iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 **Issue:** X **Month of publication:** October 2017

DOI: http://doi.org/10.22214/ijraset.2017.10232

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue X, October 2017- Available at www.ijraset.com

Strength Variation in PPC Concrete by Replacement of Cement with Fly ASH

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Abstract: Sustainability is considered to be highly important for preserving continued industrial growth and human development. The thermal power plants are the main sources of power in the world. To growing demand of power and increasing industrialization huge quantity of fly ash produced every year. Fly ash is a spherical particles obtained during coal burning process in the thermal power plants. The utilization of fly ash in concrete as partial replacement of cement is considered as an effective implement in the recent day's observance the aspects of durability and ecological benefits. In the present experimental study it was intended to explore the possibility of utilization of fly ash in concrete using Portland Pozzolana Cement (PPC). Portland Pozzolana Cement was replaced by fly ash in the range of 30% to 70% at an interval of 10% with 5% and 6% (by weight of cement) additional lime content. M25 (1:1.54:3 at 0.45 water/cement ratio) concrete specimens at different replacement level of Portland Pozzolana Cement (PPC) were cast for compressive strength after 7, 28 and 56 days curing. Result showed that Portland Pozzolana Cement (PPC) can be replaced up to 40% by fly ash without considerable change in compressive strength.
Key word- PPC Concrete, Fly ash, Compressive strength, lime

I. INTRODUCTION

Fly ash is a by-product from burning pulverized coal in Thermal power plants. During combustion, mineral impurities in the coal (clay, feldspar, quartz, and shale) bring together in suspension and float out of the combustion chamber with the exhaust gases. It cools and solidifies into spherical glassy particles called fly ash. Fly ash is collected from the exhaust gases by electrostatic precipitators or bag filters.Fly ash use creates significant benefits for our environment. Fly ash use conserves natural resources and avoids landfill disposal of ash products. By making concrete more durable, life cycle costs of roads and structures are reduced. Furthermore, fly ash use partially displaces production of other concrete ingredients, resulting in significant energy savings and reductions in greenhouse gas emissions.Chemically, fly ash is a Pozzolan. When mixed with lime (calcium hydroxide), pozzolans combine toform cementitious compounds. Concrete containing fly ash becomes stronger, more durable, and moreresistant to chemical attack.Mechanically, fly ash also pays dividends for concrete production. Because fly ash particles are small,they effectively fill voids. Because fly ash particles are hard and round, they have a "ball bearing" effectthat allows concrete to be produced using less water. Both characteristics contribute to enhancedconcrete workability and durability. Replacement of Portland Pozzolana Cement with fly ash and hydrated lime does not solve this multifarious issue. Since, each binder has its own chemical reaction, it is important to highlight the significance of curing time and conditions. Cement hydration completes in 28 days as cement attains its compressive strength. Though, lime carbonation is comparatively a slower reaction. Even though, pozzolanicity does have the ability to consume calcium hydroxide to form calcium silicate hydrate (C-S-H) which is essential for strength development, especially at early stages. The rate of reaction is also comparatively slower. In addition to that, it has also been criticized that various experimental studies conducted on concrete incorporated with hydrated lime and pozzolans have been cured for short interval of time.Emission of large amount of Carbon dioxide gas into atmosphere during production of cement is a major contribute for green house effect and the global warming, hence it is inevitable either to search for another material or partially replace it by some other material. Disposal of large quantity of fly ash may cause pollution of land, water bodies and air. Disposal of used fly ash is a major problem in the present age, so effective ways to recycle & reuse of fly ash are being formulated. Recycling of fly ash to produce new materials like concrete or mortar appears as one of the best solution for disposing of fly ash, due to its economic and ecological.

Siddique (2003) found that the increase in strength with fly ash replacing fine aggregate, however, the rate of increase of strength decreases with increase in fly ash content. At 50% replacements of fine aggregate by fly ash, compressive strength of concrete increased by 51.5% and 67.1% at 28 and 365 days respectively. Jamkar et al. (2013) found that the compressive strength results show that the fly ash fineness plays a vital role in the activation of geopolymer concrete. An increase in the fineness increased both workability and compressive strength. It was also observed that finer particles resulted in increasing the rate of reaction needing less heating time to achieve a given strength. R.Bansal et al. (2015)found that the replacement is of fly ash with cement having been studied for partial replacement of fly ash with cement at 10%, 20%, 30%. It was observed that 10% replacement of fly ash was 20% and 50% decrease the compressive strength at the age of 7 and 28 days respectively In 20% replacement 7% and 11% increase in compressive strength was observed at the age of 7 and 28 days respectively. In 30% replacement 23% and 19% increase the compressive strength was observed at the age of 7and 28daysrespectively.

