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IMPACT OF QUARRY DUST AND FLY ASH ON THE FRESH AND HARDENED PROPERTIES OF SELF COMPACTING CONCRETE

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Abstract-*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. The objective of this study is to investigate the influence of partial replacement of natural river sand by quarry dust in different percentages and to study the effect of replacement of cement by fly ash in the preparation of self compacting concrete. Mix design of SCC with various dosages of quarry dust and fly ash was done for diffent cementitious content and the effect on fresh and hardened properties was studied. SCC trial made with flyash addition at 20% as a partial replacement with cement has shows similar results as that of trial with no flyash addition. Flyash addition around 50% has shows extended (more than 24 hours) setting time of concrete and compressive strengths are not conforming to even M20 grade requirements for the trial made with 400 kg/m^3 of Cementitious content. In order to affect the advantage of flyash utilization there shall be a minimum of 30% flyash replacement for cement. Usage of quarry dust decreases workability and with the usage of admixtures the workability of the mix was well maintained.*

Key Words: Self compacting concrete, Quarry Dust, Fly Ash

1. INTRODUCTION

Self-compacting concrete (SCC) can be made with various combinations of materials. Hence it becomes necessary to freeze its constituents to focus on the investigations to few parameters. In this study Flyash is used as a pozzolanic material as a partial replacement to ordinary Portland cement. Both crushed and uncrushed (natural river sand) fine aggregates are used. Coarse aggregates of 20 mm maximum size (blending of 20 mm and 12.5 mm) are used. This study includes SCC proportioned with minimum powder content (Cementitious content materials) of 400 kg/m^3 without the use of Viscosity Modifying Agent (VMA). Pulverized Fuel Ash or fly ash conforming to IS 3812 (Part 1)-2003 is sourced from Raichur Thermal Power Station. Polycarboxylic Ether based superplasticiser conforming to IS 9103-1999 (Reaff.2008) is used to achieve SCC properties in fresh state.

2. PRELIMINARY EXPERIMENTAL WORK

A brief description of preliminary experimental work carried out is given below:

1. Ordinary Portland Cement (OPC) of 53 Grade conforming to IS 12269 and Fly ash conforming to IS 3812 (Part 1) are used during investigations. Three cementitious content per cubic meter of concrete considered were 400kg, 450kg and 500kg. In the first set of trials, the cement replacement was done with fly ash at 0%, 20%, 35% and 50% of total cement by weight.

2.Fine aggregates from following two sources conforming to Zone-II as per IS 383-1970 are used:
a) Natural River Sand (NRS)
b) Crushed Rock Fines (CRF)

3.Two sizes of Coarse aggregates one of maximum size 20 mm and the other of maximum size 12.5 mm conforming to IS 383-1970 (Reaf. 2007) from a Cone crusher.
4.Water conforming to requirements of IS 456-2000.
5.Polycarboxylic Ether (PCE) based superplasticiser conforming to IS 9103-1999.

Conventional mix proportioning method, i.e. absolute volume method was adopted in accordance with IS 10262 for arriving at mix proportions for SCC trials. **Twenty four (24)** trials were carried out with water paste (W/P) ratio ≤ 0.40 for the finalized mix proportions. As the total Cementitious content varied from 400 kg /m^3 to 500 kg /m^3, water content was also varied from 160 kg /m^3 to 185 kg /m^3.

The proportioned mix was batched, mixed and slump flow properties as per EFNARC specification viz. slump flow in millimeter and T_{50cm} slump flow in seconds were determined and then the mix was finalized. For this finalized mix the remaining fresh properties were determined.

