International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume: 3 | Issue: 4 | May-Jun 2019 Available Online: www.ijtsrd.com e-ISSN: 2456 - 6470

Experimental Investigations on Influence of Silica Fume and Steel Fiber on Concrete

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***How to cite this paper**:* Vikas Arya | Er. V. S. Sagu "Experimental Investigations on Influence of Silica Fume and Steel Fiber on Concrete" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-3 | Issue-4, June 2019, pp.1169-1175, URL: https://www.ijtsrd.com/papers/ijtsrd25085.pdf

IJTSRD25085

ABSTRACT

In today's modernization of technological field lot of studies and trials are being carried out for manufacturing an excessive strong, long lasting and heavy duty concrete. In this study how the silica fume and steel fibers are beneficial if added to normal concrete is discussed. The results of this study depicts that the addition of silica fume and steel fibers in the normal concrete enhance the concrete properties like workability, brittleness, bond strength, corrosion resistance, fire resistance, acid resistance and ultimately increased durability of the structure which can be achieved by adding the appropriate quantity of silica fume and steel fibers.

Lot of fact finding experimental examination and there analysis were carried out for fining out the compressive, split tensile and flexural behavior of composite concrete with adding different proportion of silica fume and steel fibers. The concrete mix used for this study was M30 and the addition of silica fume and stainless steel fibers was experimented with different proportions like 0%, 4%, 8%, 12% & 16% and 0%, 0.5%, 1.0%, 1.5% & 2.0% respectively. The steel fibers used in this study were of .50 mm diameter and 40 mm in length as a partial replacement of cement weight. The result after analyzing showed that when the normal concrete is mixed with silica fume and straight steel fibers in proper proportions it improves the properties and execution of composite mixture as compared to the ordinary concrete. This rational advancement can be positively accepted and utilized in the regular constructions.

***Keywords:** Silica Fume, Straight Stainless Steel Fiber, Compressive Strength, Split Tensile Strength, Flexural Strength*

1. INTRODUCTION

Concrete is not a natural material it has to be manufactured with many process. The concrete is used in the construction as it has properties like structural stability, strength and durability. It also has the ability of getting molded in any shape and size.

Though having the properties like structural stability, strength and durability in strange ecological conditions such as soaring temperature, heavy rain fall the regular concrete gives a poor strength and durability due to which it was necessary for inventing new concrete combinations for achieving suitable results. In today's scenario the construction cannot be carried out without concrete. Hence concrete is the most commonly used construction material which is available in different types and can be used in various types of construction works like highways, tunnels, small buildings, multistoried towers, water tanks, thermal power projects, bridges, dams and other huge structures. The concrete can be made with special types of cement, admixtures, aggregates with batching and mixing for the utilization in different environments.

Normal concrete has many limited or inadequate properties like a high permeability, low workability and tensile strength. The normal concrete is very porous due to the deficient bonding between cement and aggregates after drying. The tensile strength of concrete is very low as the normal concrete contains many micro and macro cracks. These micro and macro cracks under applied loads are responsible for the low tensile strength of mixture.

These disadvantages tended the researchers for investigating and developing the permeability and brittleness characteristics of concrete. This study has helped in developing a new concept for reducing the permeability of the concrete and increasing the workability, ductility, energy absorption capacity and durability.

2. MATERIALS AND THEIR PROPERTIES

A. Silica Fume

The silica fume or the silica powder is a shapeless and non-crystalline material. It is a minute or subtle leftover collected as a secondary product of the silicon. The silica particles are circular in shape with the diameter of less than 1 micron (μm) in diameter. The average diameter of each particle is about 0.15 μm. The discrete steel or synthetic fibers are also added into the normal concrete for changing its properties. Stainless steel fibers help in managing shrink cracking.

The silica fume and steel fibers help in modifying the porousness of normal concrete and hence reduce the flow of water and save the material from erosion or decomposition. There are different type of steel fibers out of which some types of fibers produce superior impact, abrasion and shatter resistance in the normal concrete.

Silica fume with fineness by residue on 45 micron sieve = 0.8%, specific gravity =2.2, moisture content =0.7% were used. The chemical analysis of silica fume (Grade 920-D): silicon dioxide =89.2%, LOI at 975* Celsius = 1.7% and carbon = 0.92%, are conforming to ASTM C 1240-1999 standards.

