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CHLORIDE ION PENETRATION AND CORROSION RESISTANCE OF SLAG INCORPORATED SELF COMPACTED CONCRETES

C. Rajamallu[1], T. Chandrasekhar Reddy[2] and E. Arunakanthi[3]
[1]JNTUA Anantapur, Andhra Pradesh, India
[2]Department of Civil Engineering, G. Pulla Reddy Engineering College, Kurnool, Andhra Pradesh, India
[3]Civil Engineering Department, JNTUA, Anantapur, Andhra Pradesh, India
E-Mail: rajamalluneraniki@gmail.com

ABSTRACT

Basically many of researchers and guidelines were defined as Self-compacting concrete is a highly flowable and it can totally fill the form work under the action its own weight, even with a high congestion of steel reinforcement, it can compact totally without segregation and bleeding. Since from earlier 1983, durability of concrete structures was major problem of interest in Japan, for making concrete durable structures, cementitious materials replaced partly with pozzolanic materials like GGBS and SF. This study aims to focus on the possibility of using industrial by-products like Ground Granulated Blast Furnace Slag (GGBS) and Silica fume in preparation of SCC. Eight numbers of SCC mixtures and one number of control concrete mix were prepared for this investigation. The quantity of the cementitious materials and water cementitious ratio was maintained constant i.e. cementitious materials (500 kg/m3), while the water cementitious ratio ranged from 0.35 to 040. The self-compacted concrete mix has prepared with a cement replacement of 30%, 50% and 70% by GGBS and Silica fume (by 2% weight of GGBS) in addition Auromix 300 plus is used as Chemical admixture to achieve the required flow ability, Compressive tests and flexural Tests were done on hardened properties and T50, Slump flow, L-Box, V-Box, and U-Box tests were done on fresh properties of self compacted concretes. The test results show that an economical self-compacting concrete could be successfully developed by incorporating high-volumes of GGBS, and also it proves that making of self-compacting concrete more affordable and low cost for the construction market by replacing high volumes of Portland cement by GGBS. The Cube and beam specimens were casted and cured in to NaCl solution (3.5% by weight of water) after normal 28days curing. Durable Studies have been carried out, such as Chloride penetration by chemical analysis, Corrosion of reinforcement by RPS system and Micro analysis of SCC by XRD,EDX and SEM tests for exposure ages of 28, 56, 84 and 98days.

Keywords: ground granulated blast furnace slag , silica fume, self-compacted concretes, chloride ion penetration, water cement ratio, corrosion of reinforcement, micro analysis.

1. INTRODUCTION

Basically, many of researchers and guidelines explored self-compacting concrete which is a highly flowable and it can totally fill the form work under the action its own weight, even with a high congestion of steel reinforcement, it can compact totally without segregation and bleeding. Since from earlier 1983, durability of concrete structures was major problem of interest in Japan, for making concrete durable structures, cementitious materials replaced partly with pozzolanic materials like GGBS and SF. The use of GGBS minimizes the need for viscosity-modifying chemical admixtures, heat of hydration and escalates the slump flow of the SCCs mixes [2]. Recently silica fume has been found to be very effective in manufacturing of high strength self compacting concrete. Moreover, the use of both silica fume and a suitable super plasticizer is beneficial, as it allows use of low water/cement ratios for a given workability. The research deals with Mix proportion, chloride Ion penetration and corrosion of reinforcement caused by the chloride attack for SCC.

2. OBJECTIVES OF THE PRESENT STUDY

The research work focus on conducting a practicability study of generating self compacting concrete by replacing the cement with various percentages of Ground Granulated Blast furnished Slag and SF (by 2% weight of GGBS) The research described in this research is aimed at examining the behaviour of SCC structural elements concerning strength and durability. The related objectives of the study are:

a) To develop the Optimum M40 mix proportions and study the Fresh and Harden properties of SCC mix by replacing cement with various percentages of GGBS (Ground Granulated Blast Furnace slag), and Silica fume.

b) To study the durability properties such as Chloride Ion penetration test, Corrosion

c) Resistance test and Micro Structural Analysis for developed mix proportions of SCC.

3. MATERIALS AND METHODOLOGY

3.1 Materials

The materials utilized in this experimental work are presented in detail.

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a) Cement

Ordinary Portland cement of grade 53 was used confirming to Indian Standard code specification IS: 12269-2013.

b) Fine Aggregate

Fine aggregate which is taken from Krishna river located nearby Vijayawada, Andhrapradesh belongs to zone II confirming as per IS code 383-1970as shown in Figure-1, The following tests have been done and the outcomes are for Physical properties of Fine Aggregate i.e. Specific Gravity-2.603, Fineness Modulus-2.7, Bulk Density (loose) -1610kG/m^3, compacted-1682Kg/m^3, Absorption of Water-1.0, Relative density of sand-2.61%.

Figure-1. Fine aggregate.

c) Ground Granulated Blast Furnish Slag

The GGBS shown in Figure-2 was collected from VTPS, Gannavaram, Andhrapradesh. The chemical properties of GGBS are Lime (CaO)-34.5%,Silica (SiO2)-32%, Alumina (Al2O3)-14.5%, Ironoxide (Fe2O3)-0.7% and physical properties of GGBS are Specificgravity-2.90, Blaine'sfineness-3350cm^2/gm, Bulkdensity-1.0 and colour-white.

Figure-2. GGBS.

d) Silica Fume

Silica fume as shown in Figure-3 is a by-product of producing silicon metals or ferrosilicon alloys. SF mainly consists of amorphous (non-crystalline) silicon dioxide. The particles are very small and approximately 1/100th size of an average cement particle. Silica fume is a very reactive pozzolanic material because of its fineness, large surface area and high silicon dioxide content. ASTM C 1240 and AASHTO M 307 specified the quality of silica fume. By adding silica fume to the concrete its compressive strength, bond strength and abrasion resistance should increase and also reduces the permeability of concrete to chloride ions, segregation and bleeding. The physical properties of silica fume are Specific gravity-2. 1, color-dark gray and chemical properties of silica fume are SiO_2-75%, Al_2O_3-1.07%, CaO-0.7%, Fe_2O_3-1.25%.

Figure-3. Silica fume.

e) Coarse Aggregate

Hard broken granite as shown in Figure-4 was used as Coarse aggregate of size 10-12 mm in this experimental work which was collected from local quarry located nearby Vijayawada, Andhrapradesh.

Figure-4. 10-12 mm aggregate.

f) Water

This is the low exclusive but one of the important components in the concrete. The water to be used in the concrete must be clean and free of harmful impurities such as oil, alkalis and acids, as a whole, the water is suitable for drinking and must be used for the production of concrete. The water used in this research for blending the concrete is potable and test result soft water are pH-6 to 8,

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Taste-Agreeable, Odour-Agreeable, Turbidity (NTUnits) - 4.

g) Admixture

Auromix 300plus is used as an admixture, which was collected from FOSROC, Kenya LTD. The properties are Relative Density-1.085 kg/liter, $P_H \geq 6$, Principle constituent-Polycarboxylate ether.

3.2 Mix Design

SCC mixes were manufactured with substitution of cement by GGBS and Silica fume in various percentages from 0 %, 30%, 50% up to 70 % respectively [3]. To assess the fresh properties of SCC, W/C was kept at 0.35 and 0.4 (by weight of cementitious) for all SCC mixes. Table-1 shows for various SCC mix quantities for M40 Grade.

Table-1. SCC mix quantities for M40 Grade.

