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Effect of Blended Fly Ash on the Compressive Strength of Cement Paste

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Abstract

In this paper, the effect of fly ash percentage of different fields or hoppers on the compressive strength of cement paste with and without superplasticizer has been studied. The accelerated pozzolanic activity of fly ash of each field and their blending has been evaluated with and without superplasticizer. The pozzolanic activity increases from field I to V as expected, the noticeable observation is that with the use of superplasticizer, the pozzolanic activity of the first field is comparable to control value of 340 kg/cm^2. Further, the pozzolanic activity of blended fly ash of first field with fly ash of other fields, the pozzolanic reactivity is comparable to control value. In case of 50-50 blending of first field and second field fly ash the pozzolanic activity is approx 7% more than control.

Keywords: fly ash; hopper; pozzolanic activity; compressive strength.

1. Introduction

Fly ashes are the major combustion residues produced during the combustion of pulverized coal in thermoelectric power stations and collected by the cleaning equipment of flue emissions (commonly electrostatic precipitators). Fly ash collected from each hopper in the ESP system are transported and stored in the silo. It is known that the properties of fly ashes collected from each hopper in an ESP system varies as we move from the boiler [1-5]. The hopper which is farthest from the boiler have finer particle size, greater density, lower carbon content, and higher glass content [6-8].

There is no great difference in the chemical composition of fly ash of different hoppers. Therefore, in ESP systems the hopper itself is expected to have the effect of classifying fly ashes. However, fly ash of different fields when added to cement will affect the particle size distribution of fly ash – cement system by way of packing densities of the pastes so that the retention water of the pastes varies. Thus it is expected that the fluidity of pastes will change [9-11].

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This paper reports the effect of fly ash collected from different fields with different percentages on the compressive strength of cement paste. Further, effect of first field fly ash when blended with different fields on the accelerated pozzolanic activity strength has also been determined.

2. Materials

Cement: Ordinary Portland cement 43 grade (OPC) conforming to BIS 8112(2005).

Fly ash: The fly ash of different hoppers H-1to H-5 or (fields I-V)) was obtained from a National Thermal Power Station, New Delhi.

Superplasticizer: Sulphonated Naphthalene Formaldehyde Condensate (SNF) conforming to BIS 9103 (2004) was used in the present study.

3. Experimental Procedures

3.1. Particle Size Analysis

The particle size analysis of fly ash sample of various hoppers was determined using Malvern laser particle size analyzer.

3.2. Accelerated pozzolanic activity

The pozzolanic activity of fly ash of each hopper and blending of first field fly ash with remaining hoppers is determined as given below:

3.3. Control Mixture

The control mixture was prepared with 250 gm of portland cement with 687.5gm of graded sand and 121 ml of water.

3.4. Test mixture

The test mixture was prepared with 225 gm of cement and 25 gm of pozzolana (Fly ash from 1-5 fields, blended fly ash field I (90%) plus 10% with 2-5 fields, Field I (50%) plus 50% with 2-5 fields and field I 70%, plus 30% with 2-5 fields) respectively. The above set of experiments was repeated with 1.0% superplasticizer.

3.5. Mixing Procedure

The mortar mixes were prepared using ELE (UK) Automatic Mortar mixer. 50 mm cubes were cast for the present study.

3.6. Storage of Specimens

After 24 hours of initial curing in a moist room($25 \pm 2^{\circ}C$) with relative humidity not less show 95%.The cubes were placed in a air tight glass containers and stored at $65 \pm 2^{\circ}C$ for 6 days.

3.7. Determination of Compressive Strength

The compressive strength of mortar cubes after 7 days of domoulding of control and test mixture was determined and average of the three samples.

3.8. Paste Studies

Cement cubes of 25mm were cast with various percentages (10, 30 and 50%) of fly ash of different fields with and without superplasticizer at the same consistency level. The compressive strength of these cubes was determined at different time interval of 1,3,7,28,90 and 360 days.

4. Results and discussions

4.1. Characteristic of fly ash

The physical and chemical properties of fly ash and cement are summarized in Tables (1-4). The fineness of the first field is 2850 cm^2/g, which is lower that of Portland cement. The fineness of the fly ash increases from first field to field 5 and also the specific gravity. The surface area of the field 5 fly ash is 4950 cm^2 indicating fine fly ash portion and specific gravity 2.24. The significant difference in the specific gravity of fly ash of different fineness values is mainly due to the incomplete burning of the larger particles and hence the difference in the physical and chemical properties.

