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Evaluation of Strength and Durability of Steel Fibre Blended Concrete

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***Abstract* - Concrete is one of the versatile heterogeneous materials, civil engineering has over known. The addition of admixtures to the concrete mixture increases the strength by pozzolanic action and by filing in the small voids that are created between the cement particles. The use of Silica Fume (SF) in short period of time had one of the most dramatic impacts on the industry's ability to routinely and commercially produce SF modified concrete of flowable in nature but yet remain cohesive, which in turn would develop both high early and high later-age strengths including resistant to aggressive environments.**

In this experiment, the strength and durability of steel fibre blended silica fume concrete were investigated. The steel fibre with aspect ratio 60 was used in the experiment and volume fraction of steel fibre was 0.5%, 1.5% and 2%. Additions of silica fume into the concrete were 0%, 5%, 10%, 15%, and 20% by weight of cement content. In this study M30 grade concrete were used. The fresh concrete is tested for slump test and compaction factor test, while the hardened concrete for compressive, tensile, flexural, strength and durability.

I. INTRODUCTION

The construction activities in last few decades have increased many folds in almost all the developing countries of the world. It is interesting to note that over six billion tons of concrete is produced each year, and is the second most widely used substance. Concrete is specific to different applications like rebuilding, mending and construction. Concrete building components in different sizes and shapes are also made before hand and later applied. They include wall panels, doorsills, beams, pillars and more. Post-tensioned slabs is a preferred method for industrial, commercial and residential floor slab construction.Cement is becoming a scarce commodity globally because of its growing demand day by day. It is the need of time to search such alternative materials that would partially or fully replace cement used in concretes and mortars without affecting its quality, strength and other characteristics. The use of supplementary cementitous materials (SCMs) or non-conventional material is vital in developing low cost construction. By addition of some pozzolanic materials, the various properties of concrete viz., workability, durability, strength, resistance to cracks and permeability can be improved.

The American concrete institute (ACI) defines silica fume as a ''very fine noncrystalline silica produced in electric arc furnaces as a byproduct of production of elemental silicon or alloys containing silicon''. Silica fume is also known as micro silica, condensed silica fume, volatized silica or silica dust. It is usually a grey colored powder, somewhat similar to Portland cement or some fly ashes. It can exhibit both pozzolanic and cementitious properties. Silica fume has been recognized as a pozzolanic admixture that is effective in enhancing the mechanical properties to a great extent. Addition of silica fume to concrete improves the durability of concrete and also in protecting the embedded steel from corrosion. Here silica fume will be used as a replacement of cement with various percentages of 0%, 5%, 10%, 15% and 20% of volume of concrete.

Fibre reinforced concrete (FRC) may be defined as a composite materials made with Portland cement, aggregate, and incorporating discrete discontinuous fibres. Now, why would we wish to add such fibres to concrete? Plain, unreinforced concrete is a brittle material, with a low tensile strength and a low strain capcity.

Here crimped steel fibres of diameter 0.5 mm Ø with an aspect ratio of 60, at various percentages as 0%, 0.5 %, 1 % and 1.5 % by the volume of concrete will be used.

II THE EXPERIMENTAL PROGRAM

A. Materials and Methods

Ordinary portland cement of 53 grade confirming to IS 12269 was used for the study. The brand of cement used was Ramco OPC 53 grade. Manufactured sand of good quality obtained from local source was used as fine aggregate The sieve analysis results of fine aggregate shows that the fine aggregate is confirming to zone 2 as per IS 383 – 1970. The specific gravity was 2.78. Coarse aggregate of size less than 20mm from local source was used. The physical property determinations were done for coarse aggregate. The super plasticizer used was cera hyper plast XR W40.Cera hyper plast XR W40 is an acrylic polymer based new range water reducing admixture. The dosage of admixture was 0.85% of weight of binder.Crimped steel fibre of aspect ratio 60 was usedfor the experiment.

