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A STUDY ON FIBRE REINFORCED CONCRETE USING SILICAFUME BY PARTIAL REPLACEMENT OF CEMENT

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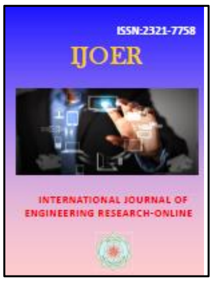


ABSTRACT

With the passage of time to meet the demand, there was a continual search in human being for the development of high strength and durable concrete. The history of high strength concrete (HSC) is about 35 years old, in late 1960s the invention of water reducing admixtures lead to the high strength precast products and structural elements in beam were cast in situ using high strength concrete (HSC). After the technology has come to age and concrete of the order of M60 to M120 are commonly used. Concrete of the order of M200 and above are a possibility in the laboratory conditions. The definition of high strength concretes (HSC) is continually developing. In the 1950s 34 N/mm^2 was considered high strength concrete, and in the 1960s compressive strengths of up to 52 N/mm^2 were being used commercially. More recently, compressive strengths approaching 138N/mm^2 have been used in cast-in-place buildings. The dawn of pre-stressed concrete technology has given incentive for making concrete of high strength. In India high strength concrete is used in pre-stressed concrete bridges of strength from 35N/mm^2 to 45N/mm^2. Presently Concrete strength of 75 N/mm^2 is being used for the first time in one of the flyover at Mumbai. Also in construction of containment dome at Kaiga power project used High Strength Concrete (HSC) of 60MPa with silica fume as one of the constituent.

High strength concrete (HSC) is used extensively throughout the world like in the gas, oil, nuclear and power industries are among the major uses. The application of such concrete is increasing day by day due to their greater structural performance, environmental friendliness and energy conserving implications. Apart from the usual risk of fire, these concretes are exposed to high temperatures and pressures for considerable period of time.

In the present study, the different admixtures were used to study their individual and combined effects on the resistance of concrete in addition to their effects on workability, durability and compressive strength by the replacement of admixtures by 10%, 15% of silica fume &10%, 20% and 30% of fly ash by the weight of cement with a constant amount of 0.5% steel hook fibers are added by volume of concrete, throughout the study.

Key Words: HSC, Workability, durability and Compressive Strength.

1. INTRODUCTION

High-strength concrete is precise, where reduced weight is important or where architectural considerations for small support elements. By carrying loads very efficiently than normal-strength concrete, high-strength concrete also reduces the total amount of material placed and lower the overall expenditure and weight of the structure. High-strength concrete columns can hold more weight and therefore be made slimmer than regular strength concrete structures, which allows for more useable space, especially in the lower floors of buildings. High Strength Concrete is also used in other engineering structures like bridges, fly-over etc. From the general principles behind the design of high-strength concrete mixtures, it is clear that high strengths are made possible by reducing porosity, in homogeneity, and micro cracks in the hydrated cement paste and the transition zone.

The utilization of fine Pozzolanic materials in high-strength concrete (HSC) like silica fume and fly ash leads to reduction in size of the crystalline compounds, particularly, calcium hydroxide. Consequently, there is a reduction of the thickness of the interfacial transition zone in high-strength concrete. Applications of mineral admixtures such as silica fume (SF), fly ash (FA) in concrete are effective and easy to future increase in the strength and make durable for high strength concrete. The addition of admixtures to the concrete mixture increases the strength by pozzolanic action and filling the small voids and that are created between cement particles.

1.1. HIGH STRENGTH CONCRETE

High-strength concrete structures can hold more weight and therefore be made slimmer than normal strength concrete columns, which allows for more useable space, especially in the lower floors of buildings. High-strength concrete is specified where reduced weight is important or where architectural considerations call for small support elements. By carrying loads more efficiently than normal-strength concrete, high-strength concrete also reduces the total amount of material placed and lower the overall cost of the structure.

