

# Effect on Fiber Reinforced Concrete Using Silica Fume and Quarry Dust as Partial Replacement of Cement and Sand on High Performance Concrete

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**ABSTRACT:** The present investigation carried out on concrete due to the effect of silica fume and quarry dust with and without steel fibers and coir fibers on ordinary Portland cement. In this study, high strength concrete of M<sub>70</sub> is tried using silica fume as partial replacement for cement at 0%,5%,10%,15%,20% and quarry dust as partial replacement for sand at 0%,10%,20%.30%,40% with addition of 0.5% hooked end steel fibers and 2% coir fibers by the volume of concrete. The effect of silica fume as cement replacement and quarry dust as sand replacement material with and without fibers on strength and durability characteristics were analyzed and compared with normal concrete. The test results shown that the 10% replacement of cement by silica fume and 20% replacement of sand by quarry dust show the good and optimized results.

**KEYWORDS:** High performance concrete (HPC), Strength and durability, Silica fume (SF), Quarry dust (QD), Super plasticizer, Water binder ratio.

## I. INTRODUCTION

Fiber reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibers that are uniformly distributed and randomly oriented. Fibers include steel fibers, glass fibers, synthetic fibers and natural fibers. Within these different fibers that character of fiber reinforced concrete changes with varying concretes, fiber materials, geometries, distribution, orientation and densities. Steel fibers can only be used on surfaces that can tolerate or avoid corrosion and rust stains. Steel Fiber Reinforced Concrete (SFRC) can be a cost effective building material because it can reduce the thickness of members and reduced thickness results in lighter structures, inevitably leading to decreased building costs. It is now well established that one of the important properties of SFRC is its superior resistance to cracking and crack propagation. As a result of this ability to arrest cracks, fiber composites possess increased extensibility and tensile strength, both at first crack and at ultimate, particular under flexural loading and the fibers are able to hold the matrix together even after extensive cracking.

Problem Context: Most of the increase in cement demand could be met by the use of supplementary cementing materials, in order to reduce the green gas emission. Industrial wastes, such as silica fume is being used as supplementary cement replacement materials. Advancement in utilization of wastes in concrete as admixture reduces pollutants in environment and maximizes usage of natural resources. During the production of cement CO<sub>2</sub> is produced which cause global warming. By reducing cement consumption environment can be protected. River sand, which is one of the constituent used in the production of conventional concrete, has become expensive and also a scarce material. In view of this, there is a need to identify suitable alternative material from industrial waste in place of river sand. The utilization of quarry dust which is a waste material has been accepted as building material in many countries for the

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past three decades. It is found that quarry dust improves the mechanical properties of concrete when used along with super plasticizers.

**Problem Definition:** In this investigation a study is carried on silica fume and quarry dust as cement and sand replacement materials in concrete. The cement is replaced by silica fume in different percentages such as 0, 5, 10, 15, 20 and sand is replaced by quarry dust in different percentages such as 0, 10,20,30,40. Steel fibers having aspect ratio of 50 are also used. The proportion of steel fibers is added at 0.5% as total volume of concrete and coir fibers is added at 2% as total volume of concrete. The various strength properties studied are compressive strength, split tensile strength and flexural strength of beams. Durability properties studied are acid effect and water absorption.



(a)



(b)



(c)



(d)

Fig 1. (a) Steel fibers (b) Quarry dust (c) coir fibers (d) Silica fume

Fig 1. Shows the materials used for casting. Silica fume and Quarry dust was replaced by cement and Sand with the addition of 0.5% of steel fibers and 2% of Coir fibers.

## II. LITERATURE REVIEW

H. Katkhuda has worked on replacing cement with different percentages of silica fume at different constant water-binder ratio keeping other mix design variables constant. The silica fume was replaced by 0%, 5%, 10%, 15%, 20% and 25% for a water-binder ratio ranging from 0.26 to 0.42.

Kanmalai Williams C has worked on the performance of concrete made with quarry dust as fine aggregate. Sand was replaced with quarry dust in steps of 0, 25, 50, 75 and 100% and cement was replaced with 7.5% silica fume, 10% fly ash and 10% slag. They added 1% superplasticizer to improve the workability. The effects of curing temperature at 320° C and 1, 7, 14, 28, 56 and 90 days compressive strength, split tensile strength, modulus of elasticity, drying shrinkage and water penetration depth were found.

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Faisal F Wafa has worked on experimental investigation on properties like, cube compressive strength, splitting tensile strength and modulus of rupture of concrete by incorporating hooked - end steel fibres with 0% to 1.5% as volume fraction. They concluded that addition of 1.50% by volume of hooked end fibres resulted in 4.6% increase in compressive strength, 59.80% increase in split tensile strength and 67% increase in modulus of rupture of plain cement concrete.