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III EXPERIMENTAL TEST RESULTS

A. Properties Of Fresh Concrete

The results of tests on the fresh concrete properties such as slump and compacting factor are presented in Table 4.1. The variations of slump and compacting factor with different percentage of silica fume with and without steel fibre are shown in Fig 4.1 and Fig 4.2. Slump and compacting factor is decreasing with percentage addition of fibre.

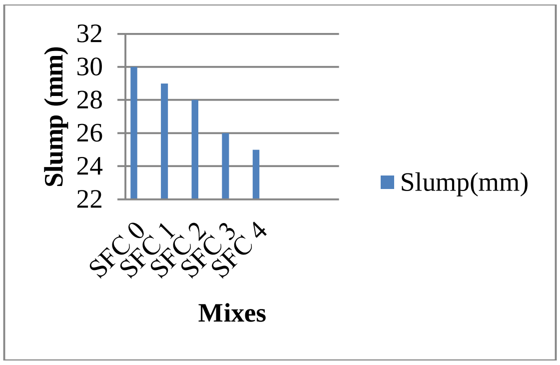

Fig 1 Variation of slump value for different mixes

TABLE 1 COMPRESSIVE STRENGTH OF CONCRETE

	Mixes	Average compressive strength (N/mm^2)	
		7days	28 days
1	SFC 0	25.21	38.30
2	SFC 1	29.33	41.29
3	SFC 2	34.12	46.6
4	SFC 3	38.3	47.3
5	SFC 4	35.9	44.27

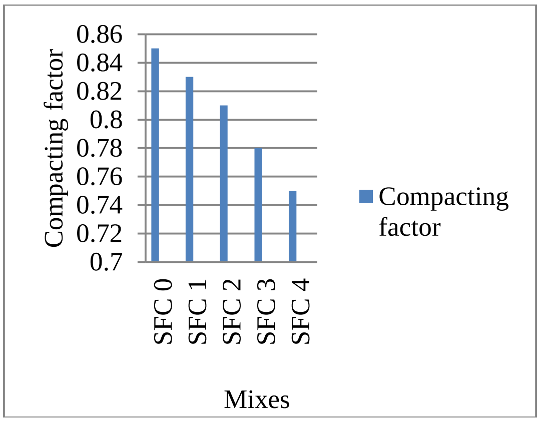

Fig. 2 Variation of compacting factor for different mixes

B. Mechanical Properties

a) Cube compressive strength of concrete without steel fibre

Compressive strength of all concrete mixes without steel fibre was determined at 7 and 28 days of curing. The compressive strength test results are given in Table 4.2. The variation of compressive strength at 7 and 28 days with different mixes is shown in Fig 4.3. From these results, it can be seen that the compressive strength of all other concrete mix were higher than the control mix SFC. There is an increase in the compressive strength with the increase in silica fume percentage up to 15% weight of concrete. Compressive strength decreases for addition of silica fume above 15%. Maximum strength at all ages occurs with 15% addition of silica fume.

From test results it can be concluded that there is an increase in early age compressive strength due to the addition of fibre in concrete. Comparing to SFC, SFC3 has showed an increase in strength of 26% at 7 days and 20% at 28 days. Hence SSFC 2 with 15 % of silica fume was obtained as the optimum mix.

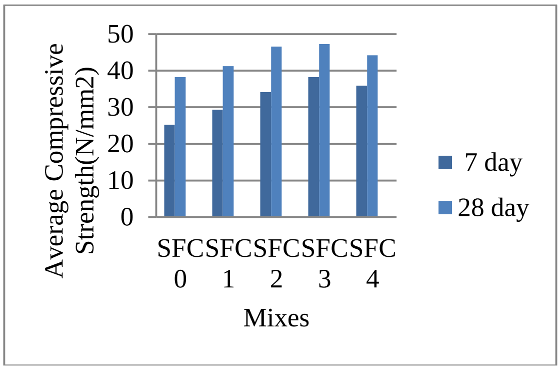

Fig.3 Variation of compressive strength for different mixes without steel fibre

b) Cube compressive strength of steel fibre blended silica fume concrete

Compressive strength of all concrete mixes with steel fibre was determined at 7 and 28 days of curing. The compressive strength test results are given in Table 4.3. The variation of compressive strength at 7, 28, 56 and 90 days with different mixes is shown in Fig 4.5. There is an increase in the compressive strength with the increase in fibre percentage due to the addition of steel fibre.

