An Efficacy of Different Percentages of Glass Fibre, Carbon Fibre And Basalt Fibre on The Mechanical Strength Properties of Self Compacting Concrete

D Sasi kumar[1], R Sai teja[2]
[1, 2] Lenora College of Engineering, E.G. Dist., AP

Abstract- *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 mixiThe 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.*

I. 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 However, various investigations are carried out to explore various characteristics and structural applications of SCC. SCC has established to be effective material, so there is a need to guide on the normalization of self-consolidating characteristics and its behavior to apply on different structural construction, and its usage in all perilous and inaccessible project zones for superior quality control

Fiber Reinforced Self-Compacting Concrete There is an innovative change in the Concrete technology in the recent past with the accessibility of various grades of cements and mineral admixtures. However there is a remarkable development, some complications quiet remained. These problems can be considered as drawbacks for this cementatious material, when it is compared to materials like steel. Concrete, which is a „quasi-fragile material", having negligible tensile strength 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 Glass,carbon,basalt fibers.

Basalt Fibers Basalt Fibers are made by melting the quarried basalt rock at about 1400^0C and extrude through small nozzles to create continuous filaments of basalt fibers. Basalt fibers have alike chemical composition as glass fiber but have better-quality strength characteristics. It is extremely resistant to alkaline, acidic and salt attack making it a decent candidate for concrete, bridge and shoreline structures. Compared to carbon and aramid fiber it has wider applications like in higher oxidation resistance, higher temperature range (-269^0C to +650^0C), higher shear and compressive strength etc. Basalt fibers are ascertained to be very efficient in conventional and SCC concrete mixes for improving their properties

Carbon Fibers Carbon fibers have low density, high thermal conductivity, good chemical stability and exceptional abrasion resistance, and can be used to decrease or reduce cracking and shrinkage. These fibers increase some structural properties like tensile and flexural strengths, flexural toughness and impact resistance. Carbon fibers also help to improve freeze-thaw durability and dry shrinkage. The adding of carbon fibers decreases the electrical resistance

II. REVIEW OF LITERATURE

M Ouchi, et al. (1997) the authors have specified the influence of Super Plasticizers on the flow-ability and viscosity of Self Consolidating Concrete. From the experimental investigation author suggested an overview the effect of super plasticizer on the fresh properties of concrete. Author found his studies were very convenient for estimating the amount of the Super Plasticizer to satisfy fresh properties of concrete

GaoPeiwei., et al. (2000) the authors has studiedspecial type of concrete, in which same ingredients are used like conventional concrete. Keeping in mind to produce high performance concrete, mineral and chemical admixtures with Viscosity Modifying Agents (VMA), are necessary. The objective is to decrease the amount of cement in HPC. Preserving valuable natural resources is the primary key, then decrease the cost and energy and the final goal is long- term strength &durability

Raghu Prasad P.S. et al. (2004) the authors has studied that the use of admixtures both initial and final setting times of cement are getting late. This is due to the delayed pozzolanic reaction affected by the addition of particular admixtures. This type of delayed setting property is occasionally helpful during the concreting in summer season. There will also significant strength gain for mixed cements and concretes after 28 days. Due to this reason concrete corrosion will be less

Lachemi M, et al.(2004)the author statedthat to getstable rheology of the SCC use of Viscosity Modifying Agents has been showed to be very operative. To know the appropriateness of four types of poly-carboxylic based VMA for the growth of the SCC mixes was studied. The author found that the new type VMA are the suitable and better for preparing the SCC mix as compared to the commercially accessible VMA. Author also suggested the amount of 0.04% of dosage fulfills the fresh and hardened properties of SCC, which is 6% less than the commercially accessible VMA.