1.2. HIGH STRENGTH FIBER REINFORCED CONCRETE

The use of high strength concrete (HSC) is continuously increasing due to its mechanical and durability advantages over normal strength concrete (NSC). In high-rise buildings, HSC can reduce the dimensions of the lower-story columns, which makes it a more cost-effective choice for builders than NSC, HSC is more brittle in comparison with NSC and that the confinement provided to HSC is less effective than in NSC. Therefore, greater confinement is required for the structures made from higher strength concrete to achieve similar strength and ductility enhancements.

The addition of high strength steel fibers to a reinforced concrete beam increased flexural strength and ductility of fiber-reinforced beams stems from the post-cracking tensile strength of high strength fiber-reinforced concrete. This residual strength also tends to reduce crack sizes and spacing's. The use of steel fibers is particularly attractive for high-strength concrete, which can be relatively brittle without fibers, or if conventional stirrups can be eliminated, which reduces reinforcement congestion.

1.3. FLY ASH

Fly ash is the most widely used supplementary cementations material in concrete. It is a byproduct of the combustion of pulverized coal in electric power generating plants. Upon ignition in the furnace, most of the volatile matter and carbon in the coal are burned off. During combustion, the coal's mineral impurities (such as clay, feldspar, quartz, and shale) fuse in suspension and are carried away from the combustion chamber by the exhaust gases.

Fig -1: Sample of Flyash going to mixed in Concrete

1.4. STEEL HOOK FIBERS

Steel fibres make considerable improvements in flexural, impact and fatigue strength of concrete. These fibres used in concrete work as crack arrester and would substantially improve its static and dynamic properties. Compressive strength of fibre reinforced concrete increased with increase in steel fibre content. The addition of steel fibres shears strength increases significantly.

2. LITERATURE REVIEW

Constantia Achilleos et al [1] examined on Proportioning of Steel Fibre Reinforced Concrete Mixes for Pavement Construction and Their Impact on Environment and Cost, Steel fibre reinforced concrete (SFRC) is a construction material investigated for more than 40 years including for pavement applications. A number of studies have demonstrated the technical merits of SFRC pavements over conventional concrete pavements; however little work has been carried out on the environmental and economical impact of SFRC during the pavement's life cycle. Therefore, extended research was undertaken within the framework of the EU funded project ―EcoLanes‖ to estimate the environmental and economical loadings of SFRC pavements. The innovative concept of the project is the use of recycled steel tyre-cord wire as concrete fibre reinforcement, which provides additional environmental benefits for tyre recycling over land-filling.

Prof. Vishal S. et al [2] examined on influence of silica fume on concrete. Traditionally, Ordinary Portland cement is used for making the civil structures. Portland cement can be partially replaced by silica fume. Silica fume is non metallic and non hazardous waste of industries. It is suitable for concrete mix and improves properties of concrete i.e. compressive strength etc. The main objective of this research work is to determine the optimum replacement percentages which can be suitably used under the Indian conditions. To fulfill the objective various properties of concrete using silica fume have been evaluated. Further to determine the optimum replacement percentage comparison between the regular concrete and concrete containing silica fume is done .It has been seen that when cement is replaced by silica fume compressive strength increases up to certain percentage (10% replacement of cement by silica fume).But higher replacement of cement by silica fume gives lower strength. The effect of Silica fume on various other properties of Concrete has also been evaluated. This paper is a very good tool for the beginners to understand the effect and have an overlook of Silica Fume on Concrete.

Jacek Katzer [3] carried out an investigation on Steel Fibers and Steel Fiber Reinforced Concrete in Civil Engineering. Since the beginning of applications of civil engineering materials based on clay, lime, and cement, there has been a need to find a way to decrease their brittleness. In ancient times, the problem was solved by modifying brittle clay bricks with the addition of fibers of an organic origin. These approaches can be examined through a reading of the descriptions of Roman baths construction (Vitruvius 1999). Today it is steel fiber which is mainly used to reinforce concrete and overcome the problem of brittleness. This paper describes the most interesting applications of steel fiber reinforced concretes (SFRC) all over the world. Firstly, the author presents the evolution of steel fibers and SFRC. Secondly, the paper covers the contemporary importance of SFRC in civil engineering.

