Flexural Strength of Self Compacting Concrete using Polypropylene Fibres and Fly Ash without Reinforcement

K.S. Johnsirani[1] Dr. A. Jagannathan[2]
[1]Research Scholar [2]Professor
[1,2]Department of Civil Engineering
[1,2]Pondicherry Engineering College Puducherry 605 014

Abstract—Self-Compacting concrete gets compacted due to its own weight without any external vibration. The trial mix whish satisfies the fresh concrete properties as per EFNARC guidelines and the one which gives maximum compressive strength is used in the work. The proposed experimental program is aimed to evaluate performance of SCC with varying percentage of polypropylene fibers. An attempt has been made to study the fresh and hardened properties of self-compacting concrete with 10% of class F flyash to the weight of cement and super plasticizer. The self-compacting concrete with 0.1% of polypropylene fiber satisfies EFNARC guidelines and showed better results when compared to other trial mixes.

Key words: SCC, Polypropylene Fibres, Fly Ash, Superplasticizer, Flexural Strength

I. INTRODUCTION

Self-compacting concrete (SCC) is considered as a concrete which can be placed and compacted under its self-weight with little or no vibration effort, and which is at the same time cohesive enough to be handled without segregation or bleeding of fresh concrete. SCC mixes usually contain superplasticizer, high content of fines and/or viscosity modifying additive (VMA). Whilst the use of superplasticizer maintains the fluidity, the fine content provides stability of the mix resulting in resistance against bleeding and segregation. The use of fly ash and blast furnace slag in SCC reduces the dosage of superplasticizer needed to obtain similar slump flow compared to concrete mixes made with only Portland cement. It is estimated that SCC may result in up to 40% faster construction than using normal concrete. The special rheological properties of SCC could be achieved, through the use of chemical and mineral admixtures and mixture modifications, including:

- Superplasticizer (SP)
- Viscosity Modifying Agent (VMA)
- Fly ash (FA),
- Reduced water/powder ratio(powder = cement + FA)
- Limited coarse aggregate size and content

Significant water reduction ability of SPs is essential to provide the necessary workability; high fluidity, however, can increase the tendency of a mix to segregate. Therefore maintaining homogeneity is an important issue for the quality control of SCC. Polycarboxylate Ether (PCE) based superplasticizers represent a major breakthrough in concrete technology as they can reduce the water requirement by as much as 40% and impart very high workability that can be extended up to 60 minutes for good flowability (the diameter of slump flow is larger than 600mm) without the undesirable effects of postponement and segregation. With proper use of viscosity modifying agents, SCC could achieve higher flowability and higher slump without segregation, and also maintain better slump retention, thus making concrete also more durable.

Polypropylene (PP), also known as polypropene, is a thermoplastic polymer used in a wide variety of applications including packaging and labeling, textiles (e.g., ropes, thermal underwear and carpets), stationery, plastic parts and reusable containers of various types, laboratory equipment, loudspeakers, automotive components, and polymer banknotes. An addition polymer made from the monomer propylene, it is rugged and unusually resistant to many chemical solvents, bases and acids.

II. PREVIOUS STUDY

Zoran grdic et al (2008)[1] studied the properties of self-compacting concrte with defferent types of additives and this work presents the properties of self-compacting concrete, mixed with different types of additives: flyash, silica fume, hydraulic lime and a kixture of flyash and hydraulic lime.

C.Selvamony et al [2] in his investigations on self - compacted self –curing concrete using lime stone powder and clinkers indicated the use of silica fume in concrete significantly increased the dosage of Superplasticizer (SP). Silica fume can better reducing effect on total water absorption while quarry dust and lime powder will not have the same effect, at 28 days

Kazumasa Ozawa [3] carried out an research on the development of self-compacting concrete. Ozawa (1989) completed the first prototype of self-compacting concrete using materials already on the market. By using different types of superplasticizer, he studied the workability of concrete and developed a concrete which was very workable.

