 6 are represented graphically in figures 2, 3, 4, 5 and 6.

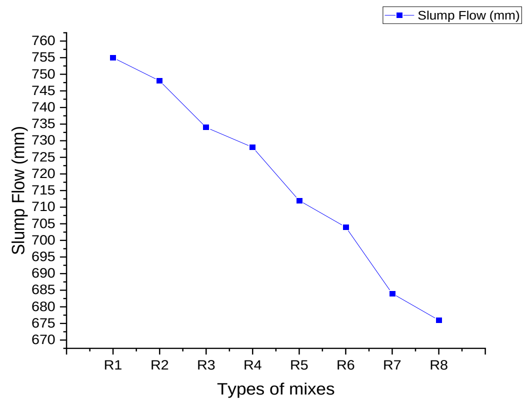

Figure 2. Slump Flow Vs Types of mixes

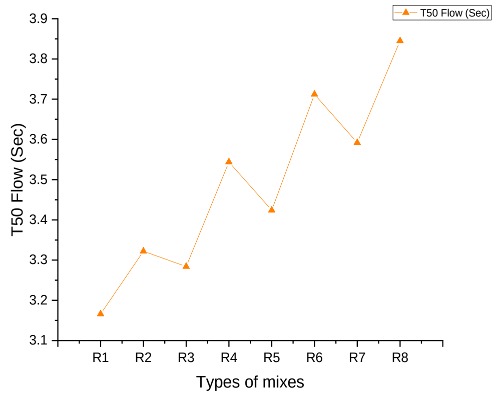

Figure 3.T_{50cm} Flow Vs Types of mixes

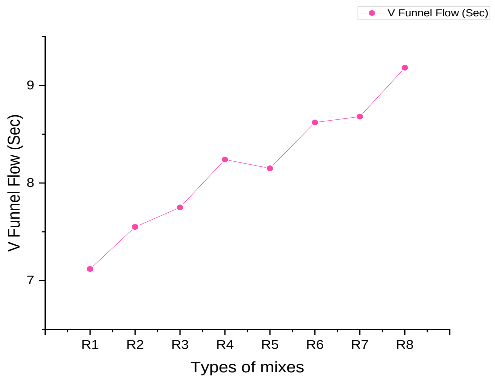

Figure 4. V-Funnel Vs Types of mixes

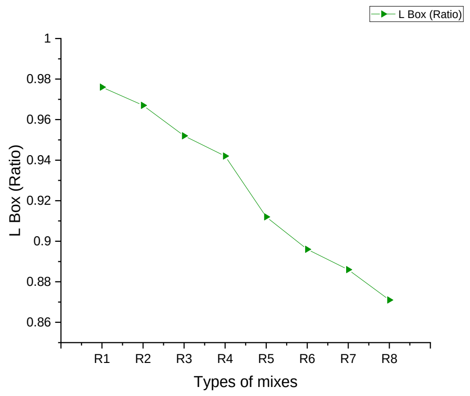

Figure 5. L-Box Vs Types of mixes

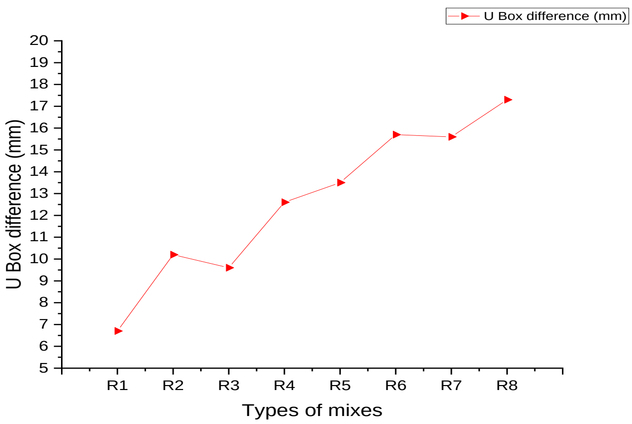

Figure 6. U-Box Vs Types of mixes

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VII. HARDENED PROPERTIES

The results shown in the table 6 and figures 2, 3, 4, 5 and 6 are within the EFNARC acceptance criteria for SCC mix. All the mixes obtained are within the SCC mix criteria and hence tested for compressive strength and flexural strength.