TABLE 1: PHYSICAL CHARACTERISTICS OF FLY ASH SAMPLE OF DIFFERENT FIELDS

S.NO	***Sample Details***	***LOI***	***Specific Gravity***	***Surface Area (m^2/kg)***
1	Fly Ash Hopper-I	1.32	2.05	285.0
2	Fly Ash Hopper-II	0.75	2.10	340.0
3	Fly Ash Hopper-III	0.70	2.16	387.0
4	Fly Ash Hopper-IV	0.67	2.20	440.0
5	Fly Ash Hopper-V	0.64	2.24	495.0

TABLE 2: CHEMICAL CHARACTERISTICS OF FLY ASH OF DIFFERENT FIELDS

S.NO	**Sample Details**	**SiO_2**	**R_2O_3**	**CaO**	**SO_3**
1	Fly Ash Hopper-I	60.24	28.02	3.10	1.35
2	Fly Ash Hopper-II	60.8	28.10	3.0	1.25
3	Fly Ash Hopper-III	61.07	28.22	3.50	1.07
4	Fly Ash Hopper-IV	62.0	29.55	3.25	1.15
5	Fly Ash Hopper-V	62.5	30.12	3.20	1.18

TABLE 3: PARTICLE SIZE DISTRIBUTION OF FLY ASH PARTICLES OF DIFFERENT FIELDS PARTICLES FINER THAN (μm)

Sample Details	20.1(μm)	11.1(μm)	7.2(μm)	5.3(μm)	3.4(μm)
Field I	49.5	49.5	5.3	1.2	0
Field II	94.8	94.8	24.7	3.1	0
Field III	100	97.9	30.7	3.0	0

Field IV	100	98.7	61.7	26.8	17.7
Field V	100	100	88.1	28.0	18.7

TABLE 4: PHYSICAL AND CHEMICAL PROPERTIES OF PORTLAND CEMENT

Compressive Strength		**BIS 8112-2005**
3 Day	260 kg/cm^2	$\nless$ 230 kg/cm^2
7Day	370 Kg/cm^2	$\nless$ 330 kg/cm^2
28Day	450 kg/cm^2	$\nless$ 430 kg/cm^2
Fineness	334m^2/kg	$\nless$ 300 m^2/kg
Setting Time		
Initial	185 minutes	$\nless$ 30 minutes
Final	230 minutes	$\ngtr$ 600 minutes
Insoluble Residue	1.2	
Magnesia	3.2	
Alkalies	0.40	
SO_3	2.5	
Silica Content	20.5	
CaO	60.5	

The chemical analysis of fly ash and Portland cement are given in Tables (2-4). The total amount of oxides (Fe_2O_3 and Alkali) which has the effect on the melting temperature of the ash increases as one move from first field to field 5. Similarly LOI decreases from field 1 to field 5. Effect on physical and chemical properties of fly ash with fineness has been reported [4-5]. It has been observed that in case of class Fly fly ash there is no appreciable change in the mineralogical analysis and as such change in strength is mainly due to the particle difference between the size fractions used. Further, the specific gravity of the fly ashes is expected to increase from the standpoint of the mass proportion because the finer particles are, more likely the glass content of low specific gravity will increase.

Pozzolanic activity of pozzolanic material has been determined by several methods [12-13]. In the present study method based on compressive strength has been used to evaluate pozzolanic activity.

Table (5) gives the pozzolanic activity of fly ash of field I-5 with and without superplasticizer. In both the cases the pozzolanic activity increases as we move from field I to field 5. It is also clean from the Table (1) that the surface area of fly ash increases as we move from fields I to 5. The fineness of fly ash is one of the most important properties affecting pozzolanic activity. Watt and Thorne [14-15] have suggested that fly ash with larger median particle size are more reactive than expected from model. This was related to the spongy form of larger particles. The microscopic observation confirmed that the larger particle becomes perforated during reaction with lime. Further field IV pozzolanic activity is comparable to control activity in both the cases. However, the noticeable point is that with the use of superplasticizer, the field I pozzolanic activity (340 kg/cm^2) is same as control. Thus with the use of superplasticizer it is possible to enhance the first field fly ash activity, which is normally not used in concrete.