S. Deepa shri et al [4] carried out an research on the development of self-compacting concrete, in their study they analyzed the mechanical properties of SCC with polypropylene fibers at different ratios and found the optimum percentage of 0.3 percentage of cement and they also utilized the silicon fume as a partial replacement of cement. According to their studies they made the following conclusion.

- The mix (1:1.2:0.8) satisfies the fresh concrete properties as per EFNARC Guidelines with the average compressive strength of 27.2 N/mm2.
- As the percentage of polypropylene fiber increases, the strength characteristic of concrete also increases
- Addition of 0.3% polypropylene fiber and 25% silica fume increases the cube compressive strength by 19%, splitting tensile strength by 61% and flexural strength by 54%.

III. PROPERTIES OF MATERIALS USED

A. Cement

Ordinary Portland cement of 53 grade from the local market was used and tested for physical and chemical properties as per IS: 4031 – 1988and found to be conforming to various specifications as per IS: 12269-1987.

1) Normal consistency: 30%
2) Initial setting time: 95 min
3) Final setting time: 155 min
4) Specific gravity: 3.01
5) Compressive strength
   - 7 days :37 N/mm2
   - 14 days: 47 N/mm2
   - 28 days: 53 N/mm^2

B. FlyAsh

Class F fly ash is designated in ASTM C 618 and originates from anthracite and bituminous coals. It consists mainly of alumina and silica and has a higher LOI than Class C fly ash. Class F fly ash also has a lower calcium content than Class C fly ash.

1) Typical Oxide Composition of Fly Ash

Sl No	Characteristics	Percentage
1	Silica, Sio_2	49-67
2	Alumina Al_2O_3	16-28
3	Iron Oxide Fe_2O_3	10-Apr
4	Lime CaO	0.7-3.6
5	Magnesia MgO	0.3-2.6
6	Sulphur Trioxide SO_3	0.1-2.1
7	Loss On Ignition	0.4-1.9
8	Surface Area M_2/Kg	230-600

Table 1: Typical Oxide Composition of Fly Ash

C. Super Plasticizer

Super plasticizer is essential for the creation of SCC. The job of SP is to impart a high degree of flow ability and deformability, however the high dosages generally associate with SCC can lead to a high degree of segregation. CON XL – PCE (VMA blended) is utilized in this project, which is a product of Don Chemicals having a specific gravity of 1.222. Super plasticizer is a chemical compound used to increase the workability without adding more water i.e. spreads the given water in the concrete throughout the concrete mix resulting to form a uniform mix. SP improves better surface expose of aggregates to the cement gel. The property of the sp used is shown below.

Properties of Super Plasticizer	
Name	CON XL 8860 PCE (VMA Blended)
Form Or State	Liquid
Type	Polycarboxylate Ether
Color	Dark ambient color
Specific Gravity	1.14
Solid content	40%
Chlorine content	Nil
Water Reduction	Reduces Upto 40% Of W/C Ratio And Other Mix Parameters
P[H]	8.0

Table 2: Properties of Super Plasticizer

D. Polypropylene Fiber

Polypropylene fiber is a unique technology that creates additional micro fibrils that are attached to the principle fibrillated network. These additional anchorage sites provide increased bonding between the mortar matrix and the fiber network. The increased performance attributable to Master Fiber F100 product makes it an excellent candidate as a shrinkage and temperature (secondary) reinforcement. Additionally, Master Fiber F100 product exhibits excellent finishing properties, which is atypical for fibrillated polypropylene fibers. It also provides reinforcement against cracking due to plastic shrinkage and settlement.

Properties	**Values**
Absorption	Nil
Specific Gravity	0.91
Fiber Length	6 mm – 10 mm
Thermal Conductivity	Low
Modulus of Elasticity	5.52 GPa
Melt Point	320 °F (160 °C)
Ignition Point	1,094 °F (590 °C)
Electrical Conductivity	Low
Alkali Resistance	Excellent
Aspect Ratio	29
Tensile Strength	415 MPa

Table 3: Polypropylene fiber Properties

E. Fine Aggregate

In the present investigation fine aggregate is natural sand from local Quarry is used. The physical properties of fine aggregate, specific gravity and fineness modulus are tested in accordance with IS: 2386.