7.1 Compressive Strength

Concrete was filled into cylinders without compaction and top surfaces are leveled with the help of trowel. Cylinders of size 150 mm x 300 mm are casted to determine the compression behavior of concrete for curing periods of 7 days, 28 days and 90 days. Compressive strength results obtained are shown in Table 7 and graphically in Figure 7.

Table 7 Compression Strength Test Results of SCC Mixes

S.no	Mixes	Compressive strength (Mpa)		
		7 days	28 days	90 days
1	R1	14.58	22.74	27.32
2	R2	15.22	23.38	28.06
3	R3	15.79	23.94	28.53
4	R4	16.63	24.78	29.37
5	R5	18.00	26.15	30.74
6	R6	18.84	27.99	31.58
7	R7	20.21	29.36	33.94
8	R8	21.05	30.20	35.78

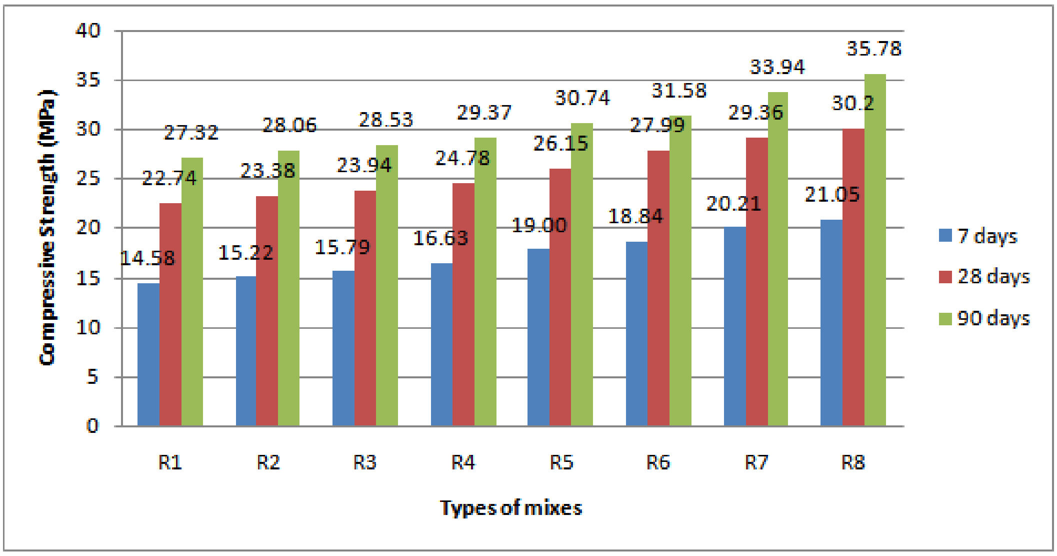

Figure 7. Compressive strength of concrete vs Types of mixes

In the Figure 7, compressive strength of all types of mixes are represented graphically for curing periods of 7, 28 and 90 days respectively. The figure clearly shows that there was increase in the compression strength from mixes R1 to R8 for all the curing periods due to presence of silica content in both Silica fume and GGBS and incorporation of MSF in the Concrete mix. Maximum value of compression strength is obtained in mix R8 which consists of 5% Silica Fume 5% GGBS and 1.5% MSF.

