Mechanical and Durability Properties of Steel Fiber Reinforced Concrete using Silica Fume

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***Abstract* - In this study steel fiber reinforced concrete incorporating silica fume has been investigated, crimped steel fiber is used by volume of 1%, 1.5%, 2%, and 2.5%, silica fume content is 5% and 10% as partial replacement of cement. For better workability high range superplasticizer is used to reduce the amount of water and maintained workability. Moreover, mechanical and durability properties of SFRC are investigated, the compressive strength of steel fiber reinforced concrete is increased with increasing in content of silica fume and steel fiber at 7, 28, and 56 days. Highest result of compressive strength is achieved in the mixes with content of 2.5% of steel fiber and 10% of silica fume. The split tensile strength is conducted for all the mixes, steel fiber has significant result against peck loads, split tensile strength has significant results in all the mixes. Flexural strength of SFRC concrete has improved with content of steel fiber, increased in volume of steel fiber has increased in flexural strength. for durability properties water absorption and acid resistance tests are conducted and the results are given in the results and discussion.**

***Index Terms* - mechanical properties, steel fiber reinforced concrete, compressive strength, split tensile strength, silica fume, flexural strength, durability properties.**

I.INTRODUCTION

Construction industry is the one the biggest industry in the world, in the current decade the requirements and demand of the constructions works are more as compare to the past decades. the development in technology and rising the population are the two main reasons which leads construction industry over others, moreover the growth in population of the world and development in technology have their big effect in the field of civil engineering, thus the engineering and construction technology getting advanced, and many new powerful machineries have launched which are help manpower to build different types of structures. In the current time the engineering projects are more advanced, and they belt many mega projects such as high-rise building, skyscrapers, long span bridges, dams etc. all over the world. Concrete and cement-based materials are most using materials in the construction industries because of their huge availability of natural materials and production of cement in big amount in the manufacturing companies. Concrete has incredible properties such as workability, mechanical properties, durability that can easily workable and has perfect result against loads and environmental effects. Moreover, the existence of natural materials makes concrete economical and less in cost, so in this regards concrete has most usage in the construction projects. concrete is the composition of cement with fine aggregate, coarse aggregate mixing with water, cement particles has poured the voids bonding the sand and coarse aggregates. Concrete has various ingredients and materials like minerals admixtures, chemical admixtures, industrial waste etc. each of these materials is using as per design mix and aim of work. Concrete has several types such as plain/ ordinary/ conventional or normal concrete, Steel fiber reinforced concrete, high performance concrete, fiber reinforced concrete, light weight concrete, self-compacting concrete, polymer concrete etc. every type of these concrete has their own usage as per the design mix and requirement of the project work. Conventional or normal concrete using more in construction projects because in the mixes of this concrete using cement, fine aggregate, coarse aggregate and water, there are no need of any mineral admixture or chemical admixtures. Steel fiber reinforced concrete is the one of the important types of concrete that has huge usage in current time in civil engineering, the importance of steel fiber concrete has significant results in tension. Steel fiber concrete are using in mega projects in civil engineering such as roads pavements, runways, long span bridges most important in construction of tunnels, in short create concrete. tunnel construction is become more important in the current time all over the world, now days the requirement of tunnels constructions is more as compare to past time, developed machinery and technology are the major reasons for construction of tunnels. Long tunnels are constructed all over the world to reduce long distance between one place to another, tunnel construction is become easy with the help of drill machineries, steel fiber concrete and short create technology.

II. EXPERIMENTAL PROGRAM

2.1. Materials

The materials that used in the current experimental work are Portland cement type 53 river sand as fine aggregate, crush as coarse aggregate with maximum size of 20mm, silica fume or micro silica fume that is available in the market silica is by product of silicon and ferrosilicon alloys, small particles of silica makes concrete dense and improves both fresh and hardened properties of concrete moreover, silica fume pore voids of concrete and its particles are small as compare to cement particles it can reduce segregation in concrete. for the better workability and reduce the quantity of water in concrete used high range water reducer sulphonated naphthalene based (superplasticizer), water reducer makes concrete workable and reduce maximum 30% of water, with reducing of water concrete reached high mechanical properties as well as durability. There are various types of steel fiber that are used in concrete in the current work crimped steel fiber is used that having length of 35mm, nominal diameter of 0.55mm and aspect ratio of 64 in different volume, steel fiber improves the mechanical properties of concrete such as compressive strength, split tensile strength and flexural strength, improvement of mechanical properties has impact on durability and age of concrete.