Property	**Result**
Fineness modulus	2.72
Specific gravity	2.69

Table 4: Polypropylene fiber Properties

F. Coarse Aggregate

The crushed coarse aggregate of 12.5 mm maximum size rounded obtained from the local crushing plant, Mailam is used in the present study. The physical properties of coarse aggregate like specific gravity, bulk density, gradation and fineness modulus are tested in accordance with IS ; 2386.

Properties	**Result**
Fineness modulus	6.15
Specific gravity	2.72

Table 5: Physical properties of coarse aggregate

Cement	**Fly ash**	**Fine aggregate**	**Coarse Aggregate**	**water**	**Super plasticizer**
Kg/m^3	Kg/m^3	Kg/m^3	Kg/m^3	Lit/m^3	% of cement
431.05	47.89	561.96	1158.68	191.6	Upto 5%

Table 6: Conventional Mix Ratio=0.4:1:1.173:2.42

SCC is not achieved by the above proportion

G. Modification According To EFNARC Guidelines

Using the conventional mix proportion = 1:1:2:0.4

Cement	**Fly ash**	**Fine aggregate**	**Coarse Aggregate**	**water**	**Super plasticizer**
Kg/m^3	Kg/m^3	Kg/m^3	Kg/m^3	Lit/m^3	% of cement
490.5	54.5	545	1090	216	Upto 5%

SCC condition is not achieved

After many trail mix SCC condition is achieved by the following proportion

Cement	**Fly ash**	**Fine aggregate**	**Coarse Aggregate**	**water**	**Super plasticizer**
Kg/m^3	Kg/m^3	Kg/m^3	Kg/m^3	Lit/m^3	% of cement
540	60	840	720	216	4
22.5 %	2.5 %	35%	30%	9%	4% of cement
1	0.11	1.56	1.33	0.4	4%

SCC mix proportion = 0.4:: 1: 0.11 : 1.56 : 1.33

H. Trial Mixes

S. No.	Mix	Cement	Fly ash	Fine Agg.	Coarse Agg.	Water	PP Fiber	Super plasticizer
		Kg/m^3	Kg/m^3	Kg/m^3	Kg/m^3	Lit/m^3	% of cement	% of cement
1	SCC0	540	60	840	720	216	Nil	4
2	SCC1	540	60	840	720	216	0.05%	4
3	SCC2	540	60	840	720	216	0.10%	4
4	SCC3	540	60	840	720	216	0.15%	4
5	SCC4	540	60	840	720	216	0.2%	4

Table 7: Trial Mixes

IV. TESTING AND RESULTS

A. Slump Flow & T50 Test

Slump flow is one of the most commonly used SCC tests at the current time. This test involves the use of slump cone used with conventional concretes as described in ASTM C 143(2002).The main difference between the slump flow test and ASTM C 143 is that the slump flow test measures the "spread" or "flow" of the concrete sample once the cone is lifted rather than the traditional "slump" (drop in height) of the concrete sample. The T50 test is determined during the slump flow test. It is simply the amount of time the concrete takes to flow to a diameter of 50 centimeters .Typically, slump flow values of approximately 24 to 30 inches are within the acceptable range; acceptable T50 times range from 2 to 5sec.

Fig. 1: Slump Flow & T50 Test

B. L-Box Test

The L-box value is the ratio of levels of concrete at each end of the box after the test is complete at each end of the box after the test is complete. The L-box consists of a "chimney "section and a "trough "section after the test is complete, the level of concrete in the chimney is recorded as H1,the level of concrete in the trough is recorded as H2.The L-box value(also referred to as the "L-box ratio", "blocking value", or "blocking ratio")is simply H2/H1.Typical acceptable values for the L-box value are in the range of 0.8 to 1.0.If the concrete was perfectly level after the test is complete, the L-box value would be equal to 1.0.Conversely,if the concrete was too stiff to flow to the end of the trough the L-box value would be equal to zero.

