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EXPERIMENTAL INVESTIGATION OF FIBER REINFORCED SELF COMPACTING CONCRETE

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ABSTRACT:- Self compacting concrete (SCC) is a special type of concrete that can flow and compact under its own weight. Due to its excellent deformable and segregation resistance property, full compaction can be achieved without vibration in form works with heavy and congested reinforcement and at the same time it is cohesive enough to be handled without segregation. Fibers are added to enhance its ductility, toughness, tensile strength and to reduce drying shrinkage. In this experimental work a simple mix design method viz NAN SU method is followed to proportionate the mix design of self compacting concrete (SCC) of grade M50 and M60. At the same time, it should satisfy the EFNORC guidelines for the workability at fresh state and strength requirement at hardened state. Two SCC mixes have been developed with GGBS as mineral admixture and recron 3s and glass fibers separately. These recron 3s and glass fibers are added to M50 and M60 grades in deferent percentages like 0.25%,0.5%,0.75% fresh FRSCC separately by volume of binder and then fresh and hardened properties of the resultant mixes have been studied.

Tests have been carried out on cubes and cylinders of SCC with and without addition of Fibers to find out compressive and split tensile strengths. The volume and length of fibers combined with cementanious material in the mix influences the flow properties of wet mix. To identify this, recron 3s and glass fibers of length 12 mm and diameter 30 microns in dosages varying from 0.25% to 0.75% by volume of the binder were added. Due to the influence of maximum fiber factor unacceptable results for workability of fresh mix due to a phenomenon such as blockage of spaces through the vertical bars of L-Box is predicted. So, to reduce this, the fibers of length and dosage not more than 12 mm and 0.75% by volume of binder respectively may be used to satisfy the EFNARC workability requirements of fresh concrete. The compressive strength of SCC is found to be more or less constant whereas, the split tensile strength increases with increase in fiber content.

I.INTRODUCTION

Concrete is a type of homogeneous mixture which plays a prominent role in development of Infra-Structure and new innovative Structures in Civil Engineering. It is a mixture of different Materials such as Cement, Fine Aggregate, Coarse Aggregate and Water. Concrete it-self has an extensive role among construction materials. To enhance the workability of Concrete, Admixtures are to be added. The mix is now a tough and homogenous material which is to satisfy adequate workability with durable conditions. To compact the concrete without voids, internal and external vibration is required. To achieve good compaction of concrete, vibration is to be done. It is difficult to vibrate the concrete at places of congested reinforcement.

Concrete is one of the world's most widely used materials. Every day, research is carried out such as to improve the performance of concrete in various ways through various approaches for different applications. One such advancement in concrete led to the development of Self Compacting Concrete (SCC) by Okamura in the 1986 due to the unavailability of skilled workers for proper compaction and vibration of concrete in Japan.Fiber Reinforced self-Compacting Concrete is a type of concrete consisting of discrete fibers which are added to SCC and has an ability to compact under its own weight. Hardened properties of concrete are increased by the addition of fibers. Fiber reinforced self compacting concrete should satisfy the workability properties specified by theEFNARC[2]guidelines. These fibers acts as crack arresters and increases the structural integrity.

II. LITERATURE REVIEW

Hajime Okamura of Tokyo University first introduced the SCC in the year 1986.The main aim behind the concept of Self-Compacting Concrete is to overcome the difficulty of non availability of skilled labour. Non availability of skilled workers led to sub-standard construction of structures, in turn causing serious durability related problems. Khayatet al[30] had proposed the application of SCC in the members with congested reinforcement. This valuable characteristic of Self-Compacting Concrete encourages its use in heavily reinforced members which are popularly used today.

Rajamaneet al studied the properties of HPC in which cement was replaced partially with GGBS. They identified that the 28 days cube strength increased by 10.2MPa in comparison with the Conventional Concrete showing the increased strength efficiency of GGBS.

Bhalachandra and Pawase followed rational method to proportionate SCC of M30 grade and identified the significant improvements in the cube strength of mix containing fly ash upto 33%by the cement weight with the 3% of type 1 dramix 8040 hook-end fibers. At the3% dosage, the 7 days average cube strength increases from 35.55Mpa to 43.14Mpa and at 28 days increases from 45.63Mpa to 70.04Mpa over the Normal mix.

Mazaheripour et al (2013) conducted a comparative study on the behavior of glass fibre reinforced polymer concrete (GFRPC) and steel fiber reinforced self-compacting concrete (SFRSCC). Results showed that pull-out failure occurred in all the specimens. SFRSCC cover thickness and bond length affected the ultimate value of the bond stress of GFRP bars.

Zheng et al (2007) developed a tri-linear relationship between moment and curvature. The results were compared with the test data of five concrete beams reinforced with glass fiber reinforced polymer (GFRP) bars tested under two-thirds-point flexure until failure. It showed that there was a good correlation between the experimental and theoretical results.

Wegian and Abdalla (2005) evaluated the shear capacity of concrete beams and slabs reinforced with different types of fibre reinforced polymer (FRP) bars. Seven prototype concrete beams reinforced with glass fibre reinforced polymers (GFRP) and carbon fibre reinforced polymers (CFRP) were subjected to four-point loading up to failure. Steel stirrups were used as shear reinforcement in all the beams. Based on this investigation a simplified expression for the shear capacity of FRP reinforced concrete members was introduced.

III. MATERIALS

A. CEMENT

Cement is a grey color fine powder which is a mixture of calcareous and argillaceous material used for binding between the materials of concrete. In this dissertation ordinary Portland cement(Deccan) of 53 grade has been used in accordance with IS 12269:1987.

