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Utilization of fly ash and lime in PPC concrete

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***Abstract*— Owing to growing demand of power and increasing industrialization huge quantity of fly ash produced every year. It is expected that very soon production of fly ash in India will reach 400 MT per annum. Presently in Portland Pozzolana Cement (PPC) fly ash is a significant constituent however much scope is still available for utilization of fly ash. In the present 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 3% and 4% (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 PPC were cast and tested for workability at fresh stage and for compressive strength after 7, 28 and 56 days curing. Result showed that PPC can be replaced up to 40% by fly ash without considerable change in compressive strength.**

***Index Terms*— Concrete, fly ash, workability and compressive strength.**

I. INTRODUCTION

Concrete is a heterogeneous mix of binding material (mostly cement), fine aggregate, coarse aggregate and water. Some admixtures are also added in concrete to improve some of the properties as desired. Fly ash is one of occurring products from the coal combustion process and is a material similar to volcanic ash. Volcanic ash concrete was used thousands of years ago to produce Roman concrete structures that exist and functions today; e.g., the Pantheon, Coliseum, and ancient aqueducts. Owing to modernization in all aspect of life and upliftment of living standard energy requirement is increasing exponentially day by day. Thermal power plants are the major source of energy generated and used in India. The non-combustible minerals that naturally occur from burning coal form bottom ash and fly ash. Fly ash consists of fine, powdery particles that are mostly spherical in shape, either solid or hollow, and predominantly glassy in nature. The carbonaceous material in fly ash is composed of angular particles. The particle size distribution of most bituminous coal fly ashes is usually similar to that of silt (less than a 0.075mm). These particles consist of Silica, Alumina, Oxides of Iron, Calcium, and Magnesium and toxic heavy metals like Cobalt Arsenic, Lead and Copper . This poses problems in the form of land use, health hazards, and environmental impact. Thermal Power stations using crushed coal or lignite as fuel generate large quantities of ash as a by-product. With the commissioning of super thermal power plants and with increasing use low grade coal of high ash content, the current production of ash is about 190 million ton per year. 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 advantages. **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 d respectively. **Basheer et al.(2009)** investigated the properties of fly ash concrete incorporating either hydrated lime or silica fume to improve the early strength of concrete. Test results indicated that the addition of lime and silica fume improved the early age compressive strength of fly ash concrete. The inclusion of silica fume was also found to increase the 28 days strength significantly. The air permeability of concrete containing lime and silica fume either decreased or remained almost the same when compared to the referral conventional concrete. The addition of lime and silica fume also improved the sorptivity of concrete. Through the use of differential scanning calorimetric and thermo gravimetric analysis (DSC/TG), it was demonstrated that the addition of hydrated lime increased the Ca(OH)2 content; whereas the addition of silica fume decreased the Ca(OH)2 content in the cement paste. **Gayathri et al.(2014),** reported that fly ash and water softening sludge (lime sludge) may be utilized in mortar. The large amount of silica and alumina available in fly ash and rich content of calcium oxide in lime sludge, make them compatible with each other and can replace cement also.

II. MATERIALS AND METHODOLOGY:-

Cement:- Portland Pozzolana cement (PPC) of single batch was used throughout the investigation. The properties of PPC are as follows-

Fineness of cement (3.77) , Normal consistency (31.5%), initial setting time (165 minutes), final setting time(215 minutes), and Specific gravity of cement(2.67).

Coarse and Fine aggregate:- Locally available sand conforming to IS 383 was used as fine aggregate. The foundation of fine aggregate (Zone-II) was maintained through out of investigation.

The properties of fine aggregate are as follows-

Fineness (2.84) and specific gravity (2.2).

Coarse aggregate**:-**In present investigation 'Bharatpur' stone aggregate passing through 20mm and 10mm sieve was used as

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coarse aggregate. Fraction of 20mm and 10mm size aggregate kept as 60% and 40% respectively, for maintaining proper grading.

