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EXPERIMENTAL STUDY ON HYBRID FIBER SELF COMPACTING CONCRETE

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Abstract:

Self-Compacting Concrete is a recently developed concept in which the ingredients of the concrete mix are proportioned in such a way that it can flow under its own weight to completely fill the formwork and passes through the congested reinforcement without segregation and self-consolidate without any mechanical vibration. Several studies in the past have revealed the usefulness of fibres to improve the structural properties of concrete like ductility, post crack resistance, energy absorption capacity etc. Fiber reinforced self-compacting concreting combines the benefits of self-compacting concrete in fresh state and shows an improved performance in the hardened state due to the addition of fibers. In this project, glass fibres and polyester fibres were added to self-compacting concrete and Hybrid Fibre Reinforced Self Compacting Concrete was developed. An attempt has been made to study mechanical properties of self-compacting concrete and glass fibre reinforced self-compacting concrete with addition of mild steel reinforcement. A strength based mix proportion of self-compacting concrete was arrived based on Nan-Su method of mix design and the proportion was fine-tuned by using Okamura's guidelines. Self-compacting concrete mixes with partial replacement of cement by mineral admixture like fly ash were taken for investigation with and without incorporating glass fibres and polyester fibres.

Key Words: Self Compacting Concrete, Segregation, Hybrid Fibre, Nan-Su Method, Okamura's Guidelines & Mineral Admixture

1. Introduction:

Current scenario in the building industry shows increased construction of large and complex structures, which often leads to difficult concreting conditions. When large quantity of heavy reinforcement is to be placed in reinforced concrete members it is difficult to ensure that the form work gets completely filled with concrete that is fully compacted without voids or honeycombs. Vibrating concrete in congested locations may cause some risk to labour and there are always doubts about the strength and durability of concrete placed in such locations. One solution for the achievement of durable concrete structures independent of the quality of construction work is the employment of Self Compacting Concrete (SCC). SCC is that concrete which is able to flow under its own weight and completely fill the formwork without segregation, even in the presence of dense reinforcement, without the need of any vibration whilst maintaining homogeneity. Hybrid Fiber Reinforced Concrete (HFRC) is composed of concrete, reinforced with glass fibers and polyester fibres to produce a thin, lightweight, yet strong material. Though concrete has been used throughout the ages, HFRC is still a relatively new invention. High compressive and flexural strengths, ability to reproduce fine surface details, low maintenance requirements, low coefficients of thermal expansion, high fire resistance, and environmentally friendly made HFRC the ideal choice for civil engineers. The strength of HFRC is determined by glass content, fiber size, fiber compaction, distribution and orientation.

2. Materials Properties:

Cement: Ordinary Portland cement of 53 grades available in local market is used in the investigation. The Cement used has been tested for various proportions as per IS 4031-1988 and found to be confirming to various specifications of are 12269-1987.The specific gravity was 3.14 as shown in Table 1.

Table 1: Specific Gravity of Cement

Wt of Empty Beaker (W1) g	Wt of Beaker + Water (W2) g	Wt of Beaker + Kerosine (W3) g	Wt of Beaker + Kerosine + cement (W4) g	Wt of Cement (W5) g	Specific Gravity of Kerosine (G)	Specific Gravity of Cement (Sc)
35	230	190	235	60	0.79	3.12
35	230	190	241	70	0.79	3.01
35	230	190	286	75	0.79	3.14

Specific Gravity of Cement: Weight of specific gravity beaker dry (W1). Fill the beaker with distilled water and weigh the beaker (W2). Dry the specific gravity beaker and fill, it with kerosene and weight. Pour some of the kerosene but and it reduces a weighted quantity of cement in to the bottle. Roll the bottle gravity in the inclined position until to further air bubble rise to the surface. Fill the beaker to the top with the kerosene and weight it (W4)