2.2. Preparation of samples

The specimens of experimental work for all the tests such as cubes, cylinders, beams are of standard sizes steel molds. Inside of the specimens used machine oil before casting as well as tight all the bolts, the concrete mixes casting in proper way inside the molds and each layer of concrete compacted with steel rod, after completing casting the specimens compacted with shacking table. All the samples are demolded after 24 hours and put it in the water for curing. Cubes having size of (150 x 150 x 150mm) used to determine compressive strength test, (100 x 200mm) cylinder used to determine splitting tensile strength test and (100 x 100 x 500) prisms used to determine flexural strength test. All tests have been determined according to IS 519 – 1959.

2.3. Test methods

Compressive strength test is one the common test on concrete, as we know concrete is good in off in compression. Moreover, the compressive strength test is conducted for more important characteristic property of concrete and structural design purpose related to compressive strength. the compression machine of having 3000KN capacity was used to determine the compressive strength test, the sample has fixed in the machine and load has been applied in constant, the maximum load applied in which sample got failed and failure has been recorded. The maximum applied load divided by the cross section of the specimen gave as the compressive strength of the cube. compressive strength test was done on three cubes specimens for each group of samples and taken the average value. the figure below is shown the setup of the test. Compressive strength test done at the age of 7, 14, 28, and 56 days. Split tensile strength test is conducted on cylinders that having 100 mm diameter and 200 mm height, the teste has done on the compression machine that has 1000 KN of capacity. The splitting tensile strength test is doing on concrete to know the impact of indirect tensile strength of concrete. For each group of samples there were tested three cylinders and takes the average results of the cylinder specimens. The flexural strength test conducted on the prism specimens that have (100 x 100 x 500) mm dimension, the test has been done on flexural strength machine, the beam specimen is subjected to two-point loading system to determine the flexural strength of concrete. the test has done on three specimen and taken the average results for each group of samples. water absorption test conducted on cubes specimens of 150 mm at the age of 28 days the specimen drying in the oven at 105C° constant temperature, curing according to ASTM 642 then the specimens taken out from oven and cooling to room temperature and immersing in water. The specimens are taken out at regular intervals of time and weighted. This process has been continued till the weight of specimens become constant or fully saturated. The results are given from difference of the water saturated mass and oven dry mass shown as a percentage of oven dry mass given the saturated water absorption. Cubes of 150 mm are casted and stored at 27 C° temperature for 24 hours after the specimens were kept water curing for 28 days, moreover the specimens taken out after curing and allowed it for one day to dry, cube specimens are weighted and noted the reading forward for acid attacks 5% of sulphonic acid (H2SO4) is used by volume of water, the cubes are immersed in the acid for 30 days. The acid resistance of concrete got as weight loss and residual compressive strength.

Table 2.1 Mixture proportion kg/m^3

Mix ID	W/C	Cement	RS	CA	SF	Steel fiber	SP	Water
CC	0.28	420	610	1233	-	-	-	202
SFRC1S	0.28	450	610	1233	35	-	2.53	202
SFRC2S	0.28	450	610	1233	35	-	2.53	202
SFRC1	0.28	450	610	1233	-	12	2.53	202
SFRC2	0.28	450	610	1233	-	12	2.53	202
SFRC3	0.28	450	610	1233	-	12	2.53	202
SFRC4	0.28	450	610	1233	-	12	2.53	202
SFRC1*	0.28	450	610	1233	35	12	2.53	202
SFRC2*	0.28	450	610	1233	35	12	2.53	202
SFRC3*	0.28	450	610	1233	35	12	2.53	202
SFRC4*	0.28	450	610	1233	35	12	2.53	202
SFRC5*	0.28	450	610	1233	35	12	2.53	202
SFRC6*	0.28	450	610	1233	35	12	2.53	202
SFRC7*	0.28	450	610	1233	35	12	2.53	202
SFRC8*	0.28	450	610	1233	35	12	2.53	202

III. RESULTS AND DISCUSION

Impact of crimped steel fiber on the compressive strength of SFRC incorporating silica fume with various percentages the average of three specimens at 7 days, 28days and 56 days are given in the table 2.4, the volume of steel fiber are 1%, 1.5%, 2% and 2.5% in the mixes, with increasing in the volume of steel fiber there are increase in the compressive strength of steel fiber reinforced concrete about 2.5% to 10% at the age of 7,28 and 56 days. Increasing in the content of steel fiber are effects directly, the compressive strength the maximum compressive strength is achieved in the mixes of SFRC8* that has steel content of 2.5% and silica fume content of 10%. The results of splitting tensile strength of SFRC with silica fume, for all the mixes splitting tensile strength have been done the maximum strength is achieved in the mix of SFRC4S with content of 10% silica fume as partial replacement of cement. the split tensile strength of steel fiber reinforced concrete are achieved in the mixes of SFRC4 with steel fiber content of 2.5% the results are compute from the average of three specimens. For the third group mixes that are the combination of steel fiber and silica fume, there are total of eight combinations, the highest split tensile strength achieved in the mixes of SFRC8* that having 2.5% volume of steel fiber and silica fume content of 10%.