C. V-Funnel Test & Funnel Test at T5 Minutes

V-funnel test is used to determine the filling ability (flow ability) of the concrete with a maximum aggregate size of 20 mm. The funnel is filled with about 12 liters of concrete and the time taken for it to flow through the apparatus is measured .After this the funnel can be refilled concrete and left for 5 minutes to settle .If the concrete shows segregation then the flow time will increase significantly.

Fig. 2: V-Funnel Test & Funnel Test at T5 Minutes

Acceptance Criteria For SCC (Typical range of values)				
S. No.	Method	Unit	Mini.	Maxi.
1.	Slump flow test	Mm	650	800
2.	T50cm slump flow	Sec	2	5
3.	V-funnel test	Sec	6	12

4.	V-funnel at T5minutes	Sec	6	15
5.	L-Box test	H2/H1	0.8	1.0

Table 8: Acceptance Criteria for SCC (Typical range of values)

V. PREPARATION OF SCC SPECIMENS

A. Proportioning

The quantity of cement, fine and coarse aggregates, fly ash, water and SP for each batch of proportion is prepared as mentioned in design of SCC.

B. Mixing of Concrete

Mixing of the SCC is carried out by the manual mixing, the best homogeneous mix is achieved by 5 minutes continuous mixing after placing all the materials. Initially the tray is moisture with a cloth. Cement, fly ash and sand are mixed thoroughly to form the dry mixture with the gravel. And the 50 % of the water is added with it and then mixed well, after that every 10 % of the water, which is mixed with superplasticizer is added with it. SCC is achieved by increasing the SP content.

C. Moulds

The concrete is casted in to cube moulds of size 100mm×100mm,beam moulds of size 100×100×500mm and cylindrical moulds of 200 mm height ×150 mm dia. The moulds used for the purpose are fabricated with steel seat. It is easy for assembling and removal of the mould specimen without damage. Moulds are provided with base plates, having smooth to support. The mould is filled without leakage .In assembling the moulds for use joints between the section of the mould are applied with a thin coat mould oil and similar coating of mould oil is applied between the contact faces of mould and the base plate to ensure that no water escape during filling .The interior surfaces of the assembled mould shall be thinly coated with mould oil to prevent adhesion of concrete.

D. Placing of Mix in Moulds

After mixing the proportions in the mixing machine, it is taken out into the bucket. The concrete is placed in to the moulds (cubes, beams & cylinders), which are already oiled simply by means of hands only without using any compacting devises. It is important that the concrete should be poured at a minimum height of 50cm from the mould to avoid the air entertainment and good finish.

E. Curing

After 24 hours the specimens were removed from the moulds and immediately submerged in clean fresh water and kept there until taken out just prior to testing.

VI. TESTS ON HARDENED SCC SPECIMENS

In this study hardened state properties considered are Compressive strength of cubes for 7 and 28 days, and Flexural strength for beams with and without reinforcement for 28 days.

A. Compressive Strength of Concrete

Compressive strength of concrete is defined as the load, which causes the failure of a standard specimen.(Ex 100 mm cube according to ISI)divided by the area of cross section in uniaxial compression under a given rate of loading. The test of compressive strength should be made on 150mm size cubes.

Fig. 3: Compressive strength test

B. Split Tensile Strength of Concrete & Flexural Strength of Concrete

A concrete cylinder of size 150mm dia×200mm height is subjected to the action of the compressive force along two opposite edges, by applying the force in this manner .The cylinder is subjected to compression near the loaded region and the length of the cylinder is subjected to uniform tensile stress.