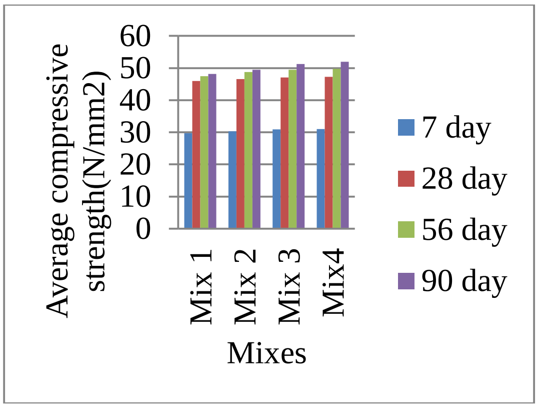

Fig. 3 Variation of compressive strength for different mixes with steel fibre

c) Splitting tensile strength

Splitting tensile strength of cylinder was determined at 28 days of curing. The test results are given in Table 3 and Fig.4.4 shows the variation of splitting tensile strength of cylinder with different mixes. From these results, it can be seen that the splitting tensile strength of cylinder of SSFRC3 was higher than SSFRC. Percentage increase in strength of SSFRC3 was 49%.

TABLE 2 SPLITTING TENSILE STRENGTH OF CONCRETE

Sl. No	Mixes	Average Splitting Tensile Strength (N/mm^2)
1	SSFC 0	4.67
2	SSFC 1	4.54
3	SSFC 2	4.65
4	SSFC 3	4.23
5	SSFC 4	4.12

TABLE 3 COMPRESSIVE STRENGTH OF STEEL FIBRE BLENDED SILICA FUME CONCRETE

Serial Number	Mix Designation	Compressive Strength			
		7 days	28 days	56 days	90 days
1	SSFC 0	37.8	46.18	47.21	47.38
2	SSFC 1	37.75	46.94	47.51	48.21
3	SSFC 2	38.32	47.03	48.73	49.5
4	SSFC 3	38.89	47.54	49.46	51.28
5	SSFC 4	38.98	47.94	49.75	51.95

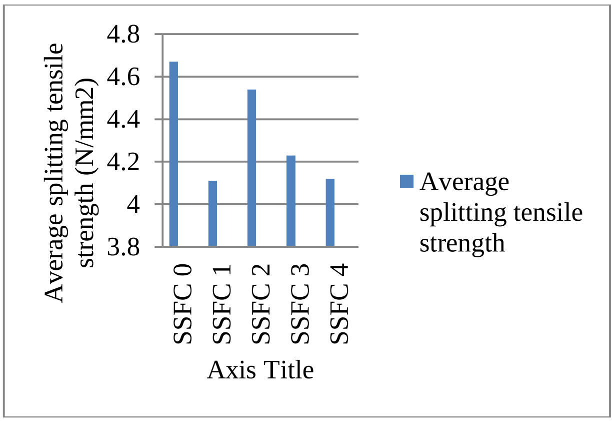

Fig.4 Variation of splitting tensile strength for different mixes

d) Flexural Strength Test

Flexural strength was determined at 28 days of curing. The test results are given in Table 4.4.The variation of flexural strength of beams with different mixes is shown in Fig 4.5. From these results, it can be seen that the flexural strength of SSFC 2 was higher than SSFC 0 and SSFC 3. Percentage increase in strength of SSFRC3 was 39%.