Das Gupta concluded that the tensile strength and modulus of rupture of cement paste reinforced with different volume fractions ranging from 2 % to 6 % of 38 mm long coconut fibres was increased up to 4 % and then decreased. With 4 % volume fraction, they also studied the tensile strength of cement paste reinforced with different lengths of coconut fibres.

From the above literature review we have studied that as percentage of steel fibers and coir fibers increase the strength of the concrete increases. So we have concluded to add 0.5% of steel and 2.0% of coir fibers in concrete to test for 7days and 28days to the volume of concrete with the addition of silica fume replacement to cement and quarry dust replacement to the sand.

### III. EXPERIMENTAL PROGRAMME

Materials Used: The two major components of fiber-reinforced cement composites are the matrix and the fiber. The matrix generally consists of Portland cement, aggregates, water and admixtures.

Ordinary Portland cement, Fine Aggregate, Coarse Aggregate, Water, Silica Fume, Quarry Dust, Chemical Admixture (Glenium 8233), Steel Fibers, Coir Fibers.

Cement (OPC): In the present work, Birla Super 53 Grade OPC conforming to IS: 12269-1987 has been used.

Table-1: Properties of Cement (53-Grade OPC)

Properties	Obtained values	Requirements as per IS:12269-1987
Fineness	4.8%	Not more than 10%
Soundness	1mm	Not more than 10mm
Initial setting time	48min	Not less than 30 min
Final setting time	240 min	Not more than 600 min
Standard consistency	33%	-
Specific gravity	3.14	-

Aggregates: Locally available clean river sand passing IS: 480 sieves have been used with water absorption of 1.5%. The results of sieve analysis conducted concluded is tabulated in Table 2 and it confirms to Zone II as per the specifications of IS: 383-1970(Reaffirmed 2007). Crushed granite of 20mm maximum size and retained on IS: 480 sieves have been used as coarse aggregate.

Table-2: Properties of Fine Aggregates

Property	Fine aggregate	Coarse aggregate
Dry compacted bulk density	1624 kg/m <sup>3</sup>	1532 kg/m <sup>3</sup>
Loose bulk density	1428 kg/m <sup>3</sup>	1398 kg/m <sup>3</sup>
Specific gravity	2.56	2.6
Fineness modulus	3.50	2.90

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**Water:** In this experimental work, ordinary potable tap water available at laboratory was used for mixing the concrete and curing the concrete specimen.

**Chemical Admixtures:** Super plasticizer GLENIUM 8233 of M/s. BASF Construction Chemicals Pvt. Ltd, conforming to IS: 9103: 1999 has been used.

**Silica Fume (SF):** The fumes generally contain more than 90 percent silicon dioxide, mostly amorphous. Other constituents are carbon, sulphur and the oxides magnesium, sodium and potassium.

Table-3: Chemical Composition of Silica Fume

Constituent	Percentage (%)
SiO <sub>2</sub>	90-96
Al <sub>2</sub> O <sub>3</sub>	0.5-0.8
MgO	0.5-1.5
Fe <sub>2</sub> O <sub>3</sub>	0.2-0.8
CaO	0.1-0.5
Na <sub>2</sub> O	0.2-0.7
K <sub>2</sub> O	0.4-1.0
C	0.5-1.4
S	0.1-0.4

**Quarry Dust (QD):** Quarry rock dust can be an economic alternative to the river sand. Quarry rock dust can be defined as residue, tailing or other non-volatile waste material after the extraction and processing of rocks to form fine particles less than 4.75mm. Usually, quarry rock dust is used in large scale in the highways as a surface finishing material and also used for manufacturing of hollow blocks and lightweight concrete prefabricated elements.

Table-4: Chemical Composition of Quarry dust

Constituents	Quarry dust (%)	Natural Sand (%)
SiO <sub>2</sub>	62.48	80.78
Al <sub>2</sub> O <sub>3</sub>	18.72	10.52
Fe <sub>2</sub> O <sub>3</sub>	6.54	1.75
CaO	4.83	3.21
MgO	2.56	0.77
Na <sub>2</sub> O	Nil	1.37
K <sub>2</sub> O	3.18	1.23
TiO <sub>2</sub>	1.21	Nil
Loss of ignition	0.48	0.37

**Mix design:** The mix design was carried out for M<sub>70</sub> grade of concrete. Mix design is based on IS: 10262:2009.

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Table- 5 Details of mix proportion with constant super plasticizer, W/C ratio and fiber

SF and QD replacement	Mix proportion (kg/m <sup>3</sup> )				C.A	SP (%)	Steel fibers (%)	Coir fibers (%)
	C	SF	S	QD				
FRC 0%	527.6	0	613.6	0	1200	0.6	0.5	2
SF5%+QD10%	501.2	26.38	552.2	61.3	1200	0.6	0.5	2
SF10%+QD20%	474.9	52.76	490.8	122.7	1200	0.6	0.5	2
SF15%+QD20%	448.5	79.15	429.5	184.0	1200	0.6	0.5	2
SF20%+QD30%	422.1	105.5	368.1	245.4	1200	0.6	0.5	2

C-cement, SF- silica fume, S-sand, QD-quarry dust, CA-coarse aggregate, SP-super plasticizer

## IV. RESULTS AND DISCUSSIONS

In current study cement has been partially replaced by silica fume in varying proportion and sand is replaced by quarry dust with the addition of fibers (0.5% of steel fibers/ 2% of coir fibers) to the volume of concrete.