TABLE 5: POZZOLANIC ACTIVITY INDEX OF FLY ASH OF DIFFERENT FIELDS WITH AND WITHOUT SUPERPLASTICIZER.

System	**(Without Superplasticizer) c.s (kg/cm^2)**	**(With Superplasticizer)* c.s (kg/cm^2)**
Control	340.0	420.0
Field I	296.0	340.0
Field II	310.0	360.0
Field III	325.0	400.0
Field IV	356.0	415.0
Field V	376.0	425.0

* **1% of Superplasticizer by weight of cement was used**

Table (6) gives the pozzolanic activity of blended fly ash (first field with fly ash of other fields). It is clear from the Table 6 that blending of first field fly ash (90% with 10% and 70% with 30% second field fly ash, the pozzolanic reactivity is comparable to control value of (340 kg/cm^2). Where as in case of 50-50 blending of first field and second field fly ash the pozzolanic activity in approx 7% more than control. It has been observed that fly ash particles with larger medium particle size are more reactive than expected. This is based on the theoretical model developed by Watt and Thorne [14-16] where authors have studied the rate of degree of reaction of fly ash with lime and the fineness of the fly ash. The results were compared with calculated values and those with obtained experimentally.

In the present studies the particles of first field and second field are mostly between 7.2 and 11.1 μm. The same is true for third field also, but the quantity of fly ash collected in third ESP is less and commercially not possible to blend with first field for regular use in cement/concrete. This blending allows saving cost of superplasticizer. The pozzolanic activity of blended fly ash with superplasticizer in more compares to control mix. Thus depending upon the quantity of fly ash collected from higher fields, these can be blended according to requirement.

The results of the compressive strength of cement paste with different percentages (10, 30 and 50%) of fly ash of fields I-V with and without superplasticizer up to 360 days are given in Fig.1-6.

It is clear from the Fig. 1-2 that the compressive strength of cement paste increases from field I to field V. Since the fineness of fly ash increases from field I to field V, this indicates that the fine fly ash is very reactive and has larger influence on the strength even though the water/binder ratio (w/b) of field V is 0.305 compare to control 0.30 with maximum for field II (0.32) for 10% replacement of fly ash. However with increase in fly ash content the effect on w/b ratio has been observed with 0.39 w/b ratio for first field fly ash as compare to 0.302 for field V fly ash when 50% fly ash from first field is blended with fly ash of remaining fields.

TABLE 6: POZZOLANIC ACTIVITY INDEX OF BLENDED FLY ASH OF DIFFERENT FIELDS WITH AND WITHOUT SUPERPLASTICIZER

System	**W/C Ratio**	**Without SP c.s (kg/cm^2)**	**W/C Ratio**	**With SP* C. S. (kg/cm^2)**

Control	0.30	340.0	0.26	420.0
Field I+Field II (90%+10%)	0.32	320.0	0.28	350.0
Field I+Field III (90%+10%)	0.32	325.0	0.27	360.0
Field I+Field IV (90%+10%)	0.31	325.0	0.26	360.0
Field I+Field V (90%+10%)	0.31	328.0	0.26	365.0
Field I+Field II (70%+30%)	0.33	330.0	0.29	380.0
Field I+Field III (70%+30%)	0.32	340.0	0.28	390.0
Field I+Field IV (70%+30%)	0.32	350.0	0.27	395.0
Field I+Field V (70%+30%)	0.31	355.0	0.25	402.0
Field I+Field II (50%+50%)	0.39	360.0	0.35	390.0
Field I+Field III (50%+50%)	0.36	400.0	0.30	430.0
Field I+Field IV(50%+50%)	0.33	440.0	0.27	440.0
Field I+Field V (50%+50%)	0.31	415.0	0.26	460.0

*1% of Superplasticizer(SP) by weight of cement was used

Figs. (1-2) gives strength data of cement paste with 10% fly ash of different fields with and without superplasticizer up to 360 days. The high pozzolanic activity of fly ash of fields III-V the strength is 10-15% more at one day. The trend is similar up to one year. However, for Field I & II the strength is slightly less compare to control up-to 7days but beyond that it is comparable to control. With the use of superplasticizer the 1 & 3 day strength is more than the control without superplasticizer and the gain in strength is observed up to one year.