Design Mix	% of (GGBS+SF)	W/C	Water quantity	Cement kg/m^3	Silica fume kg/m^3	Fine Aggregate kg/m^3.	Admixture kg/m^3	Coarse Agregate kg/m^3	GGBS kg/m^3	Measured C.F.
A2	0	0.4	200	500.0	Nil	866.667	2.5	839.86	Nil	.854
B2	30			350.0	3.0	866.667		827.038	147.0	.843
C2	50			250.0	5.0	866.667		818.077	245.0	.840
D2	70			150.0	7.0	866.667		810.35	343	.858
A1	0	0.35	175	500.0	Nil	900.0	2.5	830.92	Nil	.847
B1	30			350.0	3.0	883.33		877.99	147.0	.955
C1	50			250.0	5.0	883.33		870.26	245.0	.852
D1	70			150.0	7.0	883.33		862.54	343	.860

3.3 Methodology

In this section the test methods that are used for testing the fresh, hardened properties of SCC are presented.

3.3.1 Fresh properties of SCC

As per EFNARC [2002], test methods like slump flow, T_{50}cm slump flow, V funnel and L box has to be performed. Slump flow test is planned to determine fresh properties by the method of spreading [4]. T_{50} cm is measured to indicate the viscosity of SCC, V-funnel time is measured to indicate the filling capability of SCC whereas L-box test are conducted to determine the passing capability of SCC. Fresh properties pertaining of slump flow, T_{50} cm, V-funnel, L-box are illustrated in below Table-2 and shown in Figure-5 Graphical representation of Fresh properties of SCC pertaining of T_{50}, V-funnel, L-box, slump flow are shown in Figure-6.

Figure-5. Fresh properties of SCC pertaining of T_{50}, V-funnel, L-box, slump flow.

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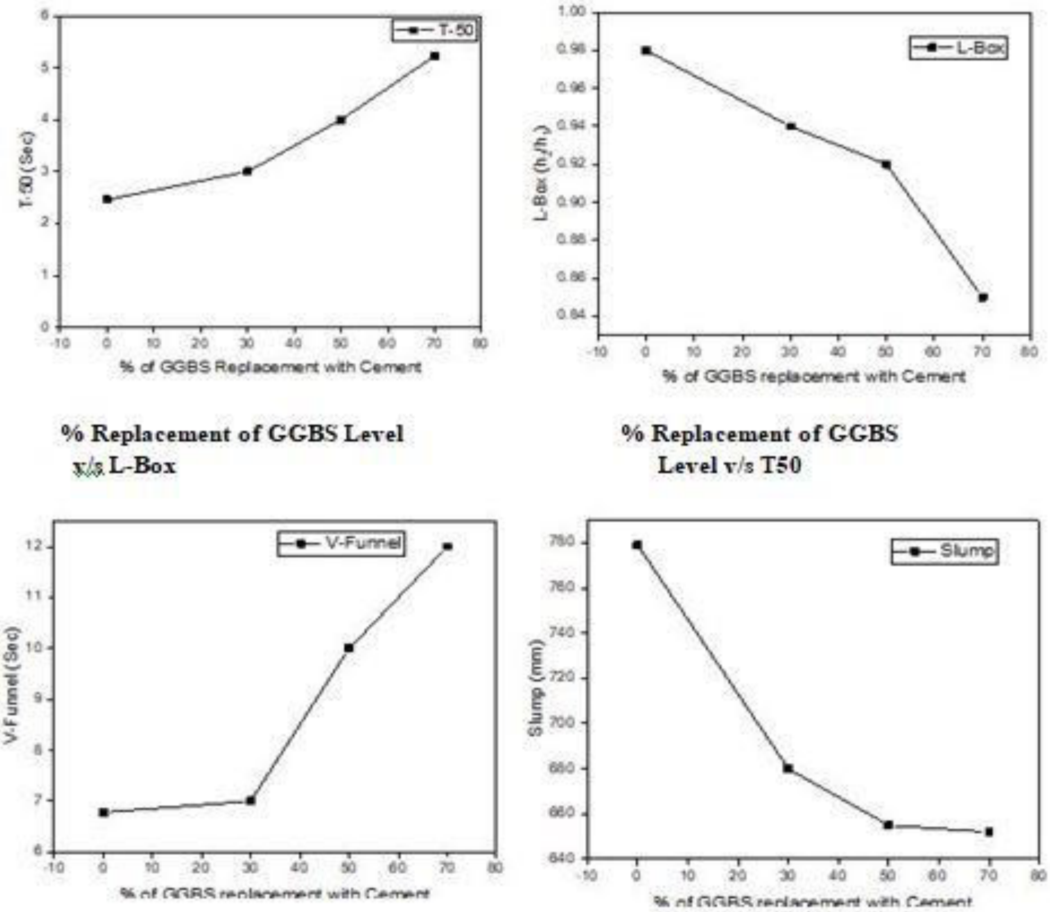
Table-2. Testing fresh properties of self compacted concrete.

Test	Mix	Limits	GGBS (0%)	GGBS (30%)	GGBS (50%)	GGBS (70%)
U-Box (h_1-h_2)	M40	0 -30mm	10mm	15mm	22mm	29mm
L-Box(h_2/h_1)		0.8 -1.0mm	0.98	0.94	0.92	0.85
Slump Flow		650 to 800mm	779mm	680mm	655mm	652mm
V-Funnel		6-12sec	6.78sec	7sec	10sec	12sec
T50		2-6sec	2.46sec	3sec	4sec	5.23sec



% Replacement of GGBS Level v/s L-Box

% Replacement of GGBS Level v/s T50

%Replacement of GGBS level v/s V- Funnel

%Replacement of GGBS level v/s Slump

Figure-6. Graphical representation of fresh properties of SCC pertaining of T_{50}, V-funnel, L-box, slump flow.

3.3.2 Casting and curing of specimens

Firstly, the required number of cube and beam moulds were cleaned and oiled properly and securely tightened to correct dimensions before casting. Care should be taken such that there is no gap left in between the joints of the moulds, in such way that no leakage of slurry can be happened. Care should be taken such that batching, mixing and casting operations were done properly. Initially the preparation of concrete mixture should be done in pan miller only. The procedure adopted for concrete mixing was, firstly fine and course aggregates were mixed thoroughly by dry mixing and then cement was added. These three were mixed to uniform colour. Then water was added mean while care should be taken no water was lost during mixing, then after suitable admixture was added along with it. After proper mixing concrete is checked for fresh properties. After testing the fresh properties, the concrete can filled completely in to cube and beam specimens. The casted specimens are removed from the moulds only after completion of 24 hours, then kept in water under normal curing at 28 days and NaCl (3.5% by weight of water) curing at 56,84, and 98 days as shown in Figure-7.

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Figure-7. Specimens left for normal and NaCl curing.

3.4 Hardened Properties of SCC

3.4.1 Testing cubes and beams - experimental test set up

The experimental schedule is planned to cast and testing of SCC with Replacing the Cement with 0%, 30%, 50% and 70% of GGBS and SF. The standard dimensions of cube specimen of size 150x150x150mm and the beam specimen of size 1000x150x150 mm. The moulds were taken out after one day and kept in water for seven and twenty-eight days in water curing pond. When the curing period is completed the samples will undergo testing for seven and twenty-eight days to calculate the strength in compression and Flexural of each sample. Three cubes for compressive strength and three beams for flexural strength were tested and the mean of the values are considered as strength of the mix [4] [5]. The details of number of cube and beam specimens casted are displayed in Table-3.

Table-3. Details of number of cubes and beams cast.

Mix	Grade	No. of Cubes	No. of Beams
0%GGBS	M40	15	15
30%GGBS	M40	15	15
50%GGBS	M40	15	15
70%GGBS	M40	15	15

3.4.2 Compressive strength analysis

The test results of various percentages of GGBS substitution levels were noted in Table-4 and comparison bar chart of test results are presented in Figure-8.

Table-4. Compressive strength results of SCC at 7 ans 28 days (MPa).