M.Collepardi, et al.(2006)the author studied the role of VMA with the non-availability of the chosen volume range 170-200 liters /m^3 of binding material (max size = 90µm) to create consistent SCC and determined that the combination of VMA and without mineral filler. In such a case, a minor increase convoyed by cement content must be in the dosage of VMA (for instance from 3 to 8 Kg/m^3 to attain an unsegregable SCC without mineral filler. In short, the dosages of mineral and chemical admixtures are necessary in keeping the fresh and hardened properties, and improving the durability characteristics of SCC

Okamura et al. (1995) author established a special type of concrete that flows and gets compacted at every place of the formwork by its own weight. This research work was started combined by prof. Kokubu of Kobe University, Japan andProf. Hajime Okamura. Previously it was used as anti washout concrete. They initiate that for attainment of the self-compact ability, usage of Super Plasticizer was necessary.The water/cement ratio should be in between 0.4 to 0.6. The self-compactability of the concrete is mainly affected by the material characteristics and mix proportions. Author restricted the coarse aggregate content to 60% of the solid volume and the fine aggregate content to 40% to attain self-compact ability

Yin-Wen Chan,et al. (1999)by enhancing the micromechanical parameters which control composite properties in the hardened state, the author developed self-compacting Engineered Cementitious Composite (ECC), and the treating parameters, which control the rheological properties in the fresh state. For the growth of self-compacting ECC, micromechanics was accepted to suitably select the matrix, fiber, and interface properties so as to show strain hardening and various cracking behavior in the composites. Self-compact ability of ECC was then understood by the organized rheological properties of fresh matrix,comprising deformability and flow ratewith the certain ingredient materials. Self-compactability was a result of accepting an optimum mixture of super plasticizer and viscosity modifying agent.

Kung-Chung Hsu, et al. (2001) Authors projected a new mix design technique for SCC and their main emphasis was with binder paste to fill voids of loosely filled aggregate. They familiarized a factor called Packing Factor (PF) for aggregate. It is the ratio of mass of aggregates in firmly packed state to the one in loosely packed state. The method completely influenced bythe Packing Factor (PF). The amount of binders used in the proposed method can be less than that required by other mix design methods due to the increased sand content. Packing factor influence the aggregate content and that affects the fresh properties of concrete.

M. Sonebi,et al. (2002) Thisresearch shows results of fresh properties of self-compacting concrete, like, filling ability measured by slump flow apparatus and flow time measured by orimet apparatus and plastic fresh properties measured by column apparatus. The fresh properties were affected by water/binder ratio, nature of sand, slump were estimated. The fresh tests and hardened test results like compressive strength and splitting tensile strength were compared to a control mix. The properties of fresh SCC improved by increasing in water/binder ratio and nature of sand but the volume of coarse aggregate and dosage of chemical admixture kept constant

Frances Yang,et al. (2004) this paper investigates the technique to develop SCC as well as its components and mix proportioning methods. It highlights several benefits of using SCC and mentions to several tools used to measure its properties. Again, it reports the protective measures that should be taken for preparing and developing the mix and some model applications of SCC was proposed by the author, for example, Toronto International Airport. A high strength SCC was used for constructing compactly reinforced elements poured in beneath freezing weather for the 68 Story Trump Tower in New York cityof USA

T. SeshadriSekhar, et al. (2005) the authors established SCC mixes of grades M30, M40, M50 & M60. Again as compared to the lower grade of SCC mixes, cast 100 mm dia. cylinders so as to test the permeability characteristics by loading in the cells duly applying constant air pressure of 15 kg/mm^2 along with water pressure of $2Kg/ mm^2$ for a definite period of time and found coefficient of permeability to determine that the higher the grade of SCC mixes

Chihuahua Jiang, et al (2014) in this field, the effects of the volume fraction and length of basalt fiber (BF) on the mechanical properties of FRC were Analyzed.The outcomes indicate that adding BF significantly improves the tensile strength, flexural strength and toughness index, whereas the compressive strength shows no obvious gain. Furthermore, the length of BF presents an influence on the mechanical properties

III. METHODOLOGY

3.1 Materials Used And Their Properties;- 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

CEMENT: Portland slag cement of Konark brand available in the local market was used in the present studies. The physical properties of PSC obtained from the experimental investigation were confirmed to IS: 455-1989

FINEAGGREGATE: Aggregate whose sizes are lesser than 4.75 mm are fine aggregate which satisfied the required properties for experimental work and conforms as per the specification of IS: 383- 1970.Sand is a naturally and obviously occurring granular material collected of finely divided rock and mineral particles. The composition of sand is extremely variable, depending on the local rock sources and conditions, but the for the most part frequent constituent of sand in inland continental settings and non-tropical coastal settings is silica (silicon dioxide, or $SiO2$), usually in the form of quartz.

