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EXPERIMENTAL STUDY ON SELF COMPACTING CONCRETE

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ABSTRACT

Concrete is a mixture of cement, sand, gravel and water which dries hard and strong and is used as a material for building. Concrete has to be heavily vibrated for flow into very intricate forms or forms that have a lot of reinforcing bars. Hence to overcome these defects the self-compacting concrete is used. Self-compacting concrete is a flowing concrete mixture that is able to consolidate under its own weight. The self-compacting concrete flows easily at suitable speed into formwork without blocking through the reinforcement without being heavily vibrated. This project deals with the self- compacting concrete where the cement is partially replaced with fly-ash and silica fume. Here Ordinary Portland Cement is replaced with 5%, 10%, 15%, 20% and 25% of fly-ash and 2.5%, 5%, 7.5%, 10% and 12.5% of silica fume. From the experimental investigations, it is observed that there is increase in the fresh properties (workability) and increase in the hardened properties (split-tensile strength and compressive strength) for replacement of silica fume. Similarly, there is increase in the fresh properties (workability) and decrease in the hardened properties (split-tensile strength and compressive strength) for replacement of fly ash.

KEYWORDS: Self-compacting concrete; Fly-ash; Silica fume; Fresh properties; Strength parameters.

INTRODUCTION

Self-compacting concrete (SCC) is a flowing concrete mixture that is able to consolidate under its own weight. The highly fluid nature of SCC makes it suitable for placing in difficult conditions and in section with congested reinforcement. Use of SCC can also help minimize hearing-related damages on the worksite that are induced by vibration of concrete. Another advantage of SCC is that the time required to place large sections is considerably reduced.

When the construction industry in Japan experienced a decline in the availability of skilled labor in the 1980s, a need was felt for a concrete that could overcome the problems of defective workmanship. This led to the development of self-compacting concrete, primarily through the work by Okamura. A committee was formed to study the properties of self-compacting concrete, including a fundamental investigation on workability of concrete, which was carried out by Ozawa et al. at the University of Tokyo. The first usable version of self-compacting concrete was completed in 1988 and was named “High Performance Concrete”, and later proposed as “Self-Compacting High Performance Concrete”.

Current studies in SCC, which are being conducted in many countries, can be divided into the following categories:

- Use of rheometers to obtain data about flow behavior of cement paste and concrete,
- Mixture proportioning methods for SCC,
- Characterization of SCC using laboratory test methods,
- Durability and hardened properties of SCC and their comparison with normal concrete, and
- Construction issues related to SCC.

These will be relevant to the immediate needs. In addition, the following questions also need particular attention, from a long-term perspective:

- Development of mixture design guideline tables similar to those for normal concrete,
- A shift to more ‘normal’ powder contents in SCC, from the existing high powder mixtures,
- Better understanding of the problems of autogenous and plastic shrinkage in SCC, and
- Development of site quality control parameters such as in ‘all-in-one’, acceptable tests.

MATERIALS AND METHODS

Cement

Cement is a binder, a substance used in construction that sets and hardens and can bind other materials together. The most important types of cement are used in the components in the production of mortar in masonry, and of concrete, which is a combination of cement and an aggregate to form strong building materials. Concrete produced from Portland cement is one of the most versatile construction materials available in the world.

Fly-ash

Fly-ash also known as 'Pulverized Fuel Ash' is one of the coal combustion produce, compost of the fine particles that are driven out of the boiler with the flue gases. Ash that falls in the bottom of the boiler is called bottom ash. In modern coal fired power plants, fly-ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys. Together with bottom ash removed from the bottom of the boiler. It is known as coal ash.
Fly-ash can significantly improve the workability of concrete. Recently, techniques have been developed to replace particles in it with high volume fly-ash.

Table 1.Physical properties of fly ash

S.NO.	PARTICULARS	VALUES
1.	Specific gravity	2.85

Table 2. Chemical properties of fly ash

S.NO.	CHEMICAL COMPONENT	% OF CHEMICAL COMPONENT
1	SiO_2	42
2	Fe_2O_3	28
3	Al_2O_3	22
4	CaO	2
5	MgO	1
6	K_2O	1.30
7	Na_2O	0.30
8	SO_3	1

Silica fume

Silica fume also known as condensed silica fume or micro silica is very fine, non-crystalline silica produced in electric arc furnaces as a by-product of the production of elemental silicon or silica-alloys. The specific gravity ranges from 2.2 to 2.3.
Silica fume is added to Portland cement concrete to improve its properties, in particular its compressive strength, bond strength and abrasion resistance. These improvements stem from both the mechanical improvements resulting from addition of a very fine powder to the cement paste mix as well as from the pozzolanic reactions between the silica fume and free calcium hydroxide in the paste.

