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Experimental Study on Strength and Microstructure of Synthetic Fibre Reinforced Concrete with Use of Ground Granulated Blast Furnace Slag and Silica Fume

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Abstract: ***Fibre Reinforced Concrete can be defined as a composite material consisting of mixtures of cement, mortar or concrete and discontinuous, discrete, uniformly dispersed suitable fibres. Fibre reinforced concrete is of different types and properties with many advantages. Also Fibre reinforced concrete help to make a high strength concrete of High-performance concrete. High-performance concrete is defined as concrete that meets special combinations of performance and uniformity requirements that cannot always be achieved routinely using conventional constituents and normal mixing, placing, and curing practices. Ever since the term high-performance concrete was introduced into the industry, it had widely used in large scale concrete construction that demands high strength, high flow ability, and high durability. A high-strength concrete is always a high-performance concrete, but a high-performance concrete is not always a high-strength concrete. Durable concrete Specifying a high-strength concrete does not ensure that a durable concrete will be achieved. It is very difficult to get a product which simultaneously fulfils all the properties. So the different pozzolanic materials like Ground Granulated Blast furnace Slag (GGBS), Silica Fume, Rice husk ash, Fly ash, High Reactive Metakaolin, etc. are some of the pozzolanic materials which can be used in concrete as partial replacement of cement, which are very essential ingredients to produce high performance concrete. So, here in this project Ground granulated blast furnace slag (GGBS) (10%, 20%, 30%, 40%, and 50%) and Silica Fume (5%, 10%, and 15%) is considered as a cement replacement in different percentage with fibre. For the fibre reinforced concrete used Synthetic fibre (i.e. Recron 3s polyester fibre) in different percentage (0%, 0.1%, 0.2% and 0.3%) of total weight of concrete and casting was done. For this study OPC 53 grade cement use of Ultratech and carry out workability test (Slump test), Compressive strength test, Split Cylinder test, Flexural strength test and for durability test RCPT and Water Sorptivity test was conduct. And also for microstructure examination SEM EDX test has been carry out.***

Keywords: FRC, Recron 3s fibre, GGBS, silica fume

I. INTRODUCTION

Concrete is the most widely used man-made construction material in the world. It is obtained by mixing cementations materials, water, aggregate and sometimes admixtures in required proportions. Fresh concrete or plastic concrete is freshly mixed material which can be moulded into any shape hardens into a rock-like mass known as concrete. Fibre Reinforced Concrete can be defined as a composite material consisting of mixtures of cement, mortar or concrete and discontinuous, discrete, uniformly dispersed suitable fibres. Fibre reinforced concrete is of different types and properties with many advantages. Fibre is a small piece of reinforcing material possessing certain characteristics properties. They can be circular or flat. The fibre is often described by a convenient parameter called “aspect ratio”. The aspect ratio (l/d) is calculated by dividing fibre length (L) by its diameter (d). Typical aspect ratio ranges from 30 to 150. Fibres with a non-circular cross section use an equivalent diameter for the calculation of aspect ratio. The amount of fibres added to a concrete mix is expressed as a percentage of the total volume of the composite (concrete and fibres), termed "volume fraction" (V_F). V_F typically ranges from 0.1 to 3%. Many types of fibre are used in concrete here in this study Synthetic fibre (Recron 3s polyester) are used with different volume fraction (0%, 0.1%, 0.2%, and 0.3%) and also some pozzolana materials (GGBS and Silica fume) are added in concrete as cement replacement (0%, 10%, 20%, 30%, 40%, 50% and 5%, 10%, 15% respectively). And some test has been carrying out Workability (Slump test), Compressive test, Flexure test, Split tensile test, RCPT, Water sorptivity and SEM EDX test for microstructure examination.

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II. LITERATURE REVIEW

The literature study concludes that the fibre reinforced concrete are help to make a high strength concrete or high performance concrete with use of different fibre. The fibres are help to improve the strength of concrete compare to normal concrete. If GGBS and Silica Fume are used in concrete as cement replacement then it helps to improve more strength with fibre. This review also concludes that the synthetic (Recron 3s polyester) fibres are improving strength of concrete with low volume fraction of fibres compare to other fibres and help to improve some properties of concrete such as compressive strength, tensile strength and flexural strength. If SEM EDX test has been carryout than it give some more information about the micro structure of concrete like particle size, shape of particle, physical bond between the fibre and the hydrated matrix, effect of mixing method on surface of fibre, interlock of fibre with each other and EDX analysis is give some information about the chemical composition of sample so, we can determine the how many chemical are present in how much percentage.

III. OBJECTIVES OF WORK

1) To study effect of GGBS and Silica fume on strength and durability of synthetic fibre reinforced concrete.
2) To study microstructure and chemical composition of synthetic fibre reinforced concrete with GGBS and Silica fume as cement replacement.
3) To determine the optimum percentage of fibre that can be added to concrete to achieve desired needs.
4) To determine the optimum percentage of GGBS and Silica Fume that can be replaced with cement in Fibre Reinforced Concrete.

IV. MATERIALS

Concrete is mixture of cement, fine aggregate, coarse aggregate, water and admixtures (if required). Here in this study fibre reinforced concrete is used so, in concrete fibres are also added for better strength. So, for this study Recron 3s polyester fibres are used in different volume fraction (0%, 0.1%, 0.2%, and 0.3%). Also some pozzolanic material (Ground Granulated Blast Furnace Slag (10%, 20%, 30%, 40%, 50%) and Silica Fume (5%, 10%, 15%) are used as replacement of cement in different percentages. So, for this study cement, fine aggregate, coarse aggregate, fibres (Recron 3s polyester fibre) and pozzolanic materials (Ground Granulated Blast Furnace Slag and Silica Fume) are used.

