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Study on Mechanical Properties of Self Compacting Concrete with Mineral Admixture and Glass Fibre

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Abstract— **In recent years, Self Compacting Concrete (SCC) has gained wide attention owing to their placement use in congested reinforced structures with difficulties in casting condition. For such applications fresh concrete must possess high fluidity and good cohesiveness. One of the disadvantages of self compacting concrete is its cost due to the usage of high volume of Portland cement and chemical admixture. One way to reduce the cost of self compacting concrete is by adding mineral admixtures such as fly ash, silica fume as a replacement to cement by 5%, 10%, 15% and 20%. Moreover, by the addition of mineral admixture in the manufacturing of self-compacting concrete, cost and heat of hydration get reduced. Also parameters like environmental consciousness and sustainable development plays an important role. Keeping this in mind, research was carried out by partial replacement of foundry sand with fine aggregate at 50%. Knowing that concrete is weak in tension, glass fibres are added at 1% to improve the tensile property. The initial results of experimental programs aimed at producing and evaluating SCC made with fly ash, silica fume, foundry sand and glass fibres are presented and discussed. The mix design of SCC was arrived as per guidelines of European Federation of National Associations Representing for Concrete (EFRNAC).**

Keywords— Self compacting concrete, Fly ash, Silica fume, Foundry sand, Glass fibre, Hardened properties.

I. INTRODUCTION

Self-Compacting Concrete (SCC) is a concrete which can be placed and compacted under its own weight with little vibration. Self-compacting concrete is cohesive enough to be handled without bleeding and segregation. SCC was first developed in Japan in late 1980's to be used mainly in congested reinforced areas.

The increase of paste volume with emphasis to low water powder ratio (w/p) in the presence of compatible chemical admixtures further strengthens the fluidity and helps in attaining homogeneity. Adequate homogeneity improves viscosity of the mix, which in turn enhances the segregation resistance. An optimum balance between fluidity and viscosity is the key to achieve efficient self-compacting characteristics of the concrete mix in fresh state.

II. BACKGROUND AND RELEATED WORKS

Concrete is a mixture of cement, fine aggregate, coarse aggregate, water and sometimes chemical and mineral admixture. Due to increase in construction activities, the demand of concrete is increasing and at a certain point of time the availability of cement and other constituents of concrete will be exhausted. This can be reduced by the use of waste materials (or) by-products from the industries as a replacement material which will not affect the concrete properties. Past research have concluded that the use of fly ash, silica fume and foundry sand increases the mechanical properties of concrete and also by addition of these materials in Self Compacting Concrete (SCC) there is negligible change in properties. In [1, 2, 3] the cement is replaced with fly ash by a maximum of 50% and has shown that the addition of fly ash will increase the flow property and strength parameter of the Self Compacting Concrete (SCC). From [4, 5] the cement is replaced with silica fume, a by-product obtained from ferro-alloy industry. By replacing it with cement by 20% an increase in the strength properties is noted and it affects the flow ability of the Self Compacting Concrete (SCC). The black foundry sand can be used in concrete compared to other foundry sands [6]. In [7, 8] the incorporation of waste foundry sand increased the hardened properties of self compacting concrete by a huge margin compared to normal concrete. [9] Addition of fly ash not only increases the hardened properties of concrete but also the tensile property knowing that glass fibre is adopted to increase the tensile property of self compacting concrete. [10] Addition of glass fibre by 1-1.5% increases the tensile property of self compacting concrete by 5% compared to normal concrete.

III. MATERIAL PROPERTIES

A. *Cement*

Ordinary Portland cement of grade 43 is used with confirmation of IS 8112 – 19890. Its physical properties are given in the table 1.

TABLE 1 Physical properties of cement

S.No.	Physical Properties	Values
1.	Specific gravity	3.14
2.	Initial setting time	90min
3.	Final setting time	300min
4.	7 days compressive strength	34 N/mm^2
5.	28 days compressive strength	45 /mm^2

B. *Fly ash*

Class F fly ash obtained from thermal power plant is used for the process. The physical properties are given in table 2.

