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Development and Properties of Self Compacting Concrete Mixed with Fly Ash

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Abstract

Self compacting concrete is one of "the most revolutionary developments" in concrete research; this concrete is able to flow and to fill the most restacked places of the form work without vibration. There are several methods for testing its properties in the fresh state: the most frequently used are slump flow test, L box and V funnel. This work presents properties of self compacting concrete, mixed with fly ash. The test results for acceptance characteristics of self-compacting concrete such as slump flow; V-funnel and L-Box are presented. Further, compressive strength at the ages of 7, 28 days was also determined and results are included here.

Keywords: Compressive strength, fly ash, self-compacting concrete, slump flow test, superplasticizer.

Introduction

Self compacting concrete (SCC), which flows under its own weight and does not require any external vibration for compaction, has revolutionized concrete placement. SCC, was first introduced in the late 1980's by Japanese researchers, is highly workable concrete that can flow under its own weight through restricted sections without segregation and bleeding[1].

Such concrete should have a relatively low yield value to ensure high flow ability, a moderate viscosity to resist segregation and bleeding, and must maintain its homogeneity during transportation, placing and curing to ensure adequate structural performance and long term durability. The successful development of SCC must ensure a good balance between deformability and stability. Researchers have set some guidelines for mixture proportioning of SCC, which include i. reducing the volume ratio of aggregate to cementitious material[1-2], ii. increasing the paste volume and water-cement ratio (w/c), iii. carefully controlling the maximum coarse aggregate particle size and total volume; For SCC, it is generally necessary to use superplasticizer in order to obtain high mobility. Adding a large volume of powdered material or viscosity modifying admixture can eliminate segregation. The powdered materials that can be added are fly ash, Since, self-compatibility is largely affected by the characteristics of materials and the mix proportions, it becomes necessary to evolve a procedure for mix design of SCC. Okamura and Ozawa have proposed a mix proportioning system for SCC[3].

In this system, the coarse aggregate and fine aggregate contents are fixed and self-compatibility is to be achieved by adjusting the water /powder ratio and super plasticizer dosage. The coarse aggregate content in concrete is generally fixed at 50 percent of the total solid volume, the fine aggregate content is fixed at 40 percent of the mortar volume and the water /binder ratio is assumed to be 0.4 -0.5 by weight depending on the properties of the powder and the super plasticizer dosage. The required water /binder ratio is determined by conducting a number of trials.

Material and Methods

Cement: Ordinary Portland cement (grade 43) was used[4]and conforms to IS 8112-1989. Its physical properties are as given in table 1.

Fly ash: Class F fly ash is obtained from Thermal Power Plant Brishinghpur, Pali, India. The physical and chemical properties of fly ash are given in the table 2 and table 3, respectively and conform to IS: 3812-2003[5]

Table-1
Physical properties of cement

Physical property	Results obtained	IS: 8112-1989 specifications
Fineness (retained on 90-µm sieve)	8.0	10mm
Normal Consistency	28%	Nil
Vic at initial setting time (minutes)	75	30minimum
Vic at final setting time (minutes)	215	600maximum
Compressive strength 3-days (MPa)	23	22.0minimum
Compressive strength 7-days (MPa)	36	33.0minimum
Compressive strength 28days(MPa)	45	43.0minimum
Specific gravity	3.15	-

Table – 2
Physical Properties of Fly Ash

Physical Properties	Test Results
Color	Grey Blakish)
Specific Gravity	2.27
Lime Reactivity -average compressive strength after 28 days of mixture 'A'	4.90Mpa

Table- 3
Chemical Properties of Fly Ash

Constituents	Percent by Weight
Loss on ignition	2.17
Silica (SiO_2)	57.6
Iron Oxide (Fe_2O_3)	5.73
Alumina (Al_2O_3)	25.80
Calcium Oxide (CaO)	2.47
Magnesium Oxide (MgO)	1.63
Total Sulphur (SO_3)	0.07

Admixtures: Polycarboxylic ether based super plasticizer Fairflo RMC (M) supplied by Fairmate Chemicals Pvt. Ltd.