In general, the split tensile strength are increased with increase in content of steel fiber, the reason is the division of steel fiber in three layers in each cylinder specimens. Flexural strength of SFRC mixes with silica fume are from the table it absorbed that mixes of steel fiber reinforced concrete containing silica fume are higher than control concrete at the ages of 7-day, 28 day and 56 day. The highest flexural strength is achieved in the SFRC4S mixes with content of 10% of silica fume at all the ages. Flexural strength of steel fiber reinforced concrete with steel fiber, the flexural strength of concrete containing steel fiber is higher than control concrete at all the ages the highest flexural strength is achieved in SFRC4 mixes with content of 2.5% of steel fiber at the ages of 7-day, 28 day and 56 day. Increasing in content of steel fiber has direct impact in the flexural strength of concrete. increased in content of steel fiber has increased the flexural strength. Flexural strength of steel fiber reinforced concrete with combination of steel fiber and silica fume, the flexural strength of SFRC is higher than control concrete at all the ages of testing, moreover among all eight mixes the highest strength is achieved in SFRC8* that has content of 2.5% of steel fiber and silica content of 10% at ages of 7-day, 28 day and 56 days. In over all the flexural strength are increased with increased in the content of steel fiber, load capacity of steel fiber is more in term of split tensile strength and flexural strength, the orientation of steel fiber is important in the mixes.

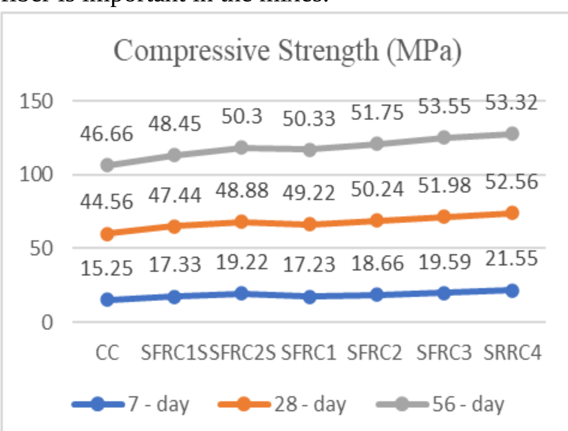

Fig: 3.1 Compressive Strength of SFRC with Silica Fume & Steel fiber

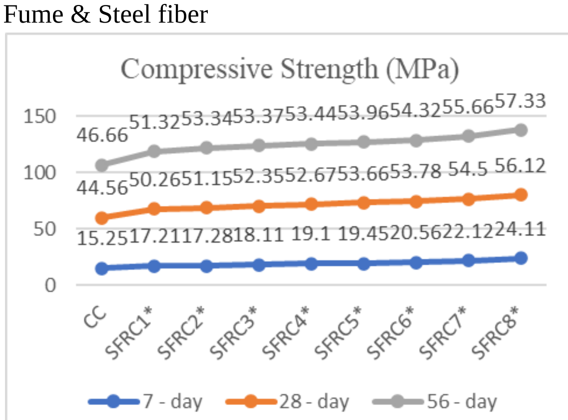

Fig: 3.2 Compressive Strength of SFRC with Combination. of Silica fume & Steel fiber.

Note. In fig: 3.1 CC represents normal concrete, SFRC1S, SFRC2S specimens presents compressive strength of concrete with 5 and 10 percent of Silica Fume respectively and SFRC1, SFRC2, SFRC3, SFRC4 represents 1, 1.5, 2, 2.5 percent of steel fiber respectively. In fig: 3.2 CC stans for normal concrete, SFRC1*, SFRC2*, SFRC3*, SFRC4* are represent 1%, 1.5%, 2% and 2.5% of steel fiber with 5% of silica. SFRC5*, SFRC6*, SFRC7*, SFRC8* are present 1%, 1.5%, 2% & 2.5% of steel fiber with 10% of silica fume.