Initial Setting Time Test on Cement: The mould and the nonporous plate are washed, cleaned and dried. 200g if the given sample of cement is kept on the Non- Porous plate. The volume of water equal to 0.85 minute the percentage of water required for standard consistency is added very carefully to the dry cement paste. The mixing is completed within 3 to 5 minutes from at the start of adding water to the cement, the time taken is noted by using stop watch. The vicat mould is placed on the non-porous plate and is filled with the prepared cement paste and the surface of the paste is made smooth is level with the mould by using a trowel. By shaking the mould slightly, air if any is expelled from the sample. The non-porous plate and the mould is replaced under the needle. The needle is gently lowered to touch the surface of the plate and then the indicator is adjusted to show zero reading. The needle is gently lowered to touch. The needle is released quickly allowing if to penetrate in to the paste. When the needle comes to rest, the

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reading on the index scale is noted. The moving rod is raised clear off the cement paste is wiped clean. The procedure of releasing the needle is repeated at every 30 seconds until the reading on the index scale shows 5 to 0.5 mm from bottom of the mould. Then the time is noted down the time elapse between the moment when water is first added to the cement and the moment at which the needle of 1mm square section failed to pierce the test block to a depth 5 to 0.5mm from the bottom of the mould is the initial setting time for the cement under the test. The initial setting time of the cement calculated is 28 minutes as per Table 2.

Table 2: Initial Setting Time of Cement

S.No	Initial Setting Time (min)	Penetration Index Reading (min)	Remarks
1.	0	0	Ordinary Portland cement 53 Grade
2.	4	0	
3.	8	1	
4.	13	1	
5.	18	1	
6.	23	2	
7.	26	3	
8.	28	5	

Fine Aggregate: River sand of 2.36 mm size sieve passed was used as fine aggregate. The specific gravity of 2.64 and fineness modulus 3.376 as per Table III. was used in the investigation. Take the sieves and place them one below the other in order to their size the one with larger aperture at the top place and place the receiver at bottom .Take 1000 grams of fine aggregate from the dry sample in the pan transfer to the most top sieve and cover it with lid provided Keep this set of sieves with the sample on the sieve shaker and start the motor to shake the sieve. (The period of shaking should not be less than 3 minutes). Allow the shaker to shake the sieves for three minutes and stop the motor find out the weight of residue on each sieve. By brushing with a soft brush on the underside of the sieve may be used to clean the sieve openings tabulate the values in each sieve. Estimate the fineness modulus of the aggregate. Draw a graph between the log of aperture size in X – axis and % of passing in the Y – axis. This curve is called the particle size distribution curve, from the curve note the uniformity co-efficient.

Weight of fine aggregate = 1000g

Table 3: Fineness Modulus of Fine Aggragate

IS Sieve	Weight (in grams)		Retained weight of sand (grams)	Cumulative weight retained (grams)	Cumulative % weight retained	% finer
	Empty weight of sieve	Retained weight of sieve				
4.75mm	400	430	30	30	3	97
2.36mm	385	450	65	95	9.5	90.5
1.70mm	360	450	90	185	18.5	81.5
1.18mm	400	510	110	295	29.5	70.5
600 µ	360	745	385	680	68	32
300 µ	410	680	270	950	95	5
150 µ	350	390	40	990	99	1
pan	450	460	10	1000	100	0

Coarse Aggregate: Crushed angular granite metal of 6 to 12.5 mm size from a local source was used as coarse aggregate. The specific gravity of 2.77 and fineness modulus 3.702 was used.

Fly Ash: Fly ash from Tuticorin Thermal Power Station, Tamil Nadu was used as cement replacement material. The properties fly ash is confirming to IS 3812 – 1981of Indian Standard Specification for Fly Ash for use as Pozzolana and Admixture. The specific gravity was 2.054.

