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Influence of GGBS and Silica Fume on Workability and Mechanical Properties of Self Compacting Concrete

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Abstract: *In this present work an attempt is made to investigate the fresh, hardened and stress-strain behaviour of SCC blended with GGBS and silica fume. Compression test is conducted by testing 150x150x150 mm cubes for each mix and stress-strain behaviour of SCC is determined by conducting test on cylinders of 150x300mm dimension. An attempt is made to find the ductility factor for different combination of GGBS and Silica fume using Saenz Model. Normalised stress v/s normalised strain graph is shown in this paper.*
Key Words: *Self compacting concrete, GGBS, Silica fume, Compressive Strength, Stress-Strain, Ductility factor.*

I. Introduction

For a long time concrete was considered to be very durable material requiring a little or no maintenance. The assumption is largely true, except when it is subjected to highly aggressive environments. Development of SCC is considered as the one of the greatest breakthrough in concrete technology for many decades due to its improved performance and working environment [1].

When large quantity of concrete is to be placed in heavily reinforced concrete members it is difficult to ensure that the form work gets completely filled with concrete that is fully compacted without voids or honeycombs. Vibrating concrete in congested locations may cause some risk to labour and there are always doubts about the strength and durability of

Concrete placed in such locations. One solution for the achievement of durable concrete structures independent of the quality of construction work is the employment of Self Compacting Concrete (SCC) [2].

Self compacting concrete is special type of concrete which flows and fills each and every corner of form work purely by means of its own weight without vibration and achieving full compaction even in presence of congested reinforcement. The concept of SCC was first introduced to concrete world in Japan in 1986 by Professor Hajime Okamura from Tokyo University. The first prototype was developed in 1988 by K. Ozawa from Tokyo University [3]. Research on under water concrete is under taken in 1980's within UK, North America, and in Japan led to the development of concrete mixes with a high degree of washout resistance. However people failed to achieve adequate compaction under water so as to make that structure durable, at the same time in Japan there was a reduction in skilled labour for compaction. These problems led the way to develop SCC [4].

II. Research Significance

Since unavailability of specific mix design for SCC, By understanding the nature and extent of work carried out on SCC using GGBS and Silica fumes as partial replacement of cement, the research work aims at

- Development of Self compacting concrete (SCC) with replacement of cement by mineral admixtures such as GGBS and Silica fumes and reduction of carbon dioxide emission.
- Assessing the influence of cement replacing materials GGBS and Silica fume on Workability and Mechanical properties of SCC.
- To study the stress-strain behavior of SCC for different mix proportions.

III. Experimental Work

3.1 Methodology

To study mechanical properties of SCC experimental investigation is carried out by replacing cement partially with GGBS and silica fume. Initially trail mixes are done by varying cement, coarse aggregate, fine

aggregate, GGBS, Silica fume, water, superplasticizer volumes. Once getting optimum mix volume of coarse aggregate, fine aggregate, water and dosage of superplasticizer is fixed .Then totally seven mixes are done by replacing GGBS with cement up to 30% and silica fume to 9%.

After that investigation of SCC is studied in two phase i.e. in fresh state and in hardened state. Standard test procedure is carried out to assess its fresh properties and mechanical properties. Fresh property check test like Slump flow, J-ring, V-funnel time, and L-box ratio.

For the second phase test specimens are cured till test day and cured specimens are used to determine the mechanical properties like Compressive Strength and stress-strain behaviour of SCC.

IV. Materials And Properties

- Cement: Ordinary Portland cement of 53 grade confirming IS 12269-1987 of specific gravity 3.15.
- Fine aggregate: Manufactured sand confirming IS: 383-1997 zone II.
- Coarse aggregate: crushed granite confirming IS 383: 1997.
- Mineral admixtures:

1. GGBS: GGBS of specific gravity 2.62 is used, Chemical components of GGBS are shown in table-1

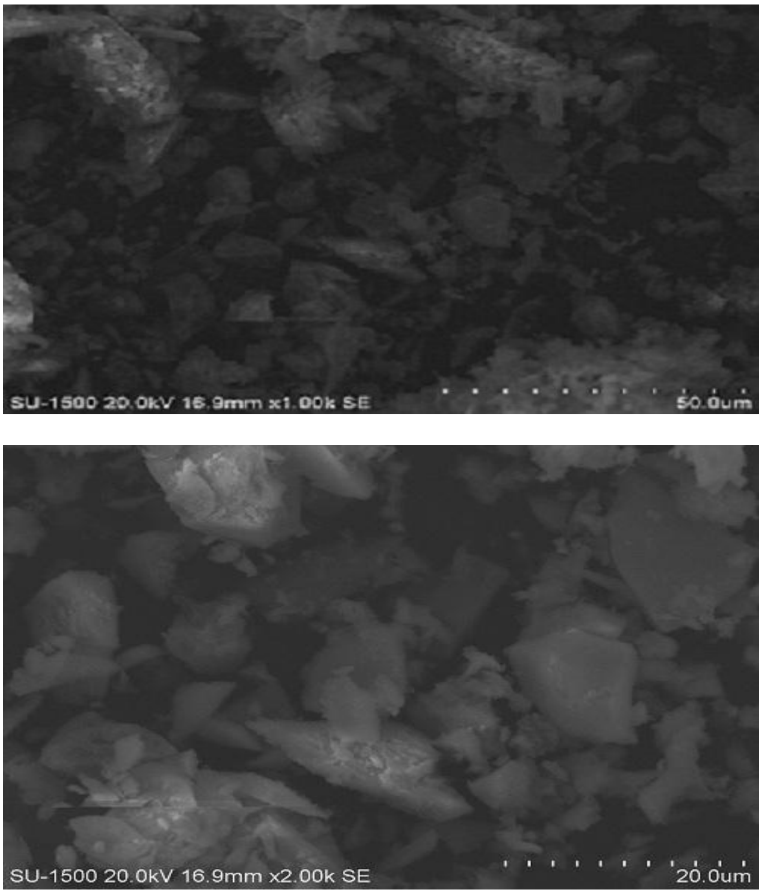


Figure-1 Scanning Electron Microscopic Images (SEM) of GGBS

Table-1: Chemical components of GGBS.

Sl No	Parameter	Quantity (% wt)
1	Insoluble residue	0.83
2	Manganese Oxide	0.25
3	Magnesium oxide	10.13
4	Sulphide sulphur	0.75
5	$CaO+MgO+1/3Al_2O_3$ $SiO_2+2/3Al_2O_3$	1.10
6	$CaO+MgO+ Al_2O_3 SiO_2$	1.84

1. Silica fume: Specific gravity of used silica fume is 2.16. Chemical components are shown below.

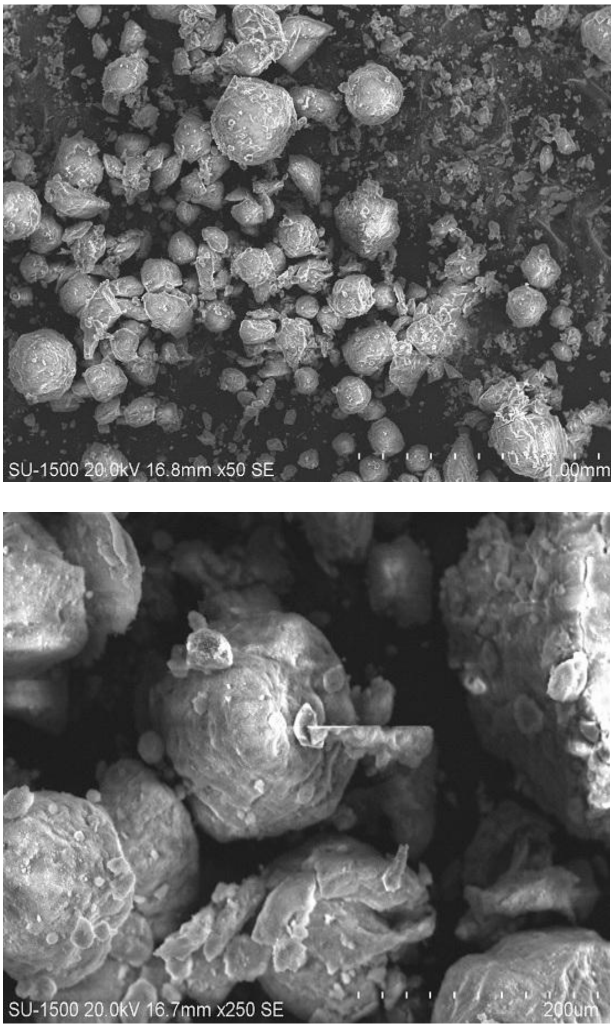


Figure-2: Scanning Electron Microscopic Images (SEM) of Silica fume.