Table 1. Properties of cement

Physical properties	Test result	Test method/ Remarks	Requirement as per IS 12269 (1987)
Specific gravity	3.15	IS 4031(1988) – part 11	-
Fineness (m^2/Kg)	311.5	Manufacturer data	Min.225 m^2/kg
Standard consistency	34%	IS 4031 (1988)- part 4	-
Initial setting time (min)	33	IS 4031 (1988)- part 5	Min. 30 min
Final setting time (min)	500	IS 4031 (1988)- part 5	Max. 600 min

B. FINE AGGREGATES

River sand confirming to ZONE-II in accordance withIS 383 (1970)[26] has been used as fine aggregate. The water absorption and specific gravity of sand according to IS 2386 (Part III, 1963)[27] are 1% and 2.65 respectively and the fineness modulus of the sand was observed as 3.38. Grading of fine aggregate was done by sieve analysis according to IS 383 (1970). The properties if fine aggregate used in this experimental investigation is as follows.

1. Specific gravity= 2.51
2. Fineness modulus = 3.38
3. The Bulk density of loosely packed aggregate =1450kg/m^3
4. The maximum size of fine aggregate used = 2mm.

C. COARSE AGGREGATE

Crushed granite stones of size not greater than 12.5 mm are used as coarse aggregate. And the properties of coarse aggregate are as follows.

1. Specific Gravity of coarse aggregate = 2.52 as per IS 2386 (Part III, 1963)[27]
2. The bulk density of loosely packed aggregates = 1550kg/m^3.

D. GGBS

Ground granulated blast furnace slag is a nonmetallic product consisting essentially of silicates and aluminates of calcium and other bases. The moulten slag is rapidly chilled by quenching in water to form a glassy sand like granulated material the granulated material then further ground to less thab 45 microns will have specific surface of above 400 to 600 m^2/kg.

Specific gravity of GGBS = 2.92

E. SUPER PLASTICIZER

New generation super plasticizer Glenium B233 confirming to IS 9103 – 1999 has been used to reduce the water demand of concrete. It is a Poly Carboxylate Ether (PCE) based superplasticizer of recent origin. And this avoids the use of viscosity modifying agent (VMA) that which is used for maintaining the stability of the fresh mix. And the properties of superplasticizer are as follows.

1. Specific gravity = 1.08
2. pH valve = 6.82
3. solid content = 40%
4. aspect = reddish brown liquid

F. WATER

Water suitable for drinking confirming to IS – 3025-1983 is used. Its pH value is 7.21.

G. RECRON 3S FIBERS

Recron 3s fibers polyester staple fibers for mixing in concrete and mortar for improving certain properties of the concrete and mortar and fibers have special triangular shape for better anchoring with other ingredients of the mix. The fibers are made from polymerization of pure teraphthalic acid and mono ethylene glycol using catalyst. recron 3s fibers are available in 6mm and 12mm length. Properties of Recron 3s fibers are as follows.

Length of the fiber = 12mm

Diameter of the fiber = 30microns

Aspect ratio = 400

Specific gravity = 1.36

Density = 1360kg/m^3

H. GLASS FIBERS

Glass fibers are also called as fiber glass. It is a material made from extremely fine fibers of glass. These fibers are light weight and extremely strong. Glass fibers are useful because of their high ratio of surface area to weight. The propertys of glass fibers are as fallows

Length of the fiber =12mm

Diameter of the fiber =30 microns

Aspect ratio =400

Specific gravity =2.68

Elastic modulus (GPa) =72

Tensile strength (MPa) =1700

IV. METHODOLOGY

A. FIXING OF MIX PROPORTIONS

Here I used **NAN SU MIX DESIGN METHOD** for fixing of mix proportions of Self Compacting Concrete. The following procedure shall be followed to design the mix proportions of Self Compacting Concrete.

Step 1:- Calculation Of Coarse And Fine Aggregate Contents
Step 2:- Calculation Of Cement Content

Step 3:- Calculatin Of Mixing Water Content Required By Cement

Step 4:- Calculation Of GGBS Content

Step5:- Calculation Of Mixing Water Content Needed In SCC

Step 6:- Calculation Of SP Dosage

Step 7:- Adjustment Of Mixing Water Content Needed In SCC

Step 8:- Trail Mixes And Tests On SCC Properties

Step 9:- Adjustment Of Mix Proportion

Table 2. Mix proportion of m50 grade scc for one cubic meter

CEMENT	GGBS	FINE AGGREGATE	COARSE AGGREGATE	WATER	SUPER PLASTICIZER
416.07kg	206.12kg	837.375kg	732.375kg	218.38kg	9.33kg

B. MIXING

Mixing procedures have a major influence on the workability of SCC. It is to be carried out very carefully to obtain desirable fresh properties. In this dissertation, ordinary concrete mixer has been used. The following mixing procedure shall be followed:

1. Powder content and both aggregates were mixed for one minute.
2. After thorough mixing of aggregates and binder 70% of mixing water is added to the dry mix and allowed to mix for 2 minutes.
3. After two minutes of mixing with some amount of mixing water Super plasticizer is added to about (15%) of remaining water and mixed for two minutes.
4. Finally VMA is blended to the mix with the remaining water and mixed for two minute.
5. Finally fibers are to be added to the concrete and mixed for one minute to avoid balling of fibers. After completion of process of mixing, it is discharged for SCC tests.

Table 3. Fresh properties of scc mix

TESTS	RESULT	SPECIFICATION
SLUMP CONE	750mm	650mm – 800mm
L – BOX	0.9	0.8 – 1.0
V- FUNNEL	8sec	6sec – 12sec

C. CASTING OF SPECIMENS

Well shaped cubical moulds of 150mm size and cylindrical moulds of 150 mm diameter and 300mm height are to be used to cast the cubes and cylindrical specimens. The moulds should free from dust particles and grease is to be applied on the inertial surface of the moulds. Level the top surface with trowel after concreting the moulds. These moulds are to be kept on a level surface to maintain unique shape.

Note:
• SCC doesn't need tampering and vibration.
• Layering of concrete can be avoided.

D. CURING OF SPECIMENS

Curing of the specimens should be done with clean and pure water with-out acids under ambient temperature. In order to maintain proper water circulation between cubes in tank spacing should be maintained properly. Specimens are cured for 7 and 28days for the experimental study on hard concrete.

