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Research paper

Performance of Self-Compacting Concrete

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Abstract

Fly ash is the combustion product of coal transported with flue gas and collected in electrostatic precipitator. Micro silica (silica fume) is a product resulting from reduction of high purity quartz with coal in electric arc furnace in the manufacture of silicon.This paper presents the experimental study carried out to evaluate strength of self-compacting concrete in which cement was partially replaced with fly ash with constant amount of micro silica (50kg/m_3). Cement was replaced with six percentages (0%, 10%, 20%, 30%, 40%and 50%) of fly ash by weight. Tests were performed for fresh properties of concrete. Compressive strength, splitting- tensile strength, flexural strength, durability test (rapid chloride penetration test) and modulus of elasticity for 7, 28, 56 & 90 days. Test results indicated maximum flexural strength and compressive strength for 30% then strength decreased.

Keywords: *Concrete, fly ash, cementitious, micro silica, compressive strength, flexural strength, test moulds (TM).*

1. Introduction

Increasing number of power plants produces lots of harmful chemicals one among those is fly ash. Fly ash is the combustion product of coal transported with flue gas and collected in electrostatic precipitator. ASTM classified fly ash into two classes they are Class F and Class C. [1]

Wherein Class F have only pozzolanic property along with less than 5% CaO and Class F Class F have both pozzolanic and cementitous properties with CaO content more than 10%.Testing of fly ash is done as per IS: 1727-1967.

In fresh stateRight quality of fly ash shows reduction in water demand. As reduction in water would mean reduction in bleeding and drying shrinkage. Since fly ash is not highly reactive, replacement of cement in concrete would mean reduction in heat of hydration.

In hardened state Fly ash due to its pozzolanic property contributes to the strength of the concrete. The strength gained cannot be observed initially as the pozzolanic activity is slow and as the concrete gets aged it gains strength. Because of which the initial strength gain of concrete with fly ash is less than without fly ash. Even if fly ash is an industrial waste it provides long term strength and durability to the concrete.

Micro silica is also known as Silica Fume or Condensed Silica Fume. Its result obtained during reduction of high purity quartz with coal in an electrical arc furnace in manufacture of silicon or ferrosilicon. It creates dense packing and pore filling for cement paste.

When water is added to OPC hydration occur forming two products

OPC + H_2O gives CSH + Ca $(OH)_2$

In the presence of micro-silica, the silicon dioxide from the micro-silica will react with the calcium hydroxide to produce more aggregate binding CSH

Ca $(OH)_2$ + SiO_2 +H_2O givesCSH [2]

In fresh state its seen 20mm maximum size aggregate concrete containing 10%of micro silica will have an increased water by about 20liters/m^3. It decreases the slump flow because of its sticky nature. There would be reduction in bleeding and they can be transported easily.

In hardened stateit helps in easy gain of strength. Curing is important as micro silica concrete observes zero bleeding. Decrease the permeability and corrosion. Modulus of elasticity of micro silica concrete is less than that of concrete without it at the same level of compressive strength.

Self- compacting concrete (SCC) was developed by Professor Hajime Okamura of “Kochi University of Technology” at Japan in 1986. [3] During his research he found that the main cause of the poor durability performances was inadequate compacting of the concrete in the casting operations. Development of concrete that can self- compact, eliminated the poor durability. In 1988, the concept of self-compacting concrete was well developed and ready to use. Self-compacting concrete (SCC) has been described as "the most revolutionary development in concrete construction for several decades". [4]

When compared to normal concrete the amount of cementitious material is more in SCC but lower water to cementitious material ratios are to be maintained to achieve characteristics of flow and self-compaction. Most importantly SCC has higher amount of super plasticizers or sometimes viscosity modifying agents when compared to normal concrete.

