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EXPERIMENTAL INVESTIGATION OF STRENGTH PROPERTIES OF SELF COMPACTING CONCRETE BY USING HYPOSLUDGE AND CARBON STEEL FIBERS

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Abstract - *To summarize the impact of carbon steel fibers on mechanical properties of self-compacting concrete. In this experiment the self-compacting concrete (SCC) was produced by the use of Portland Slag Cement (PSC) according to EFNARC guidelines. The admixture is used for replacement of cement by hyposludge in the range of 2, 4, 6, 8 and 10% by weight of cement, based on compressive strength of SCC, the optimum percentage of hyposludge was found to be 10%. For this optimum SCC mix, the 0.2 and 0.3mm diameter carbon steel fibers were added in the range of 1.4, 1.6, 1.8 and 2.0% by weight of cement. The strength tests were conducted on cubes of size 150mm×150mm×150mm for compressive strength and 150mm×300mm cylinders size for split tensile strength, for a curing period of 7, 28 and 56-days. The test results were compared with the hyposludge conventional concrete, the conclusions were drawn.*

Key Words: Self-compacting concrete (SCC), Carbon steel fibers (CSF), Hyposludge, Super plasticizer, compressive strength, split tensile strength.

1.INTRODUCTION

When we do any concrete work, for works like beams, columns, slabs, we use machines like vibrators to send the concrete to every corner. During the use of such machines the vibrations of the vibrator may cause water to come out along with the cement in the concrete and reduce the strength of the concrete. No matter how much vibrated concrete we use vibrators may not go to every corner. So, a method called self-compacting concrete was introduced to correct such mistakes and not to reduce the strength of the concrete. The chemical is used reduces the proportion of water in the concrete and makes this concrete without any reduction in the strength of ordinary concrete. By using this self-compacting concrete, the concrete will go to every corner by itself without any vibrations.

At present, BASF MASTER GLENIUM SKY 8777 was used to make self-compacting concrete in this project. Carbon steel fibers were used as a secondary reinforcement to improve the tensile strength of concrete, and hyposludge, which has almost cement properties, was used as a partial replacement material for cement.

2. LITERATURE REVIEW

ANISHA MARY (2015): Investigates the strength properties of self-compacting concrete with glass fiber and poly steel fibers varied from 0.05, 0.10, 0.15 and 0.2% by total volume of mix and replacement of fly-ash was 25%. The experimental work included the determination of the optimum fiber content which can be provided in the concrete composites. Optimum fiber content was determined based on the compressive strength, split tensile strength and flexural strength of the specimens.

ARYA AND ARUN (2017): Investigates on the properties of Silica Fumes (SF) and fly-ash (FA) when used as partial replacement for Ordinary Portland Cement (OPC) in concrete. OPC was replaced with SF and FA by weight at 0% (nominal), 5%, 10%, 15%and 20% as various combinations. The combination which the optimum compressive strength is 3rd combination i.e., 10% of silica fume and 10% of fly-ash. This combination gives higher value of compressive strength than that of conventional concrete. Flexural strength test is conducted in beams for finding out the optimum proportion for flexural strength. From the result obtained the optimum proportion obtained as 3rd combination i.e., 10% silica fume and 10% fly-ash combination.

CHNDRASHEKHARA MURTHY AND PREMA KUMAR (2019): The objective of this present experimental work is to determine the variation of shear strength of M30 and M60 grade concretes with no fiber and with various volume percentages of steel fibers using push-off specimens. The slump value/workability for both M30 and M60 grades of concrete decreases as volume percentage of fibers increases. The compressive strength at 14-days and 28-days of curing increase initially with increase in volume percentage of fibers for both M30 and M60 grades of concrete. The optimum fiber percentage from the point of view of compressive strength lies in the range 0.5-1.0%. The compressive strength decreases beyond 1.0%. An increase in the volume percentage of fibers increases the shear strength of concrete monotonically. The issue of best fiber percentage to be used in practice has to be addressed by considering concurrently the shear strength, compressive strength, and workability. If workability is addressed by adding superplasticizer, a value of 1% of steel fibers may be good and adopted in practice. The addition of fibers improves the load at first cracking, ductility, and the failure pattern of concrete.

