Correlation between Fineness and Compressive Strength of Flyash Collected from Different Sources for Partial Replacement of Cement in Mortar

Pankaj Joshi[1] Raj Kumar[2] Rajeev Kumar[3]
Scientist B[1] Scientist C[2] Scientist E[3]
[1,2,3]Central Soil & Materials Research Station Olof Palme Marg, HauzKhas, New Delhi – 110016, India

Abstract— Today construction engineers all over the world are looking for an alternative to replace cement as a binding material in concrete by a material which would have good binding properties, easily available, reduce the overall cost of production, and at the same time would be environmental friendly. In modern construction industry, fly ash is an excellent alternative to meet all such required properties and has been widely accepted. In view of global warming, every effort is being made to reduce the emission of CO2 to the environment. Cement manufacturing industries are major contributor in the emission of CO2 as for every one ton of cement manufactured; one ton of carbon dioxide is released. By replacing cement with a material of pozzolanic characteristic, such as the fly ash, the cement and concrete industry together can meet the growing demand in the construction industry as well as help in reducing the environmental pollution. A concrete mix with fly ash can also provide economic benefits. Fly Ash concrete enhances the workability, compressive strength, flexural strength and also increases its pump ability, durability and concrete finishing. The fly ash used in concrete industry by partly replacement it with cement and also in embankment for filling the material. Leaving the waste materials to the environment directly can cause environmental problem. Hence the reuse of waste material has been emphasized. These industrial wastes are dumped in the nearby land and the natural fertility of the soil is spoiled. Flyash can be used as a partial replacement of cement in concrete without compromising in strength. Replacing cement with fly ash can reduce the heat of hydration of concrete. This reduction in the heat of hydration does not sacrifice long-term strength gain or durability. The reduced heat of hydration lessens heat rise problems in mass concrete placements. Comparison and correlation between fineness of flyash and compressive strength of flyash cement mortar is presented in this paper.

Keywords: Flyash, Fineness, CSH Gel, Compressive Strength, Pozzolana

I. INTRODUCTION

Past research shows that adding fly ash to concrete, as a partial replacement of cement, will benefit both the fresh and hardened states. While in the fresh state, the fly ash improves workability. This is due to the smooth, spherical shape of the fly ash particle. The tiny spheres act as a form of ball bearing that aids the flow of the concrete. This improved workability allows for lower water-to-cement ratios, which later leads to higher compressive strengths. In the hardened state, fly ash contributes in a number of ways, including strength and durability. While fly ash tends to increase the setting time of the concrete, the pozzolanic reaction removing the excess calcium hydroxide, produced by the cement reaction and forms a harder CSH.

One of the primary benefits of fly ash is its reaction with available lime and alkali in concrete, producing additional cementitious compounds. The following equations illustrate the pozzolanic reaction of fly ash with lime to produce additional calcium silicate hydrate (C-S-H) binder:

Cement Reaction : $C_3S/\ C_2S+H$ C-S-H + $Ca(OH)_2$ (Lime)

Pozzolanic Reaction : $Ca(OH)_2$ + S $\rightarrow$ C-S-H

S —- Silica from Fly ash constituents

Above reactions indicate that during the hydration process of cement, lime is released out and remains as surplus in the hydrated cement. This leached out surplus lime renders deleterious effect to concrete such as make the concrete porous, give chance to the development of micro- cracks, weakening the bond with aggregates and thus affect the durability of concrete. If fly ash is available in the mix, this surplus lime becomes the source for pozzolanic reaction with fly ash and forms additional C-S-H gel having similar binding properties in the concrete as those produced by hydration of cement paste. The reaction of fly ash with surplus lime continues as long as lime is present in the pores of liquid cement paste. The process can also be understood as follows:

