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Experimental Study on Hybrid Fiber Self Compacting Concrete

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Abstract: ***Self Compacting Concrete is a recently developed conception in which the ingredients of the concrete mix are proportioned in such a way that it can flow under its own weight to completely fills up the formwork and passes through the crammed reinforcement with no segregation and self consolidate without any mechanical vibration. Several studies in the past have exposed the expediency of fibers to develop 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 enhanced performance in the hardened state due to the addition of fibers. In this project, glass fibers and polyester fibers were added to SCC and HFRSCC was developed. An attempt has been made to study mechanical properties of self compacting concrete and glass fiber 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 fibers and polyester fibers.***

Keywords: Self compacting concrete, Glass fibers, Polyester fibers, Fly ash, EFNARG.

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 fibers 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.

Considering the advantages of SCC and HFRC an attempt had been made to combine these two and to produce Glass Fiber Reinforced Self Compacting Concrete (HFRSCC) and to investigate the and mechanical properties, of both SCC and HFRSCC.

2. Material used in SCC

2.1 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.

2.2 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.

2.3 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 was used in the investigation.

2.4 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.

2.5 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.

2.6 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.

2.7 Glass fibers

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.

2.8 Polyester fibers

Recron 3s polyester fiber acts as "secondary reinforcement" in concrete which arrests cracks, increases resistance to impact/abrasion and greatly improves quality of construction of wall, foundations, tanks, roads and pre-cast products.

3. Material properties

3.1 Physical property

3.1.1 Specific gravity of cement

Specific Gravity of Cement = 3.09

3.1.2 Fineness test on cement

Average percentage of residue cement = 2.67%

3.1.3 Consistency test on cement

The percentage of water required 36 %.

3.1.4 Initial setting time test on cement

The initial setting time of the cement= 28 minutes

3.1.5 Specific gravity

(a) Specific Gravity of fine aggregate = 2.65
(b) Specific Gravity of coarse aggregate = 2.7

3.1.6 Bulking characteristic of sand

Maximum percentage of bulking = 22%
Water content for max % of bulking = 5%

3.1.7 Water absorption test on sand

In percentage = 0.9%

3.1.8 Voids in sand

(a) Bulk density
(1) Bulk density of FA =1600kg/m^3
(2) Bulk density of CA=1600kg/m^3

(b) Percentage of voids in sand = 33.33%

3.1.9 Fineness modulus

(a) Fineness of fine aggregate = 4.23
(b) Fineness of coarse aggregate = 5.34

4. Mix design

4.1 Mix Design for M40 Concrete

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
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 =450kg
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 = 650kg
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 liters
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

5. Other properties on SCC and HRSCC in hardened state

5.1 Compressive Strength Test

Compressive strength tests were carried out on cubes of 150 mm size using a compression testing machine of 2000 KN capacity as per IS 516:1959.

Table 1: Compressive strength test

Sr. No	Combinations	Specimen	7DAYS	28DAYS
			Stress (N/mm^2)	
1	Normal SCC	1st cube	27.28	39.89
		2nd cube	26.99	38.95
		3rd cube	27.15	39.55
2	SCC with 0.5% glass fiber and 0.3% polyester fiber	1st cube	31.15	53.95
		2nd cube	32.23	54.10
		3rd cube	31.58	53.87
3	SCC with 0.6% glass fiber and 0.2% polyester fiber	1st cube	32.98	56.80
		2nd cube	32.86	56.15
		3rd cube	32.78	55.95
4	SCC with 0.4% glass fiber and 0.4% polyester fiber	1st cube	31.20	51.20
		2nd cube	31.18	50.95
		3rd cube	30.98	51.15

5.2 Test methods & results for SCC

Table 2: Fresh Properties Test Results

Sr. No.	Methods	Unit	Normal SCC	SCC with 0.6%glass and 0.2% polyester fibers	SCC with 0.4%glass and 0.4% polyester fibers	SCC with 0.5%glass and 0.3% polyester fibers	Min. Value	Max. Value
1	Slump flow	mm	700	680	650	600	650	800
2	V - funnel	sec	9	7	8	8	6	12
3	V – funnel at T5 minutes	sec	12	10.5	9.0	9	0	15
4	U- box	(h2-h1)mm	25	21	22	21	0	30
5	L – box	(h2/h1)mm	0.93	0.94	0.93	0.96	0.8	1.0

5.3 Split Tensile Strength Test

Split tensile strength tests were carried out on cylinders of 150 mm diameter and 300 mm height using a compression testing machine of 2000 KN capacity as per IS516:1959.