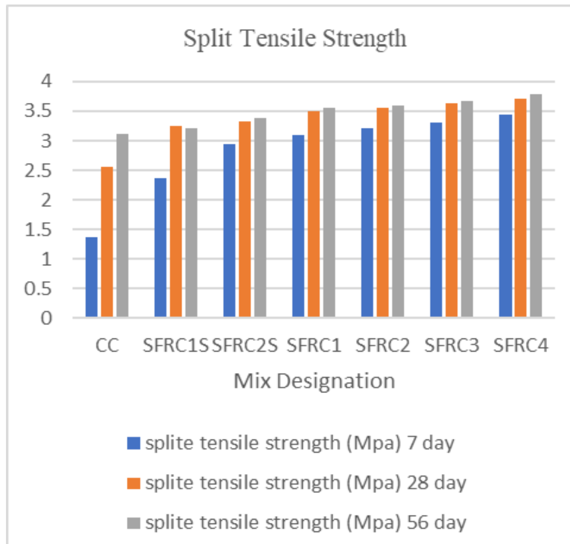

Fig: 3.3 Split Tensile Strength of SFRC with Silica Fume & Steel Fiber

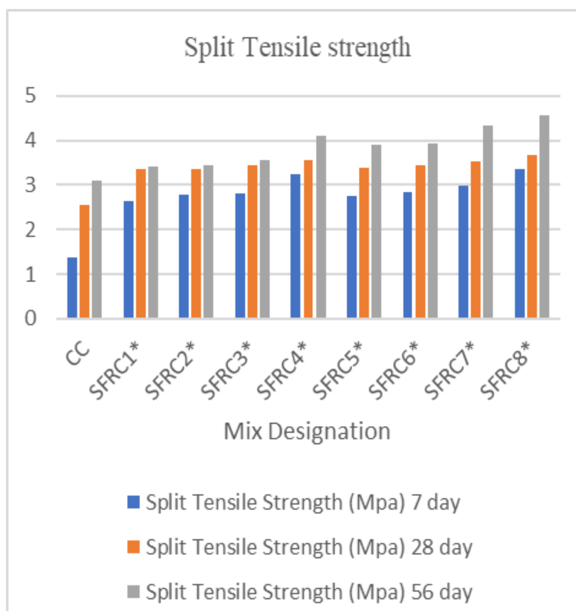

Fig: 3.4 Split Tensile Strength of SFRC with Combination of Silica Fume & Steel Fiber

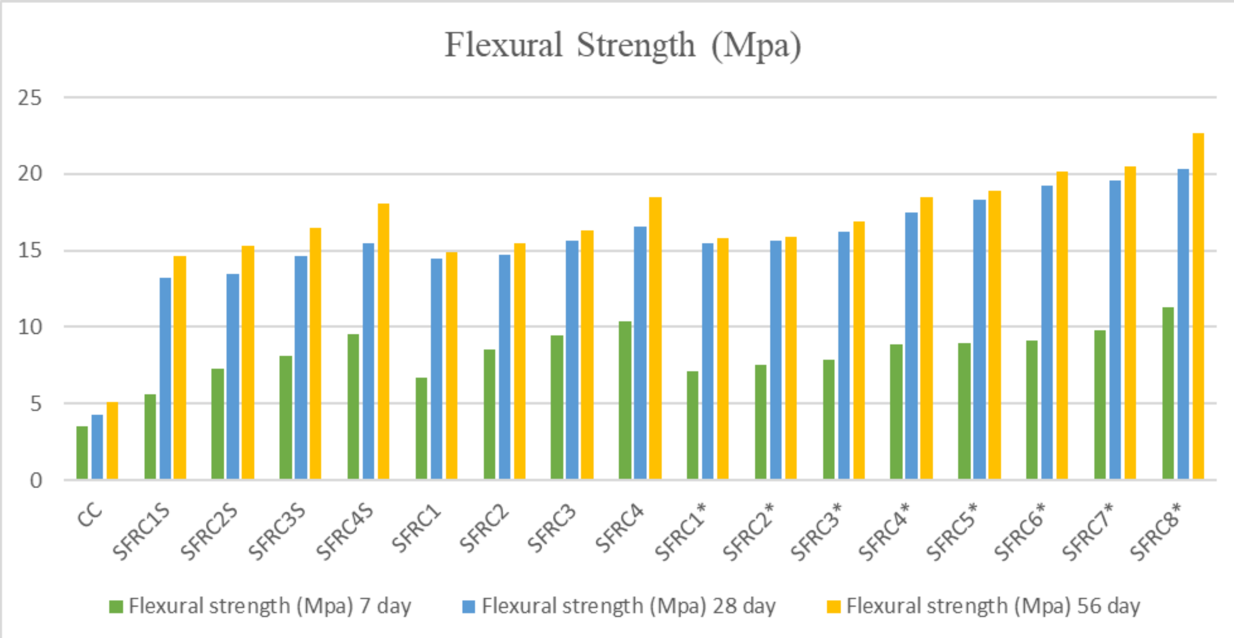

Fig 3.5 Flexural Strength of SFRC with all the mixes.

