

An Experimental Investigation on Glass Fibre Reinforced Concrete with Partial Replacement of Cement with Silica Fume

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ABSTRACT: Since advent of civilization various types of cementitious materials have been used for construction practices. The arrival of Ordinary Portland Cement (OPC) changed the construction activities completely. From olden days concrete suffers from low tensile strength, limited ductility and little resistance to cracking. To overcome these weaknesses a new variety of concrete is desired. Therefore here is an experimental study proposing changes to the conventional concrete to increase fire resistance, increase crack resistance, increase ductility and flexural strength by partial replacement of silica fume to the cement and introducing fibers in the preparation of the concrete for M30 grade of concrete.

Literature review suggests that a very few research works were reported on the concrete made with glass fibers and Silica fume combining HPC and FRC. In this connection an experimental investigation was carried out to determine the compressive, split tensile and flexural strengths with the use of glass fibers and Silica fume in concrete. The glass fibers were added by 0.5%, 1.0%, 1.5% and 2.0% by volume and cement was replaced by Silica fume in three different percentages of 5%, 7.5%, 10%, 12.5%, 15% and 17.5% by weight of cement. Glass fiber Reinforced Concrete (GFRC) is tested for Compression, split tension and flexural strengths. Therefore, the results of this study indicate the improving of compressive strength, flexural strength and tensile strength exhibited the highest improvement with 10% and 15% silica fume replacement and glass fiber at 1% respectively.

KEYWORDS: SC, Glass Fibers, Silica Fume

1. INTRODUCTION

Concrete is the mostly used construction material in structures. In fact concrete is a composite construction material, composed of cement (commonly Portland cement), coarse aggregate made of gravels or crushed rocks, fine aggregate (sand), and water. The demand and cost of cement is increasing day to day, so experts are looking for supplementary materials with the main objective of reducing solid waste disposal problem, by using waste as supplementary by maintaining the same properties or by enhancing the properties, by using selected materials. During the last three decades, great strides have been taken in improving the performance of concrete as a construction material. Particularly Silica Fume (SF) and fly ash individually or in combination are indispensable in production of high strength concrete for practical application. It can enhance various properties of concrete both in the fresh as well as in hardened states like cohesiveness, strength, permeability and durability.

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II. LITERATURE REVIEW

By Faseyemi Victor Ajileye Volume 12 Issue 1 Version 1.0 January 2012[1]. Studies Have Been Carried Out To Investigate The Possibility Of Utilizing A Broad Range Of Materials As Partial Replacement Materials For Cement In The Production Of Concrete. This Study Investigated The Strength Properties Of Silica Fume Concrete. It Was Observed That The Compressive Strength Of C30 Grade Of Concrete Is Increased From 16.15% To 29.24% And Decrease From 23.98% To 20.22%. The Maximum Replacement Level Of Silica Fume Is 10% For C30 Grade Of Concrete.

Vaishali G Ghorpade*, J.N.T.U.College Of Engineering, India 35TH CONFERENCE On Our World In Concrete & Structures: 25 - 27 August 2010, Singapore[2]. Hence, An Attempt Has Been Made In The Present Investigation To Study The Behavior Of Glass Fibres In High Performance Concrete. From Experimental Results, The Optimum Percentage Recommended As 1.0% Fibre Volume With 10% Silica Fume For Achieving Maximum Benefits In Compressive Strength, Split Tensile strength and Flexural strength.

III. EXPERIMENTAL PROGRAMME

3.1 General:

The experimental investigation consists of casting and testing of 11 sets along with control mix. Each set comprises of 6 cubes, 6 cylinders and 3 beams for determining compressive, tensile and flexural strengths respectively. By taking different percentages of silica fume to find the optimum content for the replacement of the cement, then adding Glass fibers individually to cement accordingly with the different percentages by weight of cement and finding the optimum percentage of fibres.

3.2 Description of the materials:

Concrete is an arrangement of three crude materials which are Cement, Fine aggregate and Coarse aggregate. These three crude materials assume a critical part in assembling of concrete. By interchanging the properties and differentiating the amount of these materials, the properties of concrete will change.

3.2.1 Cement:

Cement is a binder, a substance used in construction that sets, hardens and adheres to other materials, binding them together. Cement is seldom used solely, but is used to bind sand and gravel (aggregate) together. Cement is used with fine aggregate to produce mortar for masonry, or with sand and gravel aggregates to produce concrete. An OPC 53 grade of KCP cement is used in this investigation. The quantity required for this research work is estimated and the entire quantity is purchased and stored properly in casting store ward. Specific gravity of cement 3.15 & fineness modulus 1.9%.

