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A Study on Behavior of Chopped Fiber Reinforced Self-Compacting Concrete

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ABSTRACT

The growth of Self Compacting Concrete is revolutionary landmark in the history of construction industry resulting in predominant usage of SCC worldwide nowadays. It has many advantages over normal concrete in terms of enhancement in productivity, reduction in labor and overall cost, excellent finished product with excellent mechanical response and durability. Incorporation of fibers further enhances its properties specially related to post crack behavior of SCC. Hence the aim of the present work is to make a comparative study of mechanical properties of self-consolidating concrete, reinforced with different types of fibers. The variables involve in the study are type and different percentage of fibers. The basic properties of fresh SCC and mechanical properties, toughness, fracture energy and sorptivity were studied. Microstructure study of various mixes is done through scanning electron microscope to study the hydrated structure and bond development between fiber and mix.

The fibers used in the study are 12 mm long chopped glass fiber, carbon fiber and basalt fiber. The volume fraction of fiber taken are 0.0%,0.1%,0.15%,0.2%,0.25% ,0.3%. The project comprised of two stages. First stage consisted of development of SCC mix design of M30 grade and in the second stage, different fibers like Glass, basalt and carbon Fibers are added to the SCC mixes and their fresh and hardened properties were determined and compared.

The study showed remarkable improvements in all properties of self-compacting concrete by adding fibers of different types and volume fractions. Carbon FRSCC exhibited best performance followed by basalt FRSCC and glass FRSCC in hardened state whereas poorest in fresh state owing to its high water absorption. Glass FRSCC exhibited best performance in fresh state. The present study concludes that in terms of overall performances, optimum dosage and cost Basalt Fiber is the best option in improving overall quality of self-compacting concrete.

KEYWORDS: ***glass fiber, carbon fiber, basalt fiber, FRSCC,SCC, etc.***

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INTRODUCTION

Self-compacting concrete was originally developed in Japan and Europe. It is a concrete that is able to flow and fill every part of the corner of the formwork, even in the presence of dense reinforcement, purely by means of own weight and without the need of for any vibration or other type of compaction.

The growth of Self Compacting Concrete by Prof. H.Okamura in 1986 has caused a significant impact on the construction industry by overcoming some of the difficulties related to freshly prepared concrete. The SCC in fresh form reports numerous difficulties related to the skill of workers, density of reinforcement, type and configuration of a structural section, pump-ability, segregation resistance and, mostly compaction. The Self Consolidating Concrete, which is rich in fines content, is shown to be more lasting. First, it started in Japan; numbers of research were listed on the global development of SCC and its micro-social system and strength aspects. Though, the Bureau of Indian Standards (BIS) has not taken out a standard mix method while number of construction systems and researchers carried out a widespread research to find proper mix design trials and self-compact ability testing approaches. The work of Self Compacting Concrete is like to that of conventional concrete, comprising, binder, fine aggregate and coarse aggregates, water, fines and admixtures. To adjust the rheological properties of SCC from conventional concrete which is a remarkable difference, SCC should have more fines content, super plasticizers with viscosity modifying agents to some extent.

As compared to conventional concrete the benefits of SCC comprising more strength like non SCC, may be higher due to better compaction, similar tensile strength like non SCC, modulus of elasticity may be slightly lower because of higher paste, slightly higher creep due to paste, shrinkage as normal concrete, better bond strength, fire resistance similar as non SCC, durability better for better surface concrete.

At initial stage and the hardened state, Inclusion of fibers improves the properties of this special concrete. Considering it, researchers have focused on studied the strength and durability aspects of fiber reinforced SCC which are:

1. Glass fibers
2. Carbon fibers
3. Basalt fibers
4. Polypropylene fibers etc.

EXPERIMENTAL INVESTIGATION ON SELF-COMPACTING CONCRETE

In this study, the mechanical behavior of fiber reinforced self-compacting concrete of M30 grade prepared with basalt fiber, glass fiber and carbon fiber were studied. For each mix six numbers of cubes (150×150×150) mm, three numbers of cylinders (150×300) mm and six numbers prisms (100×100×500) mm were cast and investigations were conducted to study the mechanical behavior, fracture energy behavior, microstructure of plain SCC, basalt fiber reinforced SCC (BFC), glass fiber reinforced SCC (GFC), carbon fiber reinforced SCC (CFC). The observational plan was held up in various steps to accomplish the following aims:

1. To prepare plain SCC of M30 grade and obtain its fresh and hardened properties.
2. To prepare basalt, glass & carbon fiber reinforced SCC of M30 grades and study their fresh and hardened properties.
3. To analyze the load-deflection behavior of SCC, BFRSCC, GFRSCC & CFRSCC.
4. To examine the fracture energy behavior & the micro structure of plain SCC, BFC, and GFC & CFC.
5.