II. MATERIAL AND METHODOLOGY

A. Cement

In this study, Portland PozzolanaCement (fly ash based) of single batch was used conforming to IS 1489(part I):1991 specification. Properties of PPC are as listed below in table 1.

Table-1, Properties of Portland Pozzolana cement (PPC)

Properties	Result value
Initial setting time	140 minutes
Final setting time	325 minutes
Standard consistency %	31%
Fineness(% retained on 90μ in sieve)	3.5%
Specific gravity	2.71
Soundness(lechatelier expansion)	0.5 mm

B. Fine Aggregate

Fine aggregate (FA) used in this investigation was the natural river sand passing completely through 4.75 mm aperture size sieve and conforming to zone II as per IS:383-1970 specification. Its fineness modulus and specific gravity were 2.73 and 2.34 respectively. Particle size distribution as grading curve of the recorded sieve analysis test result for the same is shown in figure 1 with Upper and Lower Permissible limits (UPL and LPL) as per codal recommendation.

C. Coarse Aggregat

A Combined grading of the two individual 20 mm and 10 mm Nominal size coarse aggregate (20mm CA & 10mm CA) gradings was used with the ratio of these coarse aggregates as 60:40 respectively. Particle size distribution curve of the Achieved Combined coarse aggregate with these two (20 mm and 10 mm) coarse aggregate by the Recorded sieve analysis test result with permissible limits (UPL & LPL) is shown in figure 2. Properties of the Achieved Combined coarse Aggregate (CCA) of 20 mm Nominal size are shown in Table 2.

Table-2, Properties of Coarse Aggregate (CA)

Properties		Result value
Fineness Modulus	10 mm Aggregate(10mm CA)	5.944
	20 mm Aggregate(20mm CA)	7.021
	Combined Coarse Aggregate(CCA)	6.543
Water absorption (%)		0.85
Specific gravity		2.65

D. Fly ash

Fly Ash obtained from Thermal Power Station (NTPC Unchahar Raibareli U.P. India) is used.

E. Super Plasticizer

Sulphonated naphthalene formaldehyde (SNF) based Super plasticizer (KEM SUPLAST 101 S) of Chembond chemicals was used which conforms to IS:9103-1999 specifications. It was in liquid form compatible with the used Cement, brown in colour having specific gravity 1.2 and It showed good deflocculation and dispersion with cement particles to enhance the workability of concrete mix.

F. Mix Design of the Referral Concrete –

M-25 grade of concrete conforming to IS:10262-2009 guidelines was designed as the referral concrete with the mix proportion of (1:1.54:3)and water-cement ratio(W/C) of 0.45 by weight taking with 0.6% super plasticizer dose by weight of cement.

G. Water

Potable water was used for mixing the concrete mix in entire investigation and for curing the concrete in the determination of the optimal percentage of stone dust as fine aggregate replacement.

H. Experimental design

The cubes were cast in steel moulds of inner dimensions of 150 x 150 x 150 mm, all the materials are weighed as per mix proportion of 1:1.54:3 with a W/C ratio of 0.45 which correspond to M25 grade of concrete. Cement is replaced by fly ash. Each mix comprises of various percentages of cement replacement material in increasing order i.e. 30%, 40%,50%, 60% and 70%, with adding 5% and 6% free lime content respectively in replacement. The specimens were cured for a period of 7, 28 and 56 days.

III. RESULT AND DISCUSSION

A. Compressive Strength

Compressive strength of the concrete cube specimen was calculated by dividing the maximum load applied to the specimen during the test by the cross sectional area. The average of three values of compressive strength was taken as the representative compressive strength. In test, cube specimen was placed in the CTM machine in such manner that the load was applied to the opposite sides of the concrete cube as cast, that is, not to the top and bottom as per IS:516-1959 specification.Result of compressive strength of specimens cast for different replacement levels of Portland Pozzolana Cement (PPC), varying dose of lime (5% and 6%) and constant dose of super plasticizer are discussed here in after.