V. METHODOLOGY

A. *Mix Design*

As per IS 10262 prepare a mix design of M40 grade of concrete. In this MIX design fibres, GGBS and silica fume are added in different percentage. Table no. I show the mix design of M40 grade of concrete.

TABLE I MIX DESIGN OF M40 GRADE OF CONCRETE

Cement	Water	Super plasticizer	Sand	Coarse aggregate	Density
394.31 Kg/m^3	177.44 Kg/m^3	1.97 Kg/m^3	669.38 Kg/m^3	1297.58 Kg/m^3	2540.37 Kg/m^3
1	0.45	0.0049	1.69	3.29	-

B. *Mixing And Casting*

Hand mixing is adopted for mixing of the basic materials of concrete and mixed concrete is moulded into cube, cylinders and beam for different tests.

C. *Curing*

After casting work is over moulded specimens are stored in room temperature for 24 hours. After this period specimens are taken out from mould carefully without damaging the surface and immersed in water for 28 days.

D. *Testing*

The specimen cured as stated above tested according to IS 516: 1959 code standards and ASTM C1202, ASTM C 1585 – 04. The entire strength tests were done accordingly IS 516: 1959 and other tests of Durability were done accordingly ASTM C1202 and ASTM C 1585 – 04. The results mentioned were average of the values obtained from three specimens.

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VI. RESULTS AND DISCUSSION

A. *Slump Test*

TABLE III slump test

Sr. No.	Name of sample	Grade of concrete	% of fibre	% of S.F.	% of GGBS	Slump value (mm)
1	C-F0	M40	0.0%	0.0%	0.0%	98
2	C-F1	M40	0.1%	0.0%	0.0%	96
3	C-F2	M40	0.2%	0.0%	0.0%	96
4	C-F3	M40	0.3%	0.0%	0.0%	94
5	C-FS5	M40	0.2%	5.0%	0.0%	100
6	C-FS10	M40	0.2%	10%	0.0%	104
7	C-FS15	M40	0.2%	15%	0.0%	110
8	C-FG10	M40	0.2%	0.0%	10%	98
9	C-FG20	M40	0.2%	0.0%	20%	102
10	C-FG30	M40	0.2%	0.0%	30%	107
11	C-FG40	M40	0.2%	0.0%	40%	110
12	C-FG50	M40	0.2%	0.0%	50%	113

B. *Compressive Strength*

TABLE IIIII Compressive strength of concrete at 7 days of curing

Sr. No.	Name of sample	Grade of concrete	% of fibre	% of S.F.	% of GGBS	Strength (N/mm^2)
1	C-F0	M40	0.0%	0.0%	0.0%	31.70
2	C-F1	M40	0.1%	0.0%	0.0%	32.40
3	C-F2	M40	0.2%	0.0%	0.0%	33.33
4	C-F3	M40	0.3%	0.0%	0.0%	33.04
5	C-FS5	M40	0.2%	5.0%	0.0%	34.66
6	C-FS10	M40	0.2%	10%	0.0%	36.14
7	C-FS15	M40	0.2%	15%	0.0%	35.25
8	C-FG10	M40	0.2%	0.0%	10%	33.03
9	C-FG20	M40	0.2%	0.0%	20%	34.36
10	C-FG30	M40	0.2%	0.0%	30%	35.40
11	C-FG40	M40	0.2%	0.0%	40%	34.36
12	C-FG50	M40	0.2%	0.0%	50%	33.18

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TABLE IVV Compressive strength of concrete at 28 days of curing

Sr. No.	Name of sample	Grade of concrete	% of fibre	% of S.F.	% of GGBS	Strength (N/mm^2)
1	C-F0	M40	0.0%	0.0%	0.0%	49.03
2	C-F1	M40	0.1%	0.0%	0.0%	50.44
3	C-F2	M40	0.2%	0.0%	0.0%	51.40
4	C-F3	M40	0.3%	0.0%	0.0%	50.97
5	C-FS5	M40	0.2%	5.0%	0.0%	53.62
6	C-FS10	M40	0.2%	10%	0.0%	56.73
7	C-FS15	M40	0.2%	15%	0.0%	55.25
8	C-FG10	M40	0.2%	0.0%	10%	51.10
9	C-FG20	M40	0.2%	0.0%	20%	53.47
10	C-FG30	M40	0.2%	0.0%	30%	54.06
11	C-FG40	M40	0.2%	0.0%	40%	51.69
12	C-FG50	M40	0.2%	0.0%	50%	49.62

C. Split Tensile Strength

TABLE V Split tensile strength of concrete at 7 days of curing

Sr. No.	Name of sample	Grade of concrete	% of fibre	% of S.F.	% of GGBS	Strength (N/mm^2)
1	C-F0	M40	0.0%	0.0%	0.0%	3.16
2	C-F1	M40	0.1%	0.0%	0.0%	3.41
3	C-F2	M40	0.2%	0.0%	0.0%	3.56
4	C-F3	M40	0.3%	0.0%	0.0%	3.53
5	C-FS5	M40	0.2%	5.0%	0.0%	3.58
6	C-FS10	M40	0.2%	10%	0.0%	3.62
7	C-FS15	M40	0.2%	15%	0.0%	3.60
8	C-FG10	M40	0.2%	0.0%	10%	3.51
9	C-FG20	M40	0.2%	0.0%	20%	3.53
10	C-FG30	M40	0.2%	0.0%	30%	3.59
11	C-FG40	M40	0.2%	0.0%	40%	3.52
12	C-FG50	M40	0.2%	0.0%	50%	3.47