Slag levels	Average Compressive Strength (28 days)	Average Compressive Strength (7 days)
0%	45.69	27.31
30%	50.36	28.25
50%	34.46	25.11
70%	28.99	18.38

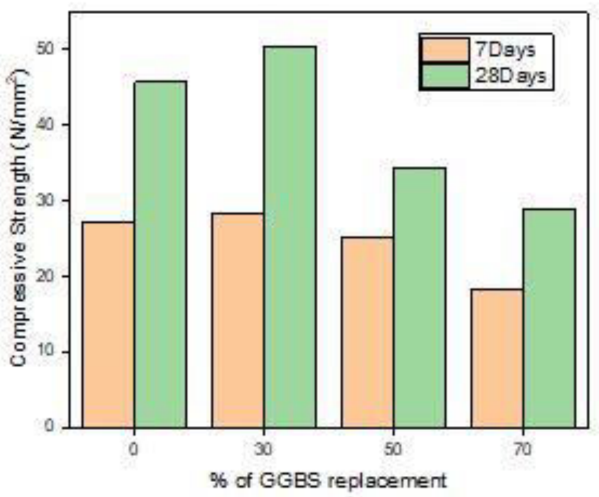

Figure-8. Comparison bar chart for test results of 0%, 30%, 50%, 70% at 7days and 28days.

3.4.2 Flexural strength analysis

For the test setup, specimens are placed on supports. Supports are fixed at one end and other at roller end. Later after placing beam on supports in order to act two-point loading, a setup has been made as shown in Figure-10. Later L.V.D.T is connected to the load cell, so that deflection can be observed by using hydraulic jack. now, start loading by using loading fame equipment from its machinery room. Flexural strength test Results of 0%, 30%, 50%, 70% Specimens which is at 7 and 28 days

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Normal Curing [6] as noted in Table-5 and comparison bar chart of test results are shown in Figure-11 and steel detailing of beam specimen as shown in Figure-9.

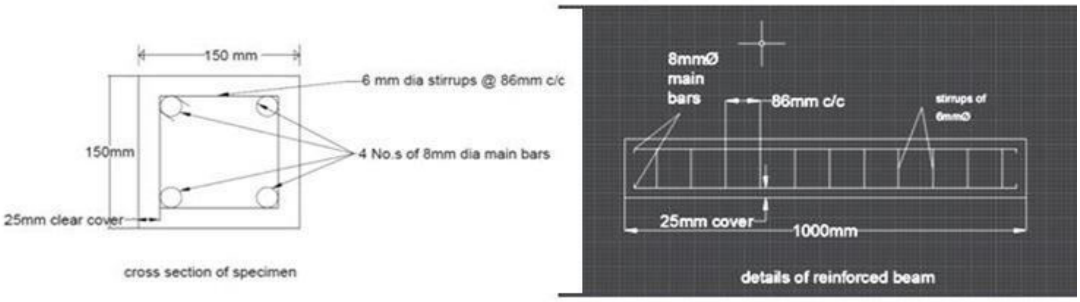

Figure-9. Steel detailing of L/S and C/S of beam specimen.

Figure-10. Test setup for flexural strength test of beam specimen.

Table-5. 7 and 28 days average flexural strength of SCC (MPa).

GGBS replacement levels	Flexural Strength (28 days)	Flexural Strength (7 days)
0%	11.91	5.98
30%	12.47	6.54
50%	16.15	9.33
70%	14.52	8.59

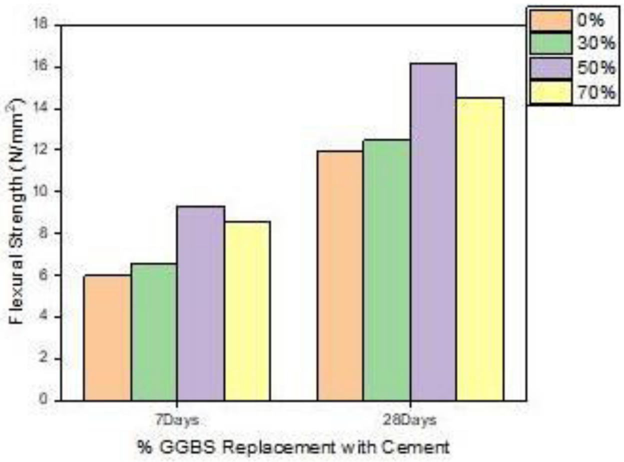

Figure-11. Comparision bar chart of flexural strength test results for 0%, 30%, 50%, 70% ggbs replacement at 7 and 28 days under normal curing.

4. DURABILITY PROPERTIES OF SCC

4.1 Chloride Ion Penetration Test: The chloride Ion content present in the specimens were detected by using chemical analysis with powder samples taken from specimens by drilling process as shown in Figure-12 The test results of various percentage of GGBS levels are noted in Tables 6 to 8 and comparison graphs with respect to test results are shown in Figure-13. From the comparison graphs, it has been noticed that as the depth keeps on increasing, the chloride penetration for different proportions was simultaneously decreasing. Hence, apart from all proportions of slag replacement levels, 50% of slag replacement level has been less corrosion [7] [8] [9].

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Figure-12. Tested cube and beam specimens under NaCl curing before and after drilling.

Table-6. Depth wise chloride content in (0%, 30%, 50% and 70%) GGBS replacements with cement for specimens under NaCl curing at 56 days.

% GGBS replacements with cement	Depth wise Chloride penetration in (%)				
	5mm	10mm	15mm	20mm	25mm
0%	3.993	3.550	2.662	1.775	1.331
30%	3.106	2.662	1.775	1.331	0.887
50%	2.662	2.218	1.331	1.331	0.443
70%	4.437	3.550	3.106	2.662	1.775

Table-7. Depth wise chloride content in (0%, 30%, 50% and 70%) GGBS replacements with cement for specimens under NaCl curing at 84 days.

% GGBS replacements with cement	Depth wise Chloride penetration in (%)				
	5mm	**10mm**	**15mm**	**20mm**	**25mm**
0%	8.875	4.881	3.106	2.218	1.775
30%	7.987	3.550	2.662	2.218	1.331
50%	7.543	3.993	2.662	1.775	0.887
70%	5.768	2.218	1.331	0.887	0.443

Table-8. Depth wise chloride content in (0%, 30%, 50% and 70%) GGBS replacements with cement for specimens under NaCl curing at 98 days.

% GGBS replacements with cement	Depth wise Chloride penetration in (%)				
	5mm	**10mm**	**15mm**	**20mm**	**25mm**
0%	8.875	7.543	5.768	3.106	1.775
30%	6.656	3.106	2.218	1.331	0.887
50%	6.212	3.550	2.662	1.331	0.443
70%	5.768	2.662	2.218	1.775	1.775