B. Compressive strength of concrete with 5% of lime

The result of compressive strength in respect of specimens cast for different replacement levels of PPC with fly ash and 5% additional lime content is presented in Table -3. The same results are produced in graphical form for visual observation in figur-1. It was observed that at 7days curing strength of fly ash Portland Pozzolana Cement (PPC) concrete decreased with increase in replacement level. It was observed that at 30% replacement of Portland Pozzolana Cement (PPC) with fly ash compressive strength at 7days curing is decreased 16.48% than that of referral concretes. Decrease in strength at 7days curing was 55.87%, 69.53%, 139.73% and 222% at replacement level of 40, 50, 60 and 70% respectively. It showed that increase in fly ash content in concrete reduced the rate of strength gain at early ages due to slow hydration process. However, the trend at 28days was not similar as the trend of 7days. At 28days curing strength of fly ash Portland Pozzolana Cement (PPC) concrete was (increase 3.45%) more than that of referral concrete at 30% replacement level. Beyond 30% replacement level decreased in strength was observed with increased in replacement level. At 40% replacement level strength of fly ash Portland Pozzolana Cement (PPC) concrete was marginally (15.20%) decreased. Decrease in strength at 28days curing was 44.77%, 95.74% and 144.5% at replacement level of 50, 60 and 70% respectively. It showed that increase in fly ash content in concrete the rate of strength gain only up to 40% replacement level after that strength decreased. It was observed that at 56days curing, strength of fly ash Portland Pozzolana Cement (PPC) concrete increased up to 40% replacement with referral concrete and then strength decreased with increase in replacement level. It was observed that 30% and 40% replacement of Portland Pozzolana Cement (PPC) with fly ash on the compressive strength at 56days curing is increased about 7.50% and 3.45% more than that of referral concrete. Decrease in strength at 56days curing was 25.69%, 47.24% and 77.01% at replacement level of 50, 60 and 70% respectively. It showed that increase in fly ash content in concrete the rate of strength gain only up to 40% replacement level.

Table-3: Compressive strength of cube with 5% lime

S.N.	Cube designation	Replacement Level (%)	Addition of Lime(%)	Average compressive strength		
				7 Days	28 Days	56 Days
1	A0	0	0	21.48	31.75	36.59
2	A1	30	5	18.44	32.88	39.37
3	A2	40	5	13.78	27.54	37.41
4	A3	50	5	12.67	21.93	29.04
5	A4	60	5	8.96	16.22	24.85
6	A5	70	5	6.67	12.96	20.67

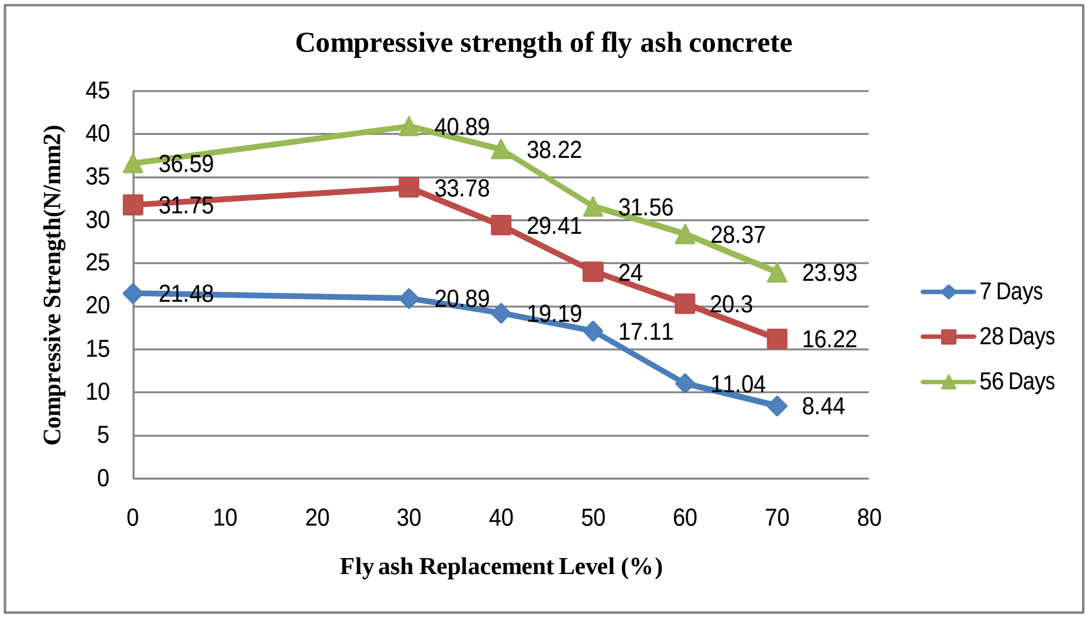

Fig-1 Variation of compressive strength (at 5% of lime) with replacement level.