COARSE AGGREGATE: Construction aggregate, or simply "aggregate", is a wide group of coarse particulate material used in construction, as well as sand, gravel, crushed stone, slag, recycled concrete and geo synthetic aggregates. Aggregates are the majority mined materials in the world. Aggregates are a constituent of composite materials such as concrete and asphalt concrete; the aggregate serve as reinforcement to insert strength to the overall composite material Silica fume-Elkem Micro Silica 920D is used as Silica fume. Silica fume is among one of the most recent pozzolanic materials currently used in concrete whose addition to concrete mixtures results in lower porosity, permeability and bleeding because its fineness and pozzolanic reactionGlass Fiber; Alkali resistant glass fiber having a modulus of elasticity of 72 GPA and 12mm length was used

Basalt Fiber: Basalt fiber of 12mm length was used in the investigations

Carbon Fiber: Carbon fiber of length 12mm was used in the investigations3.1

Table 3.1.1 Mechanical Properties of Fibers

Fiber variety	Length (mm)	Density (g/cm^3)	Elastic modulus(GPa)	Tensile strength(MPa)
BASALT	12	2.65	93-110	4100-4800
GLASS	12	2.53	43-50	1950-2050
CARBON	12	1.80	243	4600

Table. 3.2: 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)	LABEL	MATERIALS	DIMENSION (mm)		GRADE	% OF REPLACEMENT
450.33	45.03	189.13	963.36	642.24	5.553			DIAMETER	LENGTH		
1	0.10	0.42	2.14	1.42	0.012	NORMAL CONCRETE	NC	150	300	M 25	-

Mixing Of Ingredients*;* The mixing of materials was properly mixing in a power operated concrete mixer. Adding coarse aggregate, fine aggregates, cement and mixing it with silica fume were properly mixing in the concrete mixer in dry state for a few seconds. Then the water added and mixing it for three minutes. During this time the air entraining agent and the water reducer are also added. Dormant period was 5mins. To obtain the basalt fiber reinforced SCC, glass fiber reinforced SCC, carbon fiber reinforced SCC the requiredfiber percentage was added to the already prepareddesign mix, satisfying the fresh SCC requirements

Compression Test:- For each mix six numbers of cubes of (150×150×150) mm were cast to determine the compressive strength, after the required curing period the compressive strength after 7-days and 28-days. The size of the cube is as per the IS code 10086-1982.

Alkali resistance glass fibers were added in different percentages to the preparedSCC mixes.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

IV. RESULTS OF THE EXPERIMENTAL INVESTIGATIONS ON FRSCC

PREPARATION OF SCC AND FRSCC AND STUDIES ON FRESH AND HARDENED PROPERTIES - The first stage of investigations was carried out to develop SCC mix of a minimum strength M30 grade using silica fume and chemical admixtures, and to study its fresh and hardened properties. For developing SCC of strength M30 grade, the mix was designed based on EFNARC 2005 code using silica fume as mineral admixture. Finally, SCC mixes which yielded satisfactory fresh properties and required compressive strength, were selected and taken for further investigation. In the second stage of investigation SCC with different fiber contents with different volume fraction were mixed. The mix proportions are shown in table 3.2.1

Water/cement Ratio of Self-Compacting Concrete To maintain the basic characteristics of self-compacting concrete a water cement ratio of 0.42 was adopted and a % dosage of super-plasticizer Viscocrete of Sika brand were fixed for all mixes