3.2.2 Fine Aggregate

Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 3/8-inch sieve. Fine aggregate is natural sand which has been washed and sieved to remove particles larger than 5. Fine aggregate used in this investigations is river sand nearby dealer in Gudivada, which are typically the same materials used in normal concrete mixture. Aggregates of size ranges between 0.075mm – 4.75mm are generally considered as fine aggregate. The code to be referred to understand the specification for fine aggregates is: IS 383:1970. The specific gravity are 2.61.

3.2.3 Coarse Aggregate

Crushed granite aggregate available from local source was used. To obtain a good grading, 100% of the aggregate passing through 20mm and retained on 12.5 mm IS sieves was used in the preparation of concrete. Sizes of aggregates

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 5, May 2017

above 4.75mm are generally considered as coarse aggregate. The Coarse aggregate are selected as per IS-383 specifications. The specific gravity are 2.82.

3.2.4 Water

The quantity of water in the mix plays a vital role on the strength of the concrete. In this study portable water is used conforming to IS:456-2007. The water used for the study was free of acids, organic matter, suspended solids.

3.2.5 silica fume

silica fume as a “very fine non-crystalline silica produced in electric arc furnaces as a by-product 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. Silica fume is an ultrafine material with spherical particles less than 1µm in diameter, the average being about 0.15µm. This makes it approximately 100 times smaller than the average cement particle. The bulk density of silica fume depends on the degree of densification in the silo and varies from 130 (undensified) to 600 kg/m³. The specific gravity of silica fume is generally in the range of 2.2 to 2.3.

3.2.5.1 Types of Silica Fume

There are two types of silica fumes. They are

- a) Premium silica fume
- b) Standard silica fume.

Table 3.1: Physical & Chemical Properties Of Silica Fume

PHYSICAL PROPERTIES	Results
PHYSICAL STATE	Micronized powder
ODOUR	Odourless
APPEARANCE	White colour powder
COLOUR	White
PACK DENSITY	0.76 gm/cc
PH OF 5% SOLUTION	6.90
SPECIFIC GRAVITY	2.63
MOISTURE	0.058%
OIL ABSORPTION	55 ml/100gm
CHEMICAL PROPERTIES	% OF CHEMICALS
SILICA(SIO ₂)	99.886%
ALUMINIA(AL ₂ O ₃)	0.043%
FERRIC OXIDE(FE ₂ O ₃)	0.040%
TITANIUM OXIDE(TIO ₂)	0.001%
CALCIUM OXIDE(CAO)	0.001%
MAGNESIUM OXIDE(MGO)	0.000%
POTTASIAM OXIDE(K ₂ O)	0.001%
SODIUM OXIDE(NA ₂ O)	0.003%
LOSS ON IGNITION	0.015%
HEAVY METALS	
LEAD(PB)	0.000%
ARSENIC(AS)	0.000%

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

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Vol. 6, Issue 5, May 2017

3.2.6 Glass Fiber:

Fibre Reinforced concrete new construction material which is defined as composite material of Cement mortar. Concrete without fibre they may cause cracks in surface. Due to adding of Glass Fibre into cement mortar eliminates the cracks and shrinkage in the surface. The mechanical property of Glass Fibre is fibre orientation, fibre length. There are more types of Glass Fibres are available. **A-glass** - Alkali glass made with soda lime silicate. **C-glass** – Corrosive resistant glass made with calcium borosilicate.

Table 3.2 : Properties of glass Fiber

Fiber	Density (gm/cm ³)	Elastic Modulus (Gpa)	Tensile Strength (Mpa)	Diameter In Microns	Length In mm	Percent Elongation	Aspect ratio
S-Glass fiber	2.53	89	4600	10	6	5.2	600

IV. MIX DESIGN AND EXPERIMENTAL INVESTIGATIONS

The resulting concrete is proportioned for M30 grade with proportion 1:1.42:2.757 as per nominal mix design. Cement is replaced by silica fume in percentages i.e., 0%, 5%, 7.5%, 10%,12.5%,15%, and 17.5%.and Glass fibres by 0, 0.5, 1.0, 1.5 and 2%.The required quantities of materials are weighed and place over the plat form. Initially the cement and fine aggregate are mixed together in the dry state until they are thoroughly blended. Then the coarse aggregate, silica fume & glass fibres are added to dry mix of cement and fine aggregate and they are mixed thoroughly until the coarse aggregate and fibres uniformly distributed throughout the batch. water is mixed and added to uniformly distributed mass until plastic concrete of uniform colour is achieved. This plastic concrete is placed in the cube, cylinder and beam moulds. After this the filled moulds are placed over the vibrator for compaction. Later these moulds are kept for 24 hours. After 24 hours the specimens are demoulded and cured for 28 days. The table 4.1 show the Concrete mix proportions were designed as per IS:10262-2009 code for M30. Tables 4.1, 4.2and 4.3 show the number of specimens that are casted with the corresponding mix proportion.