2.1. PROBLEM IDENTIFICATION

It was observed that much work has been proceeded to find the optimum dosage of silica fume and fly ash to produce good strength and durable concrete.The maximum percentage of steel fibers to be used in concrete along with silica fume to get good outcome.The effect of silica fume and fly ash with fibers on capillary and porosity of concrete. The use of different fibers in concrete and their strength properties are studied.It was observed that optimum replacement of cement occurs at 10% silica fume and 20% fly ash, gives maximum strength.Introducing silica fume improved mechanical and durability properties of concrete.Steel fibers remarkably increased splitting tensile and strength of High strength fiber reinforced concrete.

3. OBJECTIVE OF PRESENT WORK

3.1. SCOPE AND OBJECTIVE OF PRESENT WORK

The objective of the present work is to develop concrete with good strength, less porous, less capillarity so that durability will be increased. For this purpose it requires the use of different pozzolanic materials like Fly ash and silica fume along with fiber. So the experimental program to be undertaken. To reduce the impact of waste materials on environment; to find out the percentage use of admixtures feasible for construction; to determine the mix proportion with Fly ash and silica fume with fiber to achieve the desirable needs; to determine the water/ binder ratio, so that design mix having proper workability and strength; to investigate different basic properties of concrete such as compressive strength, splitting tensile strength, flexural strength etc., and comparing the results of different proportioning. To determine the chloride penetration of concrete using Rapid Chlorine Penetration Test (RCPT).For safe construction, to find the how much percentage of silica fume and fly ash is partially replaced by cement and steel fibers as an admixture to attains strength at maximum level.

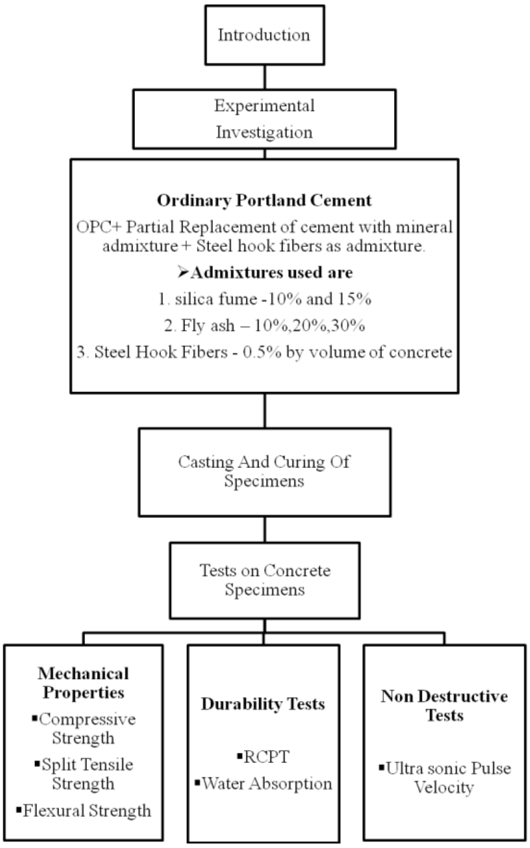


Fig -2: Flow chart represents the Objective work

4. MATERIALS AND EXPERIMENTL STUDY

4.1. MATERIALS

The materials used in present investigation include;

1. Cement-Ordinary Portland Cement (OPC)
2. Mineral Admixtures-
   a. Silica Fume and
   b. Fly-Ash
3. Fine aggregates
4. Coarse aggregates
5. Steel hook fibers as admixture and
6. Water

4.2. FINE AGGREGATE

Sand is a naturally occurring material from Rock and Minerals by weathering and is composed of majorly sio_2, and Calcium carbonate. The sand used throughout the experimental work was obtained from the Muthireveluvanka near Chittoor, Chittoor district, Andhra Pradesh. This type of sand was used by many of researchers as an ingredient in concrete. According to **IS 650:1966**, the sand used in cement concrete should confirm to the following specifications.