Table-2: Physical and chemical properties of silica fumes

Parameter	SiO2	Loss on ignition	Moisture	Pozzolonic. Activity Index	Specific Surface Area	Bulk Density	+ 45 Microns
Value	91.9%	2.8%	0.3 %	133%	22 m^2/gm	601	0.2%
ASTMC-1240	Min 85%	Max 6%	Max 3%	Min 105%	Min 15 m^2/gm	550-700	Max 10%

- Superplasticizer: Poly carbolic ether based superplasticizer is used.
- Water: Portable water Confirming IS 456.

Table-3 Mix Proportion

Mix	**Cement Kg/m^3**	**GGBS Kg/m^3**	**Silica Fume Kg/m^3**	**Fine Agg Kg/m^3**	**Coarse Agg kg/m^3**	**W/C**	**Super Plasticizer in liters**
10%GGBS+3%SF	485.89	49.60	12.27	883.09	714.42	0.346	4.38
10%GGBS+6%SF	469.14	49.60	24.54	883.09	714.42	0.348	4.35
10%GGBS+9%SF	452.38	49.60	36.80	883.09	714.42	0.351	4.31
20%GGBS+3%SF	430.04	99.20	12.27	883.09	714.42	0.350	4.33
20%GGBS+6%SF	413.04	99.20	24.54	883.09	714.42	0.353	4.30
20%GGBS+9%SF	396.53	99.20	36.80	883.09	714.42	0.356	4.26
30%GGBS+3%SF	374.19	148.81	12.27	883.09	714.42	0.357	4.28

3.3 Specimen Preparation.

Cube of 150x150x150mm are casted to know compressive strength of SCC. Cylinders of standard size 150x300mm are used for each mix to study the stress-strain behaviour and ductility factor.

3.4 Tests On Scc In Hardened State.

i. Cubes and cylinders are cured in water till testing day and then used to determine Compressive Strength and stress-strain behaviour.

ii. Compression test were conducted on 150x150x150mm cube. Test is conducted as per standard procedure explained in IS: 516-1956(1999) to get the compressive strength of the concrete.

iii. Three standard size cylinders of 150x300mm are used for finding stress-strain behaviour under uniaxial compression.

iv. Saenz model assumption[2], At 85% stress ratio the corresponding values of strain ratio is 1.3 i.e. at (σ/σ0) = 0.85 (Є/Є0) = 1.3, is used to find out the ductility factor for different mixes of SCC .

Where, σ0- corresponds to peak stress and

Є0 - corresponds to strain at peak stress

σ and Є corresponds to stress and strain values at any other point

V. Test Results

Table-4: Workability test Results of SCC for various mix proportions

Mix	Slump flow Test Dia (mm)	V- funnel Test (sec)	L – Box Ratio	J – Ring H2-H1 (mm)
Mix 1	685	8	0.92	7
Mix 2	682	9	0.89	8
Mix 3	670	9	0.85	8
Mix 4	672	9	0.82	9
Mix 5	663	10	0.8	10
Mix 6	660	10	0.8	10
Mix 7	665	12	0.79	10

Table -5: Compression test results.

Mix	Compressive Strength in MPa		
	7 days	28 days	56 days
1	40.44	56.06	57.45
2	42.50	59.94	62.16
3	48.22	63.40	65.45
4	52.72	67.50	69.27
5	61.50	69.38	70.47
6	53.93	69.06	69.98
7	50.75	66.21	69.0

Table-6: Variation of Ductility factor for various mix proportions.

mix	Peak stress N/mm^2	Strain at peak stress	$\varepsilon_{0.85\%}$ Asc X 10^{-6}	$\varepsilon_{0.85\%}$ Dsc X 10^{-6}	Ductility Factor
1	53.689	0.00155	1153.85	1346.15	1.167
2	55.203	0.0019	1307.7	1615.38	1.235
3	59.535	0.002	1400	1769.23	1.264
4	63.70	0.0023	1600	2000	1.25
5	65.744	0.0025	1692.31	1923.08	1.136
6	60.026	0.0019	1307.7	1769.23	1.35
7	58.134	0.00185	1230.8	1615.38	1.312