DHARANI, et. al (2013): Prepared M25 concrete, hyposludge was used as replacement material in cement at 0, 10, 20, 30, 40 and 50%. For each percentage of replacement of cement with hyposludge, Recron 3s fibers were added at 0.10, 0.20, 0.30 and 0.40%. They conclude 30% replacement of cement by hyposludge is optimum when Recron 3s fibers were not added and also conclude that 20% replacement of cement by hyposludge is optimum when 0.4% Recrons 3s fibers were added. The addition of Recron 3s fibers in concrete it was found decrease compressive strength, split tensile strength, and increases the flexural strength as fiber content increases.

DINESH, et. al (2017): The self-compacting concrete where the cement was partially replaced with fly-ash and silica fume. Here Ordinary Portland Cement (OPC) was replaced with 5%, 10%, 15%, 20% and 25% of fly-ash and 2.5%, 5%, 7.5%, 10% and 12.5% of silica fume. the compressive strength decreases with the increase in percentage of fly-ash and increases with the increase in percentage of silica fume. The workability of concrete when replaced with 5%, 10%, 15%, 20% and 25% of fly-ash was increased by 50%, 43.75, 37.5%, 31.25% and 25% respectively. The workability of concrete when replaced with 2.5%, 5%, 7.5%, 10% and 12.5% of silica fume is increased by 12.5%, 18.75, 25%, 43.75% and 50% respectively. When the cement is replaced with 5%, 10%, 15%, 20% and 25% of fly-ash the compressive strength of concrete is reduced by 4.55%, 7.44%, 10%, 11.71% and 13.61% respectively. When the cement is replaced with 2.5%, 5%, 7.5%, 10% and 12.5% of silica fume the compressive strength is increased by 3.95%, 5.9%, 7.56%, 9.15% and 14.05% respectively. When the cement is replaced with 5%, 10%, 15%, 20% and 25% of fly-ash the tensile strength of concrete is reduced by 3.65%, 10.48, 16.58%, 26.58% and 31.70% respectively. When the cement is replaced with 2.5%, 5%, 7.5%, 10% and 12.5% of silica fume the tensile strength is increased by 3.65%, 5.12%, 10%, 13.90 and 19.5% respectively.

3.MATERIALS

3.1 CEMENT: Portland Slag Cement (PSC) is available in the local market of standard brand JSW was used in this investigation. Care was taken to see that the procurement made from a single batch was stored in airtight containers to prevent it from being affected by the atmospheric and monsoon moisture and humidity.

Table-1: Properties of cement

Physical requirements	Requirements as per IS 455:2015	Test results
Fineness (m^2/kg) (Min)	225	361
Setting Time (minutes)		
a) Initial (Min)	30	135
b) Final (Max)	600	190

3.2 FINE AGGREGATE: The locally available river sand was used as fine aggregate in this present investigation. The fine aggregate used should conform to the standard specifications as per IS 2386-1963. The fine aggregate was river sand confirming to zone-II. The sand was free from clay, silt, and organic impurities. The specific gravity of fine aggregate is 2.60 and fineness modulus is 2.67.

3.3 COARSE AGGREGATE: Machine crushed rounded granite metal of 12.5mm nominal size from the local source was used as coarse aggregate. It was free from impurities such as dust, clay particles and organic matter etc. The coarse aggregate was also tested for its various properties. The coarse aggregate should also conform to the standard specifications. it was well graded, and its specific gravity is 2.704 and fineness modulus is 7.55 the material is of uniform color and has good angularity.

3.4 WATER: The locally available potable water accepted for local construction was used in this experimental investigation after testing. The pH value should not be less than 6. Water cement ratio of 0.35 was adopted for M30 grade of concrete in this experimental investigation.

3.5 HYPOSLUDGE: Hyposludge is the primary waste material from the paper industry. It consists of cellulose fibers, calcium carbonate, silica, magnesium, calcium chloride, and residual chemicals along with water. The presence of silica, magnesium, and calcium in hyposludge makes it similar to that of cement and hence there is a possibility to replace cement with hyposludge. The silica and magnesium improve the setting of concrete. The particles of hyposludge are extremely fine, most of them having a diameter ranging between 0.04 and 0.3μm, the median diameter is typically below 0.l μm, such a fine material as hyposludge has a very low bulk density 200 to 350kg/m^3. The hyposludge can minimize the demand for cement and reduce the cost of construction. Hyposludge was obtained from Delta paper mill at VENDRA near Bhimavaram in West Godavari District, Andhra Pradesh.