V. RESULTS

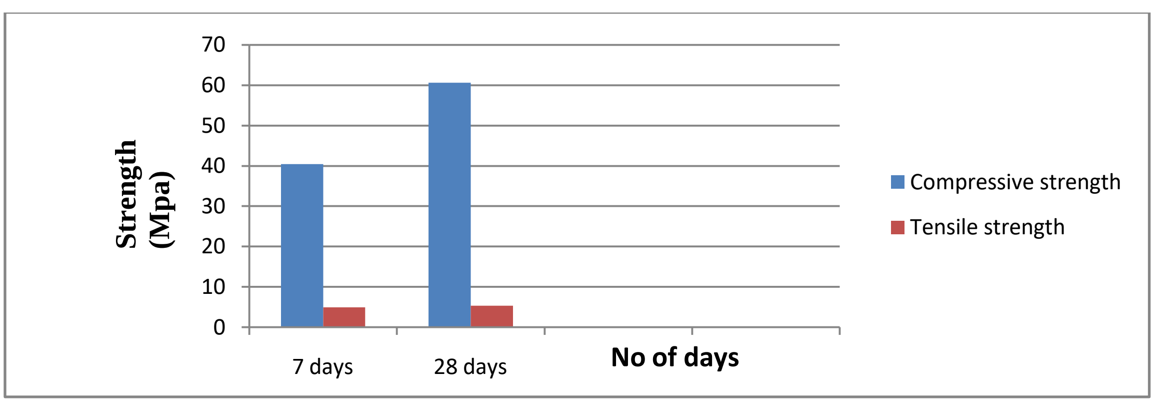

Fig. 1: compressive and split tensile strengths of m50 grade normal concrete

A. FRESH PROPERTIES OF SCC WITH 0% FIBERS

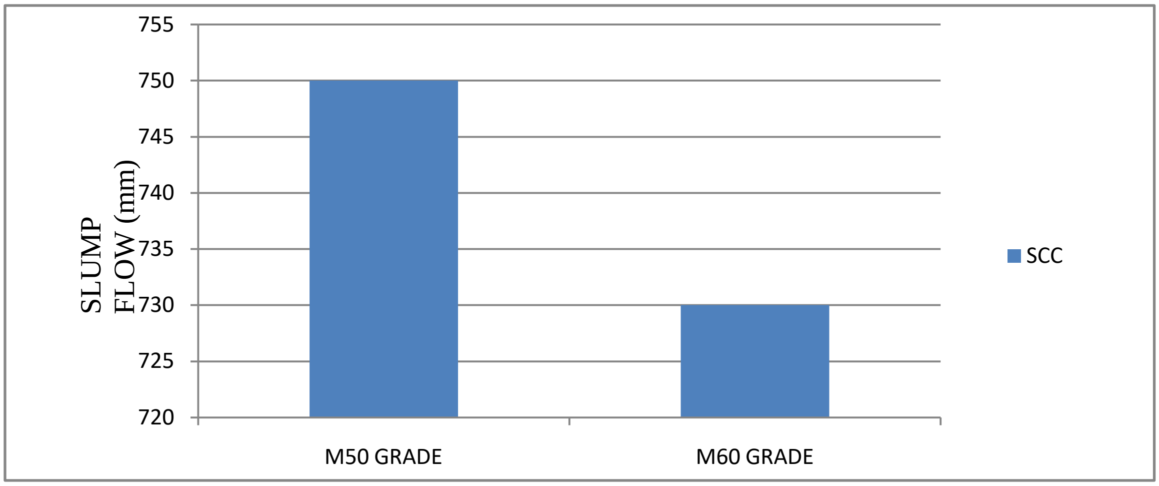

Fig. 2: slump flow results of fresh scc with 0% of fibers

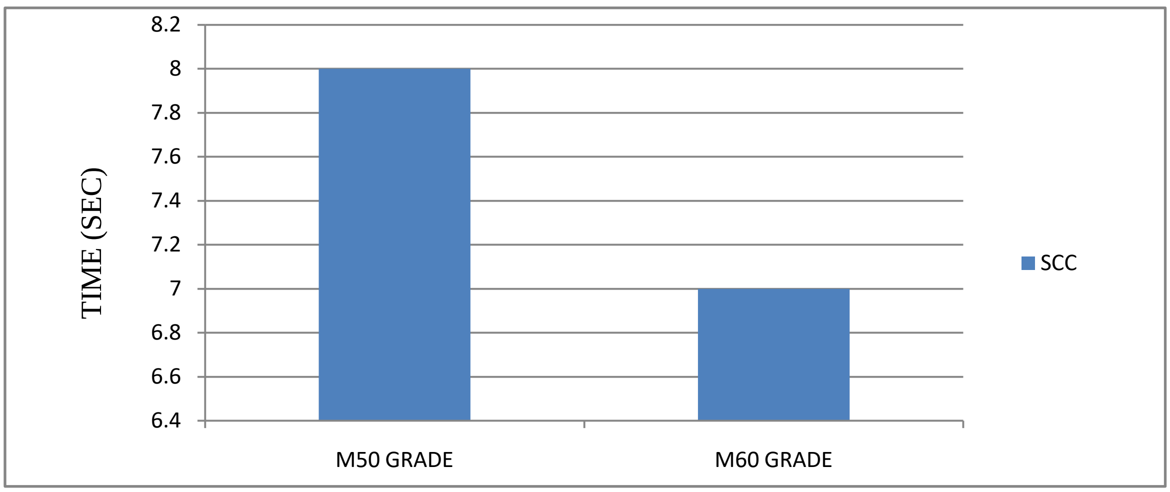

Fig.3: v- funnel test results of fresh scc with 0% of fibers