Admixture: The Modified Polycarboxylated Ether based Super Plasticizer (Glenium B233) which is light brown Color and free flowing liquid and having Relative density 1.09±0.01 and pH value as ≥ 6and Chloride Content <0.2% was used as Super Plasticizer. Optimum dosage of GLENIUM B233 should be determined with trial mixes. As a guide, a dosage range of 500 ml to 1500ml per 100kg of cementitious material is normally recommended.

Viscosity Modifying Agent: A Viscosity modified admixture (Glenium Stream 2) for Rheodynamic Concrete which is colourless free flowing liquid and having Specific of gravity 1.01±0.01 @ 25º C and pH value as ≥ 6 and Chloride Content <0.2% was used as Viscosity Modifying Agent. GLENIUM STREAM 2 is dosed at the rate of 50 to 500 ml/100 kg of cementitious material. Other dosages may be recommended in special cases according to specific job site conditions.

Glass Fibres: The chopped strands are free flowing and are designed to resist the rigors of compounding whilst allowing the finished moulding to develop satisfactory mechanical properties.

3. Mix Design:

The mix composition shall satisfy all performance criteria for the concrete in both the fresh and hardened states. The requirements of EN 206 shall be fulfilled. The method has been proposed by Nan Su, et al. Its features are described below.

Modified Nan-Su Method:

Specific gravity of cement G_c= 3.15
Specific gravity of fine aggregate G_{fa}=2.65
Specific gravity of course aggregate G_{ca}=2.7

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Assumed packing factor PF=1.2(for M40)
Bulk density of FA =1600kg/m^3
Bulk density of CA=1600kg/m^3
From modified Nan-su method,

Cement:

s/a ratio of FA = 54 %
s/a ratio of FA = 46%
correction factor for M40 =CF =1.38
Volume of cement per m^3 of concrete = CF($f_{c/0.14}$)
Weight of cement/m^3 =450 kg
Fly ash content/ m^3 =50kg

Coarse Aggregate:

Volume or weight of coarse aggregate/m^3 = PF * bulk density * (s/a)
= 1.2*1178*0.46
= 650 kg

Fine Aggregate:

Weight of fine aggregate/m^3 = PF * bulk density *(s/a)
= 1.2*1311*0.54
= 850kg

Water:

Assumed W/C ratio = 0.32
Water content /m^3 of concrete = 200 kg
= 0.2m^3
= 200 litres

Super Plasticizer:

Dosage of master glenium sky 8233 ranges between 500-1500 ml/100kg of cementitious material
= (1500/100)*(450+50)
= 7500ml

Mix Proportion = 1:1.88:1.44

4. Fresh Concrete Property Testing:

Slump Flow Test: The slump flow is used to assess the horizontal free flow of SCC in the absence of obstructions. The diameter of the concrete circle is a measure for the filling ability of the concrete.