Table-2: Chemical properties of hyposludge

S. No	Constituents	%
1	Calcium Oxide	47.84
2	Silicon Dioxide	5.28
3	Aluminium Oxide	0.09
4	Magnesium Oxide	6.41
5	Loss on ignition	40.38

3.6 BASF MASTER GLENIUM SKY 8777: BASF Master Glenium SKY 8777 is the super plasticizer based on second generation polycarboxylicether polymers, developed by using Nanotechnology. Master Glenium SKY 8777 is free of chloride & low alkali. It is compatible with all types of cements. It is suitable for making precast concrete elements at all workability's including Rheoplasticor Super workable concrete having fluid consistence, no segregation, a low water binder ratio and consequently high early and long-term strengths.

3.7 CARBON STEEL FIBERS: For this investigation 0.2mm dia. 13mm cut length and 0.3mm dia. 12mm cut steel fibers were used. A steel fiber is used for three-dimensional reinforcement of concrete and replaces steel mesh.

Table–3: Physical properties of carbon steel fibers

Product type	Carbon steel fiber
Cross-section	Circular
Cut length of 0.2mm dia.	13mm
Cut length of 0.3mm dia.	12mm
Diameter's	0.3mm, 0.2mm
Tensile strength	2110 to 2815N/mm^2
Melting point	> 2500c

4.SELF COMPACTING CONCRETE MIX DETAILS

In this present investigation mix proportioning was done using BIS method for M30 grade concrete. The result mixes were modified after conducting trials at laboratory by duly following the EFNARC guidelines to achieve the self-compacting concrete mix proportion. Mix design followed with the guidelines specified in European Federation of National Associations Representing for Concrete (EFNARC 2005). The design SCC mix 30MPa is obtained by number of trails with varying quantities of constituent material. The aforementioned mixes are prepared after different trial process. Such mixes can be made possible only by using the appropriate ingredients in proper proportions.

Table–4: Summary of Mix details

Cement (kg/m^3)	495
Fine Aggregate (kg/m^3)	977
Coarse Aggregate (kg/m^3)	793.22
Hyposludge (%)	10
Super plasticizer (%)	0.6
W/C Ratio	0.35

5.FRESH CONCRETE PROPERTIES

According to EFNARC guidelines a concrete mix can only be classified as self-compacting concrete if it satisfies the requirements for below three characteristics are fulfilled.

- Passing ability.
- Filling ability.
- Stability or segregation resistance.

Different test methods have been developed in attempts to characterize the above properties of SCC in fresh state and are given in the table with their limiting values. We conduct Slump flow, V-funnel, L-box, and J-ring test to characterize the fresh state properties of SCC.

5.1 Slump flow test: Primarily to assess filling ability, suitable for laboratory and site use.

5.2 L-box test: The L-box test is used to assess the passing ability of self-compacting concrete to flow through tight openings including spaces between reinforcing bars and other obstructions without segregation or blocking.

5.3 V-funnel test: The V-funnel test is used to assess the viscosity and filling ability of self-compacting concrete.

5.4 J-ring test: Primarily to assess filling ability, suitable for laboratory and site use.

Table-5: workability tests of self-compacting concrete (SCC)

Test method	Property	Unit	Recommended values as per EFNARC guidelines	Experimental values
Slump flow by Abram's cone	Filling ability	mm	650-800 mm	681
T_{50} Slump flow	Filling ability	sec	2-5 sec	4.2

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J-Ring	Passing ability	mm	0-10 mm	7
V-Funnel	Filling ability	sec	8-12 sec	10.2
L-Box	Passing ability	h_2/h_1	0.8-1.0	0.895

6.EXPERIMENTAL DETAILS

In this work, self-compacting concrete mix was designed for Portland slag cement. For this mix, hyposludge is 10% and carbon steel fibers of 0.2mm dia. and 0.3mm dia. were added up by weight of cement with different percentages of 1.4, 1.6, 1.8, & 2.0% in the concerned cement. After 7, 28 and 56-days curing, the mechanical properties like compression strength and split tensile strength of hyposludge conventional self-compacting concrete were found for all the mixes.