Table -1: PROPERTIES OF FINE AGGREGATES

S.no	Properties	Results
1	Specific gravity	2.583
2	Bulking of sand	4
3	particle size variation	0.15 to 4.75
4	Water absorption for sand	1
5	Bulk Density of Sand	1460
6	Fineness modulus osand.	2.8

The properties of sand like specific gravity of sand is 2.583, and Bulking of sand is 4%. Particle size variation of sand is between 0.15 to 4.75 mm. Water adsorption for sand is noticed as 1%. Bulk density of sand is abserved as 1460 kg/m^3. The fineness modulous of sand is 3.8%.

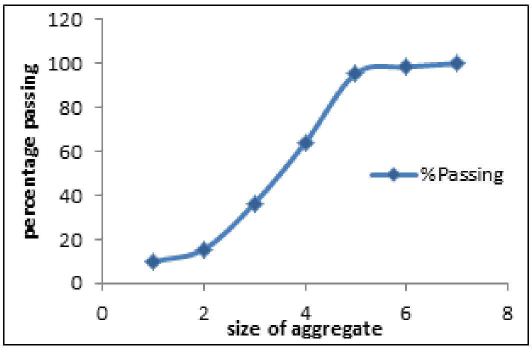


Fig -3: Fineness modulus of fine aggregate

4.3. SILICA FLUME

Silica fume is a waste by-product of the production of silicon and silicon alloys. It is available in different forms, of which the most commonly used is in a dandified form. Silica fume used was conforming to IS: 1331(PART-1) 1992 and also ASTM C (1240-2000). Silica fume was also referred as micro silica or condensed silica fume, is a byproduct material that is used as a pozzolanic. Low heat of hydration, high strength, increase sulfate

Resistance and Reduced permability.

4.4. FLY ASH

For this project Fly ash is taken from Rayalaseema thermal power plant (RTPP), Kadapa. RTPP has installed ESP for segregation and collection of fly ash into six different fields. As the field number increases the fineness of fly ash increases but the quantity decreases. Field-1 fly ash has coarse particles and is not suitable for concrete applications. Since maximum availability of fly ash is from field-2, some of them was used for our study. This fly ash conforms to the requirements of IS: 3812 part-I and also ASTMC-618 type-F.

4.5. STEEL HOOK FIBERS

Steel fibres make significant improvements in flexural, impact and fatigue strength of concrete. These fibres are used in concrete as crack arrester and would substantially improve its static and dynamic properties. Compressive strength of fibre reinforced concrete increased with increase in steel fibre content. The additions of steel fibres shear strength increases significantly. Steel hook fibers compliance to the requirements of ASTM A 820 (type-1 cold drawn wire).

Table -2: PROPERTIES OF STEEL HOOK FIBERS

S.no	Type	Hooked End
1	Diameter of fibers	0.60 mm
2	Length of fibers	30 mm
3	Aspect ratio (L/D)	50

5. METHODOLOGY

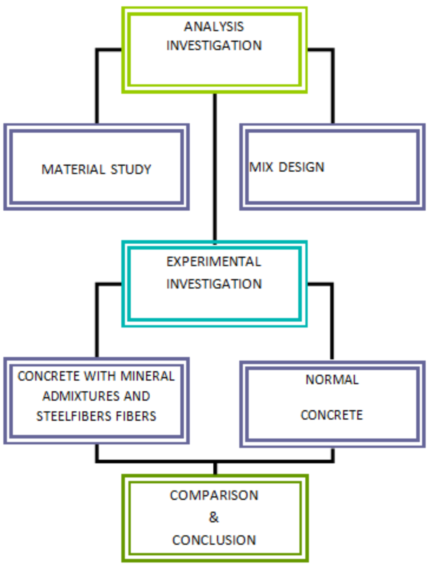


Fig -4: Methodology & Analysis Format

5.1. MIX PROPORTIONS OF HSFRC FOR M60 GRADE

Table -3: MIX PROPORTIONS OF HSFRC

Proportion	Water	Cement	Fine Aggregate	Coarse Aggregate
Proportion by Weight	147 Kg	420	650.916	1254.24
Proportion by Ratio	0.35 Kg	1	1.55	2.985