TABLE 4 FLEXURAL STRENGTH OF CONCRETE

Sl. No	Mixes	Average Flexural Strength (N/mm^2)
1	SSFC 0	5.22
2	SSFC 1	5.36
3	SSFC 2	5.43
4	SSFC 3	5.68
5	SSFC 4	5.98

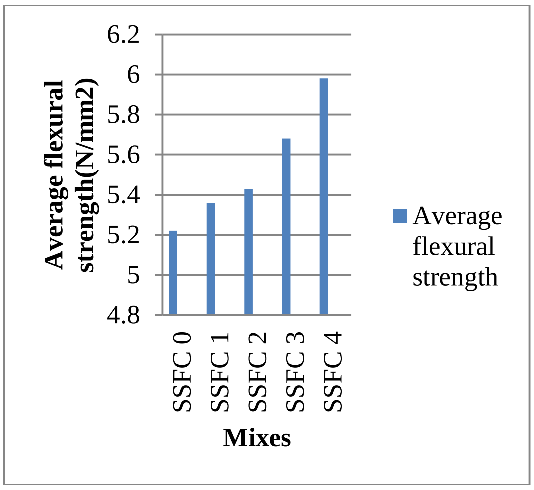

Fig.4 Variation of flexural strength for different mixes

C Durability Test Results

a) Acid attack

To check the durability of concrete mix against sulphuric acid, the concrete specimens were tested based on modified ASTM C 267 test method. For acid attack test concrete cubes of size 100mmx100mmx100mm were prepared for steel fibre blended silica fume concrete and normal concrete mix. After 7 days of curing, the specimens were immersed in 5% sulphuric acid (H_2SO_4) solution for 28 days 56 days and 90 days and the weight and compressive strength was noted. The strength loss and weight loss was calculated and compared with that of normal concrete mix exposed to the same acid environment. From the test results it is clear that optimal mix was less durable than the normal mix in acid. Test results

TABLE 5 TEST RESULTS FOR ACID ATTACK

Mix designation	Percentage strength loss			Percentage weight loss		
	28 days	56 days	90 days	28 days	56 days	90 days
SFC 0	18.59	22.85	30.21	1.45	3.32	5.8
SSFC 4	25.35	35.21	43.51	1.98	4.12	5.98

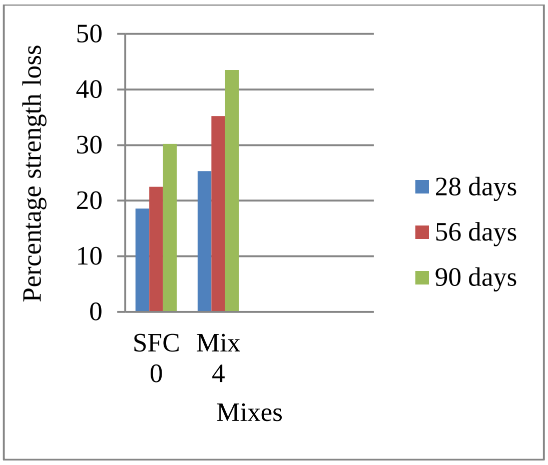

Fig.5 Variation of strength loss for acid attack

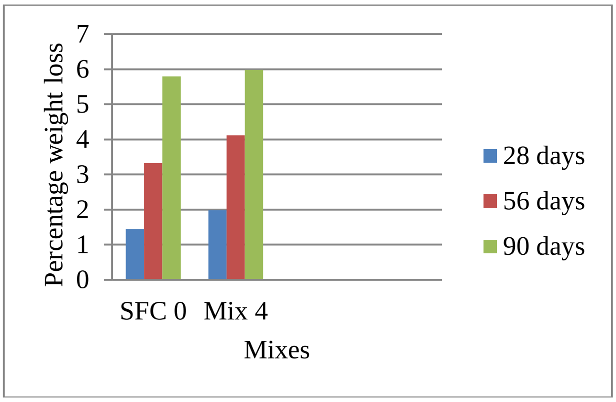

Fig.6 Variation of weight loss for acid attack

b) Alkali attack

Alkali attack test was conducted on the steel fibre blended silica fume concrete and normal mix. The weight and compressive strength were determined for the above mixes after 7 days. Then the specimens were immersed in sodium hydroxide solution for 28 days, 56 days and 90 days. The weight loss and strength loss were also determined.test results are shown in the table 6. From the results the optimum mix was more durable than the control mix.