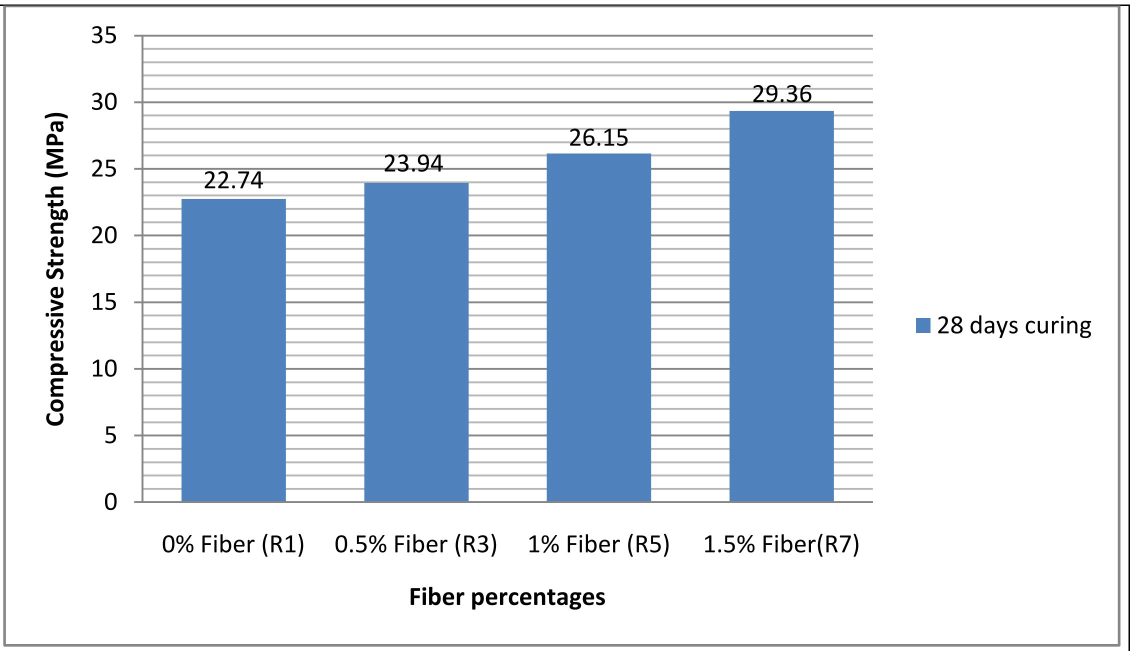

Figure 8(a). Compressive strength of concrete vs Fiber Percentages

From the Figure 8(a), it can be seen that as fiber percentages increases from 0% to 1.5% the Compressive strength also increases from mix R1 to mix R7 and the maximum strength was obtained with the addition of 1.5% fibers (R7 mix). The main reason for increase in the Compression strength with the addition of fibers is due to the fiber expansion.