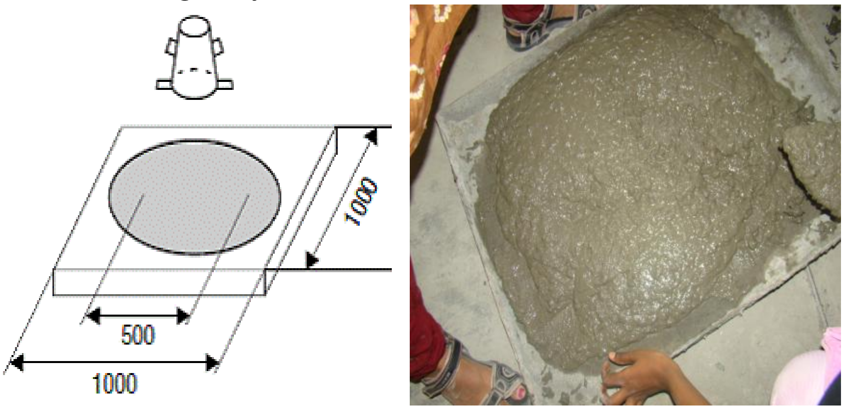

Figure 1: Slump Test for SCC

About 6 litre of concrete is needed to perform the test, sampled normally. Moisten the base plate and inside of slump cone, Place base plate on level stable ground and the slump cone centrally on the base plate and hold down firmly. Fill the cone with the scoop. Do not tamp, simply strike off the concrete level with the top of the cone with the trowel. Remove any surplus concrete from around the base of the cone. Raise the cone vertically and allow the concrete to flow out freely. Simultaneously, start the stopwatch and record the time taken for the concrete to reach the 500mm spread circle. (This is the $_{T50}$ time). Measure the final diameter of the concrete in two perpendicular directions. Calculate the average of the two measured diameters. (This is the slump flow in mm as in Fig.1). Note any border of mortar or cement paste without coarse aggregate at the edge of the pool of concrete.

V Funnel Test And V Funnel Test At T $_{5minutes}$: The described V-funnel test is used to determine the filling ability (flowability) of the concrete with a maximum aggregate size of 20mm. The funnel is filled with about 12 litre of concrete and the time taken for it to flow through the apparatus 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.

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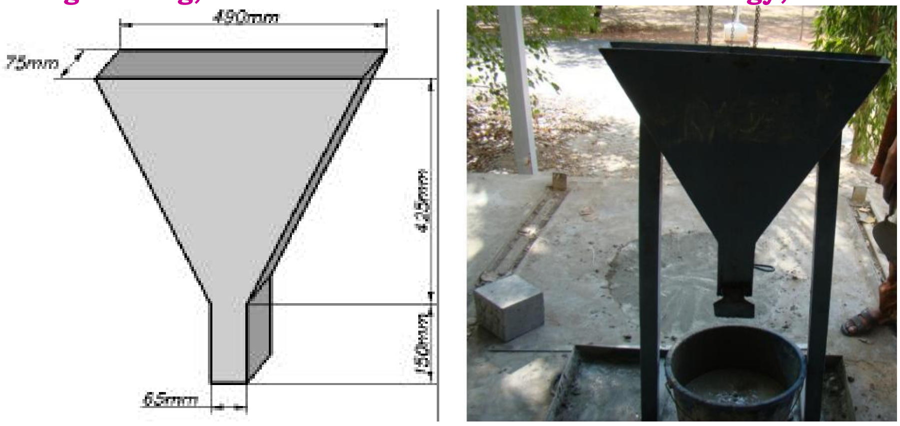

Figure 2: V Funnel Test

About 12 litre of concrete is needed to perform the test, sampled normally. Set the V-funnel on firm ground. Moisten the inside surfaces of the funnel. Keep the trap door open to allow any surplus water to drain. Close the trap door and place a bucket underneath. Fill the apparatus completely with concrete without compacting or tamping, simply strike off the concrete level with the top with the trowel. Open within 10 sec after filling the trap door and allow the concrete to flow out under gravity. Start the stopwatch when the trap door is opened, and record the time for the discharge to complete (the flow time). This is taken to be when light is seen from above through the funnel. The whole test has to be performed within 5 minutes.

L Box Test Method: About 14 litre of concrete is needed to perform the test, sampled normally. Set the apparatus level on firm ground, ensure that the sliding gate can open freely and then close it. Moisten the inside surfaces of the apparatus, remove any surplus water. Fill the vertical section of the apparatus with the concrete sample. Leave it to stand for 1 minute as in Fig.3. Lift the sliding gate and allow the concrete to flow out into the horizontal section. Simultaneously, start the stopwatch and record the times taken for the concrete to reach the 200 and 400 mm marks. When the concrete stops flowing, the distances "H1" and "H2" are measured. Calculate H2/H1, the blocking ratio. The whole test has to be performed within 5 minutes.