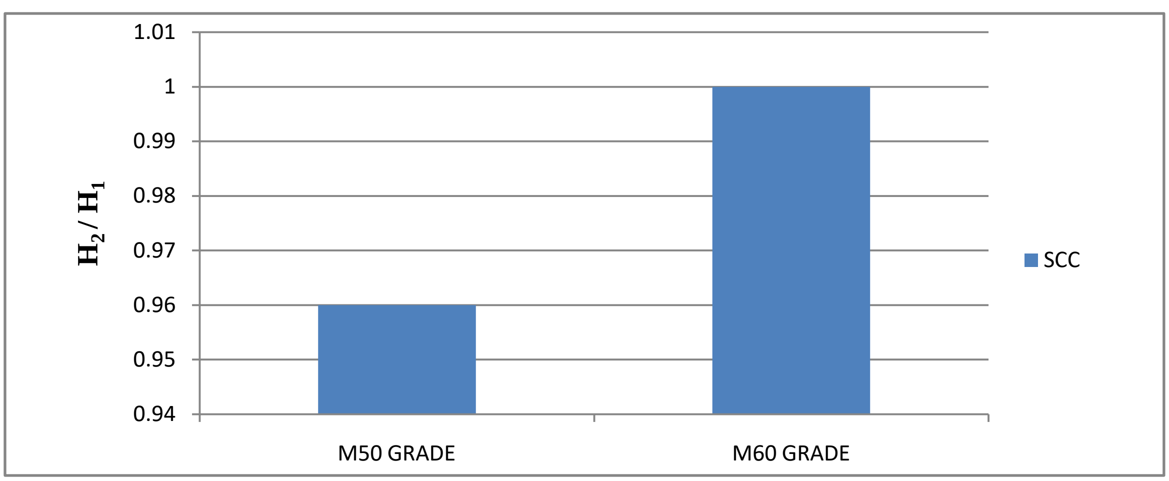

Fig. 4: l- box test results of fresh scc with 0% of fibers

B. HARDENED PROPERTIES OF SCC WITH 0% FIBERS

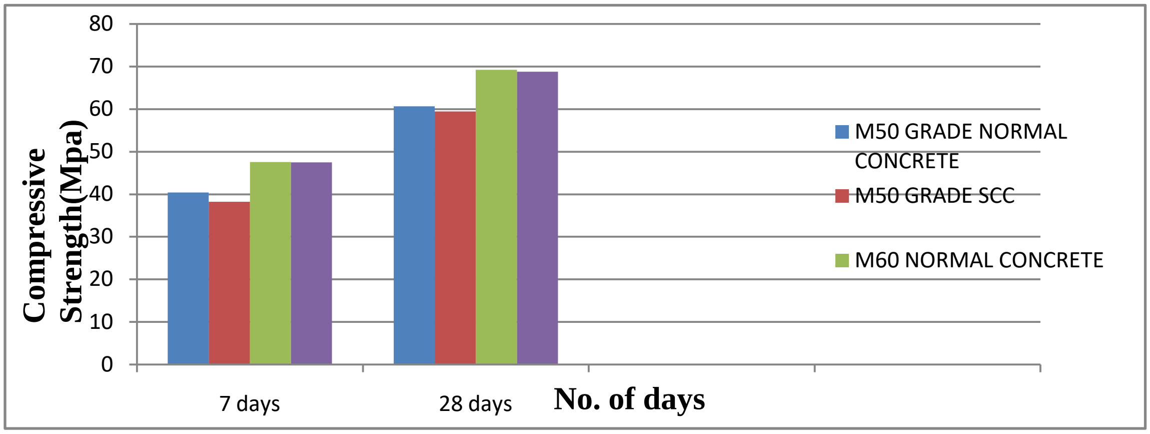

Fig. 5: compressive strength of concrete with 0% of fibers

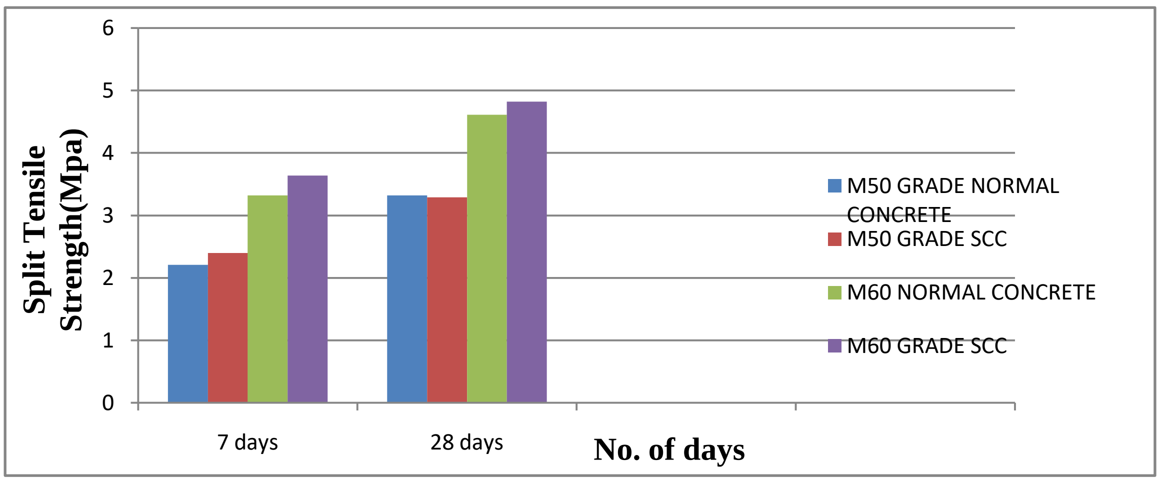

Fig. 6: split tensile strengths of concrete with 0% of fibers

C. FRESH PROPERTIES OF FIBER REINFORCED SELF COMPACTING CONCRETET (FRSCC)