Table 6 shows the results for compressive strength and split tensile strength for various proportions of fibers. Here the strength has been increased by 10% replacement of SF to the cement and 20% replacement of QD to the sand with the addition of 0.5% steel fibers and 2% of coir fibers to the volume of concrete.

Table- 6 compressive and Split tensile strength for 7 and 28 days in N/mm<sup>2</sup>

Mix proportion	Addition of fibers In percentage	Compressive Strength (N/mm <sup>2</sup> )		Split tensile strength (N/mm <sup>2</sup> )	
		7 days	28 days	7 days	28 days
CC	0.5% steel fibers	47.84	79.61	4.38	6.19
SFRC 0%		52.93	82.95	4.98	6.82
SF 5%+QD 10%		58.34	84.61	5.10	7.94
SF 10%+QD 20%		64.63	88.72	5.84	9.20
SF 15%+QD 30%		59.15	85.65	5.30	8.94
SF 20%+QD 40%		56.15	83.40	4.64	7.50
CFRC 0%	2% coir fibers	50.33	80.04	4.61	6.24
SF 5%+QD 10%		52.15	81.92	4.91	7.12
SF 10%+QD 20%		54.40	83.03	5.56	8.89
SF 15%+QD 30%		51.08	76.29	4.81	7.78
SF 20%+QD 40%		46.12	71.02	4.65	7.14

Table-7 Flexural Strength for 28 days in N/mm<sup>2</sup>

Mix proportion	Flexural strength (N/mm <sup>2</sup> )	
	Steel fibers	Coir fibers
CC	8.24	8.24
SFRC 0%	8.51	7.94
SF 5%+QD 10%	8.96	8.21
SF 10%+QD 20%	9.58	8.60
SF 15%+QD 30%	8.66	7.70
SF 20%+QD 40%	8.21	7.62

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Table 7 shows the flexural strength variation of steel and coir fibers to the volume of concrete up to 20% of Silica Fume replacement to the cement and 40% of Quarry Dust replacement to the sand.

Table-8 Percentage of Moisture Absorption for 28 days in N/mm<sup>2</sup>

Mix proportion	Water absorption in Percentage	
	Steel fibers	Coir fibers
CC	2.05	2.05
SFRC 0%	1.83	1.85
SF 5%+QD 10%	1.32	1.35
SF 10%+QD 20%	1.19	1.23
SF 15%+QD 30%	1.09	1.14
SF 20%+QD 40%	1.01	1.02

Table8 shows the percentage of Moisture Absorption of M<sub>70</sub> concrete with Silica Fume and Quarry Dust replacement up to 60% with Steel and Coir Fibers 28 Days in N/mm<sup>2</sup>.

Table-9 Acid Effect of M<sub>70</sub> concrete with steel and coir fibers for 28 days in %

Mix proportion	Addition of fibers In percentage	Loss in Weight (%)	Loss in Compressive Strength(%)
CC	0.5% steel fibers	3.50	10.01
SFRC 0%		3.31	7.05
SF 5%+QD 10%		1.31	4.65
SF 10%+QD 20%		1.12	3.50
SF 15%+QD 30%		0.97	3.00
SF 20%+QD 40%		0.87	2.05
CFRC 0%	2% coir fibers	3.15	7.20
SF 5%+QD 10%		1.36	4.76
SF 10%+QD 20%		1.22	3.70
SF 15%+QD 30%		1.01	3.10
SF 20%+QD 40%		0.94	2.15

Table 9 shows the acid effect variation of steel and coir fibers to the volume of concrete up to 20% of Silica Fume replacement to the cement and 40% of Quarry Dust replacement to the sand.

### IV. CONCLUSIONS

1. The replacement of cement with silica fume up to 10% and sand with quarry dust up to 20% with the addition of fibers leads to increase in compressive strength, split tensile strength and flexural strength for M<sub>70</sub> grade concrete.
2. The compressive strength of silica fume and quarry dust concrete with the addition of steel fibers has been increased by 10.26% and coir fibers by 4.5%.
3. The compressive strength increases significantly due to addition of silica fume and quarry dust compared with normal concrete.
4. The use of silica fume and quarry dust with low w/c ratio resulted in practically impermeable concrete.
5. Fiber addition improves ductility of concrete and its post cracking load carrying capacity.

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6. The mechanical properties of fiber reinforced concrete are much improved by the use of hooked end fibers than straight fibers.
7. Concrete mixes containing silica fume and quarry dust with addition of fibers showed lower values of acid effect and water absorption.

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