Designations used in the following trials are, if for **4**

50 kg Cementitious content trial where cement is replaced by **F**ly ash **20** % by weight then the designation for that mix will **"450 F 20".** "450" represent the total Cementitious content material in kgs. "F" represents the Fly ash "20" represents the percentage of fly ash. In the second set of trials F.A. i.e. Natural River sand was replaced by 50% with Crushed Rock fines (Quarry dust) the trial were repeated as explained before. If dust is being used in the mix then the designation of the mix will be **"D 400 F 20".** Here the "D" represents the Crushed Stone Sand (Quarry **D**ust). Concrete cubes of 150 mm x150 mm x 150 mm size were cast to determine the compressive strengths at 7 days, 28 days and 56 days. The details of the trials carried out and results obtained are given in tables 1 to 6.

Table 1. Quantities and compressive strength at various ages for various replacements of flyash of 400 kg/m^3 Cementitious content with and without replacement of river sand by quarry dust

Details of Specimen	400F0	400F20	400F35	400F50	D400F 0	D400F 20	D400F 35	D400F50
Cement (kg/m^3)	400	320	260	200	400	320	260	200
Fly Ash (kg/m^3.)	0	80	140	200	0	80	140	200
Natural River Sand (kg/m^3.)	960	975	950	945	460	440	450	435
Crushed Stone Sand (kg/m^3)	-	-	-	-	460	440	450	435
Coarse Aggregate (kg/m^3.)	792.5	750	750	725	828	800	810	775
Water (lt.)	160	160	160	160	160	160	160	160
Water / Powder	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Admixture (PCE)	1.20%	1.10%	1.10%	1.00%	1.30%	1.25%	1.10%	1.00%
Slump Flow (mm)	670	680	695	700	670	695	680	680

T_{50cm} slump flow (sec.)	3	3	2.9	3.1	3.2	3	2.8	2.9
V-funnel (sec.)	10.2	10.1	8.5	8.2	8.5	8.3	8.9	8.5
L-box	0.85	0.85	0.9	0.85	0.8	0.75	0.85	0.85
7 day Compressive strength MPa	21.4	23.3	14.3	6.9	27.5	25.92	16.89	12.15
28 day MPa	38.6	35.8	31.7	19.1	41.9	38.2	32	25.4
56 days MPa	40.5	41.4	37	24.5	43.7	44.3	37	39.2

Table 2. Quantities and compressive strength at various ages for various replacements of flyash of 450kg/m³ Cementitious content with and without replacement of river sand by quarry dust

Details Test Parameters	**Mix Designation**							
	450F0	**450F20**	**450F35**	**450F50**	**D450F 0**	**D450F 20**	**D450F 35**	**D450F50**
Cement (kg/m³)	450	360	292.5	225	450	360	292.5	225
Fly Ash (kg/m³.)	0	90	157.5	225	0	90	157.5	225
Natural River Sand (kg/m³.)	1067	950	927	1030	486	470.25	463.5	461.5
Crushed Stone Sand (kg/m³)		-	-	-	486	470.25	463.5	461.5
Coarse Aggregate (kg/m³.)	720	832	841.5	680	706.5	697.5	684	670
Water (lt.)	175.5	175.5	175.5	171	171	171	171	171
Water / Powder	0.39	0.39	0.39	0.38	0.38	0.38	0.38	0.38
Admixture (PCE)	0.83%	0.7%	0.70%	0.60%	0.82%	0.65%	0.70%	0.65%
Slump Flow (mm)	665	680	670	690	670	695	710	720

T_{50cm} slump flow (sec.)	3.2	3	2.5	2.8	3.2	3	2.9	2.8
V-funnel (sec.)	10.2	10.5	10.5	10.4	8.5	8.3	8	7.9
L-box	0.85	0.85	0.8	0.8	0.8	0.75	0.85	0.8
7 day MPa	21.4	23.3	14.3	6.9	30.3	27.4	20.7	13.04
28 day MPa	**38.6**	**35.8**	**31.7**	**19.1**	**32.22**	**26.44**	**15.11**	**13.04**
56 days MPa	40.5	41.4	37	24.5	42.2	37.7	34	29.4