Figure2.1. Silica Fume

B. Steel Fibres

The proportion for mixing of fibers is determined as a percentage of the total volume of the composite materials. The fibers are bonded to the material in adequate proportion and allowed the ready concrete mixture to withstand considerable stresses during the post-cracking stage. The steel fibers help in increasing the toughness of normal concrete.

The concrete mixtures containing silica fume and steel fibers do not fall at once after the beginning of the first crack. After the first crack the load is transferred from the concrete cast to the fibers. Hence the main role of steel fibers is necessary in stopping the advancing of crack by applying punching forces at the crack tips.

Figure 2.2. Steel Fibres

Tempered stainless steel wire of 0.5 mm diameter has been used in the preparation of mixture containing silica fume. The fibers of 40mm in length have been used giving optimum aspect ratio of 80 as suggested by Er. V.S. Sagu, Assistant Professor. The properties of fibers are given in table

Sr. No.	Tensile Strength	Young's Modulus	Specific Gravity	Length of Fiber	Diameter of Fiber	Aspect Ratio
1	362 MPa	2.04×10^4MPa	7.8	40 mm	0.5 mm	80

Table 2.1 Properties of Steel fibers used

C. Cement

Ordinary Portland Cement (OPC) of grade 43 manufactured by Ultratech Cement Company has been used in this study. Various tests regarding compressive strength, initial and final setting time of the cement were conducted and the results were tabulated as shown in Table 2.2

Sr. No.	Characteristics	Experimental value	Specified value as per IS:8112-1989
1	Consistency of cement (%)	34%	---
2	Specific gravity	2.98	3.15
3	Initial setting time (minutes)	37	>30 As Per IS 4031-1968
4	Final setting time (minutes)	286	<600 As per IS 4031-1968
5	Compressive strength (N/mm^2) (I) 3 days (II) 7 days (III) 28days	 18.46 26.28 48.52 34.37	 >23 >33 >43
6	Soundness (mm)	1.00	10
7	Fineness of Cement	5%	10% As Per IS 269-1976

Table 2.2 Characteristics Properties of Cement

Figure 2.3 Mixing of Silica Fume in the Design Mix

D. SAND

Locally available river sand passing through 4.75 mm IS sieve has been used in the preparation of mixture containing silica fume and steel fibers. The fineness modulus has been obtained from the results is 3.49. The specific gravity is tested by using the pycnometer bottle is found 2.67.

E. COARSE AGGREGATE

The Coarse aggregate was obtained from a local source. The coarse aggregate generally consist of coarse gravels (20mm) and fine gravels (10mm) are mixed in the ratio of 60:40. The fineness modulus has been obtained from the results is 2.31. The specific gravity is tested by using the pycnometer bottle is found 2.89.

Figure 2.4 Design Mix without Water

F. WATER

Filtered tap water free from injurious salts, chemicals and sulphates was used for making the mixture and curing of the specimens.All the Steel fibers used were straight having same cutting length (40 mm).

Figure2.5. Grade M-30 contains Silica Fume and Steel Fibres

3. EXPERIMENTAL INVESTIGATION

CASTING OF SPECIMENS

After preparing the design mixture now the next step is casting of specimens. Different sizes of moulds are as mentioned. Cube Size of 150mm × 150mm×150 mm, beam size of 150 x 150 x 700 mm and cylinder size is 150 mm in diameter and 300 mm in length are taken for casting the specimens.

3.1 COMPRESSIVE STRENGTH

The compressive strength was conducted on various specimens as per the guidelines given in IS 516-1959. The specimens were surface dried before testing the same on Universal Testing Machine of 100 tones capacity. The compressive strength of plane mortar and normal concrete containing silica fume and steel fibers for various percentages of fiber content has been illustrated in Table 5.1 and 5.2 which shows the compressive strength after 7 and 28 days respectively.. The compressive strength of plane mortar has been obtained as 29.35 MPa after 28 days. This strength has been obtained as 31.92 MPa, 33.66 MPa, 29.99 MPa, and 31.31 MPa for 0.5, 1.0, 1.5 and 2.0 percent fiber contents respectively in the case of normal concrete containing silica fume and steel fibers. It has been observed that the compressive strength of normal concrete containing silica fume and steel fibers is about 1.08, 1.14, 1.02 and 1.06 times higher than the compressive strength of plane mortar as illustrated in Table 5.2 and Plotted in fig. 5.2. This is due to the fact that the total length of fiber increases enormously with consequent improvements in crack control toughness and compressive strength. It has been found that compressive strength of normal concrete containing silica fume and steel fiber based specimens increased up to 14 % with 1.0 % steel fiber by weight of concrete.