Mix Proportions and Fiber Content- The number of trial mixes was prepared in the laboratory and satisfying the requirements for the fresh state given by EFNARC 2005 code . The present work involved preparation of M30 grade SCC and to study its behavior when different types of fibers were added to it. Plain SCC of M30 grade was prepared using silica fume as mineral admixture with sika viscocrete as admixture

Table 4.1.1 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 fiberreinforced SCC
GFC-2	0.2%	0.2%Glass fiber reinforced SCC
GFC-2.5	0.25%	0.25%Glass fiberreinforced SCC
GFC-3	0.3%	0.3%Glass fiber reinforced SCC
CFC-1	0.1%	0.1%Carbon fiberreinforced SCC
CFC-1.5	0.15%	0.15%Carbon fiber reinforced SCC
CFC-2	0.2%	0.2%Carbon fiberreinforced SCC

Results and Discussion

Table 4.2.1 Results of the Fresh Properties of Mixes

sample	Slump flow 500-750mm	T_{50} flow 2-5sec	L-Box(H_2/H_1)0.8-1.0	V-Funnel 6-12sec	T5 Flow +3sec	Remarks
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 Blockage (RNS)
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)

Table- 4.3.1 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
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

Compressive Strength

7-Days Compressive Strength: Compared to the plain SCC the compressive strength reinforced with basalt fiber of volume fraction 0.15%, 0.2% and 0.25% increase by 3.12%, 13.82% and 37.05% respectively. Compared with the plain SCC the compressive strength reinforced with glass fiber of volume fraction 0.15% increase by 1.76%. In this study the 7 days compressive strength of glass fiber shows no obvious improvement. Compared with the plain SCC the compressive strength reinforced with carbon fiber of 0.15% and 0.2% increase by 29.9% and 23.22% respectively

28-Days Compressive Strength

From Fig.4.3.5.Compared with plain SCC, 0.15% of BFC, GFC and CFC increase 21.72%, 10.52% and 47.6% respectively. For 0.2% of BFC, GFC and CFC increase 24.7%, 15.21% and 35% respectively. For 0.25% of BFC and GFC increases 50.16% and 11% respectively. In this study, Fig.4.2.4 shows that the optimum dosages for BFC are 0.25%, for GFC is 0.2% & for CFC is 0.15%

Split Tensile Strength: The percentage enhancement of split tensile strength for basalt fiber over plain SCC is 20.44%, 34.56%, 10.24% & 3.41% when adding 0.15%, 0.2%, 0.25% & 0.3% respectively. The percentage enhancement of split tensile strength for glass fiber over plain SCC is 17.31%, 20.73% when adding 0.15% & 0.2% respectively. The percentage enhancement of split tensile strength for carbon fiber over plain SCC is 27.56% & 10.24% respectively. The increase is due to the fiber as explained before

Flexural Strength: Table 4.3.1 & Fig. 4.3.7 shows flexural strengths of FRSCC mixes after 28 days and fig.4.2.8 shows the optimum fiber fraction imparting maximum flexural strength with different fibers. As expected, all FRSCC specimens show an increase in flexural strength with increase in fiber content. Compared with the plain SCC the enhanced percentage of the flexural strength of carbon FRSCC were observed in the range of 2.03% to 67.16% while 0.15% gave maximum strength. Increase in flexural strength were observed in ranges from 0.95% to 36.77% for GFC with the fiber percentage of 0.1% to 03% ,the and enhanced percentage flexural strength ranges from 2.37% to 61.736% were observed for basalt fiber with percentage fiber ranges from 0.1% to 0.3%. Maximum flexural strength 12.32MPa was observed for carbon FRCCC for 1.5% of fiber percentage.

V. CONCLUSIONS

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
11. Basalt FRSCC exhibited better properties in fresh state and hardened state compared to the Glass FRSCC. In terms of the cost it is cheaper than carbon hence basalt fiber performance is overall best compared with glass and carbon fiber

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