Table 3. Quantities and compressive strength at various ages for various replacements of flyash of 500 kg/m³ Cementitious content with and without replacement of river sand by quarry dust

Details Test Parameters	**Mix Designation**							
	500F0	**500F20**	**500F35**	**500F50**	**D500 F0**	**D500 F20**	**D500 F35**	**D500F 50**
Cement (kg/m³)	500	400	325	250	500	400	325	250
Fly Ash (kg/m³.)	0	100	175	250	0	100	175	250
Natural River Sand (kg/m³.)	656	650	641.6	640.6	312.5	312.5	305	297
Crushed Stone Sand (kg/m³)	-	-	-	-	312.5	312.5	305	297
Coarse Aggregate (kg/m³.)	734	725	718.8	705	734	725	720	703
Water (lt.)	185	185	185	185	185	185	185	185
Water / Powder	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
Admixture (PCE)	0.80%	0.80%	0.80%	0.70%	0.80%	0.80%	0.75%	0.75%
Slump Flow (mm)	670	675	690	700	720	710	710	2.4
T_{50cm} slump flow (sec.)	2.2	2.5	2.1	2	2.8	2.8	7.8	0.8
V-funnel (sec.)	8.5	8.2	8.3	8.5	8.1	8.3	720	2.3
L-box	0.8	0.85	0.8	0.8	0.8	0.8	7.8	0.8
7 day MPa	39.1	30.2	20.4	35.4	44.8	37.3	30.6	25.7
28 day MPa	**47.4**	**41.6**	**38.6**	**33.8**	**55.2**	**47.8**	**45.4**	**37.9**
56 days MPa	50.5	49.5	44.4	39	60.2	55.3	53.5	43.1

Properties of constituent materials of paste (Cement, Flyash, Water and PCE based admixture) used for investigations are determined and the details are given below:

Table 4. Physical properties of cement

Sl No	Test Conducted	Results	Requirements as per IS:12269-1987(RA 2008)
1	Normal consistency	27.1%	Not specified
2	Initial setting time	170 Minutes	Shall not be less than 30Minutes
3	Final setting time	345 Minutes	Shall not bemore than 600 Minutes
4	Compressive strength a) 72 ± 1h (average of three results) b) 168 ± 2h (average of three results) c) 672 ± 4h (average of three results	 43.0 MPa 53.0 MPa 68.5 Mpa	 Shall not be less than 27.0 MPa Shall not be less than 37.0 MPa Shall not be less than 53.0 MPa
5	Fineness (by Blaine's air permeability method)	344 m^2/kg	Shall not be less than 225 m^2/kg
6	Soundness (by Le-Chatelier's method)	0.5mm	Shall not be more than 10mm
7	Specific gravity	3.15	Not specified

Table 5. Chemical properties of cement

Sl No	Test Conducted	Results (%)	Requirements as per IS:12269-1987 (RA 2008)
1	Total Loss on Ignition	1.43	Not more than 4%
2	Insoluble Residue (% by mass)	1.25	Not more than 3%
3	Ratio of % of Lime to % of Silica, Alumina and Iron Oxide, when calculated by the formula:$CaO - 0.7SO_3$		Not greater than 1.02

	$2.8*SiO_2+1.2*Al_2O_3+0.65*Fe_2O_3$	0.88	And not less than 0.8
4	Ratio of % of Alumina to Iron Oxide	1.4	not less than 0.66
5	Total Sulphur content calculated as sulphuric anhydride (SO_3) (% by mass)	2.08	Not more than 2.5% for $C_3A \leq 5\%$ Not more than 2.5% for $C_3A > 5\%$
6	Magnesia (MgO), (% by mass)	1.14	Not more than 6%
7	Tricalcium aluminate (C3A), (% by mass)	8.12	-