6.1MIXING: Mixing of carbon steel fiber materials in concrete carbon steel fiber material is added to the nominal mix concrete to obtain the target mean strength. Weigh carbon steel fibers and mix it with the required water for the concrete mix and stir very well and add some amount of mixed cement & sand material. Then it is poured into the sample and mixed very well. 10% of extra fiber material is taken, when fiber material is not mixed well, the strength of the concrete mix is decreased. When we add the fiber to the concrete mix it absorbs the water in the concrete mix. After completion of casting, it releases the water slowly. After mixing fiber to the concrete mix take sample for the slump cone test, pour the sample into the slump cone, dump well, remove the cone. Note down the slump cone value and check if the value is satisfied with our mix design. If it is not satisfied leave the sample and go for a new mix unless the sample value is satisfied.

6.2 CASTING: The iron moulds are cleaned, and any dust particles are there remove them. the mineral oil is applied on all the sides of the mould. The moulds are placed on a level platform. Excess concrete is removed with trowel and top surface is finished level and smooth as per IS 516:1959. If the slump value is satisfied cast the sample into cubes and damp well for not obtaining the voids in the cubes. After casting the cubes leave them for 24 hours of an initial setting time and after 24 hours remove the mould and keep the cubes in curing tank for 7, 28 and 56-days as per our trails.

6.3 CURING: The specimens are left in the moulds undisturbed at room temperature for about 24 hours of casting. The specimens are then removed from the moulds and immediately transferred to the curing pond containing clean and fresh water and cured for required period as per IS 516:1959.

7.RESULTS

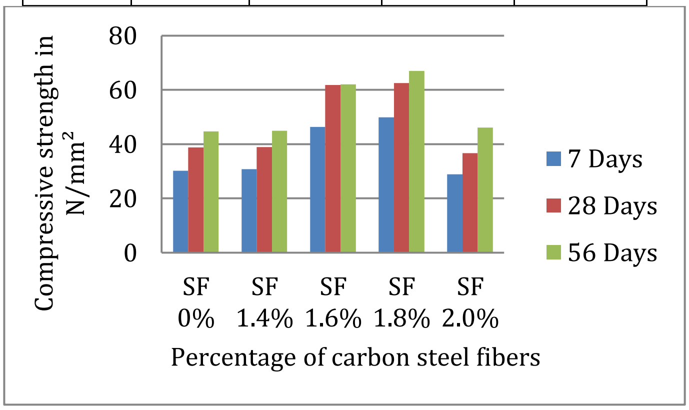
7.1 COMPRESSIVE STRENGTH: The compressive strength of concrete was measured using AIMIL compression testing machine with a loading capacity of 2000 KN confirming to IS: 14858 (2000). The compressive strength test was carried out on cubes at the 7, 28 and 56-days. Compression tests are important to measure the elastic and compressive fracture properties of brittle materials (or) low ductility materials. Compression tests are also used to determine the modulus of elasticity, proportional limit, compressive yield point, and compressive yield strength.

Table-6: Compressive strength values for 0.2mmΦ CSF

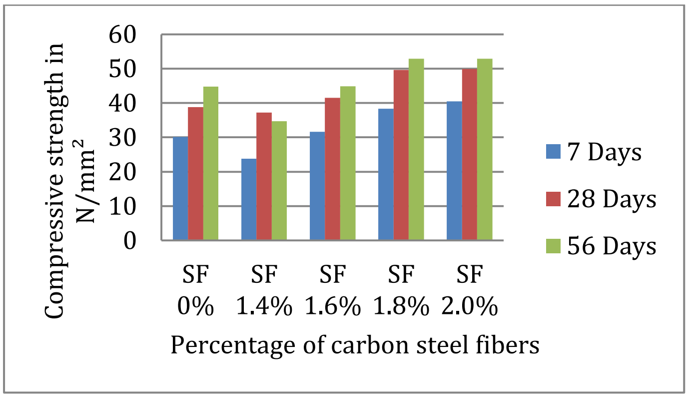
S. No	Mix	Compressive strength N/mm^2		
		7Days	28Days	56Days
1	SF 0	30.15	38.81	44.74
2	SF 1.4	30.74	38.95	44.92
3	SF 1.6	46.37	61.77	62.07
4	SF 1.8	49.92	62.51	66.96
5	SF 2.0	28.88	36.66	46.07