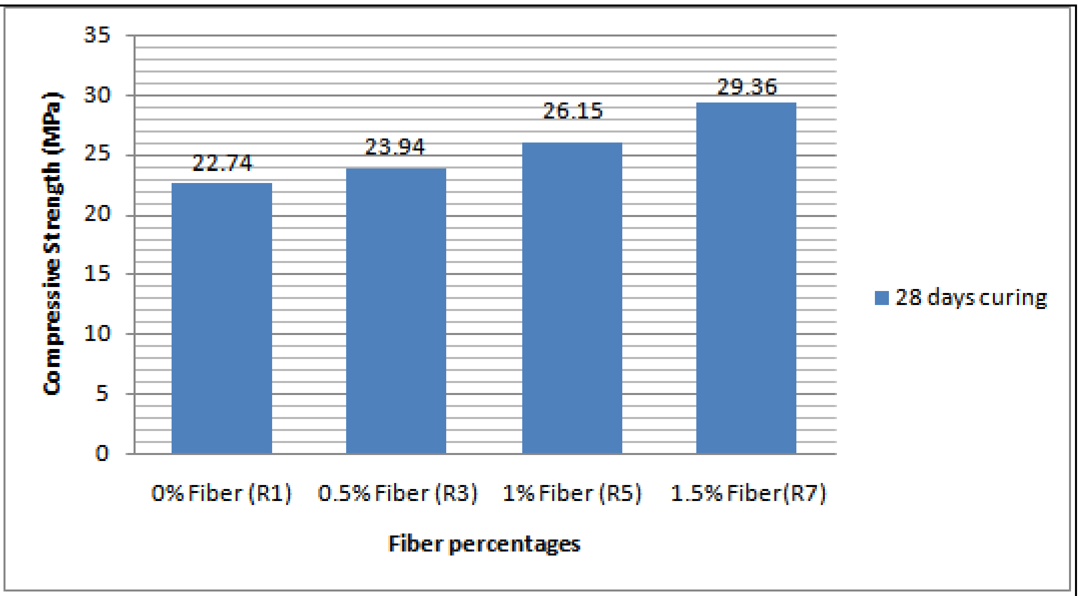

Figure 8(b). Compressive strength of concrete vs Fiber Percentages

In the Figure 8(b), Compressive strength of concerete for mixes R2, R4, R6 and R8 having Cement 65%, flyash 25%, silica fume 5%, ggbs 5% and fibers in percentages of 0, 0.5, 1 and 1.5 were compared. From the above graph we can infer that as fiber percentage increases from 0% to 1.5% the compressive strength also increases and the maximum strength was obtained with the addition of 1.5% fibers. The main reason for increase in the Compression strength with the addition of fibers is due to the fiber expansion.

7.2. Flexural Strength

After curing period, flexural strength was tested on the beams of size 700mm length 150mm width and 150mm depth. Flexural tests were conducted to find the bending strength. It is defined as maximum stresses at outermost fiber on either the compression or tension side of the specimen. This test can also be used to find the resistance of the beam member against deformation. The maximum load which the beam can resist before the complete failure of member takes place is the flexural strength of that member. In this test the member will be subjected to combined effect of all the stresses like tensile, compression and shear. The beam member was placed horizontally over the two steel rollers of 38 mm diameter and these rollers were placed at center to center distance of 600mm and the load was applied equally through two points of contacts to the beam specimens up to the failure. As the load was applied to the beam member through two points of contact it was called as Two point Load test. Flexural strength can be obtained by substituting the values of applied load (P), effective span (L), width (b) and depth (d) in the formula shown below

$$f_{cr} = \frac{PL}{bd^2}$$

Where f_{cr} is the flexural strength or bending strength in N/mm^2 of the beam member.

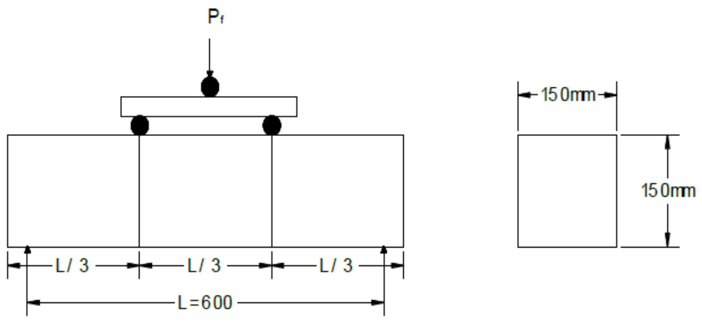

Figure 9. Two point loading setup for flexure test

Table 8. Flexural Strength Test Results of SCC Mixes

S.no	Mixes	Flexural strength (Mpa)	
		7 days	28 days
1	R1	2.24	2.98
2	R2	2.38	3.12
3	R3	2.63	3.33
4	R4	2.80	3.47
5	R5	3.50	4.34

