Utilization of Foundry Ash as Replacement to Fine Aggregate in Self Compacting Self-Curing Concrete

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Abstract— With improvement in technology, concrete had been endangered to various techniques and variation. In spite of these variations, it exhibits upright mechanical properties. Curing promotes hydration of cement, controls temperature and movement of moisture from and into the concrete. To continue hydration, the relative humidity inside the concrete should be 80%. Self-curing is the process in which the water is retained in the concrete and evaporation of water is also reduced. Self-compacting concrete (SCC) is a concrete that settles by its own weight, even in the presence of congested reinforcement with full compaction. It does not need any external vibrator to compact. In this project the performance of Self-Compacting Self-Curing Concrete (SCSCC) which consists of 25 to 100 % of foundry ash in place of river sand, BS-17 3P which is a liquid chloride free water reducing and super plasticizing admixture and self-curing compound of KEM Cure Aid 10 W. M 30 concrete mix is designed with different proportions of KEM Cure Aid 10 W from 0% to 2% by weight of cement. Fresh and hardened properties of Self-Compacting Concrete (SCC) and Self-Curing (SC) are studied in terms of flowability and workability, and Mechanical properties. The fresh properties of SCC are determined as per EFNARC.

Keywords: Compressive Strength, Flowability, Fly Ash, Foundry Ash, Self-Compaction Concrete

I. 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 sections 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 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”.

In Japan, the volume of SCC in construction has risen steadily over the years. Data indicate that the share of application of SCC in precast concrete industry is more than three times higher than that in the ready-mixed concrete industry. This is attributable to the higher cost of SCC. The estimated average price of SCC supplied by the RMC industry in Japan was 1.5 times that of the conventional concrete in the year 2002. Research studies in Japan are also promoting new types of applications with SCC, such as in lattice type structures, casting without pump, and tunnel linings.

Since the development of SCC in Japan, many organizations across the world have carried out research on properties of SCC. The Brite-Euram SCC project was set up to promote the use of SCC in some of the European countries. A state-of-the-art report on SCC was compiled by Skarendahl and Petersson summarizing the conclusions from the research studies sponsored by the Brite-Euram project on SCC. A recent initiative in Europe is the formation of the project – Testing SCC6– involving a number of institutes in research studies on various test methods for SCC. In addition, an organization with the participation from the speciality concrete product industry – EFNARC– has developed specifications and guidelines for the use of SCC that covers a number of topics, ranging from materials selection and mixture design to the significance of testing methods.

II. Literature Review

Rajendran et.al (2016) Studied on “self-curing concrete incorporated with polyethylene glycol”. The compressive strength of cube for Self-cured concrete is higher than of concrete cured by conventional curing method. The split tensile strength of self-cured concrete specimen is higher than that of the conventionally cured specimen. Self-cured concrete is found to have less water absorption values compared with concrete cured by other methods. Self-cured concrete thus has a fewer amount of porous.

Basil M Joseph (2016) Studied on self-curing concrete and PEG400 were used as a self-curing agent in concrete. M20 grade of concrete is adopted for investigation. The author added 0-1.5% of PEG400 by weight of cement for M20 grade concrete from that he found 1% of PEG400 by weight of cement was optimum for M20 grade of concrete for achieve good maximum strength. The author found that the percentage of PEG400 gets increased slump as well as compaction factor also get increased.

Shikha Tyagi (2016) Studied on self-curing concrete and had use PEG400 as a self-curing agent in concrete.M25 and M40 grade of concrete are adopted for investigation. The author added 1-2% of PEG400 by weight of cement for M25 and M40 grade concrete. The author was determining that the optimum dosage of PEG400 for maximum Compressive strength was to be 1% for M25 and 0.5% for M40 grades of concrete.

Madga et.al (2015) In their study water retention and durability of concrete with or without silica fume along with self-curing agents such polyethylene-glycol, and leca is investigated and compared to conventional concrete. The concrete mass loss and the volumetric water absorption were measured, to evaluate the water retention of the investigated concrete. significant improvement in all considered concrete properties due to the addition of 15% SF along with self-curing agents has been achieved, especially with 2% of Polyethylene-glycol which absolutely ensured the best results and good durability properties.