5.2. PREPARATION OF CONCRETE

Production of quality concrete requires meticulous care exercised at every stage of manufacture of concrete. It is interesting that the ingredients of good concrete and bad concrete are the same. If meticulous care is not exercised and good rules are not observed the resultant concrete is going to be of bad quality. With the same material if intense care is taken to exercise control at every stage it will result in good concrete. The various stages of manufacture of concrete are: Batching, Mixing , Placing, Compaction & Curing.

5.3. COMPACTION

Compaction of concrete is this process adopted for expelling the entrapped air from the concrete In the process of mixing. Transporting and placing of concrete air is likely to get entrapped in the concrete. The lower the workability higher is the amount of air entrapped. In other words, stiff concrete mix has high % of entrapped air and therefore would need higher compacting efforts than high workable mixes.

If this is not removed fully the concrete losses strength considerably. The relationship between loss of strength the air voids left due to lack of compaction. It can be seen that 5% voids reduce the strength of concrete by above 30% and 10% voids reduce the strength by over 50% .Therefore, it is imperative that 100% compaction of concrete one of the most important aim to kept in mind in good concrete-making practices.

Fig -5: Sampling of Concrete

5.4. CURING

Concrete while hydrating, releases high heat of hydration. The heat is harmful from the point of view of volume stability. If the heat generated is removed by some means, the adverse effect due to the generation of heat can be reduced. This can be done by a through water curing.

5.5. WATER CURING

This is by far the test method of curing as it satisfies all the requirements of curing, namely, promotion of hydration, elimination of shrinkage and adsorption of the heat of hydration.

Fig -6: figure shows a curing tank in which concrete specimens were kept for 3,7,28,56,90 days for hydrating of concrete.

5.6. TESTS CARRIED OUT ON FRESH CONCRETE

5.6.1. SLUMP CONE TEST

Slump cone test apparatus was made according to IS: 7320-1974 and used for calculating normal consistency of concrete Fresh concrete was filled in slump cone by tamping each layer for 25 times with a tamping rod. Later metal cone is raised slowly in a vertical direction. As soon as the settlement of concrete slump of the concrete measured by scale.

5.6.2. COMPACTION FACTOR TEST

Place the concrete sample gently in the upper hopper to its brim using the hand scoop and level it. Cover the cylinder and Open the trap door at the bottom of the upper hopper so that concrete falls in to the lower hopper .Push the concrete sticking on its sides gently with the road. Open the trap door of the lower hopper and allow the concrete to fall in to the cylinder below.

Cut of the excess of concrete above the top level of cylinder using trowels and level it. Clean the outside of the cylinder. Weight the cylinder with concrete to the nearest 10 g. This weight is known as the weight of partially compacted concrete (w1). Empty the cylinder and then refill it with the same concrete mixture in 3 layers approximately 5cm deep, each layer being heavily rammed to obtain full compaction. Level the top surface. Weigh the cylinder with fully compacted. This weight is known as the weight of fully compacted concrete (w2).Find the weight of empty cylinder (W) Compaction Factor= (W1-W/ W2-W)

5.6.3. TESTS FOR HARDENED CONCRETE

Testing of hardened concrete play an important role in controlling and conforming the quality of cement concrete works. Systematic testing of raw materials fresh concrete and hardened concrete are inseparable part of any concrete with regard to both strength and durability the test methods should be simple, direct convenient to apply one of the purposes of testing hardened concrete is to conform that the concrete used at site has developed the required strength.

5.6.4. COMPRESSIVE STRENGTH TEST

Compressive Strength Testing Machine is used for the determination of compressive strength for cubes and cylinders. The specimens after subjected to curing drying for 1 day are loaded in compressive strength testing machine. It is able to provide compressive load up to 2000kN. When tested concrete cubes should fail by developing of a crack in body of cubes.