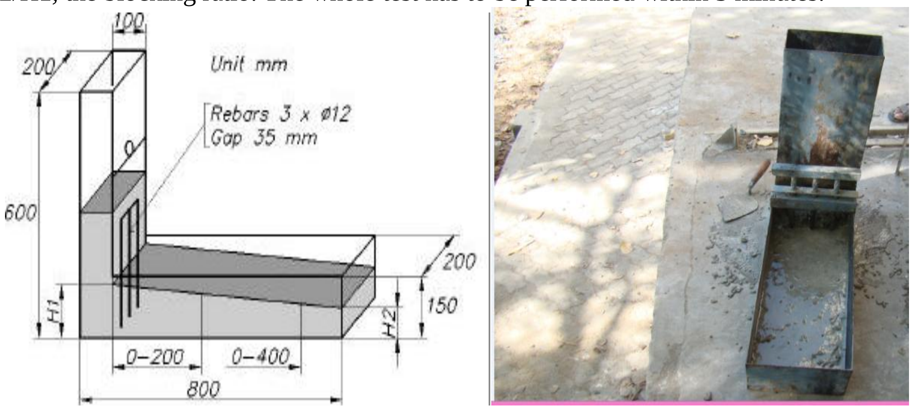

Figure 3: L Box Test

U Box Test: About 20 litre of concrete is needed to perform the test, sampled normally. Set the apparatus level on firm ground, ensure that the sliding gate can open freely and then close it.

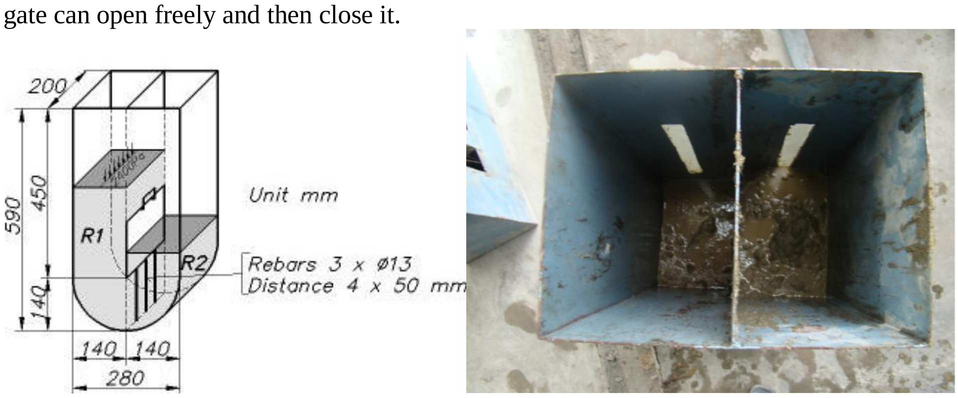

Figure 4: U Box Test

Moisten the inside surfaces of the apparatus, remove any surplus water. Fill the one compartment of the apparatus with the concrete sample. Leave it to stand for 1 minute. Lift the sliding gate and allow the concrete to flow out into the other compartment. After the concrete has come to rest, measure the height of the concrete in the compartment that has been filled, in two places and calculate the

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mean (H1). Measure also the height in the other compartment (H2). Calculate H1 - H2, the filling height. The whole test has to be performed within 5 minutes. The test results are listed in the following Table IV.

Table 4: Fresh Concrete Property Testing Results

Methods	Unit	Normal SCC	Scc with 0.6%glass and 0.2% polyester fibres	Scc with 0.4%glass and 0.4% polyester fibres	Scc with 0.5%glass and 0.3% polyester fibres	Min. Value	Max. Value
Slump flow	mm	700	680	650	600	650	800
V - funnel	sec	9	7	8	9	6	12
U- box	(h2-h1) mm	25	20	22	20	0	30
L – box	(h2/h1) mm	0.93	0.94	0.75	0.92	0.8	1.0

5. Hardened Concrete Property Testing:

Compressive Strength Test: Compressive strength tests were carried out on cubes of 150 mm size using a compression testing machine of 2000 KN (Shown in Fig. 5a) capacity as per IS 516:1959. The test Results are given in Table V.