C. Compressive strength of concrete with 6% of lime

The result of compressive strength in respect of specimens cast for different replacement levels of PPC with fly ash and 6% additional lime content is presented in Table-4. The same results are produced in graphical form for visual observation in fig-2. It was observed that at 7days curing strength of fly ash Portland Pozzolana Cement (PPC) concrete decreased with increase in replacement level. It was observed that at 30% replacement of Portland Pozzolana Cement (PPC) with fly ash compressive strength at 7days curing is decreased 2.82% than that of referral concretes. Decrease in strength at 7days curing was 11.93%, 25.54%, 94.56% and 154.50% at replacement level of 40, 50, 60 and 70% respectively. It showed that increase in fly ash content in concrete reduced the rate of strength gain at early ages due to slow hydration process. However, the trend at 28days was not similar as the trend of 7days. At 28days curing strength of fly ash Portland Pozzolana Cement (PPC) concrete was more than that of referral concrete up to 40% replacement level. Beyond 40% replacement level decreased in strength was observed with increased in replacement level. Decrease in strength at 28days curing was 32.39%, 56.40% and 95.74% at replacement level of 50, 60 and 70% respectively. It showed that increase in fly ash content in concrete the rate of strength gain only up to 40% replacement level after that strength decreased. It was observed that at 56days curing, strength of fly ash Portland Pozzolana Cement (PPC) concrete increased up to 40% replacement with referral concrete and then strength decreased with increase in replacement level. It was observed that at 30% and 40% replacement of Portland Pozzolana Cement (PPC) with fly ash on the compressive strength at 56days curing is increased about 10.57% and 5.26% respectively than that of referral concrete. Decrease in strength at 56days curing was 15.93%, 28.89%, and 52.90% at replacement level of 50, 60 and 70% respectively. It showed that increase in fly ash content in concrete the rate of strength gain only up to 40% replacement level.

Table-4

Compressive strength of cube with 6% lime

S.N.	Cube designation	Replacement Level (%)	Additionof Lime(%)	Average compressive strength		
				7 Days	28 Days	56 Days
1	A0	0	0	21.48	31.75	36.59
2	B1	30	6	20.89	33.78	40.89
3	B2	40	6	19.19	29.41	38.22
4	B3	50	6	17.11	24.00	31.56
5	B4	60	6	11.04	20.30	28.37
6	B5	70	6	8.44	16.22	23.93

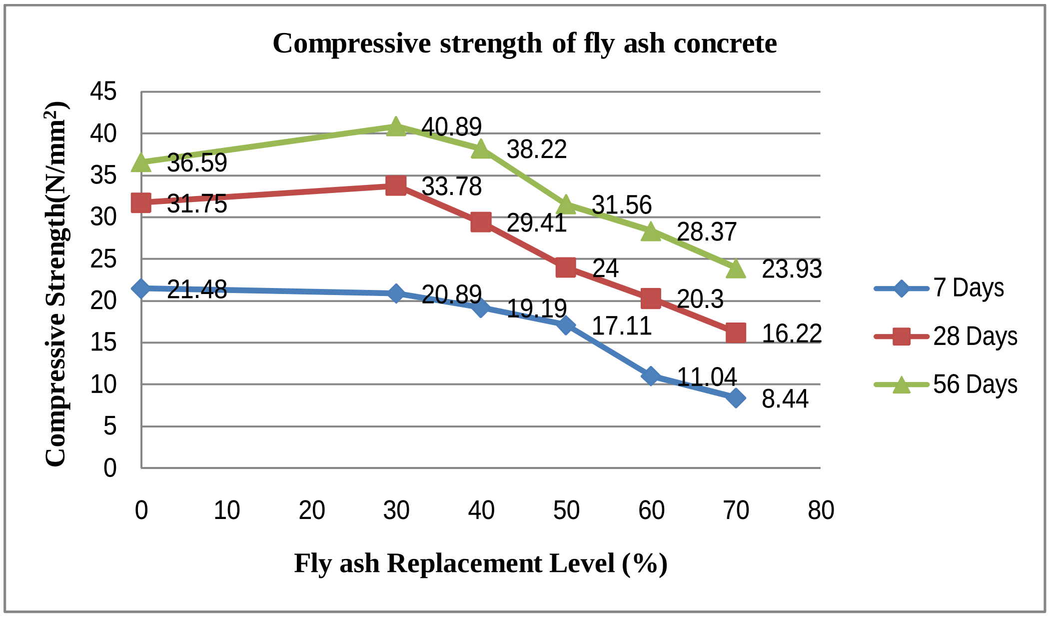

Fig-2 Variation of compressive strength (at 6% of lime) with replacement level.