Fig -7:Compressive Strength Testing Machine

5.6.5. SPLIT TENSILE STRENGTH TEST

As per IS specifications **IS 5816:1999** Split tensile test is to be conducted. The cylinder of size is 150 mm diameter and 300 mm length are taken and cylinders were placed horizontally between the loading plate surfaces of a compression testing machine. Then the load was applied to the cylinder until failure of the vertical diameter along the cylinder length. The maximum load on the cylinder was to be observed. Cylindrical splitting tension test is also sometimes referred as "Brazilian test ". This test was developed in Brazil in 1943. At about the same time this independently developed in Japan.

Fig -8:Split Tensile test on Cylinder

5.6.6. FLEXURAL STRENGTH TEST

The ultimate flexural strength analysis presented in this paper is based on the conventional compatibility and equilibrium conditions used for normal reinforced concrete except that the contribution of the fibers in the tension is recognized.

The analysis is based on the following assumptions,

1. Plane sections remain plane after bending
2. The compressive forces equal the tensile forces.
3. The internal moment equals the applied bending moment.

Fig -9: Flex strengthural test on beam

5.6.7. WATER ABSORPTION TEST

One of the most important properties of a good quality concrete is low-permeability, especially one resistant to freezing and thawing. The water absorption test is carried out at the age of 28 day according to standard procedure **ASTM C 642-11**. For the water absorption test, 100 x 200mm size of cylinder is cut into three parts (top, middle, bottom) of 50mm thickness and 100mm diameter, then specimens are dried in an oven at 100^{o} to 110^{o} C for not less than 24 hours. After removing each specimen from the oven, allow it to cool in dry air to a temperature of 20^{o} to 25^{o} C and determine the mass.

Fig -10: Concrete Specimen with Water absorption Test

5.6.8. RAPID CHLORIDE PENETRATION TEST

This test method was originally developed by the Portland Cement Association, under a research program paid for by the Federal Highway Administration (FHWA). The original test method may be found in FHWA/RD-81/119, “Rapid Determination of the Chloride Permeability of Concrete.” Since the test method was developed, it has been modified and adapted by various agencies and standard’s organizations.

Fig -10: RCPT Test Layout

5.7. NON-DESTRUCTIVE TEST ON CONCRETE CUBES

5.7.1. ULTRASONIC PULSE VELOCITY TEST

The direction in which the maximum energy is propagated is at right angles to the face of the transmitting transducer; however, it is possible to detect pulses travelling through concrete in some other direction. In other words it is possible, to make measurements of pulse velocity (BS 12504-4, 2004) by placing the two transducers on either:

- opposite faces - direct transmission,
- adjacent faces - semi-direct transmission;
- the same face - indirect or surface transmission

6. RESULTS & DISCUSSION

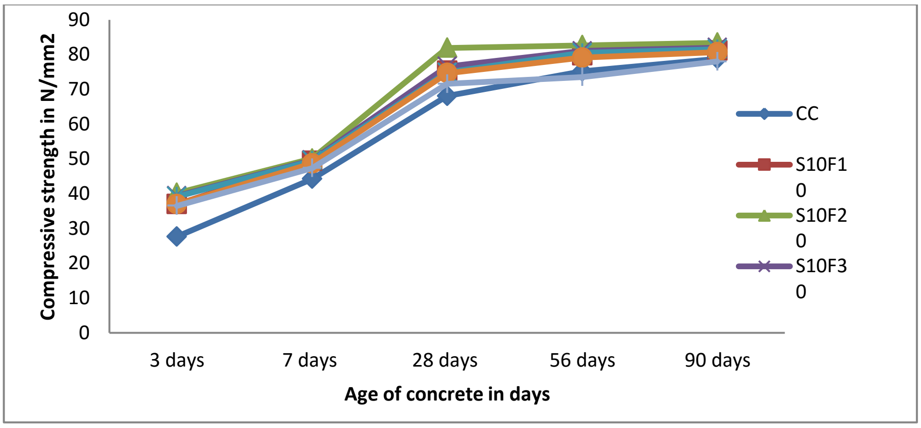
The results of present investigation are presented both in tabulated and graphical forms. In order to facilitate the analysis, interpretation of results is carried out at each phase of experimental study. This interpretation of the results obtained based on the current knowledge available in the literature as well as on the basis of results obtained. The significance of results is assessed with reference to the standards specified by the relevant IS codes.

