Self Compacting Concrete Structures with Respect to Chloride Ion Penetration under Uniform Axial Compression

M. Maneesha, C. Rajamallu

Abstract:--- Every structure has a major concern regarding corrosion of reinforcement. This leads to reduction in strength and serviceability of structures. Self compacting concrete (SCC) has a high flowing ability which fills the voids in reinforced concrete without need of any vibrator and it is known as non-segregate concrete. This paper emphasis to study the mechanical properties of concrete by partial replacement of cement with GGBS and silica fume. Chloride ion penetration is also carried out in this study. 60 cubes (150×150×150mm) were casted to determine the compressive strength (24 cubes) and percentage of chloride ion penetration (36 cubes). Effects occurred with partial replacement in SCC and corrosion characteristics were assessed from this experimental work. For this research work GGBS is partially with cement in 30%, 50%, 70% and 2% silica fume by weight of GGBS, admixture of 0.5% weight of cement is added. It is observed from this experimental study, there are a huge strength and less corrosion by partial replacement of GGBS and by addition of silica fume.

Index Terms: chloride ion penetration, Ground Granulated Blast Furnace Slag (GGBS), Self Compacting Concrete (SCC), Silica fume.

I. INTRODUCTION

Concrete technology has dramatically changed in the last few decades, which are widely used in building materials. It was the diverse opportunity for both concrete users and builders to meet their own requirements. To achieve workability, strength and durability, we need adequate compression and vibration, but because of the sputtering pressure, a large number of spaces affect the performance of structures. Self compacting concrete (SCC) is the one that can flow easily and reduce its weight without any kind of vibrator, so that it can improve the best conditions in construction sites. It gives high deformability of mortar and concrete. Especially in precast industries these self compacting concrete were far-reaching [1]. Self compacting concrete was proposed by Prof. Okamura in Japan.

Self compacting concrete also enlarges the use of GGBS and silica fume products and also offers the possibility of using dust, which is a waste product at present, without any practical and costly disposal applications [2]. It also requires a significant reduction to be achieved through the integration of several chemicals. High-elastic plastics ensure a significant deal of liquidity and reduce the proportion of water powder. The super plasticizers improve pump capacity significantly and the value of recession can be greatly increased. The use of viscosity modifying additives increases the insulation resistance of the concrete and increases the deformation without separation and then leads to the soaring degree of self-compatibility. In the present paper Auromix 300plus is used. The fresh property tests of SCC such as slump flow, V-funnel, U-box and L-box are executed .The hardened properties of concrete such as compressive strength were measured and detailed as results acquired.

A chemical such as chloride causes an unclear problem because it tends to weaken the bond between steel and concrete [3]. Chlorides can be present with varying degrees of correlation in the concrete matrix and can be identified as water solubility and acid chlorides. Corrosion which is caused by the chloride attack is the extensive problems of global deterioration in armed concrete structures [4]. The permeability of concrete clearly linked to the porosity of cement paste matrix. This will be overblown by the percentage of cement in the water of concrete, and the inclusion of additional supplementary materials that serve to divide the structure of the pores and degree of saturate of the concrete.

II. OBJECTIVE

The present study attempts to originate quantitative data and additionally upgrade the relationship between GGBS and silica fume replacement levels and water-binder ratios and the development of compressive strength and to identify the chloride diffusion content that spread in SCC.

III. MATERIALS

A. Cement

Ordinary Portland cement of grade 53 according to IS: 12269-2013 was exploited. The laboratory tests were conducted and the test results are as shown in Table I.

Table I: Properties of cement

Properties	Results
Specific gravity	3.12
Standard consistency	32%
Initial setting time	120min
Final setting time	280min
Strength for 7days	29.3N/mm^2
Strength for 28 days	50.63N/mm^2

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B. GGBS

Ground Granulated Blast Furnaces Slag (GGBS) is by-product which obtained from pig iron and steel and is also a non-metallic product consists of calcium silicates which develops from molten condition. It is used as a partial replacement of cement because it improves the durability of concrete and also increases the lifespan of the structures. The chemical and physical properties of GGBS are as shown in the Table II.

Table II: Chemical and physical properties of GGBS

Chemical properties		Physical properties	
Lime (CaO)	34.5%	Specific gravity	2.90
Silica (SiO_2)	32%	Blaine's fineness	3350cm^2/gm
Alumina(Al_2O_3)	14.5%	Bulk density	1.0
Iron oxide(Fe_2O_3)	0.7%	color	off-white

C. Silica fume

Silica fume is a by-product which is collected as a powder from silicon and ferrosilicon. It consists of very high strength and it is also very durable. The physical and chemical properties of silica fume are shown in Table III.

Table III: Physical and chemical properties of silica fume

Chemical properties		Physical properties	
SiO_2	75%	Specific gravity	2.1
Al_2O_3	1.07	color	Dark gray
CaO	0.7		
Fe_2O_3	1.25		

D. Coarse aggregate

A Coarse aggregate of size 12.5mm are used in this experimental work. According to IS 383-1970 the coarse aggregate properties such as specific gravity- 2.74, fineness modulus – 7.5, Bulk density (dense) - 15.1kN/m^3, and Bulk density (loose) - 14.56kN/m$^{3.}$

E. Fine aggregate

River sand is used as a fine aggregate which is taken from zone II. According to IS 383-1970 the fine aggregate properties such as specific gravity- 2.603, fineness modulus- 2.7, Bulk density (dense) - 16.5kN/m^3, Bulk density (loose) - 15.78kN/m^3.