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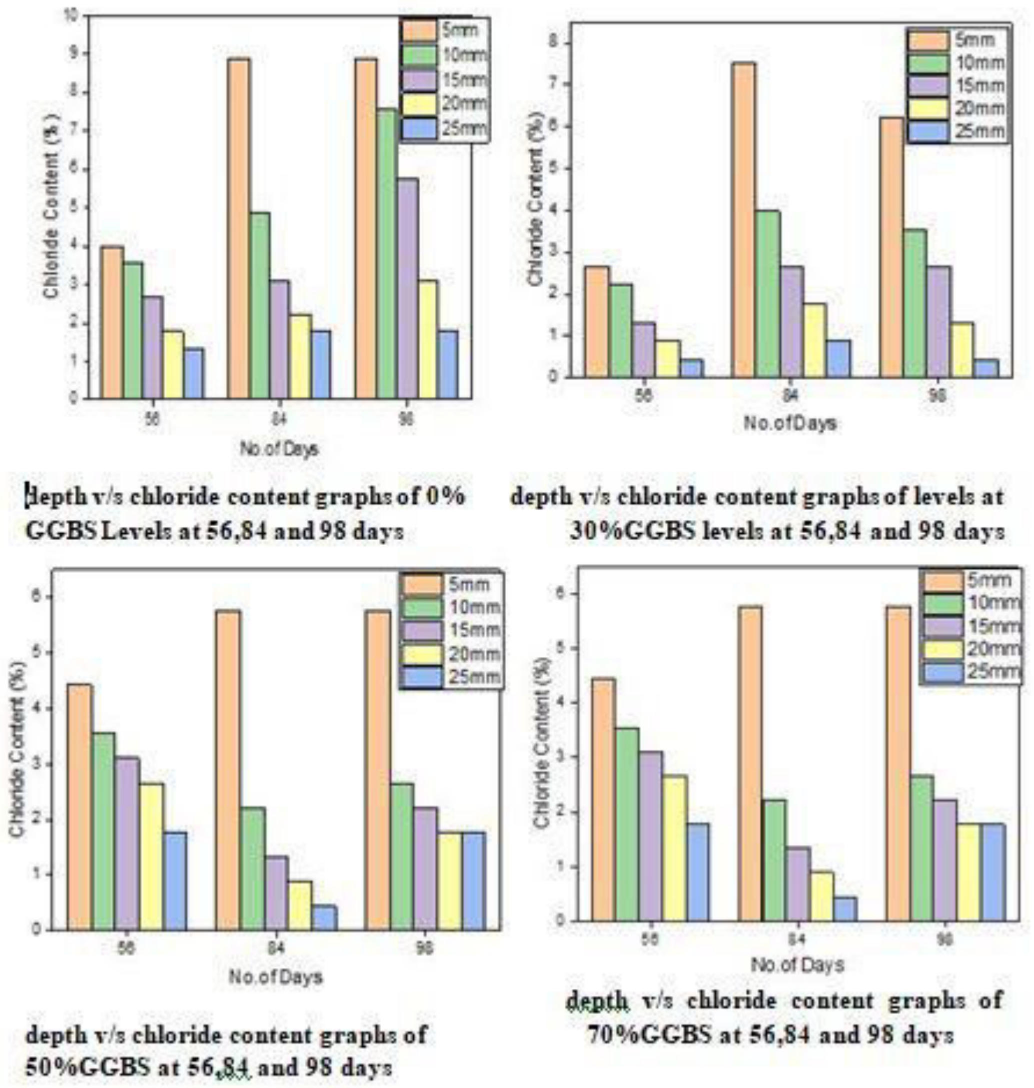

Figure-13. Comparison graphs for chloride ion test results with Depth V/S chloride content of 0%, 30%, 50%, 70% of GGBS substitution levels at 56, 84 and 98 days.

4.1.2 Compressive strength results of SCC for 0%, 30%, 50% and 70% GGBS substitution level after chloride ion penetration test

Compressive strength test has been performed for 56,84 and 98 days after chloride ion penetration test and results are noted in Table-9 and Comparison Bar chart for Compressive strength results of 0%, 30%, 50%,70% GGBS substitution levels under NaCl curing at 56,84 and 98 days after Chloride Ion penetration test are shown in Figure-14.

Table-9. Compressive strength results of SCC for 0%,30%,50% and 70% GGBS substitution level under NaCl curing at 56,84 and 98 days after chloride ion penetration test.

GGBS replacement levels	Average Compressive Strength results		
	56Days(N/mm^2)	84Days(N/mm^2)	98Days(N/mm^2)
0%	32.4433	50.19	44.4467
30%	36.7433	37.48	42.0733
50%	52.59	46.3667	33.9267
70%	35.7067	32.2967	22.2333

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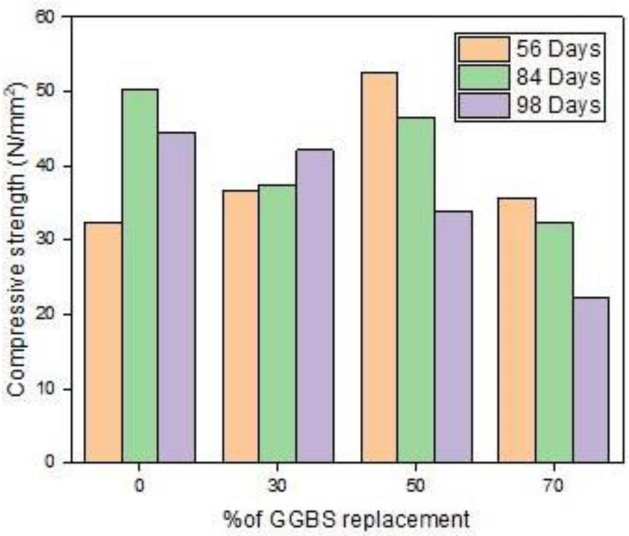

Figure-14. Comparison bar chart for compressive strength results of 0%, 30%, 50%, 70% GGBS substitution levels after chloride ion penetration test.

4.1.3 Flexural test results of SCC for 0%, 30%, 50% and 70% GGBS substitution level after Chloride Ion penetration test

After drilling, specimens are tested under flexure and test set up was shown in Figure-15. Corresponding flexural strength values are noted in Table-10 and Figure-16 indicates the Comparison bar chart for flexural test results of SCC for 0%, 30%, 50%, 70% GGBS substitution level after Chloride Ion penetration test.

Figure-15. Test setup for flexural strength test after NaCl curing.

Table-10. Flexural strength results of SCC for 0%, 30%, 50% and 70% GGBS replacement mix under NaCl curing at 56,84 and 98 days after drilling.

GGBS replacement levels	Average Flexural Strength results		
	56Days (N/mm^2)	84Day (N/mm^2)	98Days (N/mm^2)
0%	13.21	16.05	17.48
30%	13.74	14.66	16.237
50%	15.67	16.8	16.65
70%	14.75	15.28	16.592

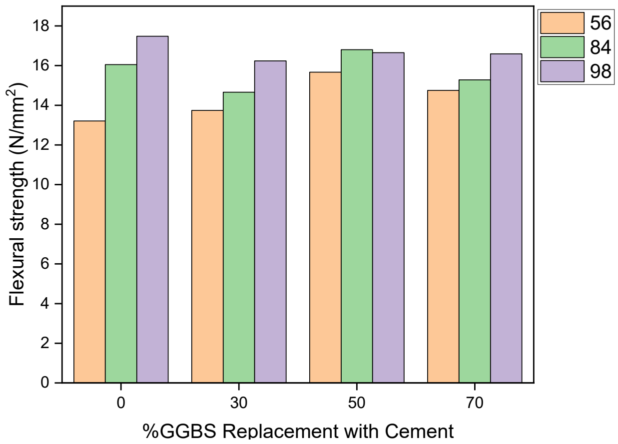

Figure-16. Comparison bar chart for flexural test results of SCC for 0%, 30%, 50%, 70% GGBS substitution level after chloride ion penetration test.

4.2 Corrosion test Analysis by Regulatory Power Supply System

The corrosion test was performed using Regulatory power supply system by applying techniques namely AC and DC measurements. The Current (I), Resistances(R) were measured at the rate of every 12 hours intervals with specific time period of 30 days to determining the electrical resistivity. The AC measurements are connected by means of two and four pin methods, test setup for RPSS shows in Figure-17. The specimens used for this test are Cylinder and beam of sizes 100mm diameter and 200mm high and 1000mmX150mmX150mm respectively. The resistivity 'ρ' can be calculated from this data as fallows (Mc carter and current, 1984) [10] [11] [12]

Resistivity of concrete (ρ) = 2ΠaR for beam specimens

Where

ρ = $(2\Pi RL)/(\log e(\frac{r1}{r2})$ for cylinder specimens

ρ is the measured resistance in ohm.

Electrical resistance(R) in ohms = $\frac{V}{I}$,

L = Length of specimen

a is the inner electrode distance in cm

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r_1 and r_2 are the radius of cylinder and the steel bar respectively in cm

It was reported that the corrosion of reinforcing steel was determinate in the form of electrical resistivity by RPS system, specifically when corrosion is originated by chloride attack. The electrical resistivity is highly dependent up on the quality of SCC and on the exposure atmospheric conditions, such as the variation of humidity, temperature and degree of pore saturation of SCC.

Figure-17. Test set up for corrosion test by RPS System.

Based up on the results obtained from Regulatory power supply system, it has been observed that 50% slag levels have less corrosion. The comparison graphs are plotted as shown in Figures 18 to 21.