6.1. COMPRESSIVE STRENGTH RESULTS

The compressive strength of concrete for different replacements of cement with 10% and 20% of silica fume and 10%,20% and 30% of fly-ash with 0.5% steel hook fibres by volume of concrete were tested for 3,7,28,56 and 90 days using compressive test machine. The water to cement ratio was taken as 0.35. Three cubes were casted for each proportion and the average of three test samples was taken for the accuracy for results. At the room temperature, the concrete cubes were cured. The values of crushing loads obtained are taken and the compressive strength obtained are shown in below table.

Table -4: Compressive Strength Comparison For all Proportions Pf Concrete With 0.5% Steel Hook Fibers As Admihture

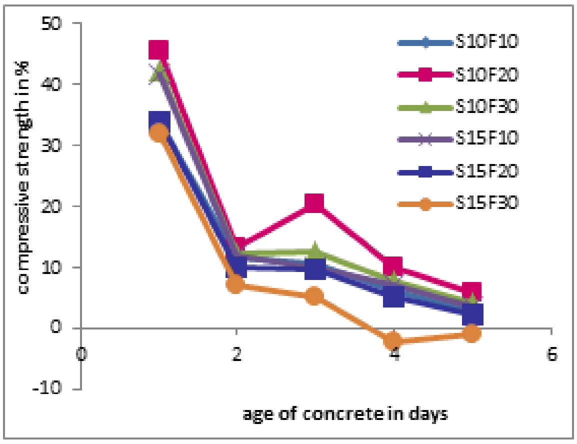
S.NO	SAMPLE	AVERAGE COMPRESSIVE STRENGTH				
		3 Days	7 Days	28 Days	56 Days	90 Days
1	Controlled mix	27.62	44.23	68.0	75.1	78.7
2	**10%SF+10%FA+0.5%SHF**	36.96	49.40	75.33	79.77	81.11
3	**10%SF+20%FA+0.5%SHF**	40.18	50.07	81.92	82.67	83.40
4	**10%SF+30%FA+0.5%SHF**	39.33	49.63	76.60	81.06	82.00
5	**15%SF+10%FA+0.5%SHF**	39.18	49.48	74.88	80.51	81.55
6	**15%SF+20%FA+0.5%SHF**	36.96	48.67	74.67	79.11	80.66



Graph 1: Compressive Strength Comparison of all proportions of concrete with 0.5% steel hook fibers as admixture.

Table -5: Percentage Change in Compressive Strength for Different Proportions of Concrete with Age.

Days	S10F10 -%	S10F20- %	S10F30-%	S15F10-%	S15F20-%	S15F30-%
3	33.76	45.42	42.34	41.8%	33.76	32.13
7	11.71	13.22	12.23	11.89	10.04	7.03
28	10.7	20.34	12.51	10%	9.8%	5.11
56	6.10	9.96	7.78	7.09	5.22	-2.17
90	3.00	5.92	4.14	3.56	2.43	-0.93

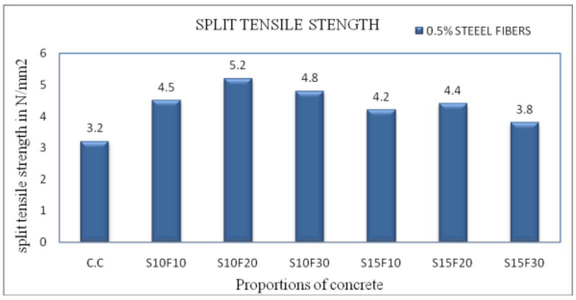


Graph 2: Percentage Compressive strength comparison of different proportions of concrete with controlled concrete.