Table I: Ordinary Portland cement

Sl no	Tests	Results
1	Specific surface (m^2/kg)	290
2	Normal Consistency (%)	30.00
3	Soundness by Le-Chatelier method(mm)	0.50
4	Soundness by Autoclave (%)	0.019
5	Initial setting time(Mins)	190
6	Final setting time (mins)	285
7	3days strength (MPa)	34
8	7days strength (MPa)	44
9	28days strength (MPa)	54

Table II: Physical Contetnts Of Fly Ash

Sl. no	Name	Results
1	Fineness	385 m^2/kg
2	Lime reactivity	5.0 N/mm^2
3	Compressive strength in percentage (28 days) Test sample Plain cement mortar cube	86 N/mm^2 23.2 N/mm^2 26.8 N/mm^2
4	Soundness	0.029

Table III: Chemical Contents Of Fly Ash

Sl.no	Percent by mass	Results
1	Silicon dioxide+ Aluminium oxide+ Iron oxide (min)	79.21
2	Silicon dioxide (min)	42.78
3	Magnesium oxide (max)	2.41
4	Total sulphur as sulphur trioxide (max)	1.41
5	Loss on ignition (max)	2.07
6	Alkalies as sodium oxide	3.41
7	Total Chlorides	0.007

2. Experimental Program

2.1 Materials

Cement properties as per IS: 12269:2013 given Table 1.Fly ash selected was as per IS: 3812:2013 given in Table 2 and Table 3. The coarse aggregate used in this investigation 12.5mm nominal size. Fine aggregate was crushed stone sand satisfying requirements as per IS 383:1970. To maintain flow workability available polycarboxylate based super plasticizer named Flowcon G 181 UL was used which conforms to IS: 9103-1999.

2.2 Mix Proportions

Micro silica content was kept constant which was $50kg/m^3$. Mix proportions 1:1.23:1.83.Six mixes casted where cement was replaced with 0%, 10%, 20%, 30%, 40% and 50% fly ash by mass respectively. All mixes had constant water dosage of 0.33. But dosage of super plasticizer varied from 0.9 to 0.6 percentage by weight of cement. Slump flow by Abrams cone was maintained between 750mm-780mm.

Table IV: Trial Mix Contents

Sl. no	Mix designation	Micro silica (Kg)	Cement (Kg)	Fly ash (Kg)	Admixture % bwoc
1	0%	50	500	0	0.9
2	10%	50	450	50	0.85
3	20%	50	400	100	0.80
4	30%	50	350	150	0.75
5	40%	50	300	200	0.70
6	50%	50	250	250	0.60

2.3 Specimens Preparation And Casting

150×150×150mm concrete cubes were cast for compressive strength, 150mm diameter × 300mm high cylinder specimen for splitting tensile strength. 100×100×500mm beam specimen for flexural strength as per IS: 516-1959. Durability test specimen cylinder of dimension Φ100mm and length 200mm.

2.4 Testing Procedure[5]

After the required period of curing specimens are taken out from curing tank and their surface were wiped off. The various tests performed were compressive strength test of cubes (150mm size), splitting tensile strength of cylinders (150mm×300mm) at 7& 28days and flexural strength of beams(100×100×500mm) at 7&28daysas per IS:516-1959.

The cylinder (100mm×200mm) were casted for rapid chloride penetration test which was done after 28days of curing specimen as per ASTM C 1202. [6]