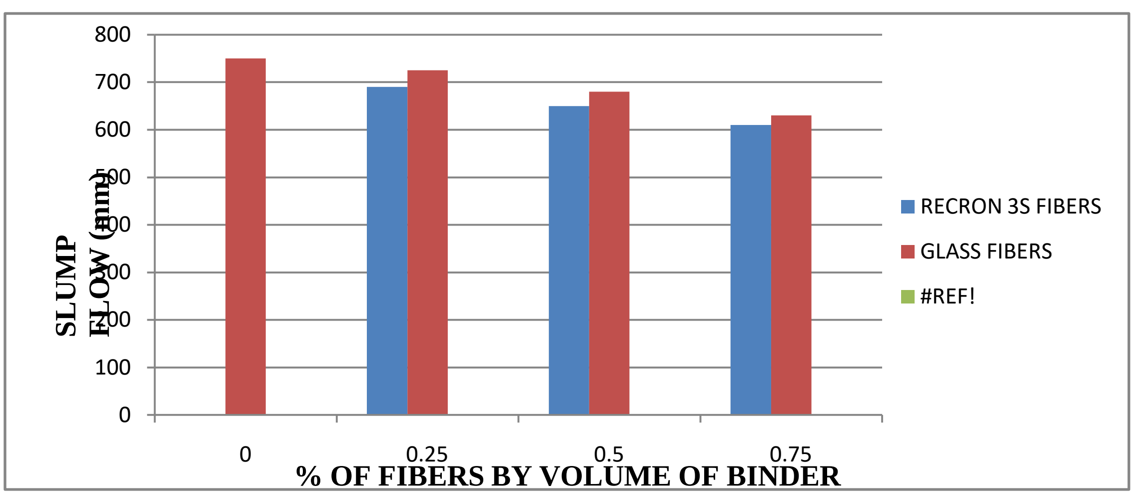

Fig. 7: slump flow test results of fresh m50 grade frscc

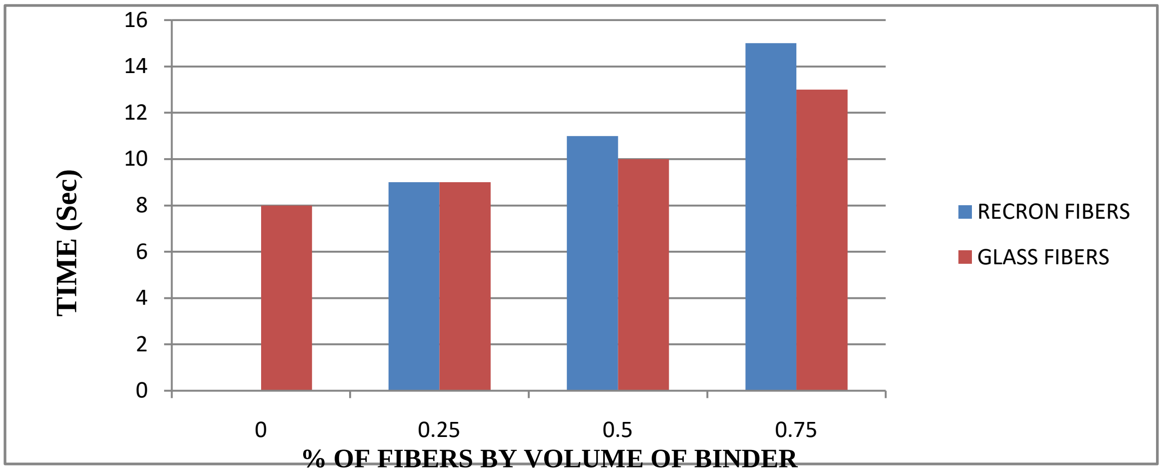

Fig. 8: v - funnel test results of fresh m50 grade frscc mixes

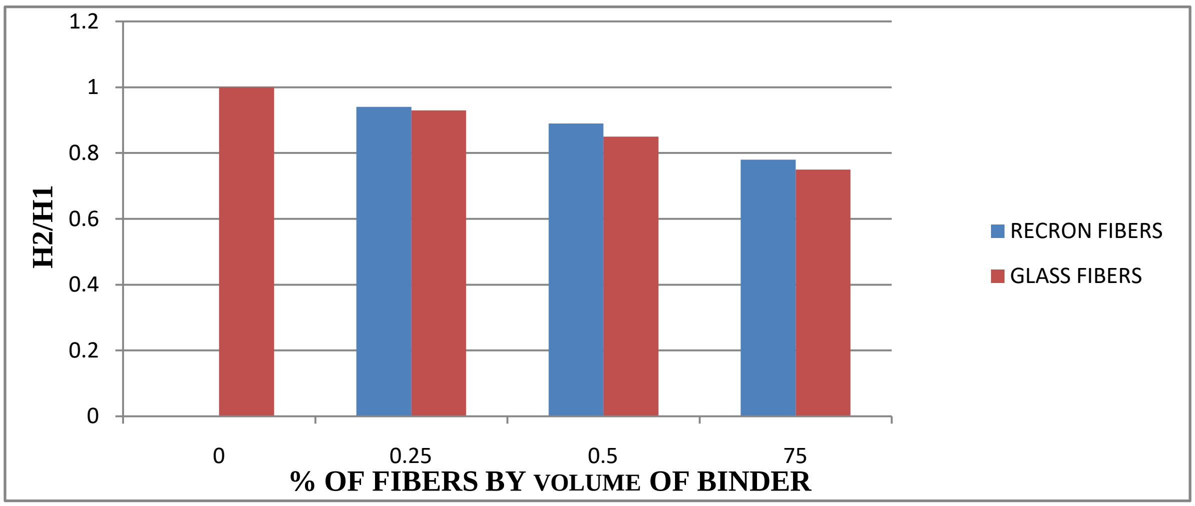

Fig. 9: l -box test results of fresh m50 frscc mixes

D. HARDENED PROPERTIES OF FIBER REINFORCED SELF COMPACTING CONCRETE