Fly ash:- In the present work the fly ash is obtained from the NTPC Unchahar Raibareli U.P. India.

Lime:-In present investigation lime obtain from 'Katani' was used. Lime was shocked in water and resulting pest was used in mix.

Water:- Potable water is used for mixing and curing. The water cement ratio (w/c) of 0.45 has been used.

Supper plasticizer: - Emceplast SP430A1 .6% is used. India lies in tropical climatic zone, where slump retention is a vital issue for better performance. The said super-plasticizer has already proved its worth for many advantages when it mixes with concrete like improved workability, slump retention, increased strength, improved quality, higher cohesion.

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 3% and 4% free lime content respectively in replacement. The specimens were cured for a period of 7, 28 and 56 days.

III. RESULTS AND DISCUSSION:-

Workability:-The workability of mixes was measured by Slump test. The variation of Slump (at 3% and 4% lime content and 0.6% super plasticizer) presented in Table 1and table 2. The some result reproduced in fig1 and fig2 respectively for visual observation. Slump values found to be decreased with increase in the dose of fly ash in the concrete mix. The decrease of workability may be due to higher water requirement for lubrication of fly ash.

Table -1 Slump value of concrete with 3% lime and 0.6% super plasticizer

Cube designation	Replacement level (%)	Lime content (%)	Slump (mm)
A1	0	0	110
A2	30	3	95
A3	40	3	80
A4	50	3	70
A5	60	3	40
A6	70	3	30

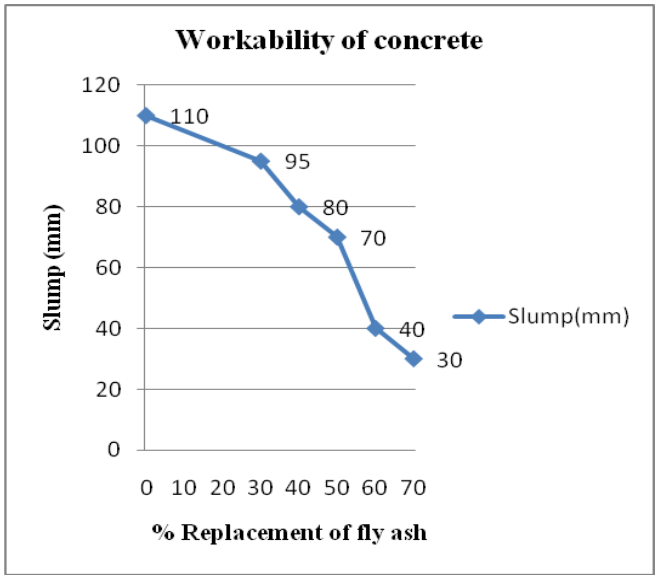

Fig-1 Variation of workability (at 3% of lime) with t replacement level

Table -2 Slump value of concrete with 4% lime and 0.6% super plasticizer

Cube designation	Replacement level (%)	Lime content (%)	Slump (mm)
A1	0	0	110
B1	30	4	100
B2	40	4	70
B3	50	4	50
B4	60	4	60
B5	70	4	40