Graphs

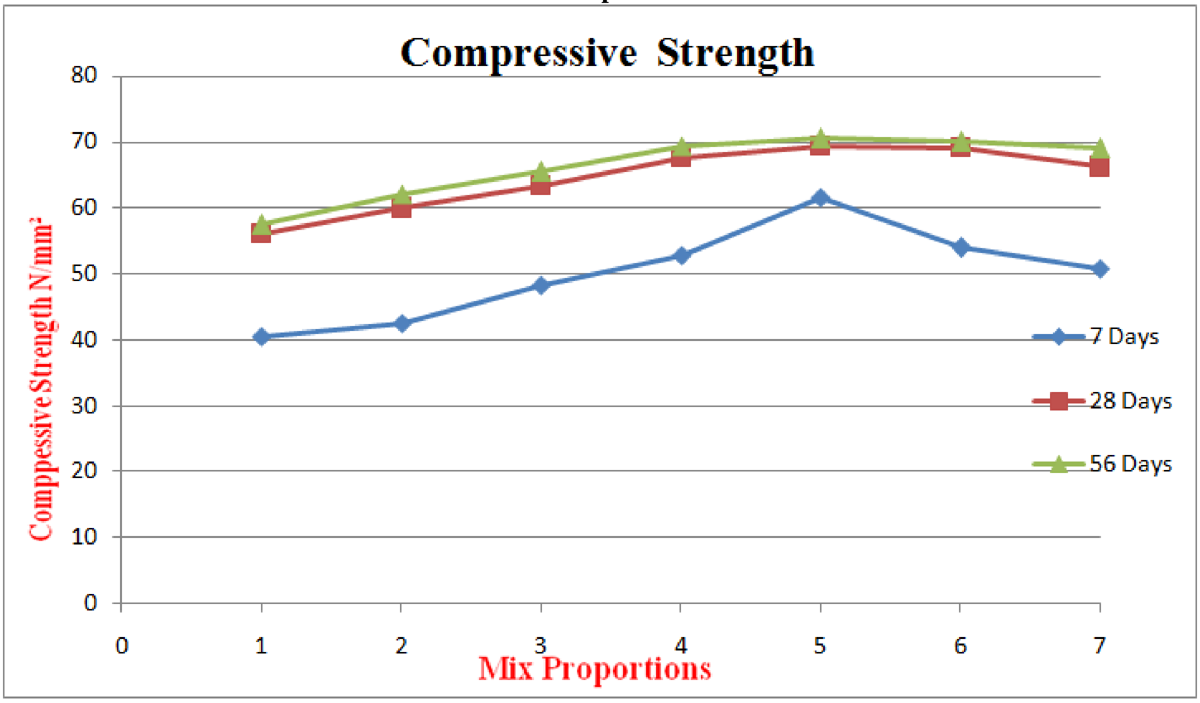
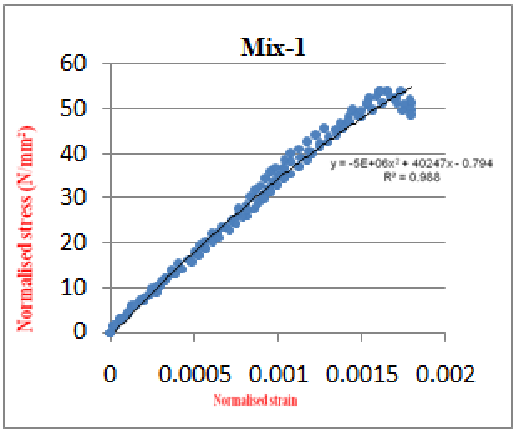
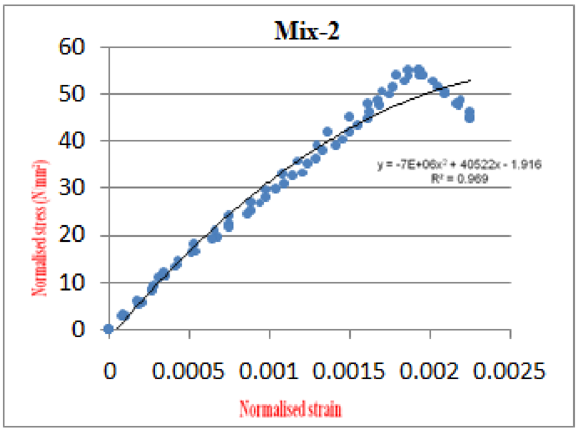


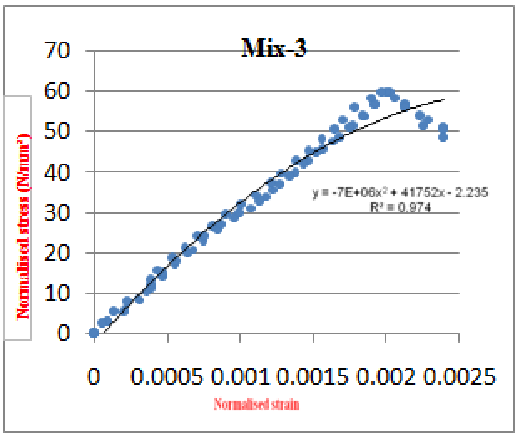
Figure-3: variation of compressive strength of different mix proportions.