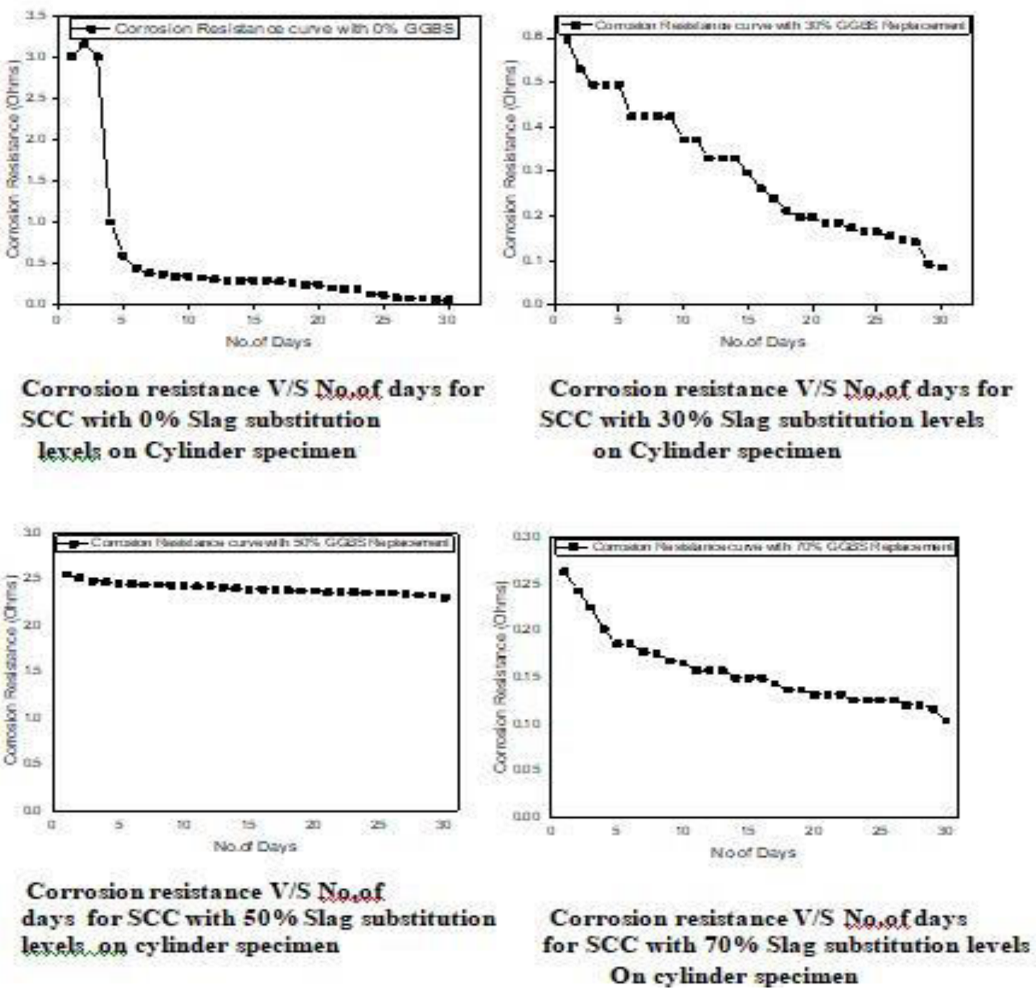

Figure-18. Graphs for corrosion resistance V/S No.of days for SCC with 0%, 30%, 50% and 70% Slag substitution levels on cylinder specimen.

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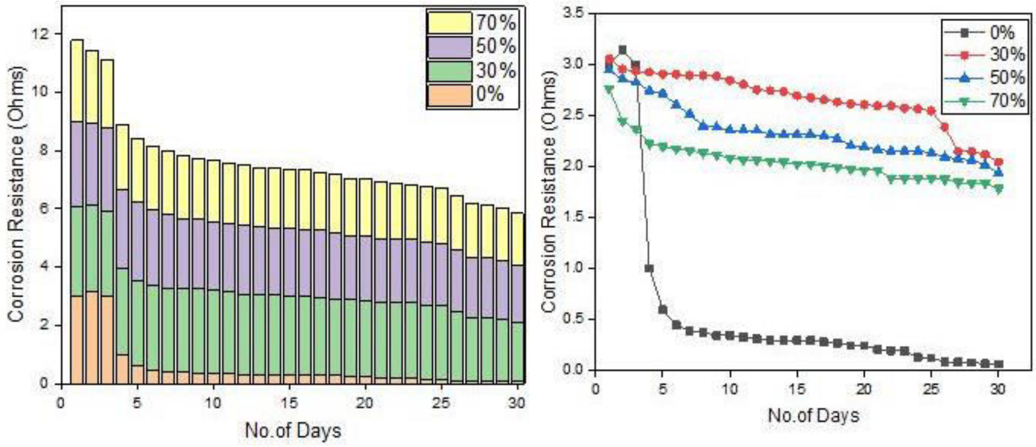
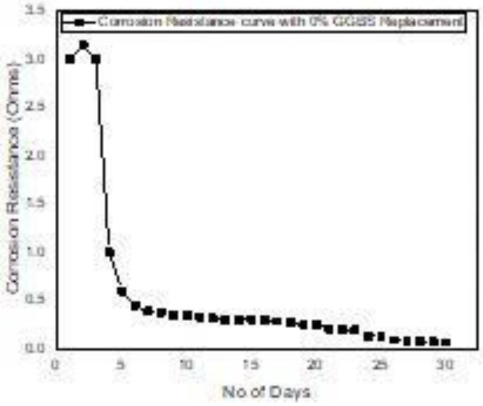
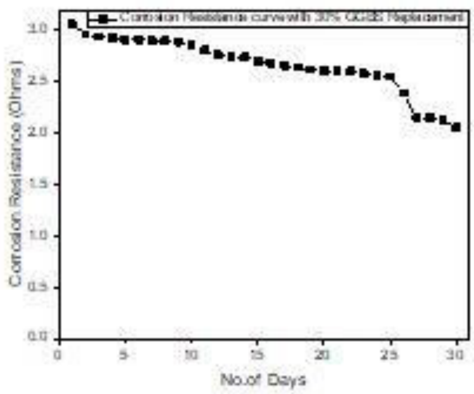


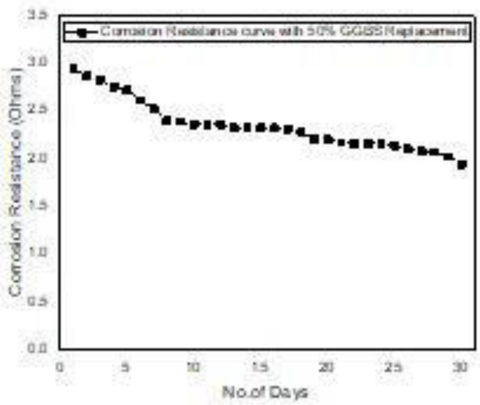
Figure-19. Comparison bar chart and curves w.r.t corrosion resistance for SCC with 0%, 30%, 50%,70% Slag substitution levels on cylinder specimen.



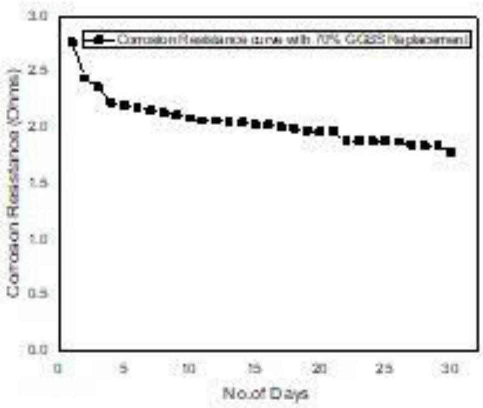
Corrosion resistance V/S No.days for SCC with 0% Slag substitution levels on beam specimen



Corrosion resistance V/S No.of days for SCC with 30% Slag substitution levels on beam specimen



Corrosion resistance V/S No.of days for SCC with 50% slag substitution levels on beam specimens



Corrosion resistance V/S No.of days for SCC with 70% slag substitution levels on beam specimens

Figure-20. Graphs for corrosion resistance V/S No. of days for SCC with 0%, 30%, 50% and 70% slag substitution levels on beam specimen.