Mix Designation	Percentage of Silica Fume	Percentage of Steel Fiber	Compressive Load(KN)	Compressive Strength (N/mm²)	Average Compressive strength (N/mm²)
MX0	0	0	406.87 427.52 433.55	18.08 19 19.27	18.78
MX1	4	0.5	499.36 546.48 539.92	22.19 24.29 23.1	23.19
MX2	8	1.0	544 583.05 517.8	24.18 25.91 23.01	24.37
MX3	12	1.5	544 507 529.2	24.18 22.53 23.52	23.41
MX4	16	2.0	420.9 478.86 462.97	18.71 21.28 20.58	20.19

Table No-3.1 Compressive Strength after 7 Days

Mix Designation	Percentage of Silica Fume	Percentage of Steel Fiber	Compressive Load(KN)	Compressive Strength (N/mm²)	Average Compressive strength (N/mm²)
MX0	0	0	667 668 667	29.64 29.68 29.64	29.65
MX1	4	0.5	790 792 794	35.11 35.2 35.28	35.19
MX2	8	1.0	850 845 863	37.78 37.56 38.36	37.9
MX3	12	1.5	850 780 840	37.78 34.67 37.33	36.59
MX4	16	2.0	690 694 691	30.67 30.84 30.71	30.74

Table3.2. Compressive Strength after 28 Days

3.2 FLEXURAL STRENGTH

Flexural strength of plane mortar and normal concrete containing silica fume and steel fiber has been investigated by testing beams of 150mm×150mm×700mm under two-point load because of small span between the supports. In this flexural strength, the effective length of the beam was 640 mm. The flexural strength of plane mortar and normal concrete containing silica fume and steel fiber for various percentages of fiber content has been illustrated in Table 5.3 and 5.4, which shows the flexural strength after 7 and 28 days respectively. The flexural Strength has been obtained as 2.34 MPa, 2.69 MPa, 3.18MPa, 2.67MPa and 3.05MPa respectively for normal concrete containing silica fume and steel fiber with 0, 0.5, 1.0, 1.5, and 2.0 percent of fiber content after 28 days.

Mix Designation	Percentage of Silica Fume	Percentage of Steel Fiber	Load Taken(KN)	Flexural Strength (N/mm^2)	Average strength (N/mm^2)
MX0	0	0	7.44 8 8.64	1.41 1.52 1.64	1.52
MX1	4	0.5	8.21 8.59 8.72	1.56 1.63 1.65	1.61
MX2	8	1.0	9.35 8.64 8.9	1.77 1.64 1.69	1.7
MX3	12	1.5	9.72 10.05 10.03	1.84 1.91 1.90	1.88

Table 3.3. Flexure Strength after 7Days

Mix Designation	Percentage of Silica Fume	Percentage of Steel Fiber	Load Taken (KN)	Flexural Strength (N/mm^2)	Average strength (N/mm^2)
MX0	0	0	12 12.5 12.9	2.28 2.37 2.45	2.37
MX1	4	0.5	12.25 12.45 13.02	2.32 2.36 2.47	2.38
MX2	8	1.0	13.75 13.5 13.9	2.61 2.56 2.64	2.60
MX3	12	1.5	14.5 14.8 14.75	2.75 2.81 2.8	2.79
MX4	16	2.0	16.62 17.32 16.48	3.15 3.28 3.13	3.19

Table 3.4. Flexure Strength after 28 Days

3.3 SPLIT TENSILE STRENGTH

Split tensile strength of plane mortar and normal concrete containing silica fume and steel fiber has been investigated by testing cylinders of 300mm × 150mm under Compression Testing Machine of 100 tones capacity. The cylinders have been tested by placing the cylinder in horizontal position. The split tensile strength of plane mortar and normal concrete containing silica fume and steel fibers for various percentages of fiber content has been illustrated in Table 5.5 and 5.6 which shows the split tensile strength after 7 and 28 days respectively. The flexural Strength has been obtained as 2.35 MPa, 2.58 MPa, 2.93MPa, 2.65 MPa and 2.53 MPa respectively for normal concrete containing silica fume and steel fibers with 0, 0.5, 1.0, 1.5, and 2.0 percent of fiber content after 28 days.