F. Admixture

Auromix 300plus is used as an admixture which gives good workability and is a high performance retarding admixture. The properties of this admixture such as relative density-1.085kg/liter and pH- 6 and appearance- light yellow colour.

IV. EXPERIMENTAL PROCEDURE

A. MIX PROPORTIONS

Mix design was carried out for M40grade of concrete according to IS: 10262-2017. Water content was about 175 liters with water-cement ratio 0.35. Table IV shows the mix proportions of M40 used in mix calculations.

Table IV: Mix proportions of M40

S. No	Materials	Quantities per m^{3}of concrete
1	Cement	500kg/m^3
2	Fine aggregates	900kg/m^3
3	Coarse aggregates	872.039kg/m^3
4	water	175L/m^3
5	Admixture	2.5

B. Detailing of specimens

In this paper the experimental process is carried out in two phases , first phase is to develop mix design for M_{40} grade and casting of concrete cubes (150×150×150mm) according to their mix proportions (0%, 30%, 50%, 70%) and Calculating the compressive strength results (24 cubes) for 7 days and 28 days. The second phase is after completion of 28 days normal curing the remaining 36 cubes of different proportions are kept for curing in 3.5% of NaCl solution by weight of water for 28 days, 56 days, and 70days. After completion of NaCl curing according to their respective dates the concrete powder has to be drilled from the concrete cubes and collecting the samples and perform the chloride ion penetration test. Fig. 1 shows the compressive testing machine at the time of cube testing and Fig. 2 shows the test cubes after testing.

Fig. 1: Compressive testing of cubes

Fig. 2: Tested cubes

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V. RESULTS AND DISCUSSION

A. Fresh properties of SCC

For every percentage of replacement such as 30%, 50%, 70%, the tests like slump flow, T_{50} slump, V-funnel, L-box, and U-box are performed to find the workability of SCC according to the EFNARC guidelines. The test results are given below in Table V.

Table V : Fresh properties of SCC

Test	Limits	30%	50%	70%
Slump flow	650-800mm	680mm	652mm	615mm
T_{50} slump	2-6sec	3sec	4sec	5.23sec
V-funnel	6-12sec	7sec	10sec	12sec
U-box(h_2-h_1)	0-30mm	15mm	22mm	29mm
L-box(h_2/h_1)	0.8-1.0mm	0.85m	0.92m	0.98m

B. Hardened properties of concrete

In this hardened properties the compressive strength is performed to determine the strength occurred.

Compressive strength test results: The compressive strength test is performed for 7days and 28 days with different kinds of proportions. The results show that the 30% proportion has shown the greater strength rather than the other proportions. Table VI shows the results for 7days and 28 days compressive testing cubes. Fig. 3 shows the bar chart representation of the strength of different proportions that are subjected to 7 days and 28 days.

Table VI : Compressive strength results

% of replacements	7 days	28 days
0%	27.31	45.69
30%	28.25	50.36
50%	25.11	34.46
70%	18.38	28.99

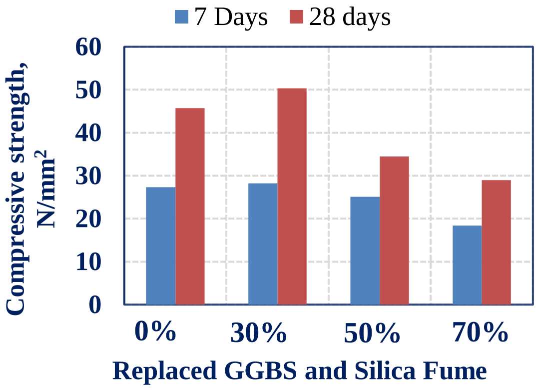

Fig. 3: Compressive strength graph results

Compressive strength test results after NaCl curing: NaCl curing was done for 28days, 56days and 70days and later after completion of curing the compressive strength test has been performed. The test results are shown below in Table VII and Fig. 4.

Table VII: Compressive strength results after NaCl curing

% of replacements	28 days	56 days	70days
0%	32.44	50.19	44.44
30%	36.74	37.48	42.07
50%	52.59	46.36	33.92
70%	35.07	32.29	22.22