TABLE VI Split tensile strength of concrete at 28 days of curing

Sr. No.	Name of sample	Grade of concrete	% of fibre	% of S.F.	% of GGBS	Strength (N/mm^2)
1	C-F0	M40	0.0%	0.0%	0.0%	4.87
2	C-F1	M40	0.1%	0.0%	0.0%	5.41
3	C-F2	M40	0.2%	0.0%	0.0%	5.47
4	C-F3	M40	0.3%	0.0%	0.0%	5.45
5	C-FS5	M40	0.2%	5.0%	0.0%	5.49
6	C-FS10	M40	0.2%	10%	0.0%	5.60
7	C-FS15	M40	0.2%	15%	0.0%	5.56
8	C-FG10	M40	0.2%	0.0%	10%	5.44
9	C-FG20	M40	0.2%	0.0%	20%	5.48
10	C-FG30	M40	0.2%	0.0%	30%	5.53
11	C-FG40	M40	0.2%	0.0%	40%	5.46
12	C-FG50	M40	0.2%	0.0%	50%	5.31

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D. Flexural Strength

TABLE VII Flexural strength of concrete at 7 days of curing

Sr. No.	Name of sample	Grade of concrete	% of fibre	% of S.F.	% of GGBS	Strength (N/mm^2)
1	C-F0	M40	0.0%	0.0%	0.0%	4.59
2	C-F1	M40	0.1%	0.0%	0.0%	5.16
3	C-F2	M40	0.2%	0.0%	0.0%	5.19
4	C-F3	M40	0.3%	0.0%	0.0%	5.17
5	C-FS5	M40	0.2%	5.0%	0.0%	5.28
6	C-FS10	M40	0.2%	10%	0.0%	5.41
7	C-FS15	M40	0.2%	15%	0.0%	5.37
8	C-FG10	M40	0.2%	0.0%	10%	5.20
9	C-FG20	M40	0.2%	0.0%	20%	5.26
10	C-FG30	M40	0.2%	0.0%	30%	5.32
11	C-FG40	M40	0.2%	0.0%	40%	5.23
12	C-FG50	M40	0.2%	0.0%	50%	5.11

TABLE VIII Flexural strength of concrete at 28 days of curing

Sr. No.	Name of sample	Grade of concrete	% of fibre	% of S.F.	% of GGBS	Strength (N/mm^2)
1	C-F0	M40	0.0%	0.0%	0.0%	7.25
2	C-F1	M40	0.1%	0.0%	0.0%	8.14
3	C-F2	M40	0.2%	0.0%	0.0%	8.19
4	C-F3	M40	0.3%	0.0%	0.0%	8.17
5	C-FS5	M40	0.2%	5.0%	0.0%	8.24
6	C-FS10	M40	0.2%	10%	0.0%	8.31
7	C-FS15	M40	0.2%	15%	0.0%	8.28
8	C-FG10	M40	0.2%	0.0%	10%	8.21
9	C-FG20	M40	0.2%	0.0%	20%	8.23
10	C-FG30	M40	0.2%	0.0%	30%	8.26
11	C-FG40	M40	0.2%	0.0%	40%	8.20
12	C-FG50	M40	0.2%	0.0%	50%	8.17

E. Rapid Chloride Permeability Test

TABLE IX RCPT test

Sr. No.	Name of sample	Grade of concrete	% of fibre	% of S.F.	% of GGBS	Charge passed In Coulombs (c)	Chloride Permeability
1	C-F0	M40	0.0%	0.0%	0.0%	2288	Moderate
2	C-F1	M40	0.1%	0.0%	0.0%	2204	Moderate
3	C-F2	M40	0.2%	0.0%	0.0%	2140	Moderate
4	C-F3	M40	0.3%	0.0%	0.0%	2137	Moderate
5	C-FS5	M40	0.2%	5.0%	0.0%	1987	Low
6	C-FS10	M40	0.2%	10%	0.0%	1823	Low
7	C-FS15	M40	0.2%	15%	0.0%	1817	Low
8	C-FG10	M40	0.2%	0.0%	10%	2110	Moderate
9	C-FG20	M40	0.2%	0.0%	20%	2040	Moderate
10	C-FG30	M40	0.2%	0.0%	30%	1967	Low
11	C-FG40	M40	0.2%	0.0%	40%	1962	Low
12	C-FG50	M40	0.2%	0.0%	50%	1959	Low