3. Results and Discussions

3.1 Compressive Strength

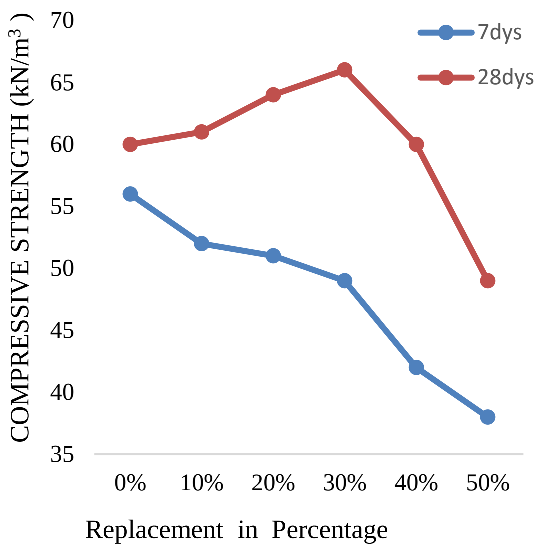

Figure 3.1: Compressive Strength Of 7 & 28 Days

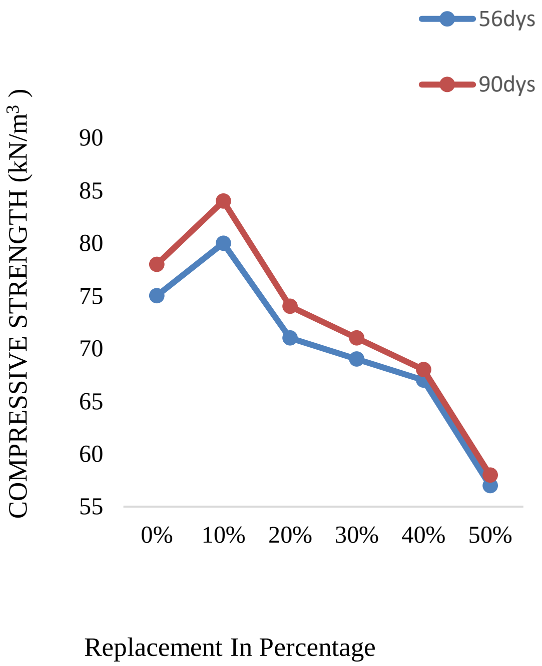

Figure 3.2: compressive strength of 56&90 days

Observations:

- In figure 3.1, 7 days strength of 0% replacement is more.
- In the same figure comparing both 7 and 28 days 30% replacement showed high strength.
- Comparing 56 and 90days strength 10% replacement showed highest strength gain.
- The outcome of compressive strength was up to 50% replacement the strength increased gradually as age of concrete increased.
- But only till 40% replacement the strength increased over the required mark (60MPa).

3.2 Split tensile Strength

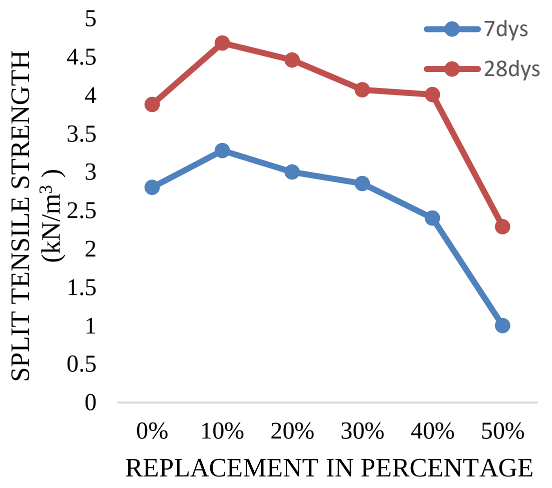

Figure 3.3: Split Tensile Strength

Splitting tensile strength is maximum for 10%. Other moulds showed decrease in strength.

3.3 Flexural Strength

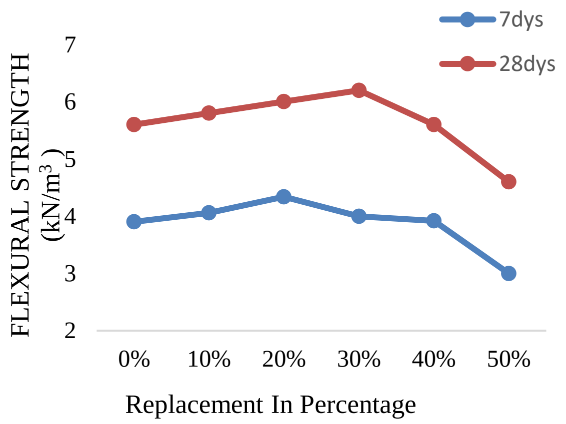

Figure 3.4: Flexural Strength Of 7 & 28 Days

Flexural strength was maximum for 30% replacement. Other moulds showed decrease in strength.