Deepak et.al (2016) presented an experimental investigation on the strength characteristics of Self-compacting concrete with mineral admixture named Fly ash. The several series of tests involving various binder combinations, water-binder ratio and high range water reducing admixtures and set retarding admixtures were used to optimize the mix proportions of SCC at different grades (M30, M35, M40, M45, M50). Various tests were carried out to study the characteristics of fresh concrete such as Slump flow, U-tube, V-funnel and L-box tests. For hardened concrete, various tests such as compressive strength, split tensile strength, and flexural strength at 7, 14 and 28 days were also investigated. The test results showed that the workability characteristics of SCC are within the limiting constraints of SCC and better strength parameters were obtained. It was observed that the self-compacting concrete gives a homogeneous and cohesive mix with marginal decrease in workability.

Karthick et.al (2016) conducted a study on Durability Properties of High Strength Self-Compacting Concrete using Fly Ash and Quarry Dust. In this study cement was replaced with Fly Ash at 20% and fine aggregate were replaced with quarry dust at 20% in M60 grade equivalent SCC. Fresh properties of concrete such as slump flow test, L-box test, V funnel test and mechanical properties such as compressive strength, split tensile strength and flexural strength were evaluated. Durability tests such as alkalinity test, water absorption test, acid attack test and chloride attack test were also evaluated. From this study it was observed that when partially replacing cement with 20% of Fly Ash and 20% fine aggregate with quarry dust show very good resistance to alkaline attack, acid attack, sulphate attack and chloride attack than conventional concrete.

Karamloo et.al (2016) had discussed the effects of water/cement ratio (w/c) on mechanical properties and fracture behavior of self-compacting lightweight concrete. For this purpose, four mix compositions with different w/c from 0.35 to 0.5 were prepared such that the nominal maximum aggregate size and weight of coarse and fine aggregates were kept constant. To determine the fracture parameters, twelve notched beam specimens were cast for each mix and the results were analyzed by means of the size effect method. The obtained results indicated that there is a remarkable relationship between the w/c, fracture behavior, and mechanical properties of the material.

Oladipupo et al. (2015) compared the rheological properties and compressive strengths of Self-Compacting Concrete (SCC) and conventional cement concrete. The flowability and segregation resistance of freshly mixed concrete specimens were examined by the V-funnel apparatus, while the characteristics of passing ability were investigated with the L-box apparatus. Cylindrical concrete specimens of 100 mm diameter × 200 mm length were investigated for compressive strength. The compressive strength results of hardened concrete showed that SCC gained strength slowly compared to the conventional cement concrete due to the presence of admixtures and its 28 days strength was lower than conventional cement concrete, but SCC eventually had potentials of higher strength beyond 90 days. Finally, the effect of water-cement ratio on the plastic properties of self-compacting concrete was quite negligible compared to conventional concrete.

Harini et.al (2015) conducted an experimental study on 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. Slump test, compressive strength test and flexural strength test were conducted to study the mechanical behavior of self-compacting concrete. From the experimental investigations, it was observed that there is an increase in the fresh properties and increase in the hardened properties for replacement of cement with silica fume. Similarly, there is an increase in the fresh properties and decrease in the hardened properties for replacement of cement with fly ash.

III. Experimental Procedure

A. Foundry Ash

Characteristics	Observed values
Water Absorption	1.79%
Bulk Density (Kg/m^3)	1442
Specific Gravity	2.62
Porosity	35.27%
Voids Ratio	0.60
Moisture Content	0.1 - 10

Table 1: Physical Properties of Cementitious materials.

Constituent	Percentage of Composition
SiO_2	87.62
Al_2O_3	4.86
Fe_2O_3	0.92
CaO	0.14
MgO	0.28
SO_3	0.08
Na_2O	0.20
K_2O	0.18
TiO_2	0.14
Mn_2O_3	0.01
SrO	0.04
Loss of Ignition	5.22

Table 2: Chemical Properties of Cementitious materials.