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TABLE 2 Physical properties of fly ash

S.No.	Physical Properties	Values
1.	Colour	Grey (Black)
2.	Specific gravity	2.32

C. *Silica fume*

Silica fume is obtained from the Ferro-silicon alloy industries. The physical properties are given in table 3.

TABLE 3 Physical properties of silica fume

S.No.	Physical Properties	Values
1.	Colour	Grey (Black)
2.	Specific gravity	2.22

D. *Chemical Admixture*

Sulphonated Naphthalene Formaldehyde based super plasticizer was used with the brand name Fosroc Conplast SP430 DSI. Dosage of super plasticizer is 1% of cementations material. The physical properties are given in table 4.

TABLE 4 Physical properties of chemical admixture

S.No.	Physical Properties	Values
1.	Colour	Dark brown
2.	Specific gravity	1.145

E. *Fine aggregate*

Natural fine aggregate available from locally available market is used. The physical properties are tested in accordance [11] to IS: 383 and are given in table 5.

TABLE 5 Physical properties of fine aggregates

S.No.	Physical Properties	Values
1.	Fineness modulus	2.72
2.	Specific gravity	2.58

F. *Foundry sand*

Foundry sand obtained from the nearest foundry industry is used. The physical properties are tested and are given in table 6.

TABLE 6 Physical properties of foundry sand

S.No.	Physical Properties	Values
1.	Colour	Red.
2.	Specific gravity	2.55

G. *Coarse Aggregate*

The coarse aggregate obtained from the locally available crushing plant is used. The physical properties are tested in accordance with [11] IS: 383 and is given in table 7.

TABLE 7 Physical properties of coarse aggregate

S.No.	Physical Properties	Values
1.	Size	10-12.5 mm
2.	Fineness modulus	6.14
3.	Specific Gravity	2.62

IV. MIX PROPORTION

Mix design is defined as the process of selecting suitable ingredients of concrete and determining the relative proportions with the objective of producing concrete of a fixed minimum strength and durability as economically as possible. The mix composition is chosen to satisfy all performance criteria for the concrete in both fresh and hardened state. However, to obtain the required properties of fresh concrete in SCC, a higher proportion of ultrafine materials and the incorporation of chemical admixture are necessary. The components shall be coordinated one by one so that segregation, bleeding and sedimentation are prevented. A rational mix design process should be used, to reduce the number or trial tests in laboratory.

Based [12] on the EFNARC guidelines mix proportion for M_{30} grade is achieved. The following table 8 gives information about EFNARC guidelines.

TABLE 8 Typical ranges of SCC suggested by EFNARC

Constituent	Typical ranges by mass (kg/m³)	Typical ranges by litre (lit/m³)
Powder	380-600	
Paste		300-380
Water	150-210	150-210
Coarse aggregate	750-1000	270-360
Fine aggregate	Constituents balance the volume of other constituents, typically 48%-55% of total aggregate weight.	
Water/Powder ratio by volume		0.85-1.10

V. EXPERIMENTAL INVESTIGATION

In this investigation the hardened properties of self-compacting concrete for various replacement percentages of fly ash, silica fume and partial replacement of foundry sand are determined. The research work is done to find out the hardened properties between silica fume and fly ash.

A. *Compressive Strength*

Compressive strength of concrete is the capacity of concrete to with stand axially directed pushing force. When the limit is reached, the brittle material (concrete) will be crushed. Compressive strength of cubes was determined using a compression testing machine. Cubes are tested for their 28 days strength. Compressive strength is calculated by the following formula,

$$\text{Compression strength} = \text{Load/Area of cube}$$

Compression strength was found on cubes with a size 150 x 150 x 150 mm using a 2000kN compression testing machine. The rate of loading was maintained at a level of 14 $N/mm^2/min$.

Fig. 1. Compression strength test

B. *Tensile Strength*

This test is carried out by placing the cylinder specimen horizontally between the loading surface of compression testing machine and by applying the load until failure of the cylinder, along the vertical diameter. It is sometimes called as 'Brazilian Test'. This test was developed at Brazil in 1943. Split tensile strength was calculated by,

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Split Tensile Strength = $2P/\pi DL$

where, P – load in kN.