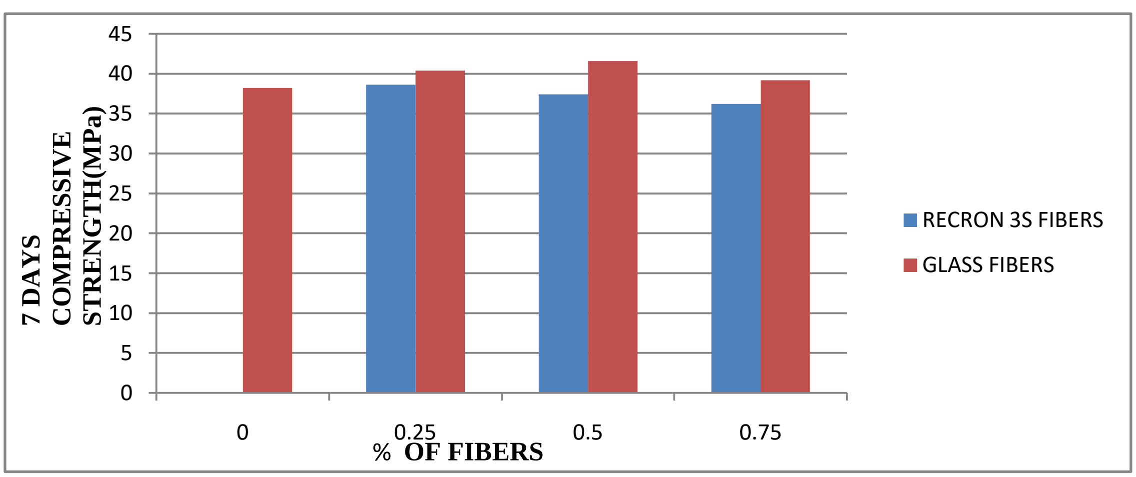

Fig.10:7 days compressive strength of m50 grade frscc for various percentages of fibers

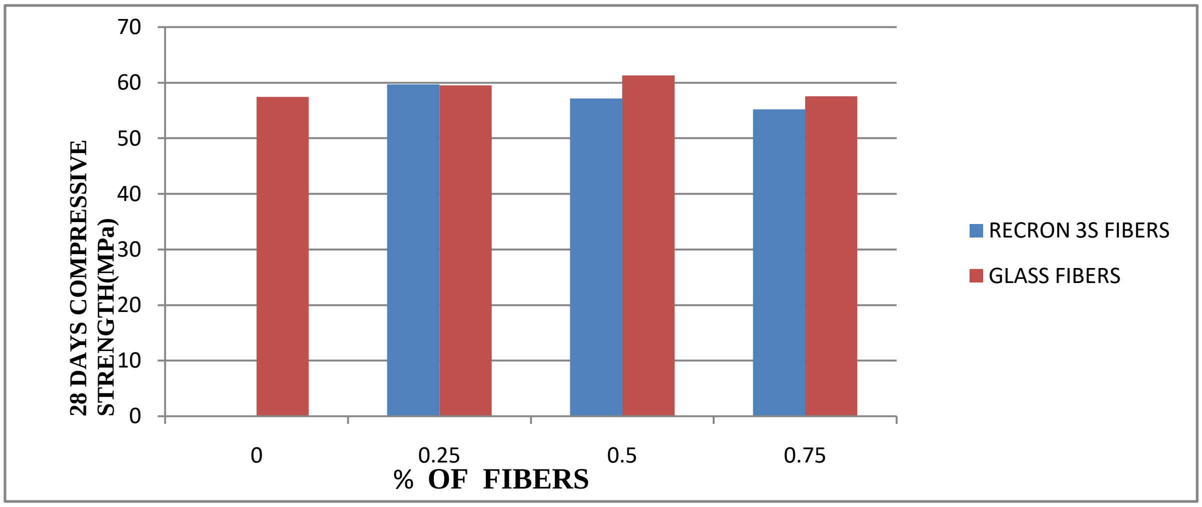

Fig. 11:28 days compressive strength of m50 grade frscc for various percentages of fibers

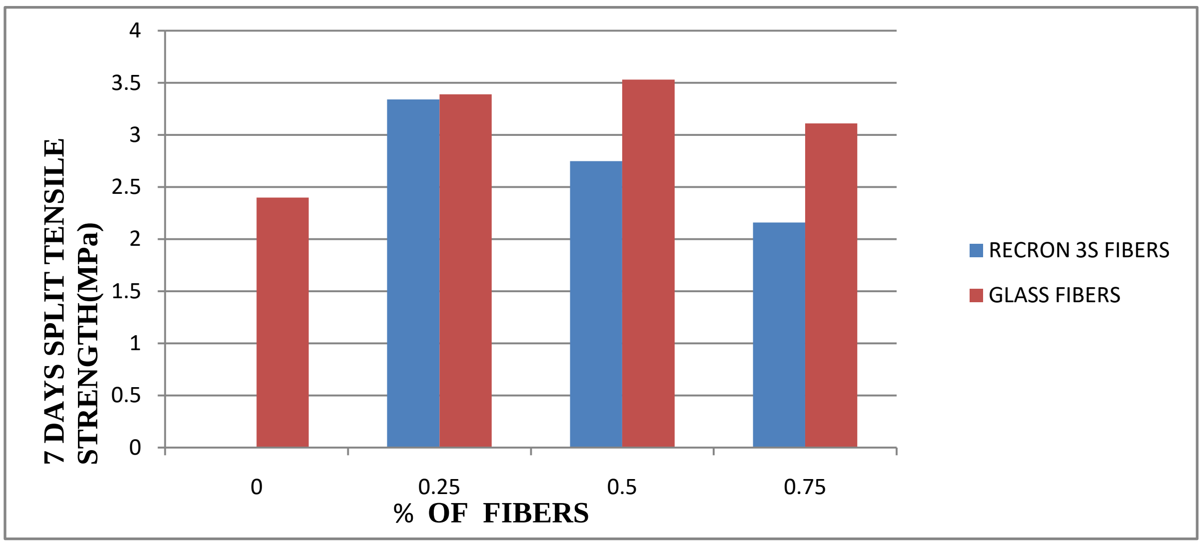

Fig.12: 7 days split tensile strength of m50 grade frscc for various percentages of fibers