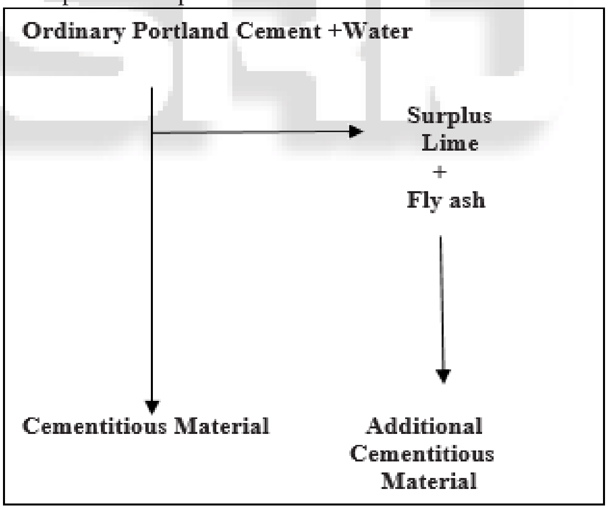

Fig. 1: Flow diagram of Pozzolanic reaction

The physical and chemical properties of flyash effect above flyash and lime reaction. Laboratory investigations for physical and chemical properties were carried out on flyash as per IS: 1727 (Reaffirmed in 2004) and compliance with IS: 3812-Part 1 ("Pulverized fuel ash- specification Part-I for use as a pozzolana in cement, mortar and concrete")

This paper shows inter relation between two physical tests results (i.e. fineness of flyash by blains air permeability method and compressive strength of flyash cement mortar when use as a partial replacement of cement in cement mortar cubes) on different flyash samples collected from different resources in India.

II. METHODOLOGY & EXPERIMENTAL PROGRAM

Five no. of samples taken from different thermal plants in India .Following Physical tests conducted on these flyash samples as per IS: 1727 (Reaffirmed in 2004) and compliance with IS: 3812-Part 1 ("Pulverized fuel ash-specification Part-I for use as a pozzolana in cement, mortar and concrete")

- Specific gravity
- Wet sieving (retained on 45 micron)
- Fineness by blains permeability apparatus
- Compressive strength with partial replacement of cement by fly ash.
- Lime reactivity test

In this paper we discussed two test data (i.e. fineness by blains air permeability method & Compressive strength with partial replacement of cement by fly ash) and their results are compared and a correlation is developed between them.

A. *Properties of Ingredients used*

Properties of concrete or mortar are significantly influenced by the basic properties of constituent materials. Therefore, the preliminary properties of ordinary Portland cement, Flyash and water evaluated accordingly to relevant codes. Standard sand as per IS: 650-1966*.is used for casting.

1) *OPC Cement 43 grade*

OPC cement sample has been tested for physical and chemical properties and results are shown below:

S. No	Test Conducted	CSM Lab. No. C-8/2018	Requirements as per IS: 269-2015
1	Normal Consistency	32.0 %	Not Specified
2	Specific Gravity	3.10	Not Specified
3	Soundness (by Le-chatelier)	2.0 mm	Expansion shall not be more than 10 mm
4	Fineness (By Blaine's)	330.0 m^2/kg	Shall not be less than 225.0 m^2/kg
5	Initial setting time, (Minutes)	90	Shall not be less than 30 minutes
	Final setting time, (Minutes)	180	Shall not be more than 600 minutes
6	Compressive strength(Mpa) 3 days 7 days 28 days	 24.34 36.70 52.24	Shall not be less than 23.0 33.0 43.0

Table 1: Physical test result

Sl. No.	Parameters determined	CSM Lab. No. C-8/2018	Requirement as per IS:269 (2015)
1	Loss on Ignition, % by wt.	3.14	5%
2	Silica +IR, % by wt.	21.35	
3	Insoluble residue, % by wt.	2.45	4%
4	Fe as Fe_2O_3, % by wt.	4.15	
5	Al as Al_2O_3, % by wt.	7.56	
6	Calcium Oxide (as CaO), % by wt.	58.75	
7	Magnesium Oxide (as MgO), % by wt.	1.38	
8	Total Sulphur content as Sulphuric anhydride (SO_3), % by wt.	1.72	6.0%
9	Na as Na_2O, % by wt.	0.24	3.5%
10	K as Na_2O, % by wt.	0.16	
11	Total alkali (as Na_2O), % by wt.	0.40	
12	Ratio of percentage of alumina to that of iron oxide	1.82	0.5%
13	Ratio of percentage of lime to percentage of silica, alumina and iron oxide, when calculated by the formula: $\frac{(CaO - 0.7SO_3)}{(2.8SiO_2 + 1.2Al_2O_3 + 0.65 Fe_2O_3)}$	0.88	0.66-1.02
14.	Chloride, % by wt.	0.016	0.1

Table 2: Chemical Test Result

2) *Standard sand*

The standard sand to be used in the test shall conform to IS: 650-1966. Standard sand comprises of 3 fractions of equal percentage: Size less than 2 mm and greater than 1 mm is 33.33%, Size less than 1 mm and greater than 500 µ is 33.33% and Size less than 500 mm and greater than 90 µ is 33.33%.