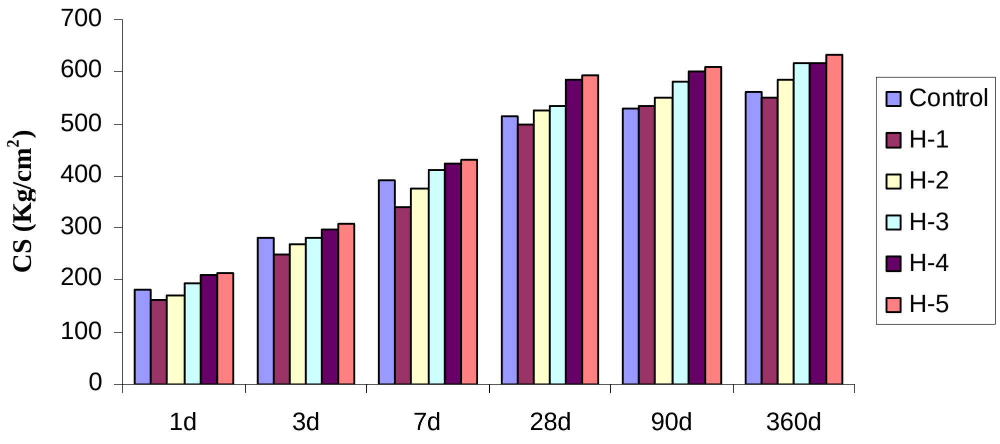

Figure 1. Compressive Strength of Cement Paste with Fly Ash (10%) of different Fields.

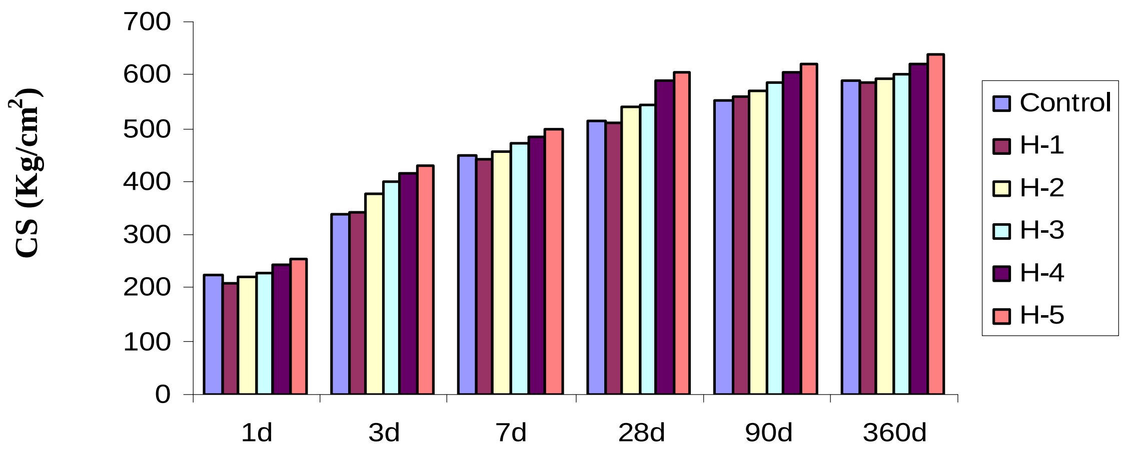

Figure 2. Compressive Strength of Cement Paste with Fly Ash (10%) of Different Fields with Superplasticizer.

The results of 30% replacement of fly ash of different fields are given in Figs. (3-4). Compressive strength of cement paste without superplasticizer exhibits lower values for field I & II upto 360 days. However in case of field III-V strength at 90 days are comparable to control and higher at 360 days. Lower strength in case of field I&II can be one due to higher w/b ratio 0.33 against 0.3 for control and coarser compare to fields III-V. With the use of superplasticizer field I & II show comparable strength at 360 days and fields III-V show comparable strength at 28 days and at 90 and 360 days the strength is approx. 10% higher than control. This gain in strength is due to reduction in w/b ratio from 0.285 to 0.24 as we move from field I to V. The control value of w/b ratio is 0.3 when no superplasticizer is used.