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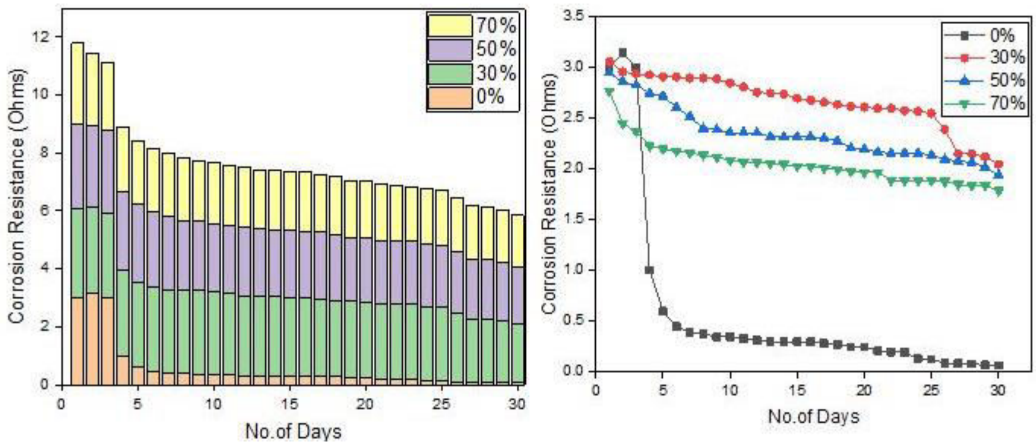
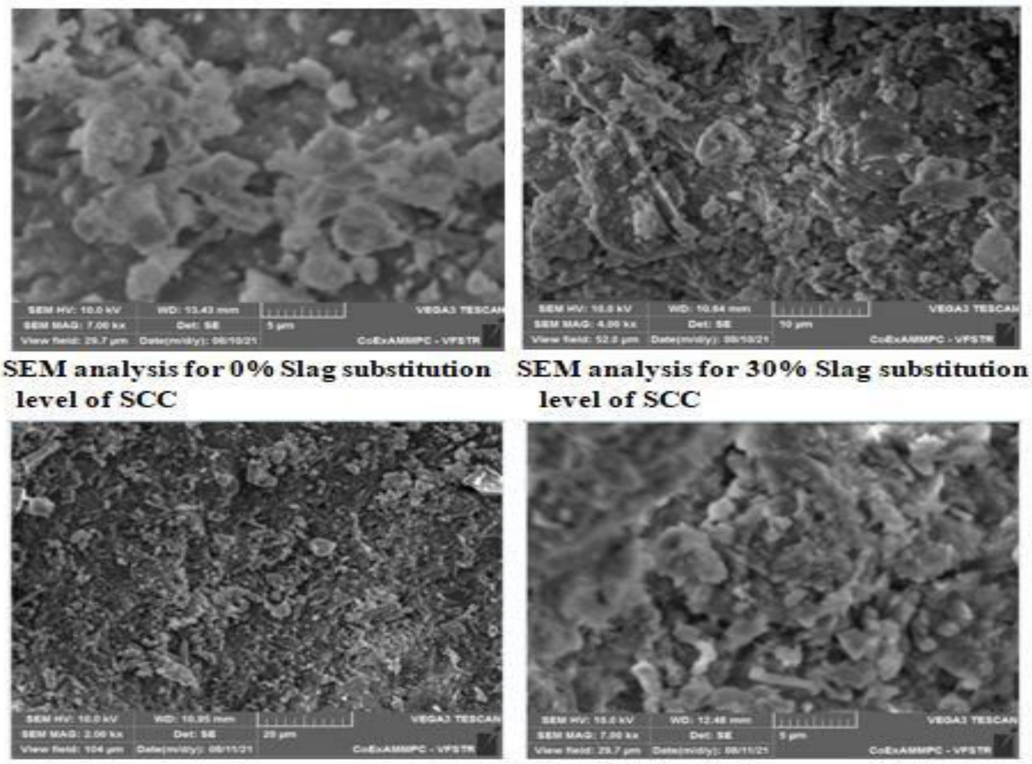


Figure-21. Comparison bar chart and curves w.r.t corrosion resistance for SCC with 0%, 30%, 50%, 70% slag substitution levels on beam specimen.

4.3 Microstructure Analysis (SEM, EDX, XRD) of SCC by Various % Of Slag Substitution Levels

4.3.1 Scanning electron micrographs (SEM) test results analysis

SEM test was carried out to know the variations in the mof the SCC before and after replacement of GGBS. The SEM results of (SCC containing 0%, 30%, 50%, 70% GGBS Replacement), shows that the physical shape of particles was irregular and angular which has a porous texture. The microstructures SEM of the composites surfaces were investigated and it represents bonding in between the GGBS particles and the SCC composition. Figure-22 illustrates that, SEM microstructure of specimen containing 0%, 30%, 50%, 70% GGBS Replacement of SCC consist large amount C-S-H gel in comparison to plain specimen which has lesser amount of C-S-H gel and unreacted calcium hydroxide in form of hexagonal shape by this clarification, it is clear that there was greater improvement in the microstructure of the GGBS-blended cement paste compared to that for plain cement paste [13]



SEM analysis for 0% Slag substitution level of SCC

SEM analysis for 30% Slag substitution level of SCC

SEM analysis for 50% Slag substitution level of SCC

SEM analysis for 70% Slag substitution level of SCC

Figure-22. SEM analysis for SCC containing 0%, 30%, 50%, 70% slag substitution levels.

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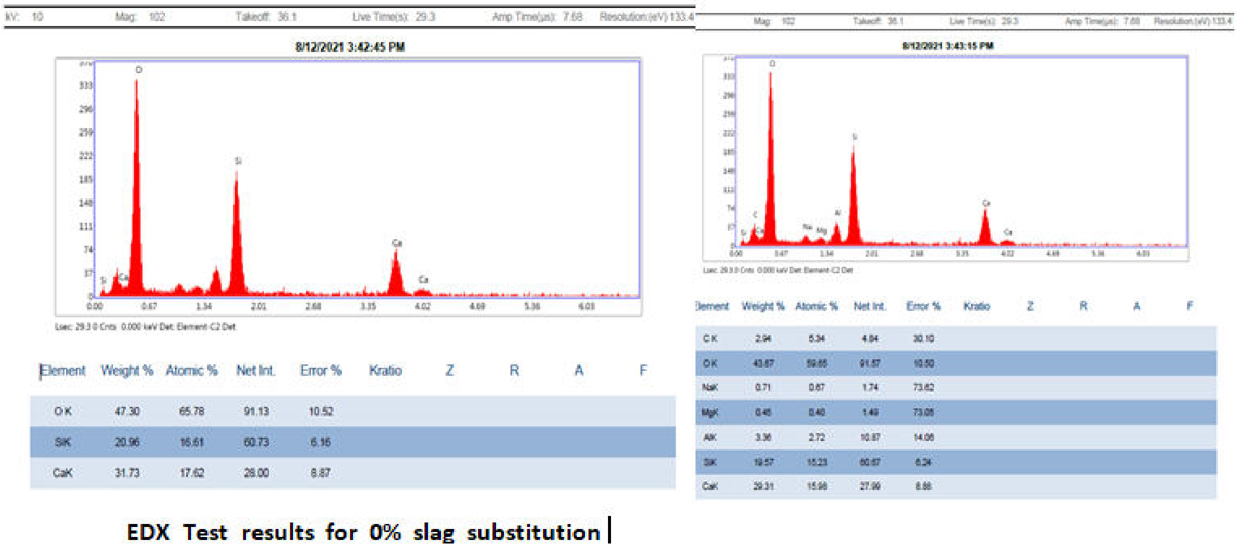
4.3.2 Energy dispersive x-ray (EDX) test results for scc of various % of slag substitution levels