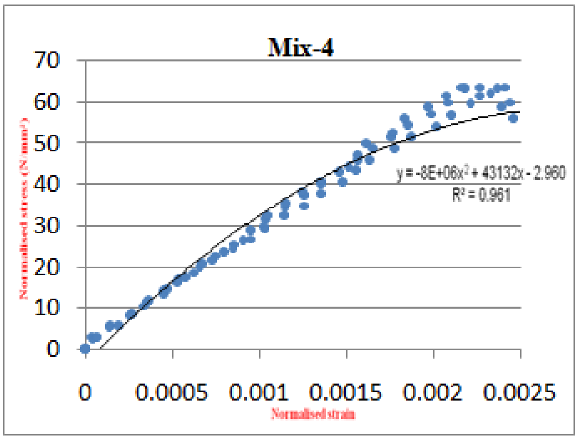
STRESS-STRAIN CURVES

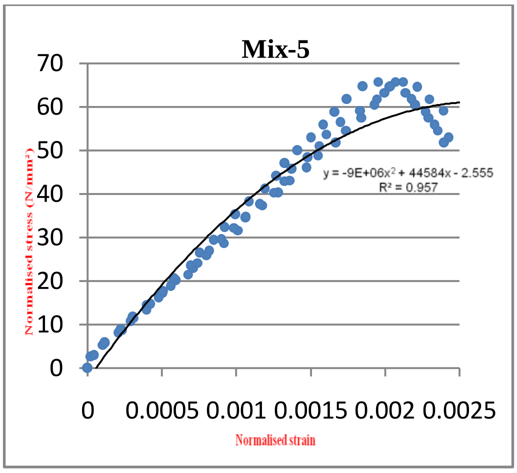
Normalised Stress v/s Normalised Strain graph of various mix proportions of SCC are shown below.

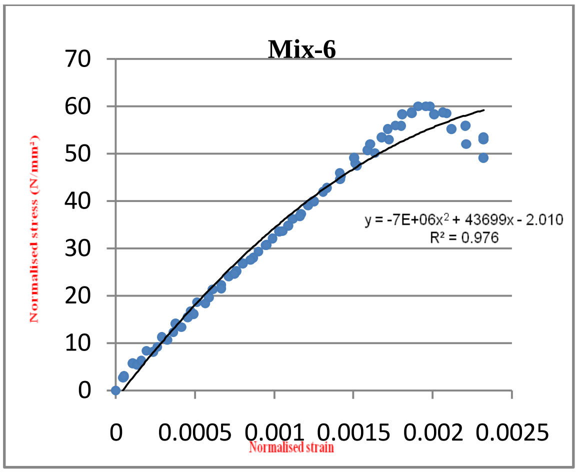


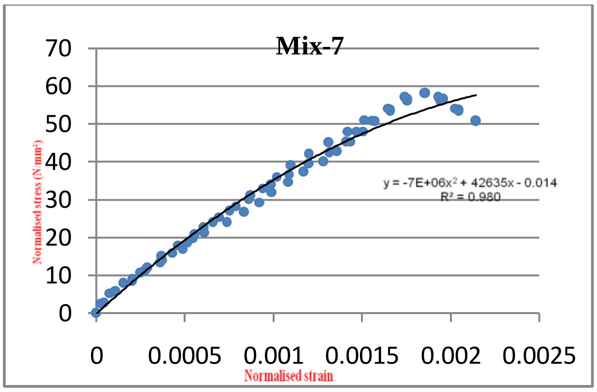












VI. Conclusion

- Developed SCC mix passed all key requirements by satisfying all recommended values mentioned in EFNARC guidelines.
- From the workability test values it is found that, as the percentage of GGBS increased Workability properties get reduced. This is because of flakiness and elongated shape of GGBS and also silica fume is denser in appearance as shown in SEM images.
- When cement is replaced by 20% of GGBS and 6% of silica fume it is found that percentage increase in compressive strength from 7 days to 28 days is about 12.8% and from 28 days to 56 days this was about 1.6%.
- From the graphs it can be observed that as the percentage of GGBS and Silica fume increasing, the peak stress and strain at peak stress also increased but incorporating GGBS above 20% and silica fume above 6% has shown decrease in values.
- Ductility factor increases with increase in percentage of silica fume.

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