Table 6. Physical properties of Fly ash

Sl No	Test Conducted	Results	Requirements as per IS:3812(Part 1) :2003 (RA 2007)
1	Specific Gravity	2.0	-
2	Fineness-Specific surface in m^2/kg by Blaine's Air-Permeability method, min.	348.0	320
3	Lime reactivity-Average Compressive Strength in N/mm^2,min	4.8	4.5
4	Comparative Compressive Strength at 28 days, percent,(Max)	86.0	Not less than 80% of the strength corresponding to plain cement mortar cubes
5	Soundness by Autoclave Test Expansion of Specimens, percent,(Max)	0.045	0.8
6	Residue on 45 micron sieve, percent,(max)	27.5	34

Table 7. Chemical analysis of fly ash

Sl No	Test Conducted	Results	Requirements as per IS:3812 (Part 1) :2003(RA 2007) Siliceous Pulverised Fuel Ash
1	Silicon dioxide (SiO_2) plus aluminium oxide (Al_2O_3) plus iron oxide (Fe_2O_3), percent by mass,(Minimum)	90.61	70.0%
2	Silicon dioxide(SiO_2), percent by mass,(Minimum)	58.83	35.0%
3	Magnesium oxide(MgO), percent by mass,(Maximum)	1.08	5.0%
4	Total sulphur as sulphur trioxide(SO_3), percent by mass,(Maximum)	0.16	3.0%
5	Loss on ignition, percent by mass,(Maximum)	0.32	5.0%

Table 8. Analysis of mixing water

Sl No	Particulars	Results	Stipulation of IS:456-2000 (RA 2005)(water for construction purpose)
1	Quantity of 0.02N NaOH required to neutralize 100ml of water sample using phenolphthalein as an indicator	2.30ml	Shall not be more than 5ml
2	Quantity of 0.02N H_2SO_4 required to neutralize 100ml of water sample using mixed indicator	24.90ml	Shall not be more than 25ml
3	Chlorides as Cl	346.00mg/l	500mg/l max. for RCC 2000mg/l max. for PCC
4	Sulphates as SO3	63.66mg/l	400mg/l max.
5	Inorganic solids	1400.00mg/l	3000mg/l max.
6	Suspended matter	467.00mg/l	2000mg/l max.
7	Organic Solids	116.75mg/l	200mg/l max.
8	Ph Value	6.98	Shall not be less than 6

Table 9. Uniformity Tests on PCE based Superplasticiser

Sl N0	Test Conducted	Results	Requirements as per Table 2 of IS:9103-1999 (RA 2008)
1	Ash Content(AC) (% by mass)	1.96	0.95T≤AC<1.05T T-manufacturer's stated value
2	Dry material content (DMC) (% by mass)	34.26	0.95T≤DMC<1.05T T-manufacturer's stated value
3	Chloride content (% by mass)	0.007	Within 10% of the value or within 0.2% whichever is greater as stated by the manufacturer
4	pH	6.8	Within ±1 of the value stated by the manufacturer
5	Relative Density	1.084	Within 0.02 of the value stated by the manufacturer