Table-7: Compressive strength values for 0.3mmΦ CSF

S. No	Mix	Compressive strength N/mm^2		
		7Days	28Days	56Days
1	SF 0	30.15	38.81	44.74
2	SF 1.4	23.77	37.18	34.66
3	SF 1.6	31.63	41.48	44.89
4	SF 1.8	38.37	49.63	52.88
5	SF 2.0	40.44	49.94	52.92



(a) Compressive strength values for 0.2mmΦ CSF



(b) Compressive strength values for 0.3mmΦ CSF

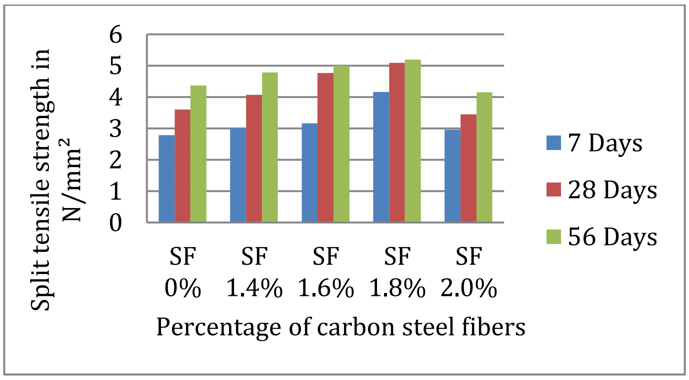
7.2 SPLIT TENSILE STRENGTH: The split tensile strength of concrete is one of the basic and important properties which greatly affect the extent and size of cracking in structures. The concrete is not usually expected to resist the direct tension due to its low tensile strength and brittle nature. Concrete structures are highly vulnerable to tensile cracking due to various kinds of effects and applied loading itself. However, tensile strength of concrete is very low in compared to its compression strength.

Table-8: Split tensile strength values for 0.2mmΦ CSF

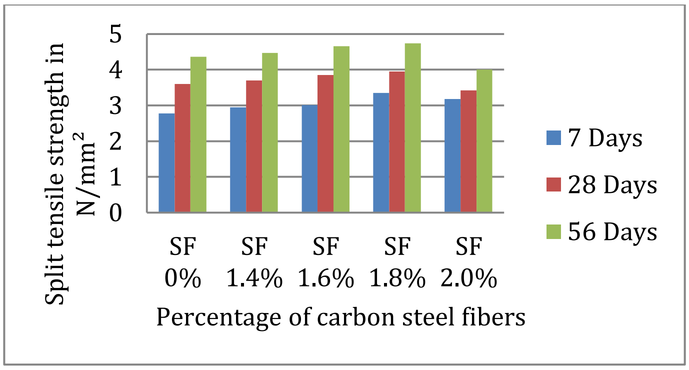
S. No	Mix	Split tensile strength N/mm^2		
		7Days	28Days	56Days
1	SF 0	2.78	3.6	4.36
2	SF 1.40	3.01	4.07	4.78
3	SF 1.60	3.16	4.76	5.00
4	SF 1.80	4.16	5.09	5.19
5	SF 2.00	2.96	3.45	4.15

Table-9: Split tensile strength values for 0.3mmΦ CSF

S. No	Mix	Split tensile strength N/mm^2		
		7Days	28Days	56Days
1	SF 0	2.78	3.60	4.36
2	SF 1.40	2.95	3.70	4.47
3	SF 1.60	3.01	3.85	4.66
4	SF 1.80	3.35	3.95	4.74
5	SF 2.00	3.18	3.42	4.00



(c) Split tensile strength values for 0.2mmΦ CSF



(d) Split tensile strength values for 0.3mmΦ CSF

8.CONCLUSIONS

Based on the experimental investigation the following conclusions were arrived.

1. From the test result, it is found that the optimal percentage of hyposludge replaced in Portland Slag Cement was 10%.
2. The maximum compressive strength and split tensile strength was occurred at 1.8% in 0.2mm dia. carbon steel fiber reinforced self-compacting concrete at 28-days curing.
3. The maximum compressive strength was occurred at 2.0% and maximum split tensile strength was occurred at 1.8% in 0.3mm dia. carbon steel fiber reinforced self-compacting concrete at 28-days curing.

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