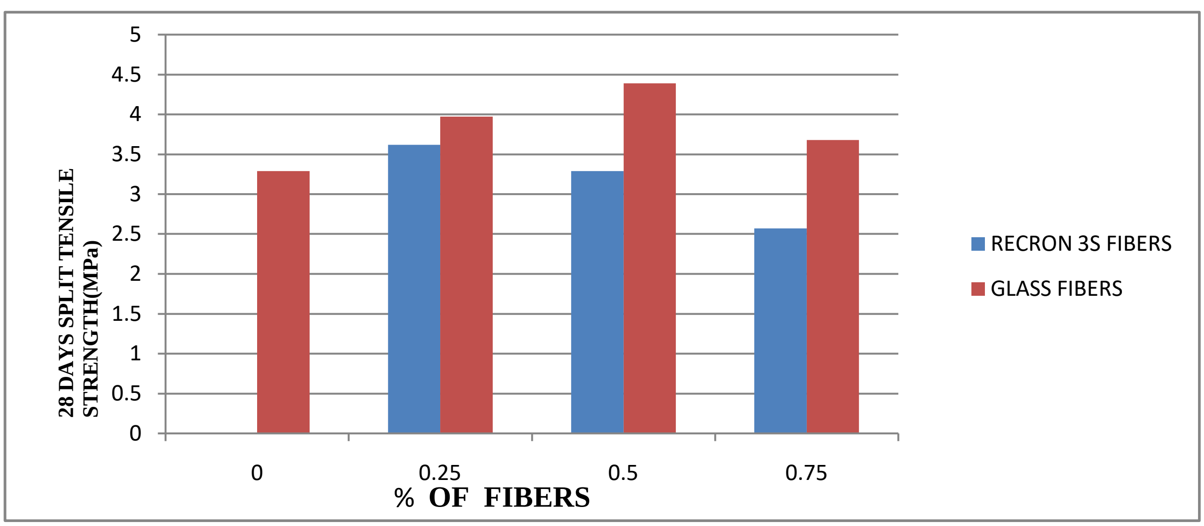

Fig. 7.13: 28 days split tensile strength of m50grade frscc for various percentages of fibers

VI. DISCUSSIONS

I. FRESH CONCRETE PROPERTIES

A. WORKABILITY OF FRESH SCC WITH 0% OF FIBERS

1. For M50 grade SCC the filling and passing abilities such as slump flow, V – funnel and L – box test results are 750mm, 8sec and 0.96 respectively.
2. For M60 grade SCC the filling and passing abilities such as slump flow, V – funnel and L – box test results are 730 mm, 7sec and 1.0 respectively.

B. WORKABILITY OF M50 GRADE FRESH SCC WITH DIFFERENT PERCENTAGES OF RECRON 3S FIBERS

1. Addition of 0.25% of fibers by volume of binder, the workability properties such as slump flow, V – funnel time and L – box ratio are found to be reduced by 8%, 11.1% and 2.08% respectively when compared to FRSCC with 0% of fibers.
2. Addition of 0.5% of fibers by volume of binder to the SCC mix reduced the workability properties such as slump flow, V – funnel time and L – box ratio are found to be reduced by 13.33%, 27.27% and 6.12% respectively when compared to SCC with 0% of fibers.
3. Reduction in workability by 18.66%, 46.66% and 18.75% has been observed in slump flow, V– funnel and L – box test results respectively when 0.75% of fibers by volume of binder were added to the SCC mix and the results cannot satisfied the workability requirements of SCC.

C. WORKABILITY OF M50 GRADE FRESH SCC WITH DIFFERENT PERCENTAGES OF GLASS FIBERS

1. SCC with 0.25% of fibers by volume of mix, the workability properties such as slump flow, V – funnel time and L – box ratio are found to be reduced by 3.33%, 12.5% and 3.12% respectively, addition of 0.50% fibers to the SCC mix reduced results by 9.33%, 20.0% and 9.37% respectively.
2. Addition of 0.75% of fibers to the SCC mix reduced the workability results drastically when compared to the SCC mix with 0% of fibers. Therefore, the mix cannot be referred to as self compacting concrete.

II. HARDENED PROPERTIES

A. COMPRESSIVE STRENGTH OF HARDENED SCC OF GRADES M50 AND M60

1. For Self compacting concrete of grade M50, the compressive strengths for 7 and 28 days are 38.21 MPa and 59.46 MPa respectively.
2. For M60 grade Self compacting concrete, the compressive strengths for 7 and 28 days are 47.47 MPa and 68.76 MPa respectively.

B. COMPRESSIVE STREGTH OF M50 GRADE HARDENED SCC WITH DIFFERENT PERCENTAGES OF RECRON 3S FIBERS

1. For FRSCC with 0.25% of fibers by volume of binder, the 7 and 28 days compressive strength increases by 1.11% and 3.73% respectively when compared to SCC with 0% of fibers.
2. Addition of 0.5% of fibers by volume of binder, the FRSCC mix decreases the 7 day and 28 days compressive strength by 2.06% and 0.48% when compared to SCC with 0% of fibers.
3. Decrease in 7 and 28 days average compressive strength of FRSCC mix added at 0.75% of fibers by volume of binder has been observed as 5.26% and 3.93%.

C. COMPRESSIVE STREGTH OF M60 GRADE HARDENED SCC WITH DIFFERENT PERCENTAGES OF RECRON 3S FIBERS

1. For FRSCC with 0.25% of fibers by volume of binder, the 7 and 28 days compressive strength increases by 2.74% and 1.34% respectively when compared to SCC with 0% of fibers.
2. Addition of 0.5% of fibers by volume of binder, the FRSCC mix decreases the 7 day and 28 days compressive strength by 2.40% and 02.07% when compared to SCC with 0% of fibers.
3. Decrease in 7 and 28 days average compressive strength of FRSCC mix added at 0.75% of fibers by volume of binder has been observed as 5.37% and 3.81%.