Combinations	Specimen	7 Days		28 Days	
		Load (kN)	Stress (N/mm^2)	Load (kN)	Stress (N/mm^2)
Normal SCC	1st cube	613.80	27.28	897.55	39.89
	2nd cube	607.25	26.99	876.35	38.95
	3rd cube	610.85	27.15	889.85	39.55
SCC with 0.5% glass fibre and0.3% polyester fibre	1st cube	700.85	31.15	1213.85	53.95
	2nd cube	725.85	32.23	1217.25	54.10
	3rd cube	710.55	31.58	1212.05	53.87
SCC with 0.6% glass fibre and0.2% polyester fibre	1st cube	742.05	32.98	1278.00	56.80
	2nd cube	739.35	32.86	1263.35	56.15
	3rd cube	737.55	32.78	1258.85	55.95
SCC with 0.4% glass fibre and0.4% polyester fibre	1st cube	702.00	31.20	1152.00	51.20
	2nd cube	701.55	31.18	1146.35	50.95
	3rd cube	697.05	30.98	1150.85	51.15

Table 5: Compressive Strength Test Results

Split Tensile Test: Split tensile strength tests were carried out on cylinders of 150 mm diameter and 300 mm height using a compression (Shown in Fig. 5b) testing machine of 2000 KN capacity as per IS 516:1959. The test Results are given in Table VI.

Cylinder Combinations	7 Days		28 Days	
	Load (kN)	Stress (N/mm^2)	Load (kN)	Stress (N/mm^2)
Normal SCC	58.85	0.83	264.95	3.75
SCC with 0.5% glass fibre and 0.3% polyester fibre	61.50	0.87	276.25	3.91
SCC with 0.6% glass fibre and 0.2% polyester fibre	62.20	0.88	279.05	3.95
SCC with 0.4% glass fibre and 0.4% polyester fibre	59.35	0.84	268.40	3.80

Flexural Strength Test: Flexural strength tests were carried out on prisms of size 100×100×500 mm on flexure testing machine of capacity 100 KN as per IS 516:1959. From the cube compression test it is noticed that 2nd combination (SCC with 0.6 % glass fibre and 0.2 % Polyester fibre gives the maximum strength among the other combinations. Hence the beam is casted for the 2nd combination mix proportions. The 7 day flexural strength of the beam tested under two point bending load is 8.247 N/mm2 as shown in the Fig.6.

A. Cube Compression Test B. Cylinder Split Tensile Test

Figure 5: Hardened Concrete Property Testing

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Figure 6: Flexural Strength of Beam casted for 2nd combo

6. Results and Discussions:

Results of experimental investigations are discussed in the following sections with respect to the characteristics of SCC & HFRSCC mixes in the fresh and hardened states. A. Characteristics of SCC Mixes In Fresh State The filling ability, passing ability & segregation resistance values of HFRSCC mixes compared to SCC mixes indicate that the presence of glass and polyester fibres. The slump value for hybrid self compacting concrete is comparatively more than the normal scc similarly the value of L box, U box, v funnel are more than normal SCC

Characteristics of SCC Mixes in Hardened State:

Compressive Strength: The compressive strength values obtained by testing standard cubes made with different SCC and HFRSCC mixes. All the mixes have shown strength above 39 MPa, which is the required strength. The mix, without fibers, containing the mineral admixture of silica fume (10%) has shown lower compressive strength compared to other HFRSCC mixes. The mix with 0.6 % glass fibers and 0.2% polyester fibres, containing the mineral admixture of silica fume (10%) has shown higher compressive strength compared to other SCC & HFRSCC mixes. Further, the HFRSCC mixes compared to normal SCC mixes have shown an improvement in compressive strength by 42% as shown in Fig.7a.

