Properties of Self-Compacting Concrete after partial replacement of cement

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Abstract:- The self-compacted concrete (SCC) is an innovative product in civil engineering field of India. The necessity of this product was felt by civil engineers to overcome in the issue of workmanship, in structural concreting of thickly/heavily reinforced sections in execution of concreting. This product was first developed in Japan in 1997 and followed by Europe and U.S.A. It does not require vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. 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.

***Key words :-* Self-compacting concrete; Fly-ash; Fresh properties; Strength parameters.**

1. 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. The main reasons behind the popularity of Self Compacted Concrete are listed as Faster construction, Reduction in Site manpower, Better surface finish, Easy placing, Improved durability, Greater freedom in design, Absence of vibration, Reduced noise levels, Safer working environment etc. When the construction industry in Japan experienced a decline in the availability of skilled labour 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 as:-

- Use of rheometers to obtain data about flow behaviour 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.

2. MATERIALS AND METHODS :-

a) 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.

b) 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.

Sr. 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_2O3	22
4.	CaO	2
5.	MgO	1
6.	K_2O	1.30
7.	Na_2O	0.30
8.	SO_3	1.0

c) 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 3. Physical properties of fine aggregate

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

d) 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.

Table 4. 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

e) 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% 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.

f) 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 required is tabulated and calculated.

Table 5. Weight of material used

BINDER (Kg/m3)	FINE AGGREGATE (Kg/m3)	COARSE AGGREGATE (Kg/m3)	WATER (lit/m3)
550	774.37	781.104	202.77

Table 6. 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

RESULTS AND DISCUSSION

Fresh Properties:-

1) Workability

Workability is one of the physical parameters of concrete which affects the strength and durability as well as the cost of labour 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 7. 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

Hardened Properties:-

2) 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 levelling is done in the mould. It is allowed to set for 24 hours and then de-moulded. Now the compressive test is carried out by testing it in Compressive Testing Machine (CTM).

Table 8. 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	**45.50**
5	FA4	**44.45**
6	FA5	**43.50**

3) 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 levelling is done in the mould. It is allowed to set for 24 hours and then de-moulded. Now the tensile test is carried out.

Table 9. Split tensile strength of concrete (fly ash)

S.NO.	SPECIMEN	TENSILE STRENGTH (MPa)
1	Conventional	***4.10***
2	**FA1**	***3.95***
3	**FA2**	***3.60***
4	**FA3**	***3.40***
5	**FA4**	***3.00***
6	**FA5**	***2.65***

CONCLUSION:-

- It is evident from the experimental results that the compressive strength decreases with the increase in percentage of fly ash.
- 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.
- 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 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.
- There is a reduction in strength due to the use of fly ash in concrete, hence we can not use fly ash in partial replacement of cement.

6. References:

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