TABLE 6 TEST RESULTS FOR ALKALI ATTACK

Mix designation	% strength loss			% weight loss		
	28 days	56 days	90 days	28 days	56 days	90 days
SFC 0	28.5	38.25	42.58	3.2	4.28	5.85
SSFC 4	21.3	31.54	35.62	3.18	3.2	4.13

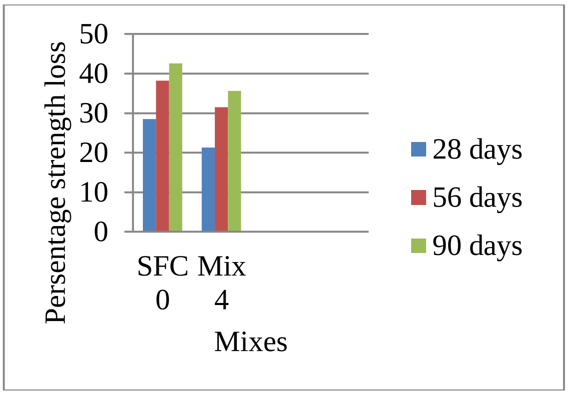

Fig.7 Variation of strength loss for alkali attack

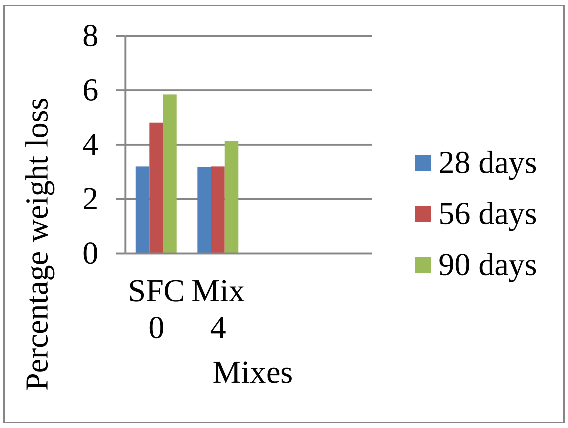

Fig.8 Variation of weight loss for acid attack

c) Sulphate attack

The sulphate attack tests were conducted on the steel fibre blended silica fume concrete and normal mix. After 7 days curing the specimens were immersed in the calcium sulphate($CaSO_4$) solution for 28 days , 56 days and 90 days. The effect of sulphate attack on concrete specimens was determined by measuring the compressive strength and weight loss of the mixes. The results are shown in table 7. The test results shows that the optimum mix was more durable than the control mix.

TABLE 7 TEST RESULTS FOR SULPHATE ATTACK

Mix designation	Percentage strength loss			Percentage weight loss		
	28 days	56 days	90 days	28 days	56 days	90 days
SFC 0	25.18	32.96	42.3	3.48	4.25	5.12
SSFC 4	23.8	28.9	38.7	3.29	3.73	4.89