Mix no.	Cement (kg)	W/c ratio	Water binder ratio	% FAsh	F.A (Kg)	F Ash	C.A (Kg)
1	454	0.35	-	-	810		1242
2	454	0.42	0.38	25	810	607.5	1242
3	454	0.46	0.38	50	405	405	1242
4	454	0.52	0.38	75	607.5	202.5	1242

5	454	0.5 7	0.38	10 0	0	810	124 2

Table 3: Mix Proportion

IV. RESULTS

Mix No.	% of F Ash	SLUMP FLOW TEST (time in sec)		
		300 mm	500 mm	700 mm
1	25	0.5	1.8	10.94
2	50	1	1.5	12
3	75	0.5	1	5
4	100	0	1	2

Table 4: Slump flow test results (2.8% BS-17 3P w.r.to Binder)

Mix No.	% F ash	Slump Flow Test (in sec.)		
		300 mm	500 mm	700 mm
1	25	1	3	7.5
2	50	0.85	1	5
3	75	1	3	7
4	100	1	3	4

Table 5: Slump flow test result (2.8% BS-17 3P +KEM)

Mix no.	% F ash	L BOX TEST	J BOX TEST
		H_2/H_1	Time in sec.
1	0	0.872	8
2	25	0.78	11
3	50	0.96	8
4	75	0.95	8
5	100	0.87	16

Table 6: Flowability test results (2.8% BS-17 3P)

Mix no.	% F ash	L BOX TEST	J BOX TEST
		H_2/H_1	Time in sec.
1	0	0.88	8.6
2	25	1	9
3	50	0.9	9.8
4	75	0.92	10
5	100	0.96	9

Table 7: Flowability test results (2.4% & 2.2% BS-17 3P +KEM)

Mix no.	%F Ash	Compressive Strength (MPa)	
		14 Days	28 Days
1	0	29.00	38.43
2	25	30.66	39.45
3	50	28.59	32.34
4	75	26.05	30.90
5	100	22.00	28.53

Table 8: Compressive strength test results of cube (2.8% BS-17 3P)

Mix no.	%F ash	Compressive Strength (MPa)	
		14 Days	28 Days.
1	0	33.90	39.82
2	25	35.10	42.15
3	50	33.50	41.42
4	75	34.77	40.82
5	100	36.72	42.96

Table 9: Compressive strength test results of cube (2.4% & 2.2% BS-17 3P +KMW)

%F Ash	Time	
	W/B = 0.38	W/B=0.36
25	8	10
50	11	12
75	8	9.5
100	8	10.2

Table 10: V Funnel test results at BS-17 3P = 2.8%

% F ash	Time	
	W/B = 0.38	W/B=0.36
25	0.87	0.87
50	0.78	0.80
75	0.96	0.98
100	0.95	1.02

Table 4.11: L Box test results at BS-17 3P = 2.8%

% F Ash	BS-17 3P +KMW	
	2.4%	2.2%
25	0.86	9.82
50	0.87	9.80
75	0.90	9
100	0.97	10.8

Table 4.12: V Funnel test results at W/B =0.36

% F Ash	BS-17 3P +KMW	
	2.4%	2.2%
25	0.86	0.90
50	0.87	0.92
75	0.95	0.96
100	0.91	0.90

Table 13: L Box test results at W/B=0.36

Mix no.	% F Ashby wt. of binder	Split Tensile Strength of Cube (MPa) 28 Days	
		W/B = 0.38	W/B = 0.36
1	25	4	4
2	50	4.8	4.6
3	75	4.2	4
4	100	4.4	4.3

Table 14: 28 days Split Tensile strength test results @ W/B ratio

V. CONCLUSION & FUTURE SCOPE

A. *Conclusion*

On the basis of available information, general conclusions derived from experimentation for studying the effects of foundary ash on self-curing self-compacting concrete from the present study are stated. The new IS: 10262:2009 code preamble was used for mix proportioning of foundary ash induced SCSCC. The following conclusions are arrived at on the basis of present investigation.

1) Slight bleeding was observed in all the trial mixes which get reduced after using KMW.
2) Better cohesive mix was observed when water to binder ratio was 0.36 and dose of BS-17 3P was 2.2% by weight of cement
3) The effect of partially replacing cement with varying percentage of foundry ash enhances the cohesiveness of SCSCC mixes because of the oxide contents present in foundry ash. Further it can be concluded that for a given flowability, however smaller quantity of water is required in case of fly ashes with high fineness and low carbon content.

4) Compressive strength showed improved results when water to binder ratio was .36 and dose of BS-17 3P was 2.2% by weight of cement.
5) When foundry ash replacement with cement was 25 percent the compressive strength increased by about 7% as compared to 30% replacement of fly ash by weight of cement.
6) The compressive and split tensile strength increase is nominal at 50% replacement of foundry ash as compared to 25% replacement of foundary ash w.r.t fine aggregate i.e. the strength decreases by about 3%.

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