Table 4.1: Mix Proportion

S. No	Material	Weight of material (Kg/m ³)	Mix ratio with respect to cement
1	Cement	448.00	1
2	Fine Aggregate	638.91	1.423
3	Coarse Aggregate	1237.40	2.757
4	Water	175.00	0.39

Table 4.2:Weights of used materials in this investigation

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 5, May 2017

Mix	%Material(cement) replacement of S.F	Mix proportions(Kg/m ³)				No of specimens		
		Cement	Fine aggregate	Coarse aggregate	Water	Cubes	Cylinders	Prisms
M30	0	448	638.91	1237.40	175	6	6	3
	5	425.6	638.91	1237.40	175	6	6	3
	7.5	414.4	638.91	1237.40	175	6	6	3
	10	403.2	638.91	1237.40	175	6	6	3
	12.5	392	638.91	1237.40	175	6	6	3
	15	380.8	638.91	1237.40	175	6	6	3
	17.5	369.6	638.91	1237.40	175	6	6	3

Table 4.3: Optimum Value Of Silica Fume With Glass Fiber

Mix	Optimum Value of SF(12.5) + % of glass fibers	Mix proportions(Kg/m ³)				No of specimens		
		Cement	Fine aggregate	Coarse aggregate	water	Cubes	Cylinders	Prisms
1	0	392	638.91	1237.40	175	9	6	3
2	0.5	392+0.196	638.91	1237.40	175	9	6	3
3	1	392+0.392	638.91	1237.40	175	9	6	3
4	1.5	392+0.588	638.91	1237.40	175	9	6	3
5	2	392+0.784	638.91	1237.40	175	9	6	3

4.1 Process Of Making Of Concrete

(i)Batching: The measurement of materials for making concrete is known as Batching.

(ii)Weigh Batching: Weigh is the correct method of measuring the material. Use of weight system is batching, facilitates accuracy, flexibility and simplicity

(iii) Measurement of water: When weigh batching is adopted, the measurement of water must be done accurately. Addition of water by graduated bucket in terms of litres will not be accurate enough for the reason of spillage of water etc.

4.2 Preparation Of Concrete Cubes

Metal moulds, preferably steel or cast iron, strong enough to prevent distortion is required. They are made in such a manner as to facility the removal of the moulded. Specimen without damage and are so maintained that, when it is assembled, the dimensions and internal faces are required to be accurate within the following limits.

4.2.1: Compacting: The testing cube specimens are made as soon as possible after mixing and in such a manner to produce full compaction of the concrete with neither segregation nor excessive bleeding.

4.2.2: Curing: The test specimens are stored in a place free from vibration in moist air of at least 90% relative humidity and at a temperature of 27o2oC for 24 hours from the time of addition of water to the dry ingredients. After this period, the specimens are marked and removed from the moulds.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 5, May 2017

4.3 TESTING

(i) **Compressive Strength:** After 7&28 days curing, cubical specimens are placed on compression testing machine having a maximum capacity of 3000 KN and a constant rate of loading of 40 kg/m² per minute is applied on test specimen. Ultimate load at which the cubical specimen fails is noted down from dial gauge reading. This ultimate load divided by the area of specimen gives the compressive strength of each cube.

(ii) **Tensile Strength:** After 7&28 days curing, cylinder specimens are placed on tensile testing machine having maximum capacity of 1000 KN and a constant rate of loading of 40 kg/m² per minute is applied on the test specimen by placing two steel plates below and above the cylinder in the horizontal direction. Ultimate load at which the cylindrical specimen fails is noted down from dial gauge reading.

(iii) **Flexural Strength:** After 28 days curing, prismatic specimens are placed on flexural testing machine having a maximum of 100 KN and a constant rate of loading of 40 kg/m² per minute is applied on the test specimen by placing the specimen in such a way that the two point loading should be placed at a distance of 13.3 cm from both the ends. Ultimate load at which the prismatic specimen fails is noted down from dial gauge reading.