3) *Water*

4) *Fresh potable water free from organic matter and oil was used for mixing. Required quantities of water were measured in graduated jar and added for mixing. Water used for mixing and curing was tested as per IS: 3025-1964 and IS: 456-2000.*

Flyash

Fly ash is composed of the non-combustible mineral portion of coal. Particles are smooth, round ball bearings finer than cement particles. Sizes of particle are 0.1Gm-150 Gm. It is a pozzolanic material which reacts with free lime in the presence of water, converted into calcium silicate hydrate (C-S-H) which is the strongest and tough portion of the paste in concrete. The fly ash is collected as a waste from various thermal power stations in India.

B. Procedure Adopted

Compressive strength has been determined using flyash cement mortar cubes of size 50x50x50 mm as per the procedure given in IS: 1727 – 1967 (Reaffirmed 1999). Mix proportion has been taken as 0.2 N: 0.8: 3 (Flyash (N): cement: Sand) where N is the ratio of specific gravity of flyash and cement. Quantity of water required for casting was determined by Flow table test. Compressive strength after 28th day was tested in compression testing machine.

Fineness is calculated in terms of m^2/kg using blains air permeability method.

III. RESULTS & DISCUSSION

Fineness and Compressive strength test results of five no. of flyash samples collected from different resources in India shown in Table III and Chemical test results are shown in Table IV.

Sample no.	Fineness by blains permeability apparatus (m^2/kg)	Compressive strength of flyash mortar cubes at 28 days (50x50x50mm) (Mpa)
F-1/2018	221.5	24.90
F-2/2018	243.2	30.03
F-3/2018	269.1	21.48
F-4/2018	387.1	32.59
F-5/2018	394.0	35.41

Table 3: Compressive strength test results

Test Results (% by wt.)	Fly Ash Samples collected from different sources in India					Limit as per IS:3812(I) 2013
	F-1/2018	F-2/2018	F-3/2018	F-4/2018	F-5/2018	
Loss on Ignition.	0.59	3.29	1.21	0.07	0.91	5% Max
SiO_2	48.76	49.52	49.94	56.75	51.45	35% Min
Reactive Silica	22.05	25.74	18.54	27.39	23.56	20% Min
Al as Al_2O_3	32.46	31.24	25.50	28.08	30.17	
Fe as Fe_2O_3	7.32	6.88	4.12	5.57	7.05	
MgO	3.22	2.46	5.22	3.40	4.27	5% Max
Total sulphur as (SO_3)	0.77	0.87	1.45	0.64	0.84	3% Max
Total alkali (as Na_2O)	0.33	0.50	0.45	0.40	0.43	1.5% Max
Chloride, % by wt.	0.05	0.03	0.05	0.02	0.04	0.05% Max
$SiO_2+Al_2O_3+Fe_2O_3$	88.54	87.64	79.56	90.4	88.68	70% Min

Table 4: Chemical Test Result

As shown in result flyash having highest surface area/fineness shows maximum compressive strength. Sample F-5/2018 flyash shows max compressive strength as well as highest surface area as 35.41 Mpa and 394 m^2/kg respectively. Vice versa Sample F-1/2018 fly ash shows minimum compressive strength and minimum surface area as 24.90 Mpa and 221.5 m^2/kg respectively. Chemical analysis represents that all flyash samples satisfy the requirements as per the IS: 3812(I) 2013, except Sample F-3/2018 flyash. Reactive silica should be minimum 20% and magnesium oxide should be maximum 5% but in Sample F-3/2018 flyash these are 18.54 and 5.22 respectively. So this flyash does not show correct relation between compressive strength and fineness.

Fig. 2 shows comparison between Fineness and compressive strength and Fig. 3 shows correlation between them.

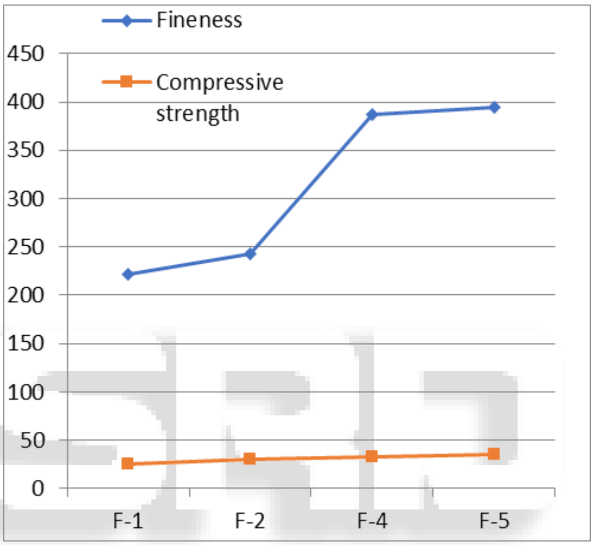

Fig. 2: Comparison between fineness and Compressive strength

Relation between Fineness and compressive strength is generated and graph is plotted with data.