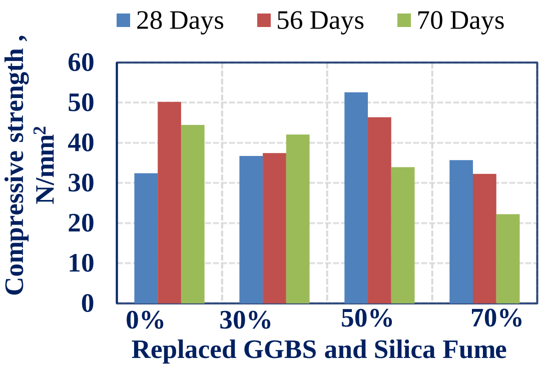

Fig. 4: Compressive strength graph results after NaCl curing

C. Chloride ion penetration

After completion of NaCl curing the concrete cubes were taken out for drilling the concrete powder according to their respective dates and samples are collected. The concrete powder from different depths such as 5mm, 10mm, 15mm, 20mm, and 25mm was drilled out from all the sides of cubes. After collecting all the samples the total chloride content was performed using the potentiometer titration of silver nitrate solution. The process is as follows, thoroughly the concrete powder is mixed which had been taken from all the faces of the cubes and then the powder is weighed and 4gms of powder has taken. The powder is placed in 250ml beaker and 10ml of dilute nitric acid (HNO_3) is added and the solution has been stirred properly and 40ml distilled water is added to the solution and again stir has been done. Now weigh the beaker and heat it and let it boil for 1-2 min and then let it be cooled down under room temperature and again weigh it. Keep the solution for 2hrs so that the particles get settled down in the beaker. Now 10ml of solution has been pipette out from that beaker and is poured in conical flask and 2-3 drops of potassium chromate has been added in the solution and titration have been done with silver nitrate solution ($AgNO_3$) and the results are noted down.

The eq. 1for chloride is given below

$$\text{Chloride content in (\%)} = \frac{K \times N \times V}{W} \times 100$$

Where,
K= Molecular weight of $AgNO_3$
N= Normality of silver Nitrate (0.01)
V= volume of titrated sample
W= weight of taken sample powder (4gms)

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Fig. 5: Collected concrete powder after drilling

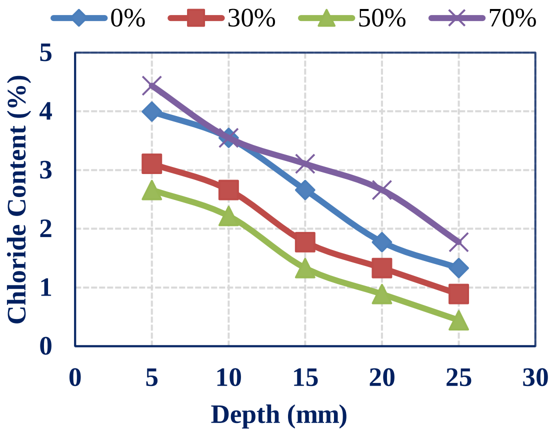

Fig. 6: Depth Vs Chloride content graph for 28 days

Fig. 5 shows the powered collected from the beams at various depth.

Fig. 6-8 shows the graphical representation of results obtaines for depth versus chloride penetration percentage.

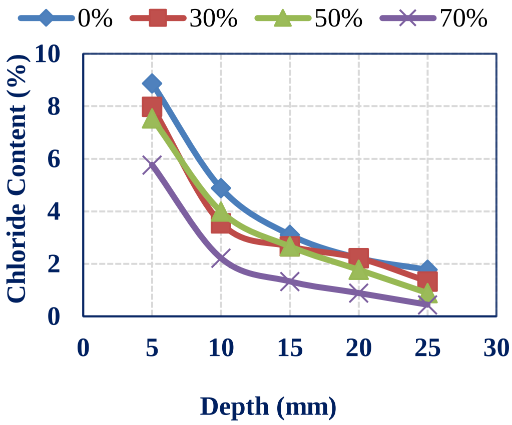

Fig. 7: Depth Vs Chloride content graph for 56 days

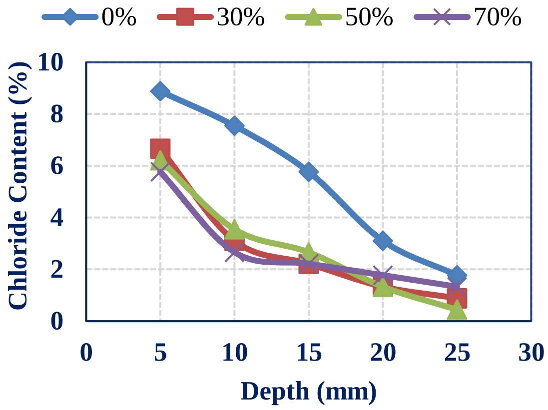

Fig. 8: Depth Vs Chloride content graph for 70 days

VI. CONCLUSION

In this Experiment the compressive strength is tested by replacing the GGBS and silica fume and chloride content has been detected.

1. Binding materials such as GGBS and Silica Fume which are used in this study has resulted in 50% increase of strength and also less in evolving heat of hydration when compared to conventional concrete.
2. Compressive results shown that upto30% GGBS can be used as a binder material to cement successfully.
3. From chemical analysis it has been observed that NaCl attack is less in filler materials which are used i.e., GGBS and Silica Fume when compared with conventional concrete.
4. By this eco-friend environment is also created due to its properties. Practically, it is proved again that by using these binding materials gives less corrosion which is more useful for structures in emerging countries like India etc.
5. Service life of structures increases because of less corrosion. Chemical analysis showed that binding material samples has less corrosion content when compared to plain concrete.

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