Table 3. Physical properties of silica fume

S.NO.	PARTICULARS	VALUES
1.	Specific gravity	2.23

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Table 4. Chemical composition of silica fume

S. NO.	CHEMICAL COMPONENT	% OF CHEMICAL COMPONENT
1	SiO_2	97
2	Fe_2O_3	0.5
3	Al_2O_3	0.2
4	CaO	0.2
5	MgO	0.5
6	K_2O	0.5
7	N_2O	0.2
8	SO_3	0.15
9	C_1	0.01
10	H_2O	0.5

Fine aggregate

The fine aggregate used is natural sand. The sand is sieved to remove all pebbles. The sieve size used is 4.75mm. The grading should be uniform throughout the work. The moisture content or absorption characteristics must be closely monitored as quality of SCC will be sensitive to such changes.

Table 5. Physical properties of fine aggregate

S.NO.	PARTICULARS	VALUES
1.	Fineness modulus	2.68
2.	Specific gravity	2.5

Coarse aggregate

Crushed gravel or stones obtained by crushing of gravel or hard stone are used as coarse aggregate. The maximum size of aggregate is generally limited to 20mm.The aggregate serves as reinforcement to add strength to the overall composition. Aggregate are formed due to natural disintegration of rock, hence they derived many of their properties from the parent rock. These properties are chemical and mineral composition, specific gravity, hardness strength, physical and chemical stability.

Among the various properties of aggregate, the important ones for SCC are the shape and gradation.

Table 6. Physical properties of coarse aggregate

S.NO.	PARTICULARS	VALUES
1.	Specific gravity	2.5
2.	Water absorption	0.67
3.	Bulk density(Kg/m^3)	1627.3

Conplast SP430

Conplast SP 430 G8 is based on sulphonated naphthalene polymers and supplied as brown liquid instantly dispersible in water. Conplast SP430 G8 has been specially formulated to give high water reduction up to 25%

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without loss of workability or to produce high quality concrete of reduced permeability. The volume of the conplast used in self-compacting concrete is taken as 1% of the volume of the cement.

Water

Water is one of the most important element in construction. It is required for preparation of mortar, mixing of cement concrete and curing work etc., during construction work. A part of mixing water is utilized in the hydration of cement to form the binding matrix in which the inert aggregates are held in suspension until the matrix has hardened and the remaining water serves as a lubricants between the fine and coarse aggregate and makes concrete workable. The range pH in surface water is 6.5 to 8.5 and the pH range for ground water is 6 to 8.5.

Control Mix Design

The mix design proportions were designed as per ACI 211.4R-93, 1:1.41:1.72:0.38 (cement: fine aggregate (FA): coarse aggregate (CA): water)
From the mix percentage the weight of fly ash and silica fume required is tabulated and calculated.

Table 7. Weight of material used

BINDER (Kg/m^3)	FINE AGGREGATE (Kg/m^{3-})	COARSE AGGREGATE (Kg/m^3)	WATER (lit/m^3)
550	774.37	781.104	202.77

Table 8. Weights of cement and fly ash required

CEMENT	Replacement % of cement by fly ash	5	10	15	20	25
	Fly ash(Kg/m^3)	27.5	55	82.5	110	137.5
	Cement (Kg/m^3)	522.5	495	467.5	440	412.5

Table 9. Weights of cement and silica fume required

CEMENT	Replacement % of cement by silica fume	2.5	5	7.5	10	12.5
	Silica fume (Kg/m^3)	13.75	27.5	41.25	55	68.75
	Cement (Kg/m^3)	536.25	522.5	508.75	495	481.25

RESULTS AND DISCUSSION

Fresh Properties

Workability

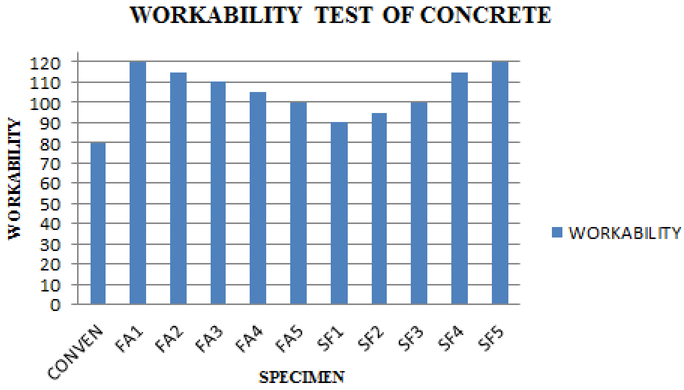
Workability is one of the physical parameters of concrete which affects the strength and durability as well as the cost of labor and appearance of the finished product. Concrete is said to be workable when it is easily placed and compacted homogeneously i.e. without bleeding or segregation.