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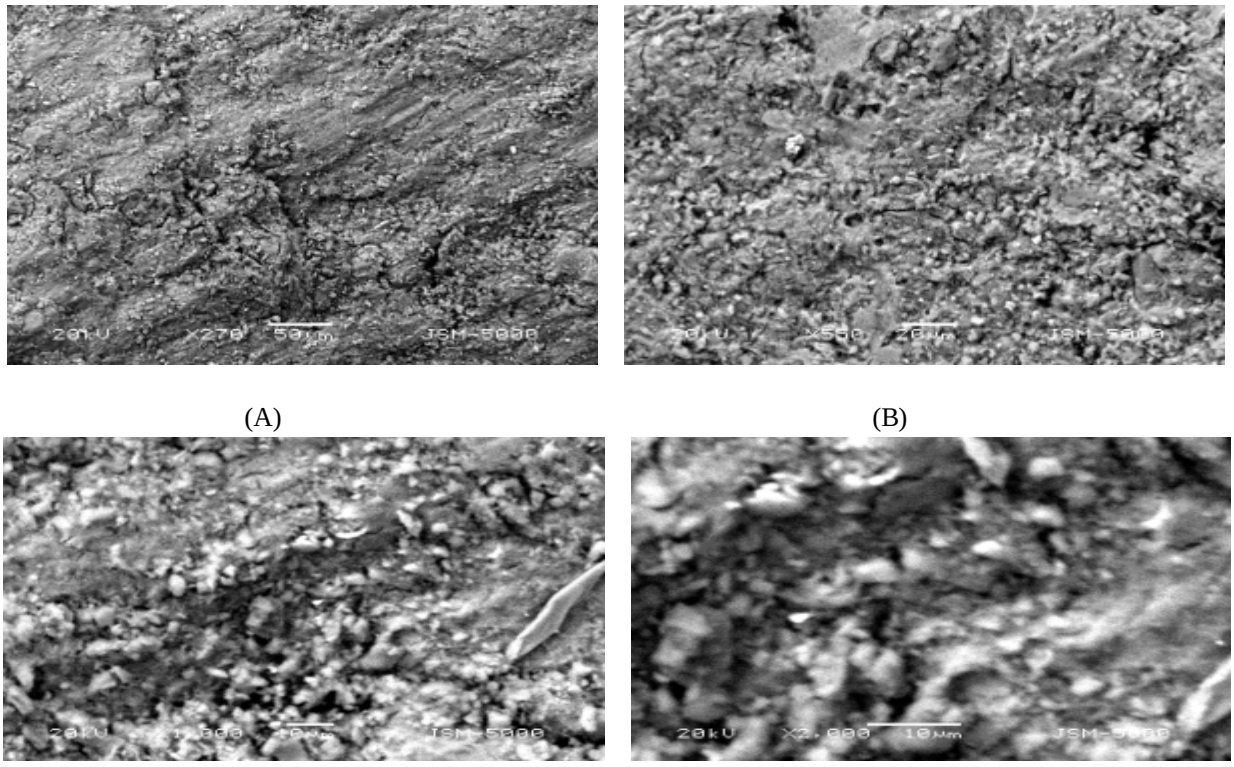
F. Water Sorptivity Test

TABLE X Water Sorptivity test

Sr. No.	Name of sample	Grade of concrete	% of fibre	% of S.F.	% of GGBS	Dry Wt in Grams (W1)	Wet Wt in grams(W2)	Sorptivity Value in mm/min$^{0.5}$
1	C-F0	M40	0.0%	0.0%	0.0%	916	917	0.0067
2	C-F1	M40	0.1%	0.0%	0.0%	919	920.5	0.0100
3	C-F2	M40	0.2%	0.0%	0.0%	915.5	917.1	0.0107
4	C-F3	M40	0.3%	0.0%	0.0%	923.1	925.3	0.0147
5	C-FS5	M40	0.2%	5.0%	0.0%	910	911	0.0067
6	C-FS10	M40	0.2%	10%	0.0%	923.8	924.4	0.0040
7	C-FS15	M40	0.2%	15%	0.0%	929	929.5	0.0033
8	C-FG10	M40	0.2%	0.0%	10%	917	918.3	0.0087
9	C-FG20	M40	0.2%	0.0%	20%	920.5	921.5	0.0067
10	C-FG30	M40	0.2%	0.0%	30%	913.6	914.4	0.0053
11	C-FG40	M40	0.2%	0.0%	40%	915.5	916.3	0.0053
12	C-FG50	M40	0.2%	0.0%	50%	919	919.7	0.0046

G. Sem EDX Test

1) M40 grade of concrete



(A) (B)

(C) (D)

Fig. 1 SEM images of M40 grade concrete.

a) Here in all the SEM images of normal concrete seen that the shapes of OPC particles are irregular and angular.
b) Well mixed and dense concrete are seeing in the all SEM images of normal concrete.
c) Some of air voids are seen in SEM images B – C – D at magnification level x550, x1000 and x2000.
d) These types of air voids are affected on Durability parameter and decrease the strength of concrete

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Fig. 2 EDX analysis of M40 grade concrete.

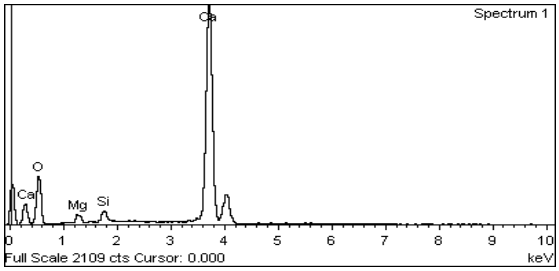


Table XI EDX analysis of normal M40 grade concrete.

ELEMENT	WEIGHT (%)
Calcium oxide (CaO)	64.65
Oxygen (O)	29.10
Silica (SiO_2)	3.32
Magnesium Oxide (MgO)	1.59
Aluminium Oxide (Al_2O_3)	1.34
Total	100.00

e) The chemicals are presents in the sample of M40 grade of concrete are shown in table 6.1.