(iv) **Durability Test:** cubes of sizes 150mm were cast and cured for 28 days. After 28 days curing cubes were taken out and allowed for drying for 24 hours and weights were taken. For acid attack 5% dilute hydrochloric acid is used. The cubes were to be immersed in acid solution for a period of 30 days.

V. TEST RESULTS AND DISCUSSION

Table 5.1: Compressive, Flexural, Tensile strength for 7 and 28 days with 5%, 7.5%, 10%, 12.5%, 15%, and 17.5% silica fume

Mix	%Material (cement) replacement of S.F	Compressive strength in (Mpa)		Split Tensile strength in (Mpa)		Flexural strength in (Mpa) 28 days
		7 days	28 days	7 days	28 days	
1	0	24.56	40.20	2.47	3.82	5.03
2	5.0	32.32	42.42	2.62	4.03	5.28
3	7.5	36.41	45.27	2.80	4.31	5.56
4	10	39.75	49.86	3.01	4.59	5.83
5	12.5	45.21	53.53	2.86	4.42	5.61
6	15.0	43.54	51.21	2.76	4.26	5.43
7	17.5	40.25	47.86	2.60	4.01	5.13

Table 5.2: Compressive, Flexural, Tensile strength for 7 and 28 days with 0%, 0.5%, 1%, 1.5%, 2% of glass fibers at 12.5% silica fume (Optimum Value)

Mix	Optimum Value of SF(12.5%) + % of glass fibers	Compressive strength in (Mpa)		Split Tensile strength in (Mpa)		Flexural strength in (Mpa) 28 days
		7 days	28 days	7 days	28 days	
1	0%	45.21	53.53	3.01	4.59	5.83
2	0.5%	47.72	54.92	3.09	4.75	6.09
3	1%	48.77	56.20	3.20	4.91	6.25
4	1.5%	46.83	55.01	3.11	4.79	6.10
5	2%	44.02	53.92	2.97	4.61	5.92

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 5, May 2017

VI. DURABILITY STUDY

6.1 General:

Cement is not completely impervious to acids. Most corrosive arrangements will gradually or quickly break down Portland bond concrete contingent on the sort and convergence of corrosive. The strength of cement in this test work was completed by measuring corrosive resistance at various periods of curing. The solid corrosive resistance was seen by two sorts of tests named as Acid assault component test and Acid toughness variable test. The convergences of acids in water are 5% HCl and 5% H₂SO₄.concrete can be assaulted by fluids with pH esteem under 6.5 and assault is extreme when pH quality is underneath 5.5. At pH esteem beneath 4.5, the assault is exceptionally extreme. As the assault continues, all the concrete mixes are split down and drained away. Here HCl and H₂SO₄ which are having pH esteem 3.01 and 2.75 which cause an exceptionally extreme assault are utilized to consider the sturdiness properties.

6.2 Requirements of Study

To check the Acid resistance of concrete Hydrochloric acid (HCl),is selected. The concentrations of acids in water are taken as 5%. The standard specifications for this study are IS 516-1959 and ASTM C666-1997.

Table 6.1: Effect of Acid Attack On Weight and compressive strength on cubes

S NO	Optimum Value of SF (12.5%)+ % of glass fibers	Loss in weight (%) at 28 days	Loss in Compressive strength (%) At 28 days
1	0%	2.53	8.00
2	0.5%	2.60	8.13
3	1%	2.66	8.24
4	1.5%	2.73	8.34
5	2%	2.78	8.41

VII. CONCLUSION

From the results it is conclude that the silica fume is a better replacement of cement. The rate of strength gain in silica fume concrete is high. After performing all the tests and analysing their result, the following conclusions can be derived:

1. With the increase in w/cm ratio strength of concrete decreases.
- 2.. Workability of concrete decreases as increase with % of silica fume.
3. The optimum value of compressive strength can be achieved in 12.5% replacement of silica fume.
4. The optimum silica fume replacement percentage is varies from 10 % to 15 % replacement level. As strength of 15% replacement of cement by silica fume is more than normal concrete.
5. Compressive strength decreases when the cement replacement is above 12.5% of silica fume.
6. Based on experimental investigation addition of Glass Fibre in reinforced concrete increases the strength and durability characteristics.
7. Initially addition of Glass Fibre in the plain concrete the strength characteristics like compressive, flexural and split tensile strength is gradually increased.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 5, May 2017

8. Finally certain percent addition of Glass Fibre attain that gradually decrease in strength. Maximum compressive, flexural and split tensile strength is attaining in 1.0% addition of Glass Fibre. So adding Glass Fibre upto 1.0% only not exceeds the limit. The durability characteristics gradually increased based on the addition of Glass Fibre.

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