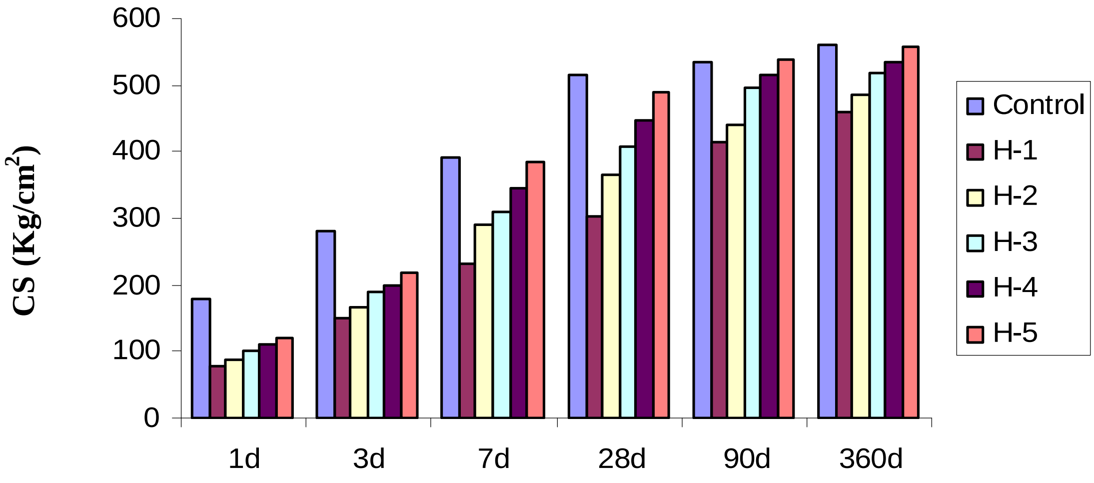

Figure 3. Compressive Strength of Cement Paste with Fly Ash (30%) of Different Fields.

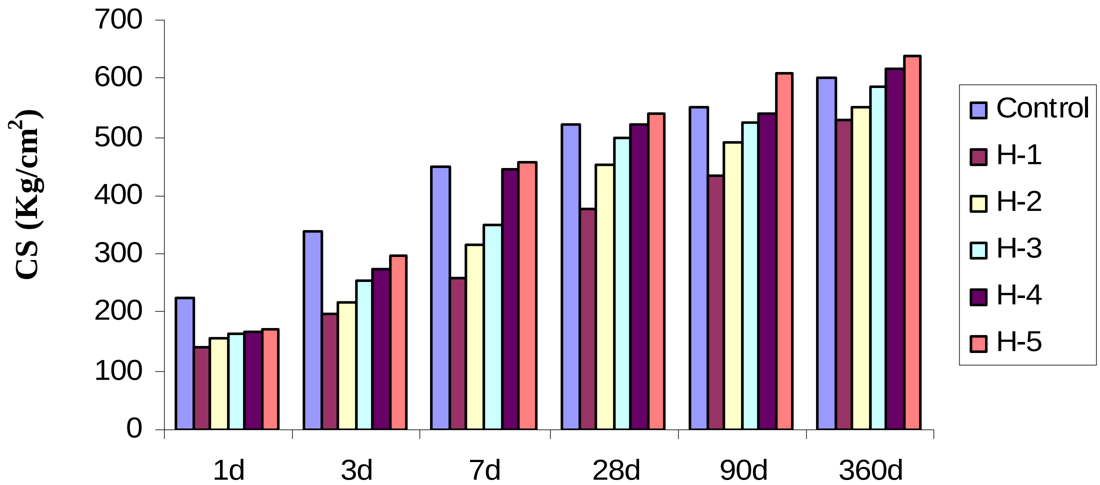

Figure 4. Compressive Strength of Cement Paste with Fly Ash 30% of Different Fields with Superplasticizer

The strength data of 50% replacement of fly ash is given in Figs. (5-6). The strength is less compare to control up to 28 days with and without superplasticizer for fly ash of different fields. At 90 days compressive strength for field IV and V is comparable to control when superplasticizer has been used. Beyond 90 days the compressive strength is either equivalent or more compare to control for field II-V. The drop in strength is attributed to higher w/b ratio. Even for field III the w/b ratio is 0.33 compare to 0.3 for control. The use of fine fly ash also has a packing effect and the filling of the small voids and this helps in the strength development [17].