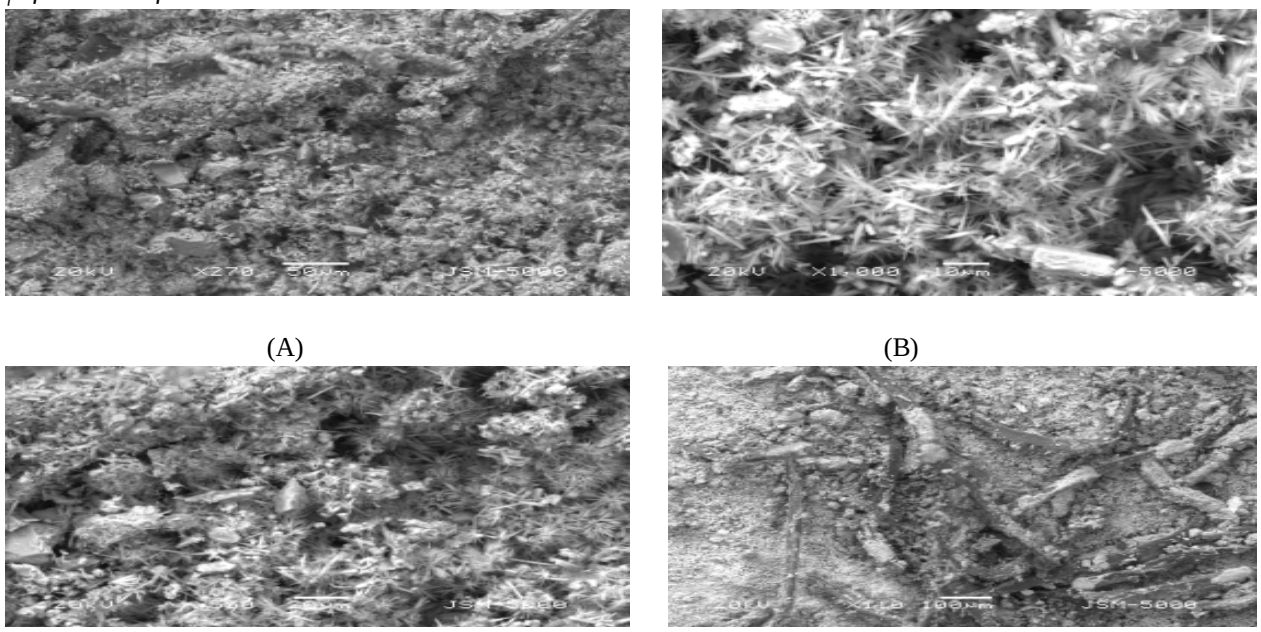
f) It was found in this EDX analysis that silica, oxygen and calcium oxide are found in large quantity and also some amount of magnesium oxide and aluminium oxide are found.

g) Here Calcium oxide reacts with Silica and gives calcium silicate, and C-S-H gel is obtained by reaction between CaO and SiO_2 in presence of water.

h) Here in this EDX analysis Calcium oxide (CaO) found in large quantity because limestone is use as a raw material during manufacturing of cement.

i) Al_2O_3 has quick setting property and MgO provide the hardness in the concrete.

2) 0.2% V_f of Fibre reinforced concrete



(A) (B)

(C) (D)

Fig. 3 SEM images of 0.2% V_f of Fibre reinforced concrete.

a) In the SEM analysis of these four images it was found that the shape of a fibre is triangle shown perfectly in image D at magnification level x110.

b) Here also seen some OPC particles having irregular shape.

c) An analysis of the SEM images it was found that the concrete and fibres are well mixed and become denser concrete and not have any air voids.

d) Fibres are well incoherent with each other at mixing of concrete and fibres are well interlocked with each other and it was shown in all images of SEM that the aggregate of concrete are well covered by fibres.

e) The way in which the image appears the structure and interlocking of fibres with each other are helpful to increasing the strength of concrete.

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Fig. 4 EDX analysis of 0.2% V_f of Fibre reinforced concrete.

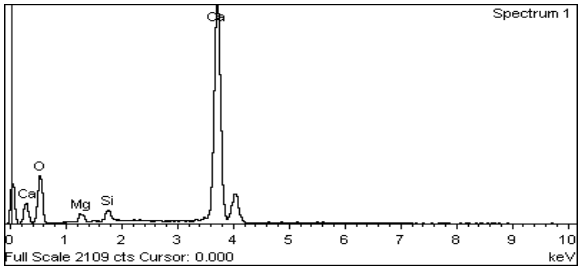
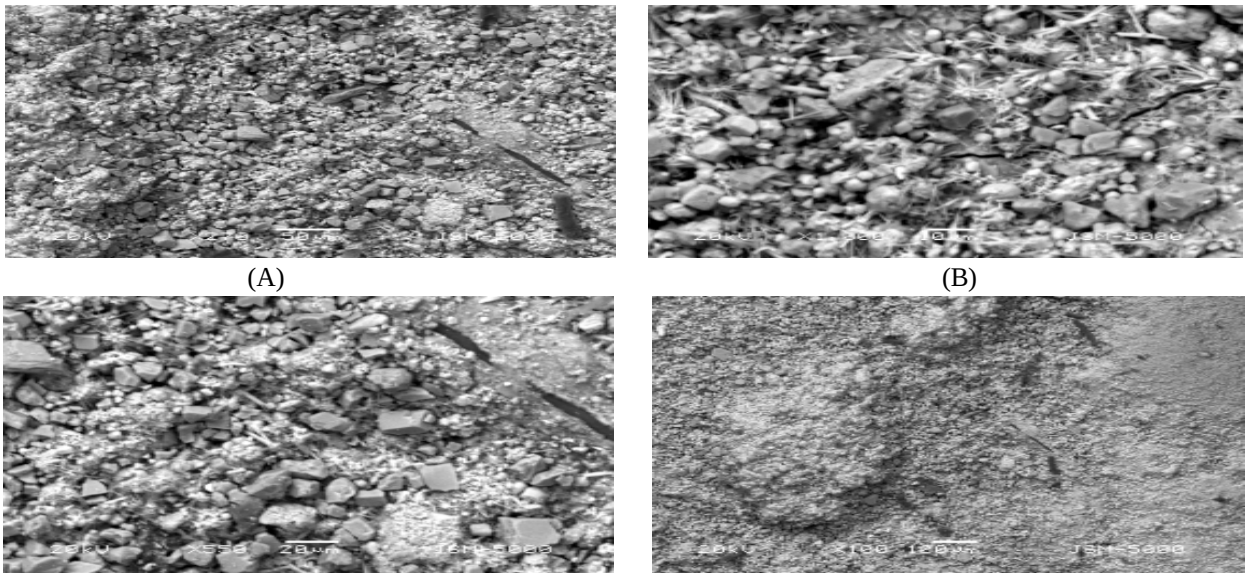