Mix Designation	Percentage of Silica Fume	Percentage of Steel Fiber	Tensile Load (KN)	Split Tensile Strength(N/mm^2)	Average strength (N/mm^2)
MX0	0	0	105.4 109.85 123.51	1.49 1.55 1.75	1.6
MX1	4	0.5	108.5 115.7 109.44	1.54 1.64 1.55	1.58
MX2	8	1.0	127.1 137.94 136.09	1.8 1.95 1.93	1.9

MX3	12	1.5	106.75 123.51 114.4	1.51 1.75 1.62	1.63
MX4	16	2.0	124.2 112.24 116.48	1.76 1.59 1.65	1.66

Table3.5. Split Tensile Strength after 7 Days

Mix Designation	Percentage of Steel Fiber	Percentage of Steel Fiber	Tensile Load (KN)	Split Tensile Strength (N/mm²)	Average strength (N/mm²)
MX0	0	0	170 169 179	2.41 2.39 2.53	2.44
MX1	4	0.5	175 178 171	2.48 2.52 2.42	2.47
MX2	8	1.0	205 209 203	2.90 2.96 2.87	2.91
MX3	12	1.5	175 179 176	2.48 2.53 2.49	2.5
MX4	16	2.0	180 184 182	2.55 2.60 2.58	2.58