Aggregates: Locally available natural sand with 4.75 mm maximum size was used as fine aggregate, having specific gravity, fineness modulus and unit weight as given in table 4 and crushed stone with 16mm maximum size having specific gravity, fineness modulus and unit weight as given in table-4 was used as coarse aggregate. Both fine aggregate and coarse aggregate conformed to Indian Standard Specifications IS: 383-1970[6], table-4 gives the physical properties of the coarse and fine aggregates.

Table-4
Physical Properties of Coarse and Fine Aggregate

Physical tests	Coarse aggregate	Fine aggregate
Specific gravity	2.70	2.60
Fineness modulus	6.86	2.56
Bulk density (kg/m^3)	1610	1650

Test Method: Self compacting concrete is characterized by filling ability, passing ability and resistance to segregation. Many different methods have been developed to characterize the properties of SCC. No single method has been found until date, which characterizes all the relevant workability aspects, and hence, each mix has been tested by more than one test method for the different workability parameters. Table 5 gives the recommended values for different tests given by different researchers[7-9] for mix to be characterized as SCC mix.

Table- 5
Recommended Limits for Different Properties

Property	Range
Slump Flow Diameter	500-700 mm
T_{50cm}	2-5 sec
V-funnel	6-12 sec
L-Box H2/H1	≥ 0.8

The slump flow test is used to assess the horizontal free flow of SCC in the absence of obstructions. On lifting the slump cone, filled with concrete, the concrete flows. The average diameter of the concrete circle is a measure for the filling ability of the concrete. The time T_{50cm} is a secondary indication of flow. It measures the time taken in seconds from the instant the cone is lifted to the instant when horizontal flow reaches diameter of 500mm.

The flow ability of the fresh concrete can be tested with the V-funnel test, whereby the flow time is measured. The funnel is filled with about 12 liters of concrete and the time taken for it to flow through the apparatus is measured. the flow time will increase significantly. According to Khayat and Manai[9], a funnel test flow time less than 6s is recommended for a concrete to qualify for an SCC.

The passing ability is determined using the L- box test[10] .The vertical section of the L-Box is filled with concrete, and then the gate lifted to let the concrete flow into the horizontal section. The height of the concrete at the end of the horizontal section indication of passing ability. The specified requisite is the ratio between the heights of the concrete at each end or blocking ratio to be ≥ 0.8.

Experimental Procedure: The proposed study is being carried out to develop self compacting concrete using fly ash and cement in varying combinations for use in the Indian conditions. Following guidelines of EFNARC for rheological properties of concrete in fresh state and using Japanese method of mix design as reference, initial mix design was carried to form S40-fo at coarse aggregate content of 30% by volume of concrete and fine aggregate content of 50% by volume of mortar in concrete and cement (480kg/cubic meter), keeping the water/binder (W/b) ratio constant 0.40 (by weight). The dosage of superplasticizer was estimated to be 2.7 % of powder content (cement, fly ash). Slump flow test, V- funnel, L box test satisfies the limits laid by EFNARC. Now 10%, 20%, 30% weight of cement is replaced by equal weight i.e. 10%, 20%, 30% weight of fly ash respectively and S40-f10, S40-f-20, S40-f30 self compacting concrete is prepared which satisfied rheological properties. Dosages of superplasticizer as per requirement of slump flow.

Repeating the process by increasing the w/b ratio to 0.45 keeping the aggregate constant and reducing the cement content 450 kg/cubic meter self compacting concrete S45f-o was prepared which satisfied the rheological properties of concrete. The quantity of superplasticizer estimated to 2.0%. S45-f10, S45-20, S45-30 is prepared by 10% ,20% ,30% weight of cement replacement by equal weight of fly ash i.e. 10% , 20%, 30% respectively. The doses of superplasticizer is estimated between 8.2 kg/cubic meter to 4.8kg /cubic meter which satisfied the slump flow V funnel test L Box test on fresher concrete.