Horizontal tensile stress=$2P/\pi DL$
Where
P=the compressive load on the cylinder.
L=length of the cylinder
D=dia of cylinder

Fig. 4: Split tensile strength test

Fig. 5: Flexural Strength test

Fig. 6: Failure of beam without Reinforcement

VII. RESULTS FOR FRESH CONCRETE TESTS

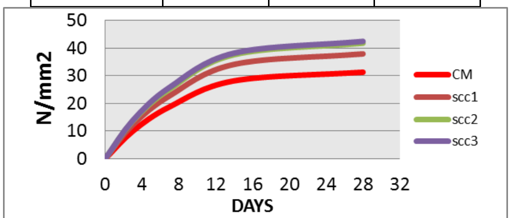
Trail Mix	Slump flow	T 50CM	V funnel T_{0mins}	V funnel T_{5mins}	H2/H1
	Value obtained (mm)	Value obtained (sec)	Value obtained (sec)	Value obtained (sec)	Value obtained
SCC0	680	3	9	11.8	0.9
SCC1	680	3	11.22	13.5	0.9
SCC2	670	4	12.78	32	0.89
SCC3	650	5	13.5	38	0.8
SCC4	620	6.5	18.5	45	0.75

Table 9: Results

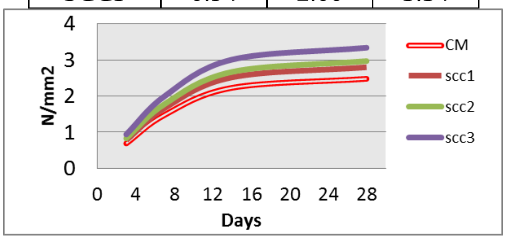
A. Properties of Hardened Concrete

The compressive strength of cubes, split tensile strength of cylinders and flexural strength of beams without reinforcement without fiber and with fiber are tabulated below

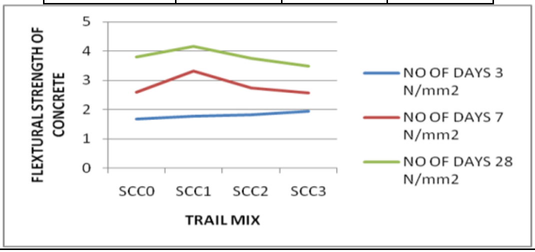
Compressive Strength of Concrete			
Trail Mix	No of Days		
	3	7	28
	N/mm^2	N/mm^2	N/mm^2
SCC0	9.95	18.78	31.29
SCC1	12.27	22.75	37.91
SCC2	13.62	25.15	41.78
SCC3	13.85	25.81	42.44



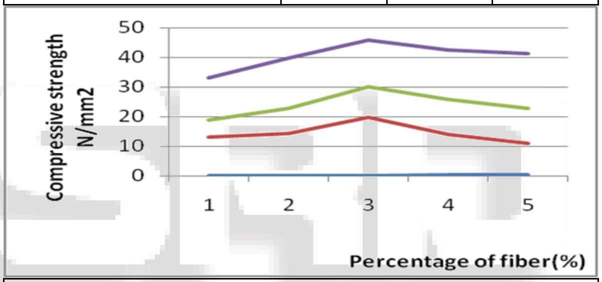
Split Tensile Strength of Concrete			
Trail Mix	No of Days		
	3	7	28
	N/mm^2	N/mm^2	N/mm^2
SCC0	0.69	1.48	2.48
SCC1	0.78	1.67	2.8
SCC2	0.83	1.78	2.97
SCC3	0.94	2.00	3.34



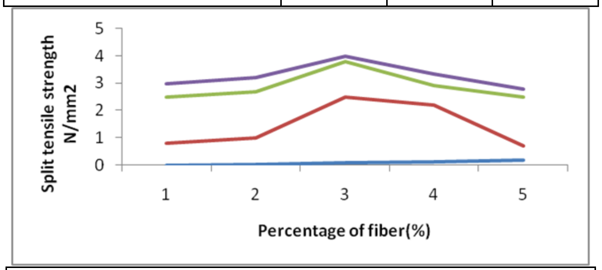
Flexural Strength Of Concrete			
Trail Mix	No of Days		
	3	7	28
	N/mm^2	N/mm^2	N/mm^2
SCC0	1.69	2.58	3.79
SCC1	1.78	3.32	4.15
SCC2	1.83	2.74	3.74
SCC3	1.94	2.56	3.48