Table XII EDX analysis of 0.2% V_f of Fibre reinforced concrete.

ELEMENT	WEIGHT (%)
Calcium oxide (CaO)	66.21
Oxygen (O)	29.21
Silica (SiO_2)	3.02
Magnesium Oxide (MgO)	1.56
Total	100.00

j) The chemicals are presents in the sample of M40 grade of fibre reinforced concrete are shown in table 6.2.
k) It was found in this EDX analysis that silica, oxygen and calcium oxide are found in large quantity and also some amount of magnesium oxide is found.
l) Here Calcium oxide reacts with Silica and gives calcium silicate and C-S-H gel are obtained by reaction between CaO and SiO_2 in presence of water.
m) In this sample not use any admixture or pozzolana materials just Recron 3s fibres are used so, the results of this EDX analysis is almost same as EDX of sample of normal concrete.

3) Fibre Reinforced Concrete With 10% Silica Fume



(A) (B)

(C) (D)

Fig. 5 SEM images of Fibre reinforced concrete with 10% Silica Fume.

a) Here in images A-B-C at the magnification level x220, x550 and x1000 the particles of cement and silica fume are seen.
b) All the particles have an angular and irregular shape are all of cement and all anther particles have circular shape and small in diameter are all of Silica fume.
c) In SEM images it is found that silica fume, concrete and fibre are well mixed.
d) Looking in the SEM images, it is found that concrete is dense and does not have any air voids.
e) Fibres are well locked to each other and it help in increasing the strength of concrete.
f) Silica fume and cement particles are found to be good layer around fibres surface or submerged in the paste of cement and silica fume.
g) Fibres are well incoherent with each other in concrete.

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Fig. 6 EDX analysis of Fibre reinforced. Concrete with 10% Silica Fume

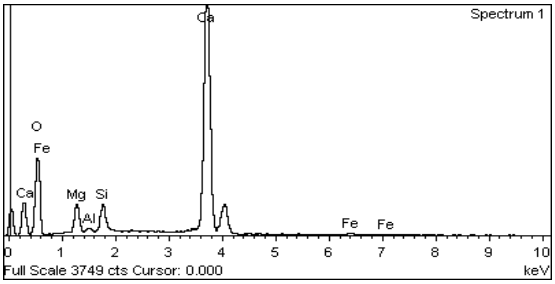


Table XIII EDX analysis of Fibre reinforced concrete with 10% Silica Fume.

ELEMENT	WEIGHT (%)
Calcium oxide (CaO)	55.23
Oxygen (O)	32.32
Silica (SiO_2)	6.35
Magnesium Oxide (MgO)	4.65
Iron oxide (Fe_2O_3)	0.80
Aluminium oxide (Al_2O_3)	0.65
Total	100

h) The chemicals are presents in the sample of M40 grade of fibre reinforced concrete with silica fume are shown in table 6.3.

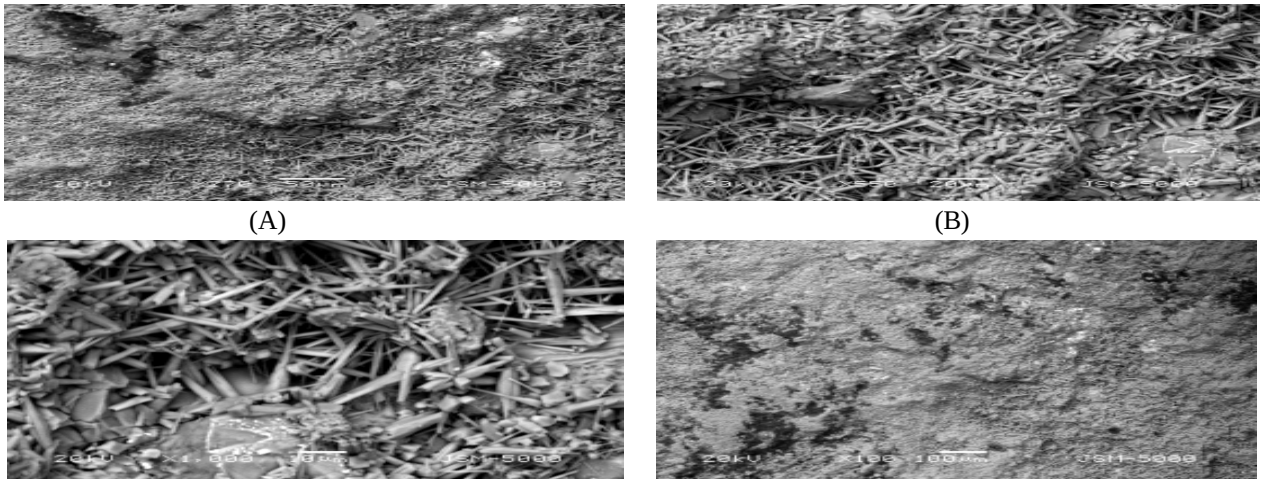
i) It was found in this EDX analysis that silica, oxygen, magnesium oxide and calcium oxide are found in large quantity and also some amount of iron oxide and aluminium oxide are found.