Compressive strength test are conducted on hardened concrete at 7 and 28 days and results are tabulated in table -7.

Results and Discussion

The rheological characteristics of mixes SF40-f0, SF40-f30 to SF45-f0, SF45-f30 are discussed below. The slump flow characteristics of the mixtures are between 650 and 695 mm, which satisfy the EFNARC requirement. Slump flow improves with the increase in cement replacement by fly ash. As far as

filling ability of the mixes was concerned, the results of V-funnel test satisfied the standard requirements-Funnel time decrease from 12 to 8 seconds with increasing fly ash content indicating increase in flow ability of concrete. The blocking ratios in the L - box test were as per the requirement laid down by EFNARC guidelines. From 7 days and 28 days compressive strength results, it has been observed that increase in fly ash content in mixes SF40-f0 to SF40-f30 and SF45-f0 to SF45-f30 from 45kg/m3 to 144 kg/m3 increase water requirement of mixes which decrease 7 day compressive strength from 36 to 24 MPa and 28 days compressive strength of concrete from 52 MPa to 39MPa. From the above discussions, it can be concluded that addition of fly ash in mix increases filling and passing ability of concrete, whereas superplasticizer imparts workability to concrete improving segregation resistance of concrete. Addition of fly ash in mix results in reduction of superplasticizer for a similar workability (flow diameter). Furthermore, as expected, for similar workability, increasing the water/b ratio reduces the amount of superplasticizer required.

Conclusion

Based on this experimentation, following conclusions are: Establishment of standard mix design procedure and appropriate testing methods is essential for widespread use of SCC. Most of Indian researchers have followed European guidelines for testing SCC. Other countries are adopting these guidelines with slight modifications as per their local conditions. Addition of fly ash in SCC increases filling and passing ability of concrete, Increase in fly ash, superplasticizer content in SCC reduced water demand and compressive strength of concrete. In the present investigation increase in fly ash content in place of cement from 48 kg/m3 to 144 kg/m3, reduced the water requirement of mix, thereby decreasing the 28 days the strength of concrete from 52 MPa to 39MPa. Fly ash is industrial waste from thermal power station. Utilization of these waste products as cement replacement will not only help to achieve economical mix, but it is envisaged that it may improve the microstructure and consequently the durability of concrete. This provides solution to disposal problems and other environmental pollution.

Table 6
Mix Proportions

Mix	Cement (Kg/m^3)	Fly ash (Kg/m^3)	FineAggregate (Kg/m^3)	Coarse.Aggregate (Kg/m^3)	Water (Kg/m^3)	S.P. Kg/m^3	W/b ratio
S40-f0	480	0	890	810	192	13.30	0.40
S40-f10	432	48	890	810	192	9.9	0.40
S40-f20	394	96	890	810	192	9.68	0.40
S40-f30	336	144	890	810	192	9.4	0.40
S45-f0	450	0	890	810	202	9.25	0.45
S45-f10	405	45	890	810	202	8.2	0.45
S45-f20	360	90	890	810	202	6.4	0.45
S45-f30	315	135	890	810	202	4.8	0.45

Table-7
Workability and compressive strength results

Mix	Slump flow (mm)	T_{50cm} (sec)	V-funnel (sec)	L-box Blocking ratio(H2/H1)	7-days (MPa)	28-days (MPa)
S-40-f0	650	5.0	12	0.87	36	52
S40-f10	665	4.0	9	0.85	33	46
S40-f20	685	3.6	8	0.80	26	42
S40-f30	680	3.0	8	0.75	24	40
S45-f0	687	4.1	9	0.79	32	50
S45-f10	689	3.5	8.6	0.76	31	47
S45-f20	690	3.0	8.4	0.75	29	41
S45-30	695	3.0	8.16	0.75	27	39

T_{50cm}: time taken for concrete to reach the 500 mm spread circle: V-funnel flow time after keeping the concrete in funnel for 10 sec, H1, H2: Heights of the concrete at both ends of horizontal section of L-box after allowing the concrete to flow.

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