3.4 Rapid Chloride Penetration Test

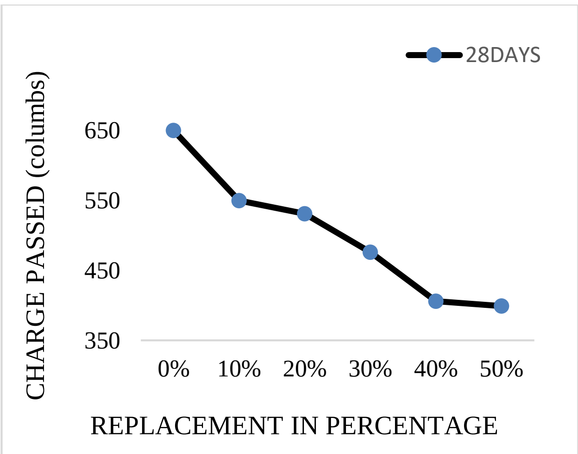

Figure3.2: Rcpt Test Results

Procedure: In this method amount of current passed through the three specimen (50mm thick). A current of 60V DC is passed. The specimen one half was immersed in sodium chloride solution which was the negative terminal of setup and other half was immersed sodium hydroxide which was positive terminal.
In data acquisition system initial settings regarding logging interval, logging period, date and time. RCPT apparatus is set to 60V DC current and readings are noted down or collected directly from computer.

Table V[6]: Rating Of Chloride Permeability Of Concrete According To The RCPT

Chloride permeability	Charge passing coulombs	Typical concrete type
high	>4000	High w-c ratio conventional PC concrete
Moderate	2000-4000	Moderate w-c ratio conventional PC concrete
Low	1000-2000	Low w-c ratio conventional PC concrete
Very low	100-1000	Latex-modified concrete, internally sealed concrete
Negligible	<100	Polymer-impregnated concrete, polymer concrete

Comparing obtained results with standards, it’s seen that the charge passing has decreased with increased percentage of replacement.

3.5 Measuring Volume Density

Density was measured using Buoyancy method.
Procedure: Volume of sample was determined by ratio of difference between weight in air and weight in water to 1000. Volume density is ratio of weight in air by volume.

Table VI: Volume Desity Results

Designation	Volume density (kg/m^3)
0%	2353
10%	2319
20%	2340
30%	2366
40%	2380
50%	2333

3.6 Modulus of Elasticity

Static modulus of elasticity as $5000\times\sqrt{f_{ck}}$(IS456:2000) (theoretical calculation)

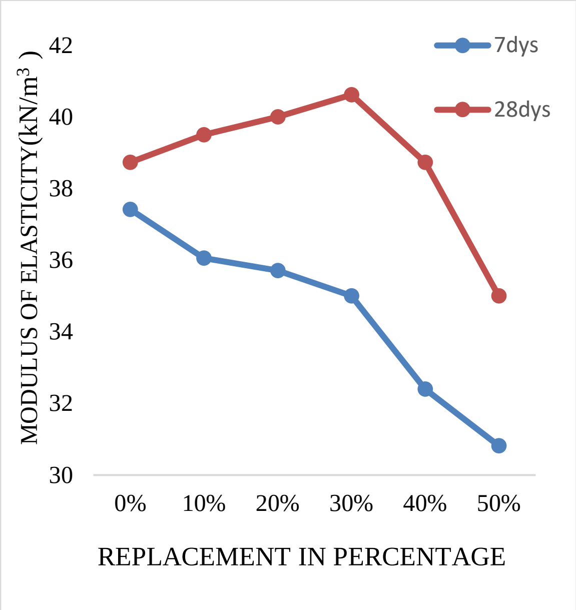

Figure 3: Static Modulus of Elasticity

4. Conclusions

- Compressive strength was maximum for 30% replacement of fly ash until 28 days test. During 90days testing 10% showed higher resistance to compression, due to the pozzolanic reaction between silica fume and free calcium hydroxide .
- Flexural strength was maximum for 30% replacement, due to interaction between fly ash and calcium hydroxide.
- Splitting tensile strength is maximum for 10% replacement of cement by fly ash.As compared with nominal mix its high due to combination of silica fume and fly ash.
- Rapid chloride penetration test showed decrease in penetration with increasing percentage of replacement. Which was due to silica fume as it has good pore filling capacity.

5. Future Scope

- Micro silica content can be varied.
- Cement content can be increased.
- Super plasticizer dosage can be kept constant.

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