Y=0.00435X + 17.193

Where X is Fineness in m^2/kg and Y is Compressive strength in Mpa.

$R^2 = 0.7985$

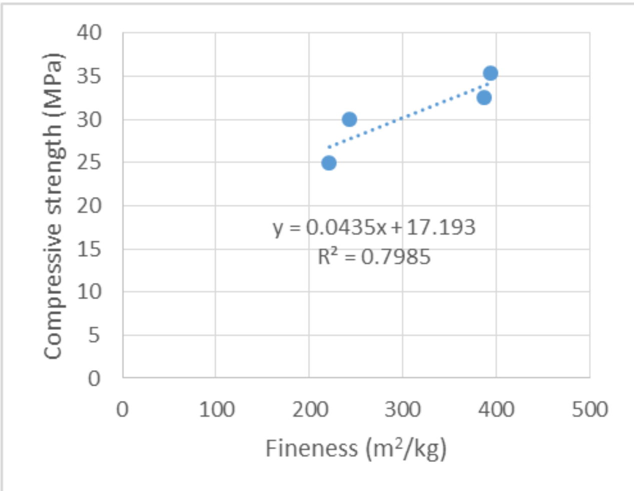

Fig. 3: Correlation between Fineness and Compressive strength

IV. RECOMMENDATION AND CONCLUSIONS

A linear relation is developed between Compressive strength and fineness of flyash when used as partial replacement of cement in cement flyash mortar .Approximate value of compressive strength after 28 days can be predicted with fineness of flyash using above correlation. The small errors in the predicted results may be because of variations in the physical and chemical composition of the cement, fly ash, aggregates, water; method of mixing, placing, curing and transportation can also affect the test results to a certain extent. This study helps to Predict Compressive strength after 28 days, using fineness data to some extent. However, exact value of compressive strength after 28 days can be achieved with original procedure as per IS: 1727 – 1967 (Reaffirmed 1999). The flyash must satisfy the chemical requirements as per the IS: 3812(I) 2013 to follow above relation.

REFERENCES

[1] International Journal of Civil Engineering & Technology (IJCIET) (2017). Vol. 8, Issue 4, April 2017, PP.1737-1745, Article ID- IJCIET _08_04_196
[2] IS: 4031 (Part 6) – 1988 Indian Standard Methods of physical tests for Hydraulic cement
[3] IS: 650-1966 Indian Standard for testing of cement
[4] IS: 1727 – 1967 (Reaffirmed 1999) Indian standard methods of test for pozzolanic material.
[5] IS: 3812 (Part 1):003 Indian Standard for Pulverized fuel ash specification, Part-1 for use as pozzolana in cement, Cement mortar & concrete.
[6] Er. Amit Ahirware, Prof. Rajesh Joshi and Er. Kapil Soni (2015). “Laboratory Analysis of Fly Ash Mix Cement Concrete for Rigid Pavement” Journal of Engineering Research and Applications www.ijera.com, ISSN: 2248-9622, Vol. 5, Issue 2, (Part -2) February 2015, pp. 86-91
[7] Subbamma and Dr. K. Chandrasekhar Reddy (2016). “Experimental Study On Compressive Strength Of Plain Cement Concrete With Partial Replacement Of Cement By Flyash & Metakaolin. International Journal of Civil Engineering and Technology (IJCIET) Volume 7, Issue 6, November-December 2016, pp. 82–89
[8] Khushal Chandra Kesharwani, Amit Kumar Biswas, Anesh Chaurasiya and Ahsan Rabbani (2017). “Experimental Study on Use of Fly Ash in Concrete”, International Research Journal of Engineering and Technology (IRJET) Volume: 04 Issue: 09, Sep -2017
[9] Venkateswara Rao and K. Srinivasa Rao (2017). “Effect of Fly Ash on Mechanical Properties of M30 and M60 Grade Concretes”, International Journal of Civil Engineering and Technology (IJCIET) Volume 8, Iss ue 3, March 2017, pp. 193–200