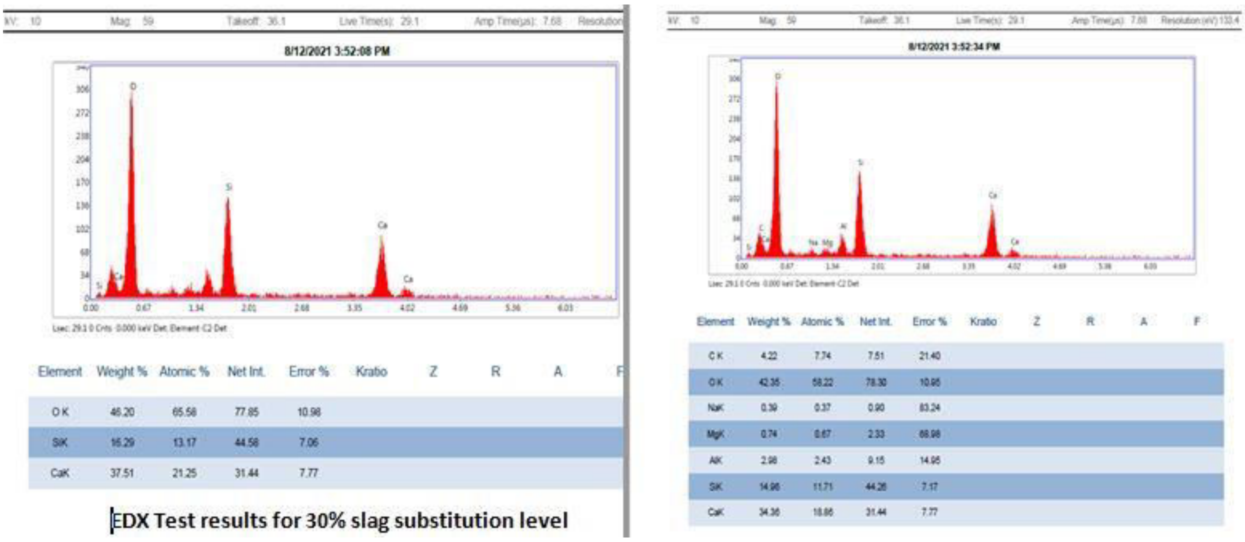
The Energy Dispersive X-Ray test was carried out to know the micro graphical structure and chemical composition such as SiO_2, Al_2O_3, Fe_2O_3, and CaO on the matrix materials of the SCC. The EDX spectrum can also shows the amorphous matrix and interfacial interaction between functional groups of the SCC like small discontinuities and uniform distribution of particles phase [14], which was shown in Figures 23, 24 & 25 respectively.



Element	Weight %	Atomic %	Net Int.	Error %	Kratio	Z	R	A	F
O K	47.30	65.78	91.13	10.52					
SiK	20.96	16.61	60.73	6.16					
CaK	31.73	17.62	28.00	8.87					

Element	Weight %	Atomic %	Net Int.	Error %	Kratio	Z	R	A	F
C K	2.94	5.34	4.84	30.10					
O K	43.87	59.65	91.57	10.50					
NaK	0.71	0.67	1.74	73.62					
MgK	0.46	0.40	1.49	73.08					
AlK	3.36	2.72	10.87	14.06					
SiK	19.57	15.23	60.67	6.24					
CaK	29.31	15.98	27.99	8.88					

Figure-23. EDX test results for SCC with 0% of slag substitution level.



Element	Weight %	Atomic %	Net Int.	Error %	Kratio	Z	R	A	F
O K	46.20	65.58	77.85	10.98					
SiK	16.29	13.17	44.58	7.06					
CaK	37.51	21.25	31.44	7.77					

Element	Weight %	Atomic %	Net Int.	Error %	Kratio	Z	R	A	F
C K	4.22	7.74	7.51	21.40					
O K	42.36	58.22	78.30	10.96					
NaK	0.39	0.37	0.90	83.24					
MgK	0.74	0.67	2.33	68.98					
AlK	2.98	2.43	9.15	14.95					
SiK	14.96	11.71	44.26	7.17					
CaK	34.36	18.86	31.44	7.77					

Figure-24. EDX test results for SCC with 30% of slag substitution level.

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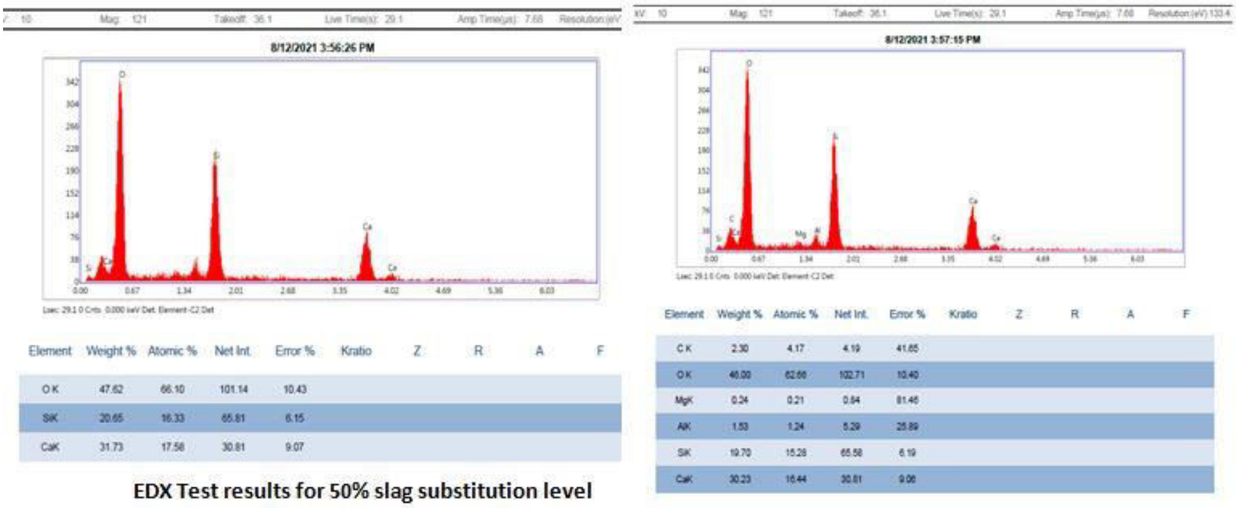
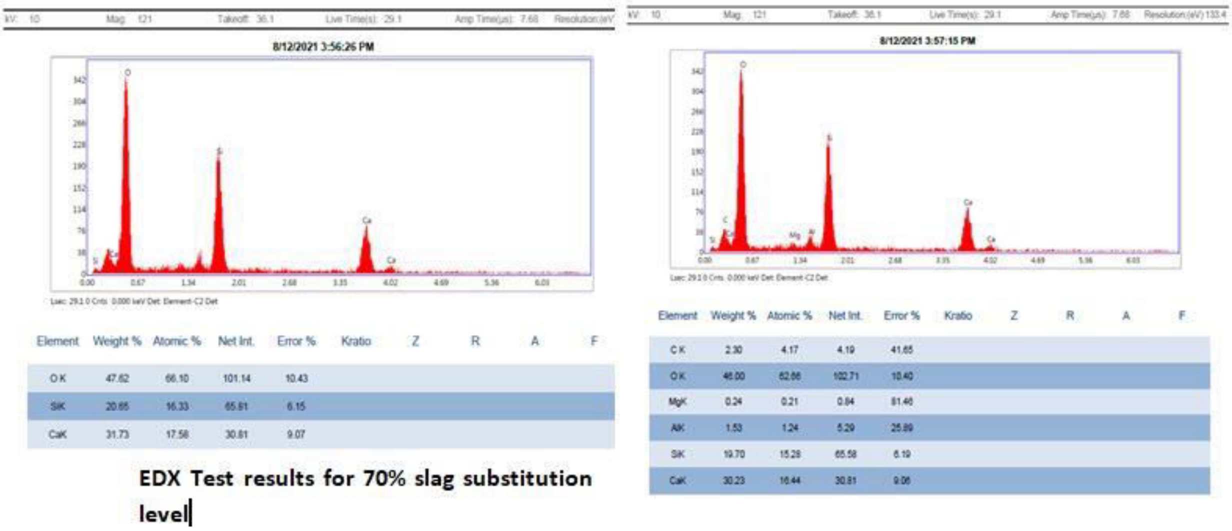