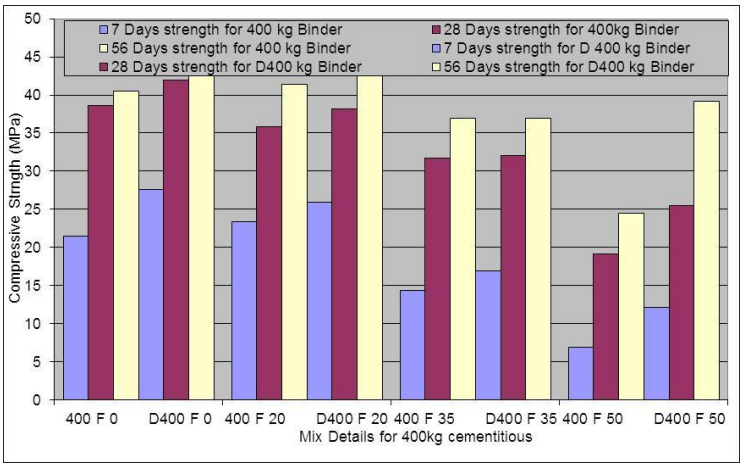

Fig. 1 Comparison Graph for 400 kg/m³ Cementitious content

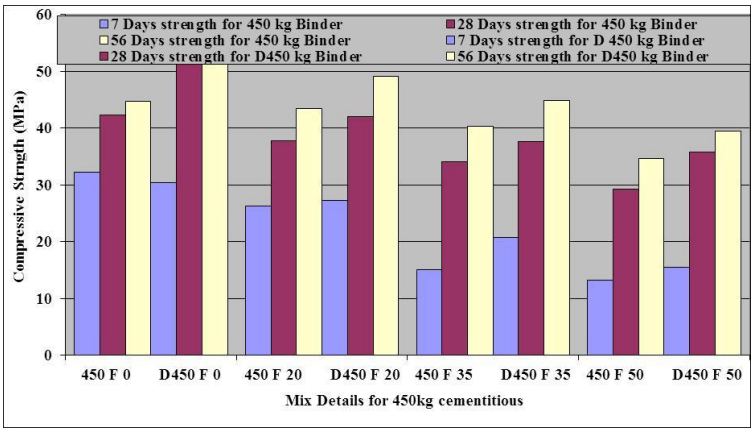

Fig.2 Comparison Graph for 450 kg/m³ Cementitious content

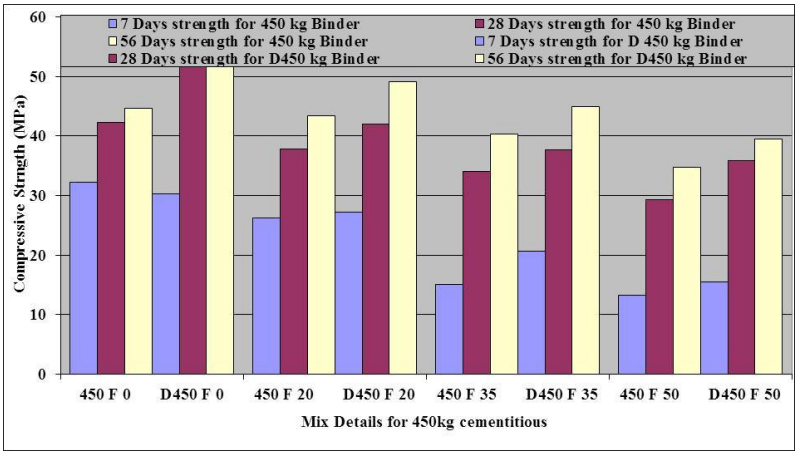

Fig. 3 Comparison Graph for 500 kg/m³ Cementitious content

3. CONCLUSIONS

From the results of the preliminary experimental work (a total of 24 trials) following conclusions are drawn:

- SCC trial made with flyash addition at 20% as a partial replacement with cement has shows similar results as that of trial with no flyash addition. Flyash addition around 50% has shows extended (more than 24 hours) setting time of concrete and compressive strengths are not conforming to even M20 grade requirements for the trial made with 400 kg/m³ of Cementitious content. In order to affect the advantage of flyash utilization there shall be a minimum of 30% flyash replacement for cement.
- Mixes with no flyash showed signs of bleeding and appeared to be less cohesive in comparison with mixes made with flyash.
- Flyash addition of 50% of the total cementitious content required a minimum powder content of 450 kg/m³ to achieve compressive strength corresponding to M 20 grade of concrete.
- SCC trials made with water contents of 160 kg/m³ required admixture dosage as high as 1.3% of Cementitious content which results in delayed setting of concrete. A water content of about 180 kg/m³ appears to be a reasonable value from the point of view of limiting the dosage of admixture and also achieving desired properties of SCC in fresh state.
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