Table 10. Workability of concrete

S.NO.	SPECIMEN	WORKABILITY (mm)
1.	Conventional	80
2.	FA1	120
3.	FA2	115
4.	FA3	110
5.	FA4	105

6.	FA5	100
8.	SF1	90
9.	SF2	95
10.	SF3	100
11.	SF4	115
12.	SF5	120

Figure 1: Workability of concrete



Hardened Properties

Compressive Strength

Cubes are used to determine the compressive strength of concrete. The dimension of the cube is 150mm X 150mm X 150mm. At first, the cube mould is prepared by connecting it properly with nuts and bolts. Then, it is thoroughly applied with grease in all the nuke and corner of the mould. Now, the dry mix consisting of the cement, fine aggregate, coarse aggregate and the replacements are added and mixed thoroughly. Now water is added slowly to the dry mix and the concrete is prepared. Now the prepared concrete is kept in three layers. For each layer compaction is done by ramming it with proctor compactor for 25 times.
Finally leveling is done in the mould. It is allowed to set for 24 hours and then demoulded. Now the compressive test is carried out by testing it in Compressive Testing Machine.

Table 11. Compressive strength of concrete (fly ash)

S.NO.	SPECIMEN	COMPRESSIVE STRENGTH (MPa)
1.	Conventional	50.405
2.	FA1	48.11
3.	FA2	46.65
4.	FA3	45.36
5.	FA4	44.50
6.	FA5	43.54

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Figure 2: Compressive strength (fly ash)

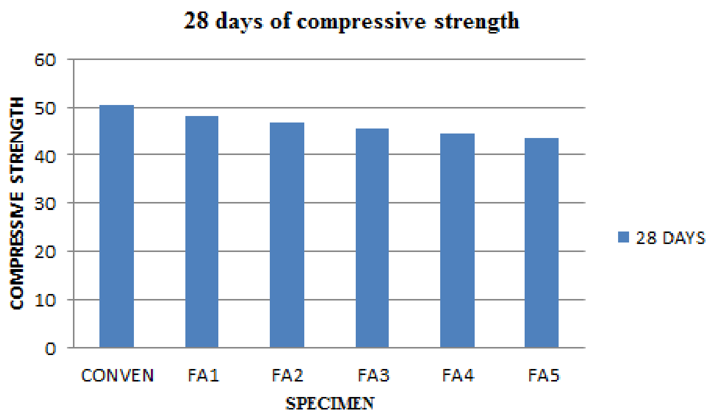
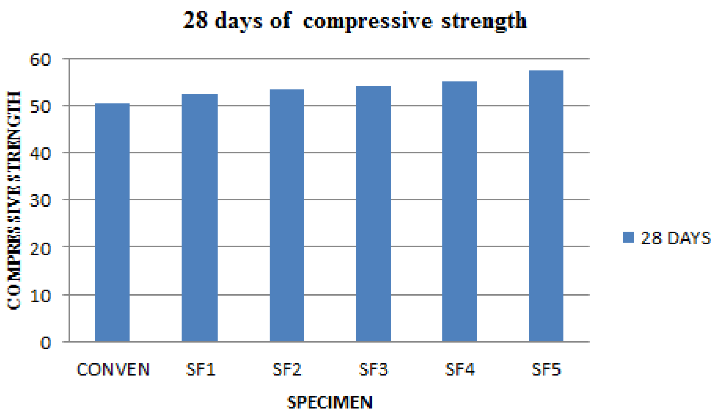


Table 12. Compressive strength of concrete (silica fume)

S.NO.	SPECIMEN	COMPRESSIVE STRENGTH (MPa)
1.	Conventional	50.405
2.	SF1	52.40
3.	SF2	53.38
4.	SF3	54.22
5.	SF4	55.02
6.	SF5	57.49

Figure 3: Compressive strength (silica fume)



Split tensile Strength

Cylinders are casted to determine the split tensile strength of the concrete. The dimension of the cylinder where height is 300mm and diameter is 150mm. At first, the cylinder mould is prepared by connecting it properly with nuts and bolts. Then, it is thoroughly applied with grease in all the nuke and corner of the mould. Now, the dry mix consisting of the cement, fine aggregate, coarse aggregate and the replacements are added and mixed thoroughly. Now water is added slowly to the dry mix and the concrete is prepared. Now the prepared concrete is kept in three layers. For each layer compaction is done by ramming it with proctor compactor for 25 times. The last layer is alone rammed by using tamping rod.