Element	Weight %	Atomic %	Net Int.	Error %	Kratio	Z	R	A	F
O K	47.62	66.10	101.14	10.43					
SiK	20.65	16.33	65.81	6.15					
CaK	31.73	17.58	30.81	9.07					

Element	Weight %	Atomic %	Net Int.	Error %	Kratio	Z	R	A	F
C K	2.30	4.17	4.19	41.65					
O K	46.00	62.66	102.71	10.40					
MgK	0.24	0.21	0.84	81.46					
AlK	1.53	1.24	5.29	25.89					
SiK	19.70	15.28	65.58	6.19					
CaK	30.23	16.44	30.81	9.06					

Figure-25. EDX test results for SCC with 50% of slag substitution level.



Element	Weight %	Atomic %	Net Int.	Error %	Kratio	Z	R	A	F
O K	47.62	66.10	101.14	10.43					
SiK	20.65	16.33	65.81	6.15					
CaK	31.73	17.58	30.81	9.07					

Element	Weight %	Atomic %	Net Int.	Error %	Kratio	Z	R	A	F
C K	2.30	4.17	4.19	41.65					
O K	46.00	62.66	102.71	10.40					
MgK	0.24	0.21	0.84	81.46					
AlK	1.53	1.24	5.29	25.89					
SiK	19.70	15.28	65.58	6.19					
CaK	30.23	16.44	30.81	9.06					

Figure-26. EDX test results for SCC 70% of slag substitution level.

4.3.4 X-Ray diffraction (XRD) test results for scc of various % of slag substitution level

The XRD Test results of SCC specimens are shown in Figure-27 between 30% and 70% GGBS replacement levels, from the XRD test results some of the major chemical compounds were found such as SiO_2, $CaCO_3$, Ca(OH)2 and CSH respectively.

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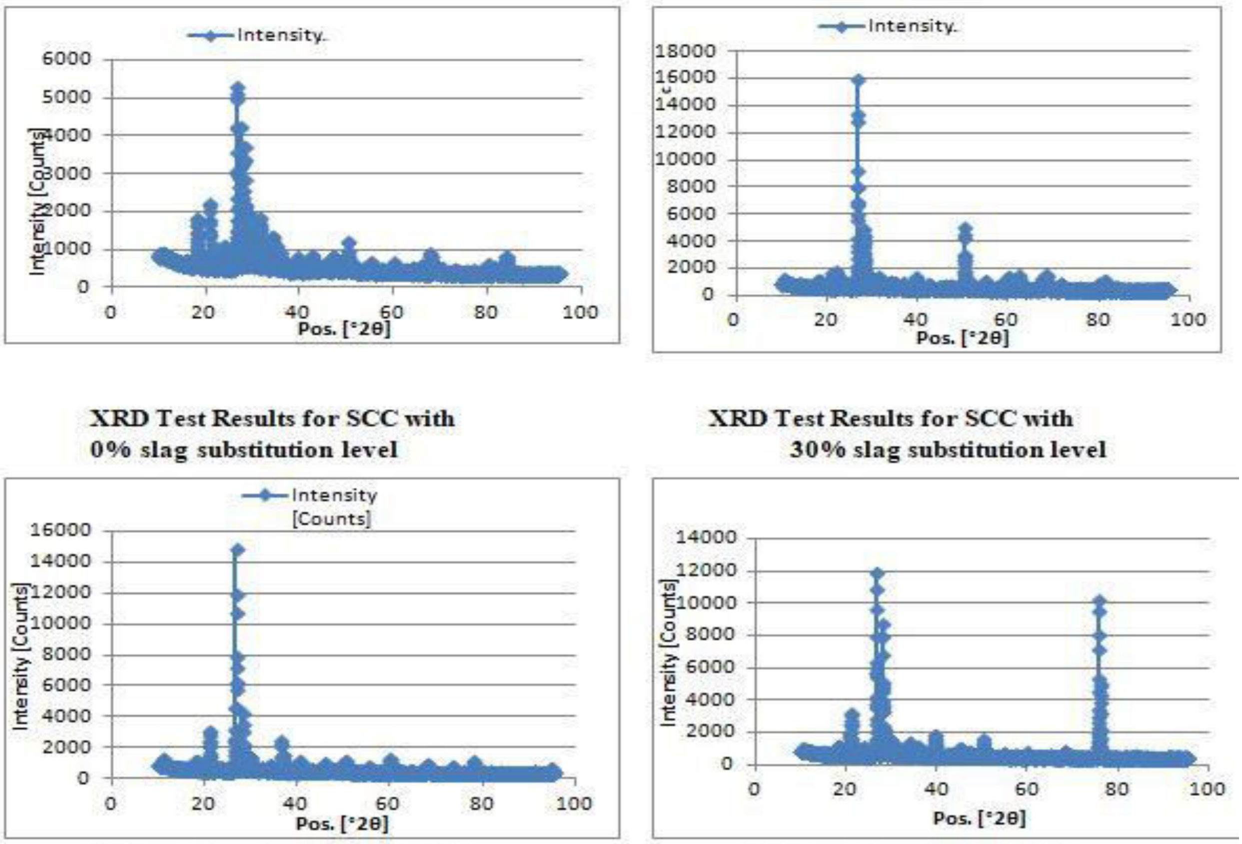

XRD Test Results for SCC with 0% slag substitution level

XRD Test Results for SCC with 30% slag substitution level

XRD test data for SCC with 50% Slag substitution level

XRD test data for SCC with 70% Slag substitution level

Figure-27. EDX test results for SCC with 0%, 30%, 50%, 70% of slag substitution level.

5. CONCLUSIONS

The purpose of this research work is to investigate about the behaviour of GGBS and silica fume in producing self compaction concrete. GGBS and silica fume are replaced in cement together. The behaviour of these two materials in compression, flexure and durability of self compacting concrete are studied.

- use of GGBS as pozzolan is an environmental friendly option. Technically and financially, GGBS has lot of potential to be used as pozzolan in concrete construction industry.
- The comparative compressive strength analysis indicated that at 28 days of testing, GGBS and silica fume mixes showed higher strength than control mix
- The workability, density and water absorption decreased with the introduction of GGBS as cement replacement.
- Mixes contain GGBS performed better than control mix against chloride attack. Hence the materials are safe for construction purpose and also increases the strength and durability of concrete for construction.
- Low cost concrete can be produced by substituting GGBS as partial replacement of cement in concrete without compromising on strength parameters.30% and 50% GGBS mix shows approximately compressive strength equal to control mix at 7, 28 and 90 days
- 70% GGBS mix shown high resistance to chloride attack when compared to OPC at 7days, 28 days and 90 days.
- The data obtained from tests clearly show that there is a rapid increase of compressive strength at 28 days for plain concrete as well as GGBS and Silica fume concrete mixture by reaching target strengths. There is a drastic reduction in chloride ion penetration in the case of GGBS concrete compared to plain concrete.
- The initial strength development is slow in concrete containing GGBS, but if curing is continued then the strength at 28 days become comparable to that OPC concrete for concrete up to 50% slag replacement.

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- From Micro Analysis of SCC concluded that GGBS and Silica fume were considered since these two elements are crucial in cement hydration.

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