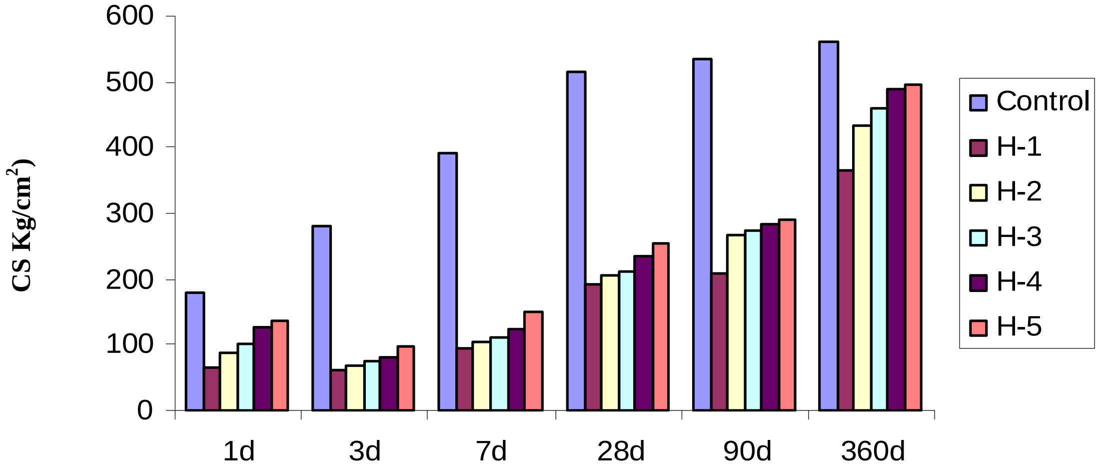

Figure 5. Compressive Strength of Cement Paste with Fly Ash (50%) of Different Fields.

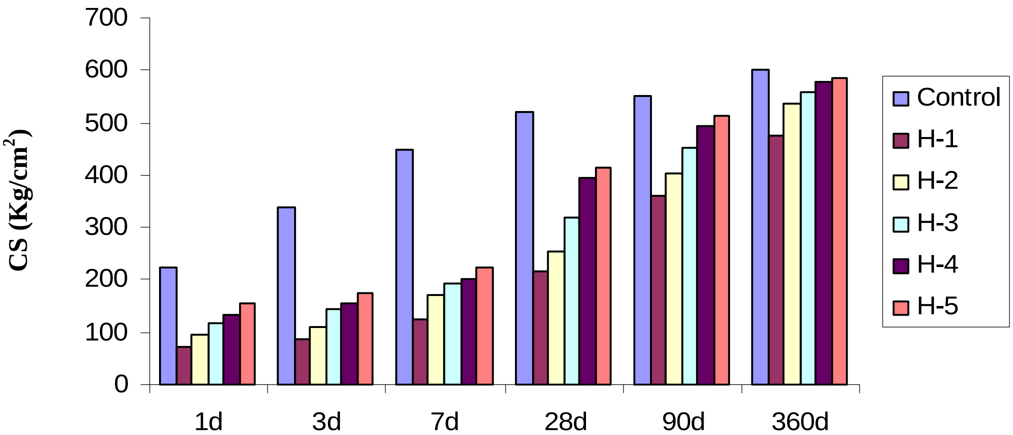

Figure 6. Compressive Strength of Cement Paste with Fly Ash (50%) of Different Fields with Superplasticizer.

5. Conclusions

From this study the following conclusions can be drawn:

1. Pozzolanic activity of fly ash of field I-III is less than control.
2. Pozzolanic activity of field IV and V is 5 and 10% more than control.
3. Pozzolanic activity of first field fly ash with 1% superplasticizer is comparable to control value. Also field II-III has more value compare to control in the presence of superplasticizer.
4. Blending of first field fly ash (90%, 70% as 50%) with remaining field has comparable pozzolanic activity to control. However, with superplasticizer blending of fly ash has more pozzolanic activity.
5. It is clear from the present study, if blending of first field fly ash which accounts for 70% of the total fly ash generated is blended with second field (50% each); the pozzolanic activity is comparable to control.
6. With 30% replacement of cement with fly ash the compressive strength of cement paste from field I to V is comparable to control in case of field I, where as for fields II-V, the strength is more at 360 days in the presence of superplasticizer. However compressive strength of cement paste with 50% replacement for fields II-V in the presence of superplasticizer beyond 90 days is either comparable or more than control.
7. Test results indicate that fly ash of different fields have noticeable effect on the compressive strength due to different fineness. The fine fly ash (field III-V) with high surface area is more reactive and thus results in increase in strength.

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