D- Diameter of Cylinder in mm.

L – Length of Cylinder in mm.

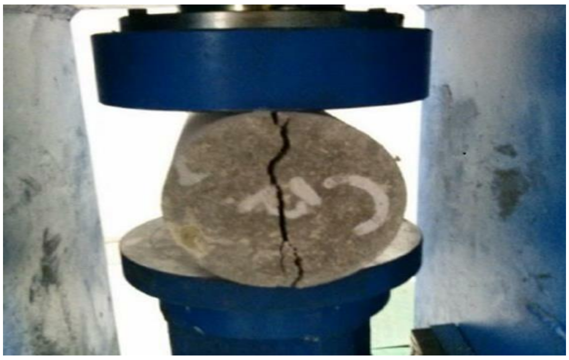

Fig. 2 Tensile strength test

Split tensile strength of cylinder specimen was found out using a specimen of 150mm diameter and 300mm length using 2000kN compression testing machine.

The test results are discussed in the tables 9-16. Graphs are plotted to compare the 7 and 28 days compression and split tensile strength of SCC with fly ash and silica fume.

TABLE 9 7 days compressive strength of SCC with fly ash

S.No.	Replacement percentage			7 days Compressive strength (N/mm^2)
	Fly ash	Foundry Sand	Glass Fibre	
1.	0	0	0	24.00
2.	5	50	1	25.12
3.	10	50	1	26.88
4.	15	50	1	28.58
5.	20	50	1	29.58

TABLE 10. 7 Days compressive strength of SCC with silica fume

S.No.	Replacement percentage			7 days Compressive strength (N/mm^2)
	Silica fume	Foundry Sand	Glass Fibre	
1.	0	0	0	24.00
2.	5	50	1	24.02
3.	10	50	1	25.30
4.	15	50	1	26.25
5.	20	50	1	27.95

The following graph shows the comparison of 7 days compression strength of SCC between fly ash and silica fume:

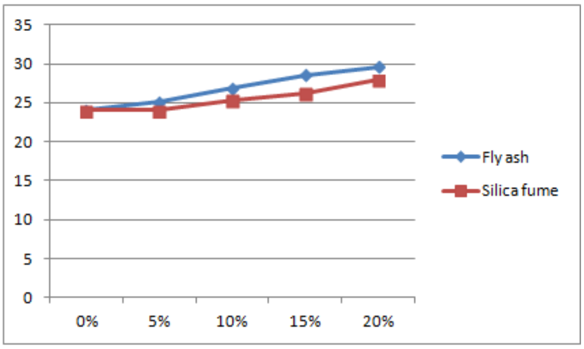

Fig. 3 Chart for comparison of 7 days compression Strength

TABLE 11 28 Days compressive strength of SCC with fly ash

S.No.	Replacement percentage			28 days Compressive strength (N/mm^2)
	Fly ash	Foundry Sand	Glass Fibre	
1.	0	0	0	33.76
2.	5	50	1	32.67
3.	10	50	1	35.88
4.	15	50	1	38.36
5.	20	50	1	40.20

TABLE 12 28 Days compressive strength of SCC with Silica fume

S.No	Replacement Percentage			28 days Compressive strength (N/mm^2)
	Silica fume	Foundry Sand	Glass Fibre	
1.	0	0	0	33.76
2.	5	50	1	34.89
3.	10	50	1	35.68
4.	15	50	1	37.88
5.	20	50	1	41.22

The following graph shows the comparison of 28 days compression strength of SCC between fly ash and silica fume:

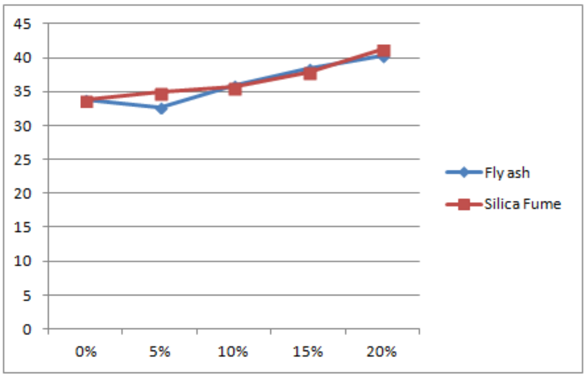

Fig. 4 Chart for comparison of 28 days compression Strength

TABLE 13 7 Days Split tensile strength of SCC with fly ash

S.No.	Replacement Percentage			7 days Split tensile strength (N/mm^2)
	Fly ash	Foundry Sand	Glass Fibre	
1.	0	0	0	1.75
2.	5	50	1	1.83
3.	10	50	1	1.97
4.	15	50	1	2.01
5.	20	50	1	2.10

TABLE 14 7 Days Split tensile strength of SCC with Silica fume

S.No.	Replacement Percentage			7 days Split tensile strength (N/mm^2)
	Silica fume	Foundry Sand	Glass Fibre	
1.	0	0	0	1.85
2.	5	50	1	1.92
3.	10	50	1	2.05
4.	15	50	1	2.10
5.	20	50	1	2.12

The following graph shows the comparison of 7 days split tensile strength of SCC between fly ash and silica fume:

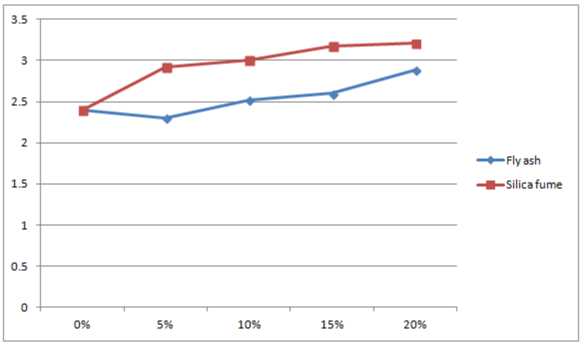

Fig. 5. Chart for comparison of 7 days split tensile

TABLE 15 28 Days Split tensile strength of SCC with fly ash

S.No.	Replacement Percentage			28 days Split tensile strength (N/mm^2)
	Fly ash	Foundry Sand	Glass Fibre	
1.	0	0	0	3.22
2.	5	50	1	3.04
3.	10	50	1	3.25
4.	15	50	1	3.35
5.	20	50	1	3.50

TABLE 16 28 Days Split tensile strength of SCC with Silica fume

S.No.	Replacement Percentage			28 days Split tensile strength (N/mm^2)
	Silica fume	Foundry Sand	Glass Fibre	
1.	0	0	0	3.22
2.	5	50	1	3.52
3.	10	50	1	3.62
4.	15	50	1	3.75
5.	20	50	1	3.82

The following graph shows the comparison of 28 days split tensile strength of SCC between fly ash and silica fume:

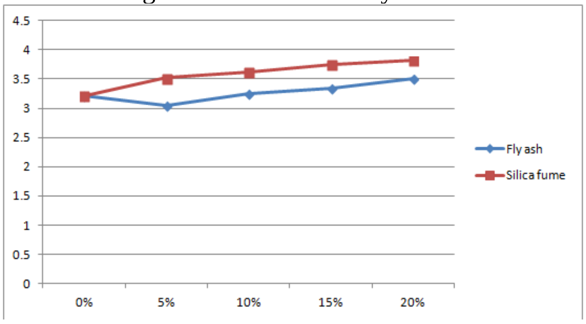

Fig 6. Chart for comparison of 28 days split tensile Strength

VI. CONCLUSION

- The addition of fly ash by a maximum of 20% increases the 7 days strength of the test specimen and decreases the 28 days strength of the concrete. But the addition of fly ash decreases the water binder ratio from 0.45 to 0.40.
- The addition of silica fume by a maximum of 20% decreases the 7 days strength of the concrete and increases the 28 days strength of the concrete. The addition of silica fume increases the water binder ratio from 0.45 to 0.50.
- The results have shown that it is possible to produce a good performing self compacting concrete with locally available fly ash and silica fume.

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