j) Here Calcium oxide reacts with Silica and gives calcium silicate and C-S-H gel are obtained by reaction between CaO and SiO_2 in presence of water.

k) Here in this sample 10% silica fume are used so, the percentage of silica is increase and percentage of calcium oxide decrease and also some other chemicals are identify.

l) Iron oxide and magnesium oxide are found so, it help to increase the strength and given hardness in the concrete.

4) Fibre reinforced concrete with 30% GGBS



(A) (B)

(C) (D)

Fig. 7 SEM images of Fibre reinforced concrete with 30% GGBS.

a) In images B - C at magnification level x550 and x1000 seen some cement and GGBS particles with irregular shape

b) Fibres found well mixed and incoherent with each other in concrete with GGBS.

c) Fibres are well cemented around cement paste and aggregate and it helps to increasing the strength of concrete and become dense concrete.

d) The interlocking between the fibres is well seeing in SEM image (C) at magnification level x1000.

e) It was seen that there is more fibre content on the surface of concrete.

f) There is not cover of GGBS and cement around fibres as seen in silica fume because in the SEM of silica fume with fibre was seen that the silica fume and cement become a layer around the fibres, here in these SEM images it was not seen any layer of GGBS and cement around fibres so, that could be the reason the strength of concrete with 30% of fibres are give less strength as compare to the strength of concrete with 10% of silica fume.

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Fig. 8 EDX analysis of Fibre reinforced. Concrete with 30% GGBS

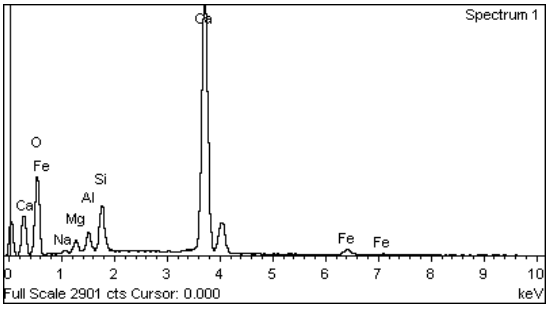

Table XIV EDX analysis of Fibre reinforced concrete with 30% GGBS

ELEMENT	WEIGHT (%)
Calcium oxide (CaO)	51.61
Oxygen (O)	33.20
Silica (SiO_2)	6.85
Iron oxide (Fe_2O_3)	2.95
Aluminium oxide (Al_2O_3)	2.82
Magnesium Oxide (MgO)	2.35
Sodium oxide (Na2O)	0.22
Total	100

g) The chemicals are presents in the sample of M40 grade of fibre reinforced concrete with GGBS are shown in table 6.4.

h) It was found in this EDS analysis that silica, oxygen, magnesium oxide, iron oxide, aluminium oxide and calcium oxide are found in large quantity and also some amount of Sodium oxide are found.

i) Here Calcium oxide reacts with Silica and gives calcium silicate and C-S-H gel are obtained by reaction between CaO and SiO_2 in presence of water.

j) Here in this sample 30% of GGBS are replaced by cement and GGBS has more calcium oxide that's why the percentage of calcium oxide was not decrease at the replacement of 30% of OPC cement and in this sample also some other chemicals are identify.

k) Iron oxide and magnesium oxide are found so, it help to increase the strength and given hardness in the concrete and aluminium oxide has quick setting properties

l) Here in this EDS analysis some alkalis (Sodium oxide) are found in lower quantities because GGBS and OPC cement both have some alkalis and sodium oxide is not good for the concrete because sodium oxide are react with active silica and made alkali silicate gel (alkali aggregate reaction) and this alkali silicate gel have swelling nature so, it is create crack in the concrete. So, the maximum percentage of alkalis (Na_2O, K_2O) should be 0.6% as per IS 12269 - 2013. In this sample 0.22% of Na_2O are identify so it is useful.

VII. CONCLUSIONS

1) The workability of fibre reinforced concrete is decrease with increase of volume fraction of fibre and workability is increase as percentage of silica fume and GGBS is increase in concrete.

2) 0.2% of volume fraction of Recron 3s fibres is giving maximum compressive, tensile and flexural strength as compare to 0.1% and 0.3% volume fraction of fibre.

3) The Recron 3s fibres are help to improve 5% of compressive strength, 12% of tensile strength and 13% of flexural strength as compare to control mix.

4) Replacement of 10% silica fume with 0.2% V_f of Recron 3s polyester fibres are giving maximum compressive, tensile and flexural strength as compare to 5% and 15% replacement of silica fume.

5) Replacement of 30% GGBS with 0.2% V_f of Recron 3s polyester fibres are giving maximum compressive, tensile and flexural strength as compare to 10%, 20%, 40% and 50% replacement of GGBS.