Finally leveling is done in the mould. It is allowed to set for 24 hours and then de molded. Now the tensile test is carried out.

Table 13. Split tensile strength of concrete (fly ash)

S.NO.	SPECIMEN	TENSILE STRENGTH (MPa)
1.	Conventional	4.10
2.	FA1	3.95
3.	FA2	3.67
4.	FA3	3.42
5.	FA4	3.01
6.	FA5	2.80

Figure 4: Tensile strength (fly ash)

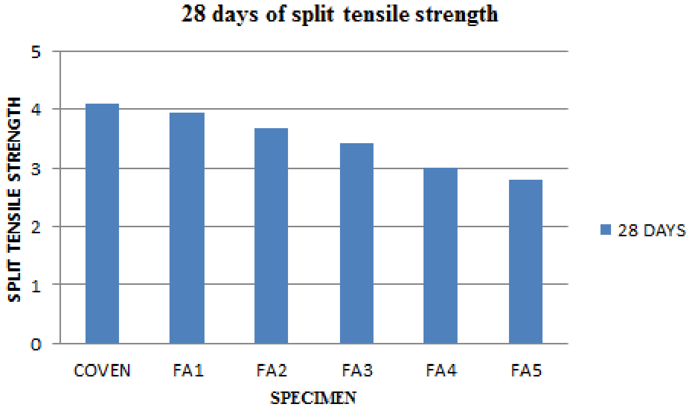


Table 14. Split tensile strength of concrete (silica fume)

S.NO.	SPECIMEN	TENSILE STRENGTH (MPa)
1.	Conventional	4.10
2.	SF1	4.25
3.	SF2	4.31
4.	SF3	4.51
5.	SF4	4.67
6.	SF5	4.90

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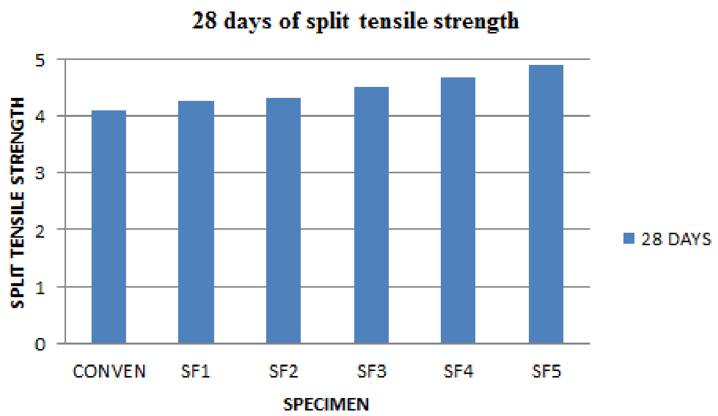
Figure 5: Tensile strength (silica fume)



CONCLUSION

It is evident from the experimental results that the compressive strength decreases with the increase in percentage of fly ash and increases with the increase in percentage of silica fume.

The workability of concrete when replaced with 5%, 10%, 15%, 20% and 25% of fly ash is increased by 50%, 43.75, 37.5%, 31.25% and 25% respectively.

The workability of concrete when replaced with 2.5%, 5%, 7.5%, 10% and 12.5% of silica fume is increased by 12.5%, 18.75, 25%, 43.75% and 50% respectively.

When the cement is replaced with 5%, 10%, 15%, 20% and 25% of fly ash the compressive strength of concrete is reduced by 4.55%, 7.44%, 10%, 11.71% and 13.61% respectively.

When the cement is replaced with 2.5%, 5%, 7.5%, 10% and 12.5% of silica fume the compressive strength is increased by 3.95%, 5.9%, 7.56%, 9.15% and 14.05% respectively.

When the cement is replaced with 5%, 10%, 15%, 20% and 25% of fly ash the tensile strength of concrete is reduced by 3.65%, 10.48, 16.58%, 26.58% and 31.70% respectively.

When the cement is replaced with 2.5%, 5%, 7.5%, 10% and 12.5% of silica fume the tensile strength is increased by 3.65%, 5.12%, 10%, 13.90 and 19.5% respectively.

Though there is a reduction in strength due to the use of fly ash and increase in strength due to the use of silica fume in concrete, as a replacement of cement, it is encouraged because it plays a significant role in reducing the environmental hazards.

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