Table 3.6 Split Tensile Strength after 28 Days

4. INTERPRETATION OF TEST RESULTS

4.1. Compressive Strength

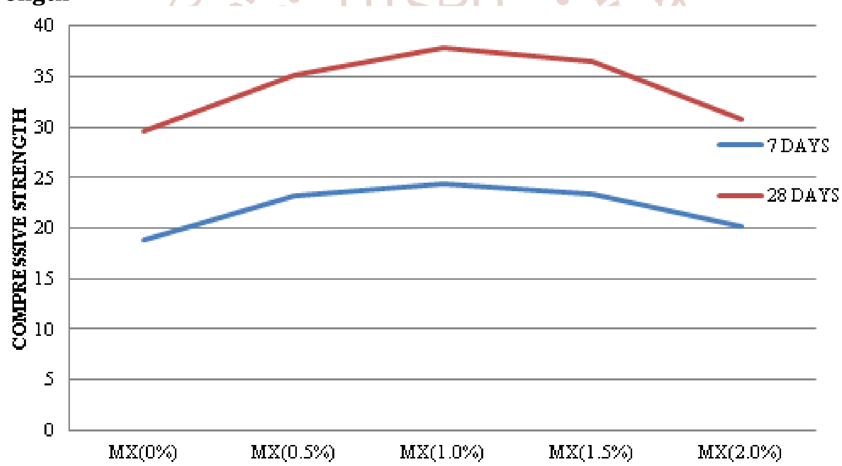

Figure4.1. Variation of Compressive Strength at different Ages

4.2. FLEXURAL STRENGTH

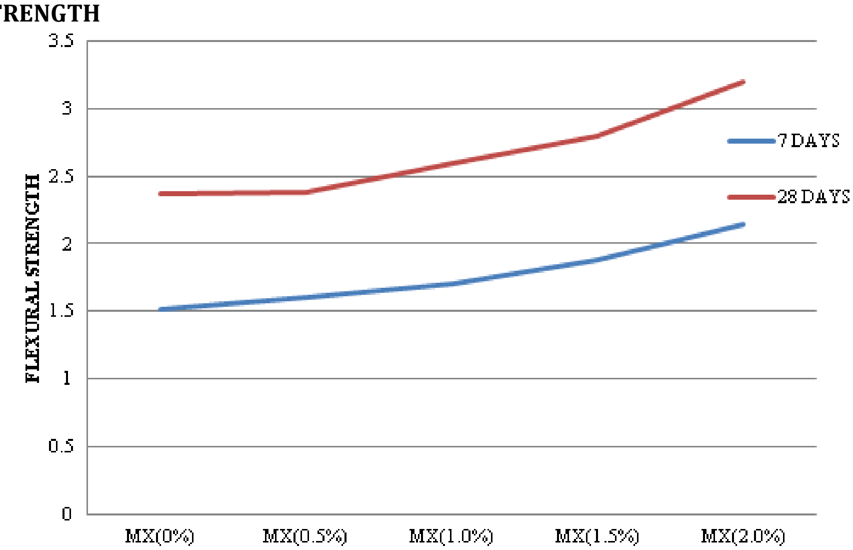

Fig 4.2. Variation of Flexural Strength at different Ages

4.3. SPLIT TENSILE STRENGTH

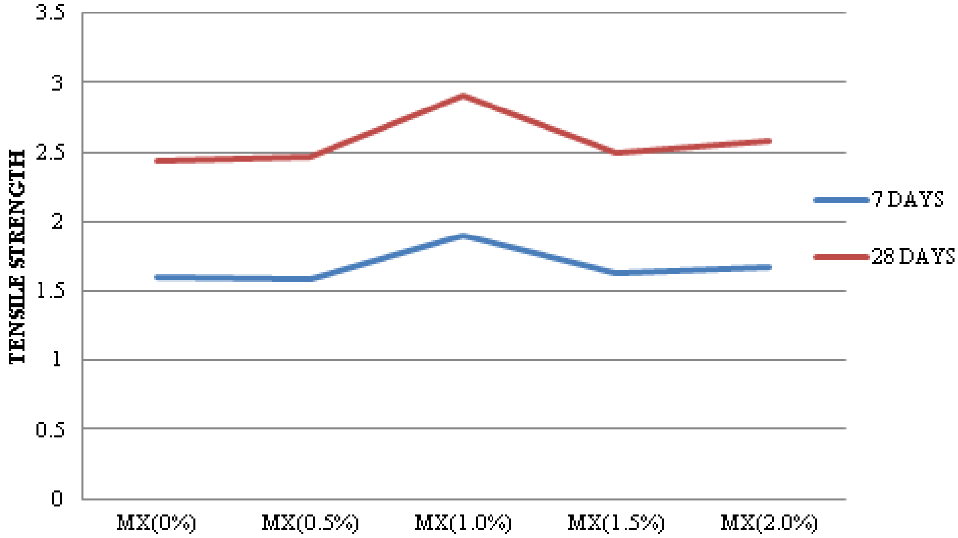

Figure4.3. Variation of Split Tensile Strength at different Ages

5. CONCLUSIONS

From the results of the present research the following conclusion may be drawn:-

A. The Experimental work shows that properties of normal concrete (M-30) gets enhanced due to addition of silica fume and steel fibers.

B. The Experimental work shows that workability of normal concrete gets reduced as we increased the silica fume and steel fibers quantity.

C. While testing the specimens, the ordinary cement concrete specimens have shown a usual crack propagation pattern which leaded into splitting of beam in two-piece geometry. But due to adding of silica fume and steel fibers in concrete cracks gets arrested which results into the ductile performance.

D. It is also observed that during testing the specimens, the specimen does not collapse as compared to ordinary concrete.

E. From the experimental investigation, it has been found that the flexural strength of normal concrete containing silica fume and steel fibers; increases very much as compared to compressive strength.

F. When we added silica fume with steel fibers to the mixture it was seen that the weight density of the concrete is increased.

G. The compressive strength increases with the increase of silica fume as compared to the normal concrete.

H. Compressive strength was increase up to 34% at 7 days and 35% at28 days by addition of 8% of silica fume and 1.0% of steel fiber in normal concrete, Also seen that, the increase of 12% and 16% of silica fume to the replacement of cement has not much significant change on the development of compressive strength. So the maximum percentage of the silica fume on the replacement of cement should be 8%.

I. There is an increase in splitting Tensile strength of cylinder concrete specimens up to 5% with the addition of silica fume and steel fibers to the concrete the flexural strength increases also increases with the addition of steel fibers as compared to silica fume concrete.

J. The increases in flexural strength are directly proportional to the fiber content and also the flexural deflection decreases with increase in steel fiber as compared to the normal concrete.

K. The optimum replacement level of cement by silica fume is found to be 8% by weight, there is a significant improvement in the compressive strength of concrete using silica fume at both 7 and 28 days as compared to the normal concrete. The workability in case of silica fume concrete is slightly enhanced.

L. Workability of concrete decreases as increase with percentage of silica fume Beyond optimum silica fume level the strength decreases but the workability increases so The optimum replacement level of cement by 8% of silica fume and 1.0% of steel fiber by weight.

M. It is also notified that normal concrete specimens showing irregular cracks and breaks in two parts during testing but normal concrete specimens contains silica fume and steel fibers get closely packed which shows the ductility property.

N. The other properties of the concrete such as workability, ductility, fire resistance, acid resistance, corrosion resistance, chemical resistance are also improved on the addition of silica fume and steel fibers in normal concrete.

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