6	R6	3.68	4.52
7	R7	3.95	4.90
8	R8	4.20	5.18

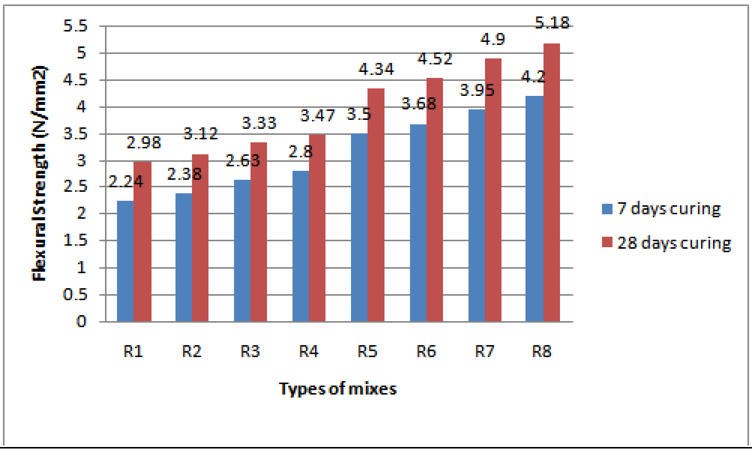

Figure 10. Flexural strength of Concrete vs Types of mixes

In the Figure 10, Flexural strength of all types of mixes are represented graphically for curing periods of 7 and 28 days respectively. The figure clearly shows that there was increase in the flexural strength from mixes R1 to R8 for all the curing periods due to presence of silica content in both Silica fume and GGBS and incorporation of MSF in the Concrete mix. Maximum value of tensile strength is obtained in mix R8 which consists of 5% Silica Fume 5% GGBS and 1.5% MSF reinforced mixes. Plain SCC mixes (Reference mixes R1 and R2) have lower flexural strength when compared to the flexural strengths of fiber reinforced mixes.