D. COMPRESSIVE STREGTH OF M50 GRADE HARDENED SCC WITH DIFFERENT PERCENTAGE OF GLASS FIBERS

1. The 7 and 28 days average compressive strength of FRSCC mix added at 0.25% of fibers by volume of binder increases by 5.42% and 3.50% respectively with respect to SCC at 0% of fibers.
2. Addition of 0.5% of fibers by volume of binder to the FRSCC mix increases the 7 and 28 days compressive strength by 8.14% and 6.31% respectively when compared to SCC with 0% of fibers.
3. Marginal increase in 7 and 28 days average compressive strengths of FRSCC mix added at 0.75% by volume of mix have been observed as 2.52% and 0.15 respectively.

E. COMPRESSIVE STREGTH OF M60 GRADE HARDENED SCC WITH DIFFERENT PERCENTAGE OF GLASS FIBERS

1. The 7 and 28 days average compressive strength of FRSCC mix added at 0.25% of fibers by volume of binder increases by 3.04% and 1.91% respectively with respect to SCC at 0% of fibers.
2. Addition of 0.5% of fibers by volume of binder to the FRSCC mix increases the 7 and 28 days compressive strength by 4.40% and 2.74% respectively when compared to SCC with 0% of fibers.
3. Decrease in 7 and 28 days average compressive strengths of FRSCC mix added at 0.75% by volume of mix have been observed as 0.29% and 0.62 respectively.

F. SPLIT TENSILE STRENGTH OF HARDENED SCC

1. For M50 grade Self compacting concrete, the split tensile strengths for 7 and 28 day are found to be 2.4MPa and 3.29MPa respectively.
2. For M60 grade Self compacting concrete, the split tensile strengths for 7 and 28 days are found to be 3.64MPa and 4.82MPa respectively.

G. SPLIT TENSILE STREGTH OF M50 GRADE HARDENED SCC WITH DIFFERENT PERCENTAGE OF RECRON 3s FIBERS

1. For FRSCC with 0.25% of fibers by volume of binder, the 7 and 28 days split tensile strength increases by 28.14% and 9.11% respectively when compared to SCC with 0% of fibers.
2. Addition of 0.5% of fibers by volume of binder to the FRSCC mix increases the split tensile strength by 12.72%and 1% respectively when compared to SCC with 0% of fibers.
3. Decrease in 7 and 28 days average split tensile strength of FRSCC mix added at 0.75% by volume of binder has been observed to be 10%and 12.76% respectively.

H. SPLIT TENSILE STREGTH OF M60 GRADE HARDENED SCC WITH DIFFERENT PERCENTAGE OF RECRON 3s FIBERS

1. For FRSCC with 0.25% of fibers by volume of binder, the 7 and 28 days split tensile strength increases by 13.94% and 8.01% respectively when compared to SCC with 0% of fibers.
2. Addition of 0.5% of fibers by volume of binder to the FRSCC mix decreases the split tensile strength by 3.84%and 8.5% respectively when compared to SCC with 0% of fibers.
3. Decrease in 7 and 28 days average split tensile strength of FRSCC mix added at 0.75% by volume of binder has been observed to be 8.51%and 17.0% respectively.

I. SPLIT TENSILE STREGTH OF M50 GRADE HARDENED SCC WITH DIFFERENT PERCENTAGE OF GLASS FIBERS

1. The 7 and 28 days average split tensile strength of FRSCC mix added at 0.25% of fibers by volume of mix increases by 29.2% and 17.12% respectively.
2. Addition of 0.5% of fibers by volume of to binder to the FRSCC mix with 0% of fibers increases the 7 and 28 days average split tensile strength by 32.01%and 25.05% respectively when compared to SCC with 0% of fibers.
3. Increase in 7 and 28 days average split tensile strength of FRSCC mix added at 0.75% of fibers by volume of binder has been observed as 22.82% and 10.59% respectively.

J. SPLIT TENSILE STREGTH OF M60 GRADE HARDENED SCC WITH DIFFERENT PERCENTAGE OF GLASS FIBERS

1. The 7 and 28 days average split tensile strength of FRSCC mix added at 0.25% of fibers by volume of mix increases by 21.55% and 14.84% respectively.
2. Addition of 0.5% of fibers by volume of to binder to the FRSCC mix with 0% of fibers increases the 7 and 28 days average split tensile strength by 16.12%and 18.16% respectively when compared to SCC with 0% of fibers.
3. increase in 7 and 28 days average split tensile strength of FRSCC mix added at 0.75% of fibers by volume of binder has been observed as0.54 % and 2.03% respectively.

VII. CONCLUSIONS

1. The Packing Factor of aggregate determines the aggregate content in the mix and influences the strength, flow ability and passing ability of self compacting concrete because, the mix contains more sand but less coarse aggregates which enhances the passing ability through gaps of reinforcement.
2. The workability of Recron 3s fiber reinforced SCC such as slump flow diameter, L-box ratio and V-funnel time has been decreased considerably when compared with Glass fiber reinforced SCC. And it is due to increase in resistance to flow by combined action of large fiber length and 12.5mm size aggregate. These properties can be improved by using fibers of reduced length.
3. The compressive strength of SCC increases marginally, where as the tensile strength increases considerably with addition of fibers. The percentage increase in tensile strength of FRSCC with 0.25% of Recron 3s fibers and that of for FRSCC with 0.5% of glass fibers.
4. The tensile strength of fiber reinforced self compacting concrete deceases with the addition of 0.75% of glass fibers and 0.5% of Recron 3s fibers.
5. When the fibers of 0.75% in volume of binder were added to the mix, the fresh concrete lost its flow properties and hence the concrete cannot be referred to as Self compacting concrete.
6. Self compacting concrete can be used in cases of congested reinforcement areas to avoid honeycombing.

Fiber reinforced self-compacting concrete helps in arresting the micro cracks and improves the ductility of the concrete.

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