water absorption test conducted on cubes specimens of 150 mm at the age of 28 days the specimen drying in the oven at 105C° constant temperature, curing according to ASTM 642 then the specimens taken out from oven and cooling to room temperature and immersing in water. The specimens are taken out at regular intervals of time and weighted. This process has been continued till the weight of specimens become constant or fully saturated. The results are given from difference of the water saturated mass and oven dry mass shown as a percentage of oven dry mass given the saturated water absorption. The results of water absorption of SFRC with silica fume content of 5% silica fume is 21% less than control samples and the mixes of SFRC2* with 10% of silica fume are 18% more than control samples. For the mixes of SFRC with steel fiber in volume of 1%, 1.5%, 2% and 2.5% are less than control specimens about 12%, 16%, 22%, and 32% respectively. The results of water absorption of SFRC with content of silica fume and steel fiber, for the mixes of SFRC1*, SFRC2*, SFRC3*, SFRC4* having 5% of silica fume and steel fiber in volume of 1%, 1.5%, 2% and 2.5% are less than control specimens about 8%, 12%, 14% and 15% respectively. In the other hand the mixes with content of 10% silica fume with steel fiber are more than control specimens, about 9%, 12%, 18%, and 24% respectively. Cubes of 150 mm are casted and stored at 27 C° temperature for 24 hours after the specimens were kept water curing for 28 days, moreover the specimens taken out after curing and allowed it for one day to dry, cube specimens are weighted and noted the reading forward for acid attacks 5% of sulfuric acid (H_2SO_4) is used by volume of water, the cubes are immersed in the acid for 28 days. The acid resistance of concrete got as weight loss and residual compressive strength.

III. CONCLUSION

Experimental findings of mechanical and durability properties of steel fiber with silica fume studied. The compressive strength, split tensile strength, flexural and few durability properties of steel fiber reinforced concrete has been studied, based on the experimental work the following conclusion can be drown.

1. The compressive strength results of steel fiber reinforced concrete including silica fume, the concrete with content of 5% and 10% the compressive strength has been increased as compare to control specimens because of influence of silica fume because of fine particles of silica fume that pore the voids and make concrete dense. the compressive strength of mixes with steel fiber have been increased with increased in content of steel fiber. Moreover, the compressive strength of mixes with combination

of silica fume and steel fiber, the mixes of SFRC1* to SFRC8* were increased. The highest result of compressive strength achieved in the mixes of SFRC8*.

2. The results of split tensile strength of steel fiber reinforced concrete including silica fume, steel fiber and combination of both steel fiber and silica fume were high as compare to normal concrete. the highest split tensile strength achieved in the mixes of SFRC1* to SFRC8* respectively.
3. Flexural strength of steel fiber reinforced concrete have significant results in all the mixes of silica fume, steel fiber and combination of both steel and silica fume as compare to normal concrete, the highest flexural strength were given in the mixes of SFRC8* with 2.5% of steel fiber because of volume of steel fiber in the mixes, steel fiber has significant results against vertical loads.
4. The results of water absorption of SFRC with silica fume content of 5% silica fume is 21% less than control samples and the mixes of SFRC2* with 10% of silica fume are 18% more than control samples. For the mixes of SFRC with steel fiber in volume of 1%, 1.5%, 2% and 2.5% are less than control specimens about 12%, 16%, 22%, and 32% respectively. The results of water absorption of SFRC with content of silica fume and steel fiber, for the mixes of SFRC1*, SFRC2*, SFRC3*, SFRC4* having 5% of silica fume and steel fiber in volume of 1%, 1.5%, 2% and 2.5% are less than control specimens about 8%, 12%, 14% and 15% respectively. In the other hand the mixes with content of 10% silica fume with steel fiber are more than control specimens, about 9%, 12%, 18%, and 24% respectively.
5. Cubes of 150 mm are casted and stored at 27 C° temperature for 24 hours after the specimens were kept water curing for 28 days, moreover the specimens taken out after curing and allowed it for one day to dry, cube specimens are weighted and noted the reading forward for acid attacks 5% of sulphonic acid (H2SO4) is used by volume of water, the cubes are immersed in the acid for 30 days. The acid resistance of concrete got as weight loss and residual compressive strength. the results of acid resistance of steel fiber reinforced concrete were significant against acid attacks, the reason is the influence of silica fume in the mixes.

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