6.2. SPLIT TENSILE TEST RESULTS

Table -6: Split Tensile Strength Results of Concrete Made with different replacement levels of silica Fume and Flyash

Days	Cases	Average Split Tensile Strength-N/mm^2
28 Days	Controlled mix	3.27
	10% SF+10% FA+ 0.5% steel fibers	4.5
	10% SF+20% FA+ 0.5% steel fibers	5.2
	10% SF+30% FA+ 0.5% steel fibers	4.8
	15% SF+10% FA+ 0.5% steel fibers	4.2
	15% SF+20% FA+ 0.5% steel fibers	4.4
	15% SF+30% FA+ 0.5% steel fibers	3.8



Graph 3: Tensile strength at 28 days for Various percentages of silica fume and Flyash

6.3. DURABILITY TEST RESULTS

Table -7: Water Absorption Test For Different Proportions of Concrete

S.No	Sample	Wet Weight	Dry Weight	Water absorption %
1	CC	9.56	9.40	1.70
2	S10F10	9.52	9.42	1.06
3	S10F20	9.53	9.45	0.84
4	S10F30	9.44	9.39	0.53
5	S15F10	9.44	9.35	0.96
6	S15F20	9.46	9.40	0.63
7	S15F30	9.49	9.44	0.53

From above table it is observed that, the percentage water absorption for different proportions of concrete varies with the silica fume and fly ash replacement. With increase in silica fume and fly ash replacement to cement shows decreased percentage of water absorption because of their fine particle size. At 10% and 15% replacement of silica fume with 30% fly ash gives low water absorption as 0.53%.

The Rapid Chloride Permeability Test results are presented in the above table 6.5 for different dosages of 10% and 15% of silica fume and 10%, 20% 30% of fly replacement to cement with a constant proportion of 0.5% steel hook fibers are added to the concrete. The results were noted for every 30min up to 6hours from RCPT apparatus by summing up the readings the calculations are done by using Table 5.7 presents the chloride ion penetrability based on charge passed as per ASTM C 1202 is decided.

The effects on different dosages of silica fume, fly ash and steel fibers, the test results of chloride permeability through Rapid Chloride Permeability Test are presented in the table 6.5.2 for different proportions of concrete. The concrete specimen tested by RCPT according to the results noted for combinations of OPC with 10% silica fume and 30% fly ash as replacement to cement and addition of steel fibers at the 0.5% showed the very low permeability to chloride ion permeability and at 15% silica fume and 30% fly ash as replacement to cement and addition of steel fibers at the 0.5% also showed very low permeability to chloride ion.

From above test results it is observed that, with increase in percentage of silica fume and fly ash replacement to cement shows higher resistance to chloride ion permeability.

7. CONCLUSION

Based on the results obtained from the present investigation the following conclusions were made;

1. By the addition of steel hook fibers in concrete leads to increase in compressive strength and makes concrete into ductile.
2. In split tensile and flexural tests, we notices that crack width reduced due to the presence of steel fibers when compared with conventional specimen.
3. When the cement is replaced with 10% silica fume and 20% fly ash gives the optimum compressive strength, split tensile strength and flexural strength.
4. At 10% silica fume and 20% fly ash replacement to cement, compressive strength were increased up to 20.34% when compared with conventional concrete for 28 days.
5. At 10% silica fume and 20% fly ash replacement to cement, split tensile strength were increased up to 60.85% when compared with conventional concrete for 28 days.
6. At 10% silica fume and 20% fly ash replacement to cement, flexural strength were increased up to 38.74% when compared with conventional concrete for 28 days
7. The addition of silica fume and fly ash as replacement to cement, its normal consistency and initial setting time increases with increase in percentage and final setting time decreases with increase in percentage.
8. The use of mineral admixtures in concrete causes considerable reduction in the volume of large pores at all ages and thereby reduces the permeability of concrete mixes because of its high fineness and formation of C-S-H gel.

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