Table 1 Mechanical Properties of Fibers

Fiber variety	Length (mm)	Density (g/cm^3)	Elastic modulus (GPa)	Tensile strength (MPa)	Elong. at break (%)	Water absorption
BASALT	12	2.65	93-110	4100-4800	3.1-3.2	<0.5

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GLASS	12	2.53	43-50	1950-2050	7-9	<0.1
CARBON	12	1.80	243	4600	1.7	

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Table 2 Adopted Mix Proportions of SCC

Cement (kg/m^3)	Silica fume(kg/m^3)	Water(kg/m^3)	FA (kg/m^3)	CA (kg/m^3)	SP (kg/m^3)
450.33	45.03	189.13	963.36	642.24	5.553
1	0.10	0.42	2.14	1.42	0.012

PREPARATION FIBER REINFORCED SELF-COMPACTING CONCRETE

Addition Of Fibers To SCC Mixes

Alkali resistance glass fibers were added in different percentages to the preparedSCCmixes.In the present study and glass fiber reinforced self-compacting concrete (GFC) was prepared. Similarly, the percentages of basalt fibers were added and basalt fiber reinforced self-compacting concrete (BFC) prepared and then the percentages of carbon fiber were added, carbon fiber reinforced self-compacting concrete (CFC) was prepared. After adding fibers to SCC mixes, again the same methods were followed for the determination of properties in the fresh state and hardened state for all these fiber reinforced SCC.

RESULTS OF THE EXPERIMENTAL INVESTIGATIONS ON FRSCC

This chapter deals in detail with the results of experimental investigations and discussion carried out in different stages.

Table 3 Description of Mixes

Designation	Fiber content (%)	Description
PSC	0.0%	Plain self-compacting concrete
BFC-1	0.1%	0.1% Basalt fiber reinforced SCC
BFC-1.5	0.15%	0.15%Basalt fiber reinforced SCC
BFC-2	0.2%	0.2%Basalt fiber reinforced SCC
BFC-2.5	0.25%	0.25%Basalt fiber reinforced SCC
BFC-3	0.3%	0.3%Basalt fiber reinforced SCC
GFC-1	0.1%	0.1%Glass fiber reinforced SCC
GFC-1.5	0.15%	0.15%Glass fiber reinforced SCC
GFC-2	0.2%	0.2%Glass fiber reinforced SCC
GFC-2.5	0.25%	0.25%Glass fiber reinforced SCC
GFC-3	0.3%	0.3%Glass fiber reinforced SCC
CFC-1	0.1%	0.1%Carbon fiber reinforced SCC

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CFC-1.5	0.15%	0.15%Carbon fiber reinforced SCC
CFC-2	0.2%	0.2%Carbon fiber reinforced SCC

RESULTS AND DISCUSSION

Table 4 Results of the Fresh Properties of Mixes

Sample	Slump flow	T_{50} flow	L-Box(H_2/H_1)	V-Funnel	T5 Flow	Remarks
	500-750 mm	2-5sec	0.8-1.0	6-12sec	+3sec	
PSC	720	1.6	0.96	5	9	Low viscosity (Result Satisfied)
BFC-1	680	2.1	0.89	8	12	Result Satisfied
BFC-1.5	645	2.5	0.85	8	13	Result Satisfied
BFC-2	620	3.8	0.81	9	14	Result Satisfied
BFC-2.5	580	5.2	0.68	10	16	High viscosity Blockage (RNS)
BFC-3	520	6	0.59	11	18	Too high viscosity Blockage (RNS)
GFC-1	705	2.0	0.90	7	10	Result Satisfied
GFC-1.5	665	3.8	0.88	7.7	11	Result Satisfied
GFC-2	650	4.7	0.84	8.5	12	Result Satisfied
GFC-2.5	640	5.0	0.82	9	12	Result Satisfied
GFC-3	530	5.9	0.70	11	15	Too high viscosity
CFC-1	560	4.8	0.80	10	14	Result Satisfied
CFC-1.5	410	_	_	18	_	Too high viscosity Blockage (RNS)
CFC-2	260	_	_	23	_	Too high viscosity Blockage (RNS)