Table 3: Split Tensile Strength Test

Sr. No	Cylinder combinations	7DAYS Stress (N/mm^2)	28DAYS Stress (N/mm^2)
1	Normal SCC	0.83	3.75
2	SCC with 0.5% glass fiber and 0.3% polyester fiber	0.87	3.91
3	SCC with 0.6% glass fiber and 0.2% polyester fiber	0.88	3.95
4	SCC with 0.4% glass fiber and 0.4% polyester fiber	0.84	3.80

Figure 1: Specimen of Cylinder

5.4 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.

Table 3: Flexural Strength Test

Sr. No	Prism	7 DAYS (N/ mm²)	28 DAYS (N/ mm²)
1	SCC	6.25	7.38

Figure 2: Casting of Prism

Figure 3: Fresh concrete of SCC

After testing the SCC and HRSCC in fresh state the concrete was poured in moulds of cubes, cylinders, prisms and beams. After 24 hours of casting the specimens were de-moulded and placed in water for curing. After 28 days of curing the specimens were taken out from water and allowed the surfaces for drying.

Figure 4: L – Box

Figure 5: V - Funnel

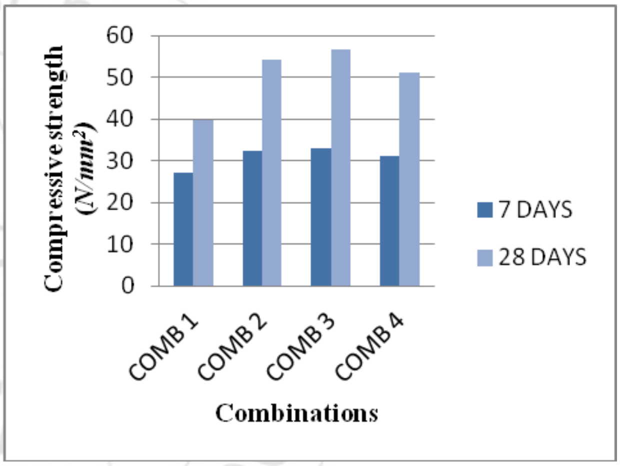

Figure 6: Chart of Compressive Strength

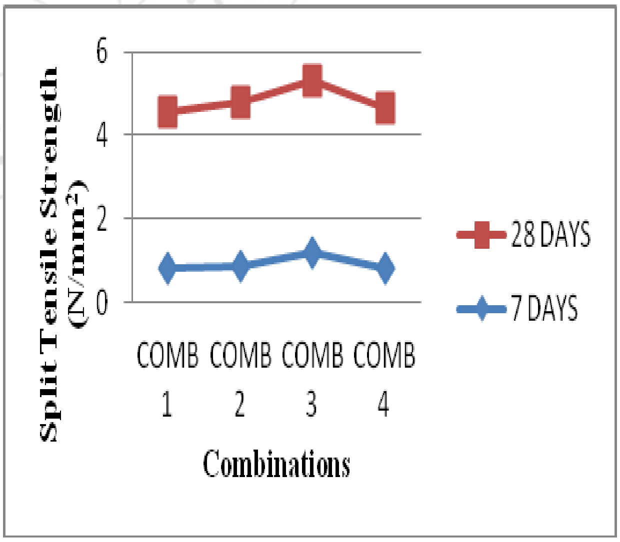

Figure 7: Chart of Split Tensile Strength

6. Discussion of Test Results

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.

6.1 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 fibers and polyester fibers did not have any pronounced effect up to 0.06% this may be due to the low dosage of fibre addition (0.06%) and also may be due to the high dispersing nature of the fibers and some effect have appeared when 0.09% of glass fibre added.

6.2 Characteristics of SCC mixes in hardened state

6.2.1 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 36 MPa, which is the required strength. The mix, without fibers, containing the mineral admixture of FLY ASH (10%) has shown lower compressive strength compared to other HFRSCC mixes. The mix with 0.6 % glass fibers and 0.2% polyester fibers, containing the mineral admixture of FLY ASH (40%) 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 1.5 to 2.0%.

6.2.2 Tensile strength

The tensile strength of mixes is obtained (i) by conducting split tensile test on standard cylindrical specimens and also by (ii) by conducting two points bend test on standard prisms. The results indicated that the incorporation of glass fibers and polyester fibers in to the SCC mixes increased the split tensile strength and flexural strengths by 44.2 to 63.33 % and 18.85 to 35.75 % respectively. The increase is significant and it may be due to high tensile strength of glass fibers and polyester fibers

7. Conclusions

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 tested improves the compressive strength, tensile strength, load carrying capacity of ordinary reinforced cement concrete in flexure even with small dosage levels of 0.6%, 0.5% & 0.4 %.

With the above discussion we found out that the results obtained in 0.6% and 0.2% polyester fibers is more when compared to the results obtained for 0.5% glass fibers and 0.3% polyester fibers and 0.4% glass fibers and 0.4% polyester fibers.

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