IV. CONCLUSION

A. From the above study following conclusions are drawn

1) The compressive strength of fly ash concrete up-to 40% replacement level is slightly more than or equal to referral concrete at 28 and 56 days.

2) Optimum replacement level of fly ash is 30%, at 30% replacement level increase in strength at 28 and 56 days is 8.94% & 13.30% respectively with 5% lime and 8.15% and 14.98% respectively with 4% lime.

3) It is observed that in PPC gains strength after the 56days curing. Increase in strength after 56days curing showed because of slow hydration process of Fly ash PPC concrete, Since Fly ash is a slow reactive pozzolans.

4) The addition of fly ash in PPC concrete increase the compressive strength with the increase of time.

5) Higher fly ash replacements in PPC concrete reduce the compressive strength.

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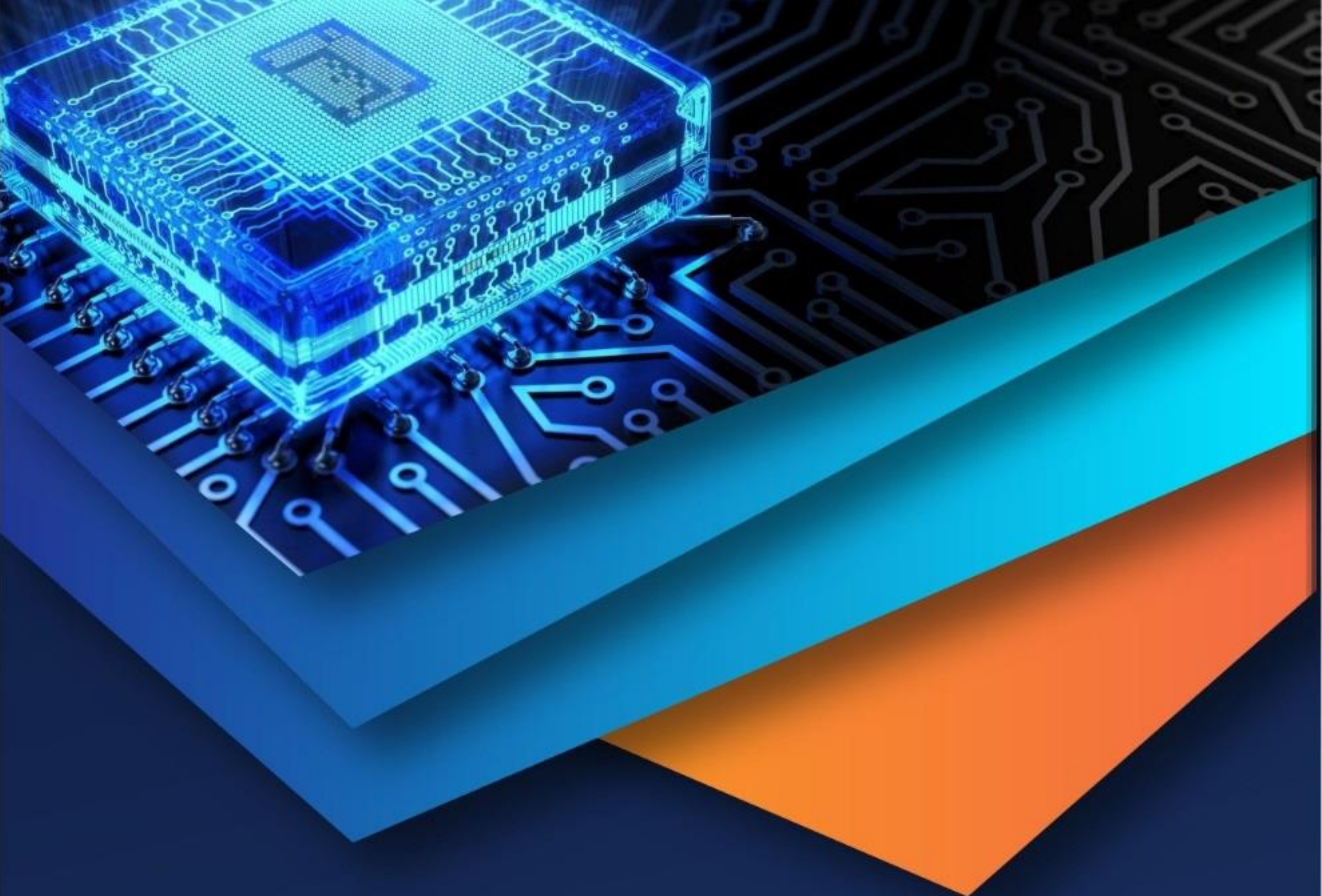

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