Hardened Properties

To compare the various mechanical properties of the FRSCC mixes the standard specimens were tested after 7 days and 28 day of curing. The results are summarized in Table 5

Table- 5 Hardened Concrete Properties of SCC and FRSCC

Mixes	7-Day compressive strength (MPa)	28-days compressive strength (MPa)	28-days split tensile strength (MPa)	28-days flexural strength (MPa)
PSC	33.185	40.89	4.1	7.37
BFC-1	31.11	38.67	3.11	7.84
BFC-1.5	34.22	49.77	4.95	11.4
BFC-2	37.77	50.99	5.517	11.78
BFC-2.5	45.48	61.4	4.52	11.92
BFC-3	20.89	32.89	4.24	7.54
GFC-1	24.88	40.89	2.97	7.44
GFC-1.5	33.77	46.19	4.81	9.74
GFC-2	32.89	47.11	4.95	10.08
GFC-2.5	31.55	45.33	3.96	9.46

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GFC-3	23.55	39.11	3.678	8.32
CFC-1	24.44	42.22	3.82	7.52
CFC-1.5	43.11	62.22	5.23	12.32
CFC-2	40.89	55.2	4.52	10.54

Table 4.4.1 Ultrasonic Pulse Velocity Results

SPECIMEN	7-DAYS AVG. UPV OF CUBE(M/SEC)	28-DAYS AVG. UPV OF CUBE(M/SEC)
PSC	4477.6	4416.34
BFC-1	4275.43	4337
BFC-1.5	4492	4493.67
BFC-2	4498.67	4505.33
BFC-2.5	4537.67	4582.33
BFC-3	4151.34	4298.33
GFC-1	4299.34	4399
GFC-1.5	4486.67	4473
GFC-2	4454	4483.67
GFC-2.5	4296.67	4469.33
GFC-3	4153	4374
CFC-1	4296.67	4434.34
CFC-1.5	4518.6	4629.66
CFC-2	4508.34	4574.67

CONCLUSION

From the present study the following conclusions can be drawn

1. Addition of fibers to self-compacting concrete causes loss of basic characteristics of SCC measured in terms of slump flow, etc.
2. Reduction in slump flow was observed maximum with carbon fiber, then basalt and glass fiber respectively. This is because carbon fibers absorbed more water than others and glass absorbed less.
3. Carbon fiber addition more than 2% made mix harsh which did not satisfy the aspects like slump value, T50 test etc. required for self-compacting concrete.
4. Addition of fibers to self-compacting concrete improve mechanical properties like compressive strength ,split tensile strength, flexural strength etc. of the mix.
5. There was an optimum percentage of each type of fiber, provided maximum improvement in mechanical properties of SCC.
6. Mix having 0.15% carbon fiber, 0.2% of glass fiber and 0.25% of basalt fiber were observed to increase the mechanical properties to maximum.
7. 0.15% addition of carbon fiber to SCC was observed to increase the 7-days compressive strength by 29.9%, 28-days compressive strength by 47.6%, split tensile strength by 27.56%, flexural strength by 67.16%.
8. 0.25% addition of basalt fiber to SCC was observed to increase the 7-days compressive strength by 37.05%, 28-days compressive strength by 50.16%, split tensile strength by 34.56%, flexural strength by 61.736%.
9. 2% addition of glass fiber to SCC was observed to increase the 7-days compressive strength by 1.76%, 28-days compressive strength by 15.21%, split tensile strength by 20.73%, flexural strength by 36.77%.
10. The FRSCC mixes exhibited increase in ductility measured through load deflection diagrams. The basalt fiber reinforced SCC exhibited maximum increment than carbon and glass FRSCC.

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