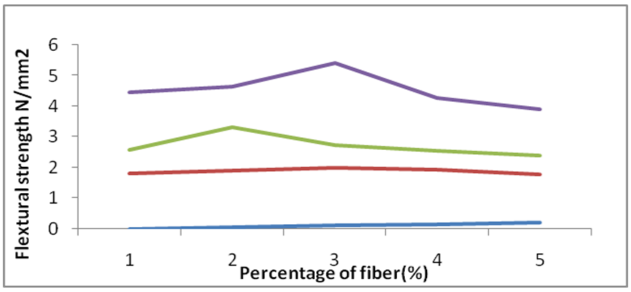
Compressive strength N/mm2			
Percentage of Fiber(%)	No of days		
	3	7	28
	N/mm^2	N/mm^2	N/mm^2
0	12.95	18.78	33.2
0.05	14.27	22.75	39.9
0.1	19.62	30.15	45.78
0.15	13.85	25.81	42.44
0.2	10.95	22.78	41.29



Split tensile strength N/mm2			
Percentage of Fiber(%)	NO OF DAYS		
	3	7	28
	N/mm^2	N/mm^2	N/mm^2
0	0.8	2.48	2.98
0.05	1	2.67	3.2
0.1	2.5	3.78	3.97
0.15	2.2	2.9	3.34
0.2	0.7	2.48	2.78



Flextural strength N/mm2			
Percentage of fiber(%)	No of Days		
	3	7	28
	N/mm^2	N/mm^2	N/mm^2
0	1.8	2.58	4.46
0.05	1.9	3.32	4.65
0.1	2	2.74	5.41
0.15	1.94	2.56	4.29
0.2	1.78	2.4	3.91



VIII. CONCLUSION

Based on the experiment of the study of polypropylene reinforced self-compacting concrete the following conclusions are arrived.

- In the fresh state of concrete as the percentage of fibres increases slump flow value decreases.
- In the hardened state of concrete there is no considerable increase in compressive strength of concrete, but there is a noticeable increase flexural strength of concrete by the addition of Polypropylene fibres.
- In the hardened state of concrete there is an overall increase in strength of concrete both in compressive and flexural strength for the 0.1% addition Polypropylene fibres

A. Percentage of increase in strength of SCC

- Compressive strength:
- 7 days:

Increase in compressive strength by 17.42% and 28 days: Increase in compressive strength by 9.0% for M30 .

- Flexural strength:
- Without Reinforcement: Increase in flexural strength by 21.30% for M30

REFERENCES

[1] The European Guidelines for Self Compacting Concrete May 2005.
[2] Guidelines for Viscosity Modifying Admixtures For Concrete September 2006.
[3] IS 3812-2003, Pulverized FuelAsh specification, part 1 for use as pozzolana in cement, cement mortar and concrete.
[4] N. Bhanumathidas &N. Kalidas 2002-FlyAsh for Sustainable Development.
[5] V. M. Malhotra and AARamezanianpour March 1994, FlyAsh In Concrete
[6] Hajime Okamura and Masahiro Ochi "Self-Compacting Concrete" journal of advanced concrete technology Vol.1, No 1.5-15. April 2003.
[7] Hashimoto. C., Maruyama.k. and Shimizu.k, „Study on visualization technique for blocking fresh concrete flowing in pipe‟ , Concrete library international, JSCE,No.12, pp.139-153,March 1989.
[8] IS269-1958, Indian standard specification for ordinary, Rapid hardening and Low heat Portland cement, revised and reprinted, Aug 1965.
[9] IS 269-1989, Indian standard specification for ordinary Portland cement, 33 grade, 4th revision, 1st reprint, June 1991, BIS 19901