6) So, optimum percentage of fibre is 0.2% and optimum percentage of silica fume and GGBS is 10% and 30% respectively along with fibres.

7) Water sorptivity results for all mixes falls in good category having values between 0 to 4.Water sorptivity value increase as percentage of fibres are increase in concrete. Water Sorptivity value decrease as the silica fume and ggbs are added in fibre reinforced concrete.

8) Rapid Chloride permeability test Results the chloride ion permeability of all mixes falls in good category (moderate and low). The chloride ion permeability decrease as the increase the percentage of silica fume and GGBS with fibres. The lowest chloride ion permeability found in concrete with silica fume along with fibre.

9) SEM images of all sample show that the concrete are very well mixed and denser but some air voids found in SEM images of control mix. In fibre reinforced concrete the fibres are well mixed in concrete and inter lock with each other. The uses of silica fume and GGBS with fibres are made denser concrete and help to increase the strength of concrete not have any air voids.

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10) Identify high amount of calcium oxide and silica (silicon dioxide) in all of four samples in EDX analysis. So, here CaO react with SiO_2 in the presence of water and make a C-S-H gel. And in the sample of silica fume and GGBS found some more chemical as compare to the sample of control mix and fibre reinforced concrete. Also some percentage of alkalis are identify in the sample of 30% of GGBS.

11) Based on the results of workability, strength, durability and micro structure it is determine that the fibre reinforced concrete with silica fume given better performance in the all parameters and especially 10% replacement of silica fume with 0.2% V_f of fibre give better results.

VIII. ACKNOWLEDGMENT

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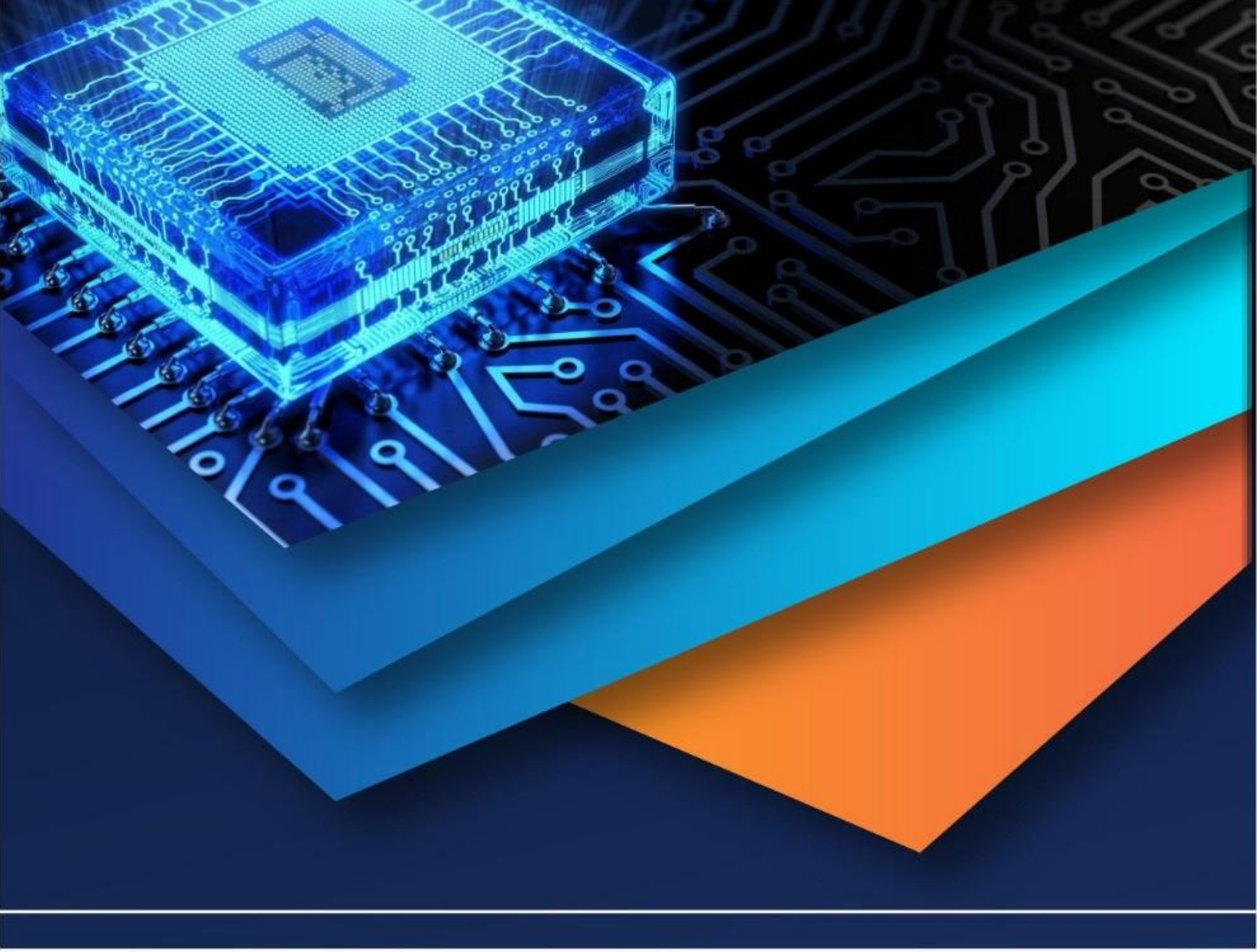

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