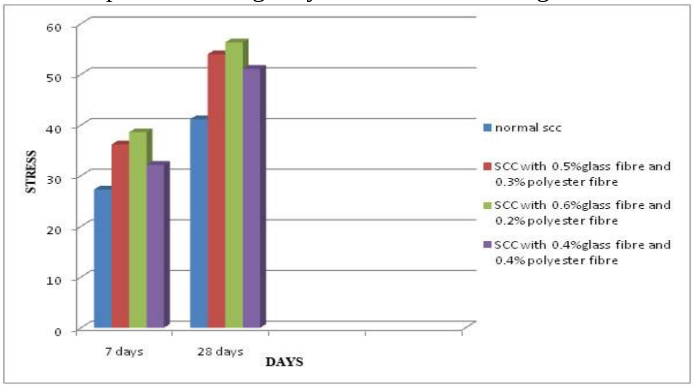

Figure 7a: Comparison of compressive strength for various combo

Tensile Strength: The tensile strength of mixes is obtained by conducting split tensile test on standard cylindrical specimens . The results indicated that the incorporation of glass fibres and polyester fibres in to the SCC mixes increased the split tensile strength by 5.55 % (as in Fig.7b) respectively. The increase is significant and it may be due to high tensile strength of glass fibres and polyester fibres.

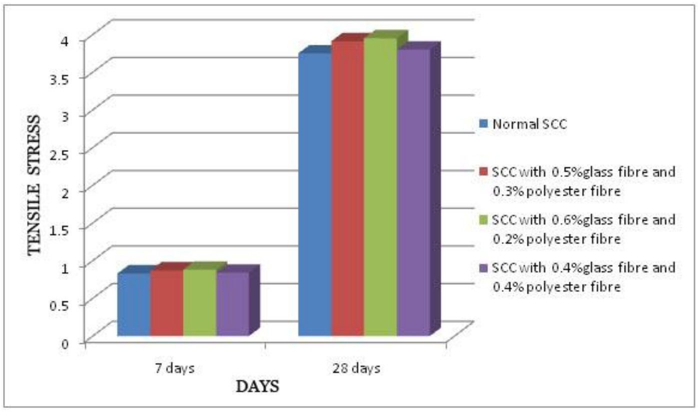

Figure 7b: Comparison of Split tensile strength for various combo

Flexural Strength: The flexural strength of mixes is obtained by conducting two point load test on standard prisms. The results indicated that the incorporation of glass fibres and polyester fibres in to the SCC mixes increased the split tensile strength. The flexural strength obtained is 8.471N/mm2. The increase is significant and it may be due to high tensile strength of glass fibres and polyester fibres

7. Conclusions:

The glass fibres and Polyester fibres are added to various combinations to normal self-compacting concrete to improve the compressive, split tensile strength of the concrete. Based on the performance of concrete casted at various fibre combinations under compressive and tensile loads the mix combination which shows the better behviour among all the other is finalized. The beam is casted for the finalized mix proportion and tested and tested under the two point bending load. By comparing the test results the following conclusions are made. All the SCC and HFRSCC mixes developed satisfied the requirements of self-compacting concrete specified by EFNARC. From above discussion of test results, it can be observed that addition of the glass fibers and polyester fibres tested improves the compressive strength, tensile strength, load carrying capacity of ordinary reinforced cement concrete in flexure even with small dosage levels of 0.8%.With the above discussion we found out that the compressive strength obtained in 0.6% and 0.2% polyester fibres is more i,e 42% when compared to 0.5% glass fibres and 0.3% polyester fibres and 0.4% glass fibres and 0.4% polyester fibres. With the above discussion we found out that the tensile strength obtained in 0.6% and 0.2% polyester fibres is more i,e 5.55% when compared to 0.5% glass fibres and 0.3% polyester fibres and 0.4% glass fibres and 0.4% polyester fibres With the above discussion we found out that the flexural strength obtained in 0.6% and 0.2% polyester fibres is 8.471N/mm2

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