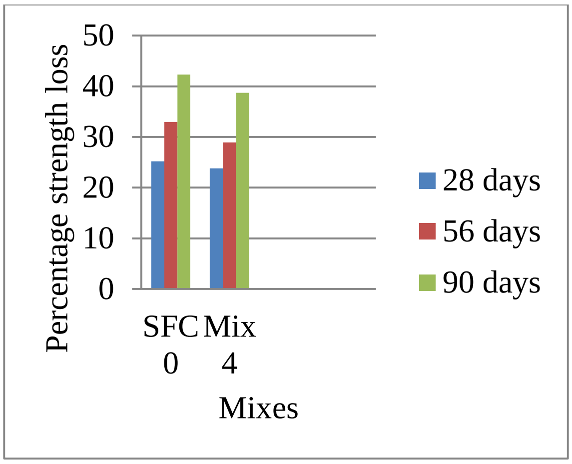

Fig.9 Variation of strength loss for sulphate attack

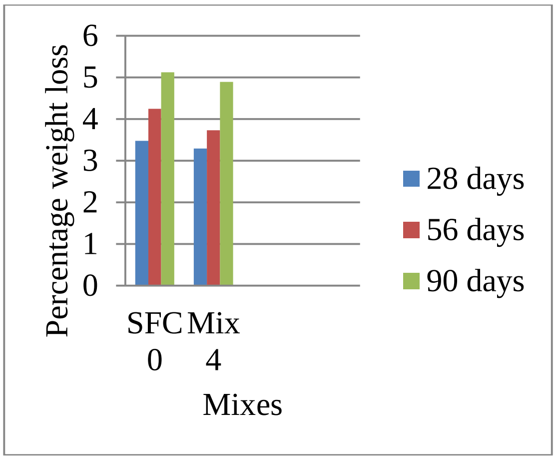

Fig.10 Variation of weight loss for sulphate attack

d) Rapid Chloride Permeability Test (RCPT)

The specimens are tested after 90 days of normal water curing. The total charge passed in six hours was determined for each mix and chloride permeability was determined. The values obtained for each mix is given in table 9.

TABLE 8 TEST RESULTS FOR RCPT

Mix designation	Total charge passed (coulombs)	Chloride permeability
SFC O	1445	Low
SSFC 4	932.53	Very low

e) Bulk diffusion test

Bulk diffusion test was conducted on two mixes, normal mix and optimum mix. The test was done at the ages of 28, 56 and 90 days. Test results are given on the table 4.11.

TABLE 9 TEST RESULTS FOR BULK DIFFUSION ATTACK

Mix	Chloride ion penetration depth		
	28 days	56 days	90 days
SFC 0	12.1	14. 8	16.2
SSFC 3	10.28	9.51	12.3

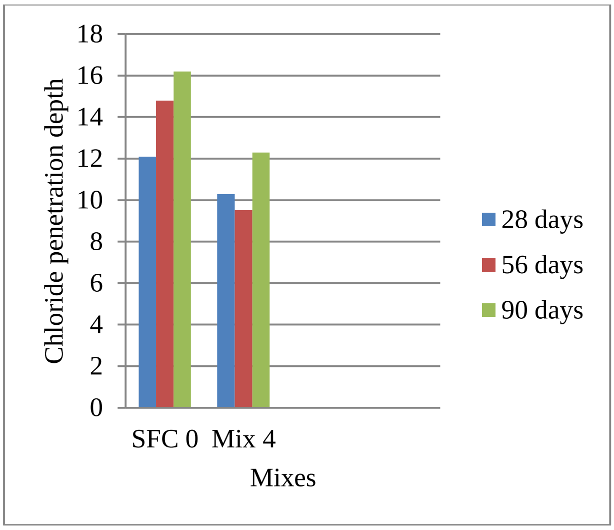

Fig.11 Variation of chloride penetration depth

V. CONCLUSION

- Workability of concrete mix decreased with increase in percentage of fibre.
- Compressive strength, splitting tensile strength and flexural strength increased up to 9% addition of fibre by weight of concrete.
- Percentage increase in 7th day cube compressive strength was 52% and that of 28th day compressive strength was 24%. Percentage increase in splitting tensile strength and flexural strength were 49% and 39% respectively.
- In case of flexural beam, the first crack load and ultimate load were more for beam FSSFRC4 with 1.5% addition of fibre.
- The final failure of the beams occurred when the concrete in the compression zone crushed, accompanied by buckling of the compressive steel bars. The failure mode was typical of that of an under-reinforced concrete beam.
- Energy absorption capacity increased up to 8% addition of fibre. An increment of 23% was noted in case of flexural failure.
- Crack width and number of cracks were less in case of fibre reinforced beam.
- The concrete mix is less durable in acid solution but much durable in alkali and sulphate solution.

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