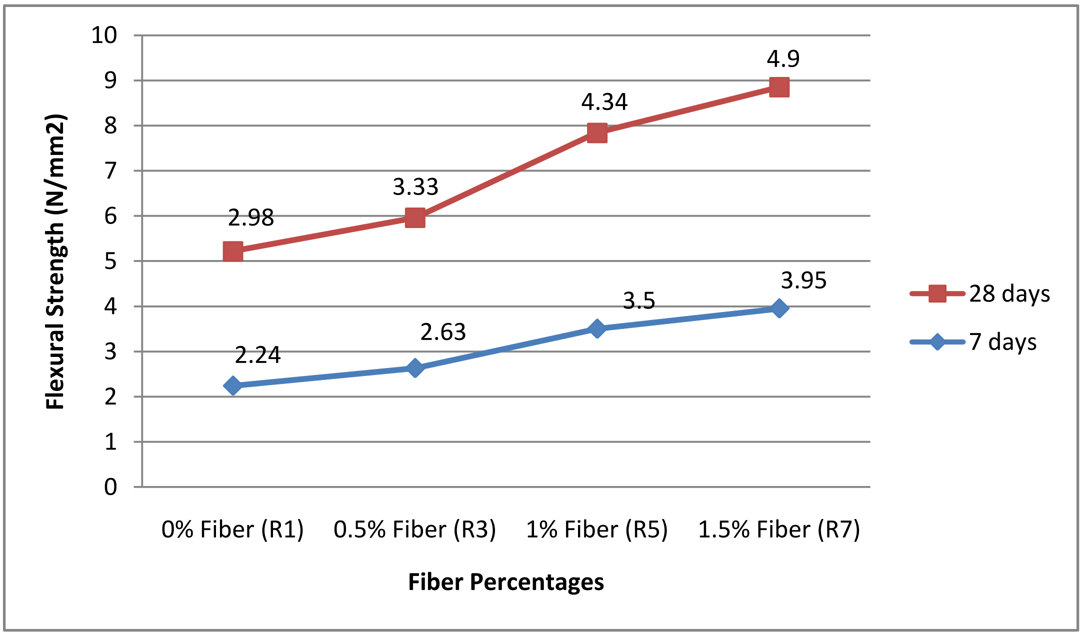

Figure11(a). Flexural strength of Concrete vs fiber percentages

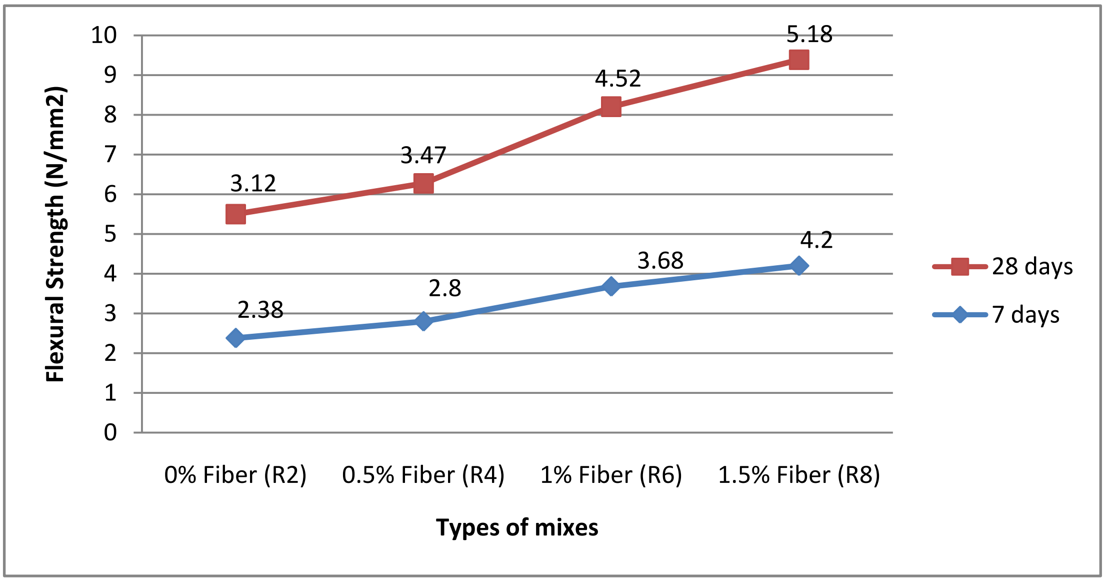

Figure11 (b). Flexural strength of Concrete vs fiber percentages

In the Figure 11(a), Flexural strength of concrete for mixes R3, R5 and R7 were compared with the reference mix R1 (65% Cement, 35% Flyash and 0% MSF). In the mixes R3, R5 and R7 cement and flyash proportions were kept constant and fibers were varied in percentages of 0.5, 1.0 and 1.5. From the graph as the fiber percentage increases flexural strength also increased due to the stretching of fibers during the application of load. From Figure 11(b) flexural strength of concrete for mixes R4, R6 and R8 were compared with reference mix R2 (Cement 65%, Flyash 25%, Silica fume 5%, GGBS 5% and Fibers 0%). From the graph it can be seen that as fiber percentage increases flexural strength also increased. With the incorporation of the MSF sudden failure of beam members was eliminated and the mode of failure was ductile in nature. Fibers are stretched during the application of load and strongly hold the beam members from breaking apart leading the beam member to fail in the ductile nature.

VIII. CONCLUSIONS

Based on the results obtained from the experimental investigation the following conclusions can be drawn

➢ The mix proportion adopted for producing Self compacting Concrete satisfied the workability requirements as per the EFNARC guidelines for all the mixes with 0% fibers, 0.5%, 1.0% and 1.5%.

➢ Filling ability of the SCC mixes is tested by conducting the slump flow, T_{50cm}, and V funnel tests. The value of slump flow decreased by 10.5% by adding 1.5% of fibers when compared with that of nominal mix . T_{50cm} slump flow increased by 21.4% and the V-Funnel flow time increased by 28.9% when compared with SCC mix having 0% fibers. All the values reached the maximum limits as fiber percentage increased.

➢ The value of blocking ratio H2/H1 of L-Box test have been decreased by 9.9% and passing ability of U-Box have been increased to 61.3 % for mixes reinforced with 1.5% fiber.

➢ Synthetic fiber reinforced SCC mix (0.5% fibers) have shown increase in compression strength by 5.3% when compared to that normal SCC mix. However ultimate compression strength is obtained for R8 mix having 1.5% fibers, 65% of cement, 25% of Fly ash, 5% Silica fume and 5% GGBS and the obtained value is 32.8% more than the nominal SCC mix.

➢ The main reason for the increase in the compressive strength is due to the expansion of the fibers during the application of load and presence of silica content in both Silica fume and GGBS.

➢ Flexural strength increased as the fiber percentage increases and the maximum value obtained is for mix R8 having 1.5% fiber. There was increase in strength about 11.74% From 0 % fibers to 0.5% fibers, 30.33% from 0.5% to 1% fibers and 12.9% from 1% to 1.5% fibers.

➢ Mixes without fiber have undergone sudden failure showing brittle nature whereas SCC mixes reinforced with fibers have shown ductile nature due to the stretching of fibers during the application of load and holds the beam member from sudden breaking.

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