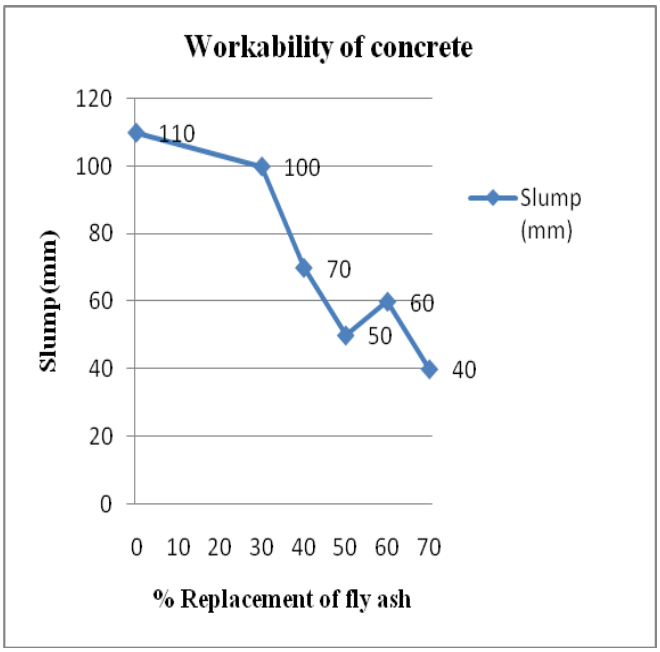

Fig-2 Variation of workability (at 4% of lime) with replacement level

Compressive Strength:-

Result of compressive strength of specimens cast for different replacement levels of PPC , varying dose of lime (3% and 4%) and constant dose of super plasticizer are discussed here in after.

Compressive strength of concrete with 3% of lime:-

The result of compressive strength in respect of specimens cast for different replacement levels of PPC with fly ash and 3% additional lime content is presented in Table -3. The same results are produced in graphical form for visual observation in fig-3.

It was observed that at 7d 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 7d curing is decreased 5.44% than that of referral concretes. Decrease in strength at 7d curing was 39.87, 54.57, 54.30 and 76% 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 28d was not similar as the trend of 7d. At 28d curing strength of fly ash PPC concrete was 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 PPC concrete was marginally decreased. Decrease in strength at 28d curing was 18, 36 and 48% 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 56d curing, strength of fly ash 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 56d curing is increased about 13.30 and 9.34% than that of referral concrete. Decrease in strength at 56d curing was 12, 25.34 and 47.73% 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 fly ash concrete with 3% lime at different replacement level

Cube designation	Replacement level (%)	Lime content (%)	Average compressive strength(N/mm^2)		
			7 Days	28 Days	56 Days
A1	0	0	29.39	31.64	36.38
A2	30	3	27.79	34.47	41.23
A3	40	3	17.67	31.07	39.79
A4	50	3	13.35	26.10	31.99
A5	60	3	13.43	20.31	27.20
A6	70	3	7.11	16.26	19.06

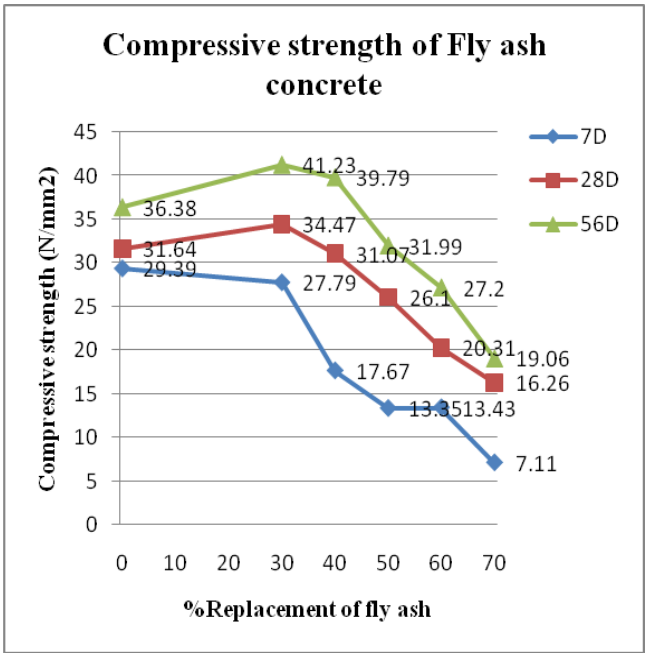

Fig-3 Variation of compressive strength (at 3% of lime) with replacement level.

Compressive strength of concrete with 4% of lime:-

The result of compressive strength in respect of specimens cast for different replacement levels of PPC with fly ash and 4% additional lime content is presented in Table-4. The same results are produced in graphical form for visual observation in fig-4.

It was observed that at 7d 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 7d curing is decreased 16% than that of referral concretes. Decrease in strength at 7d curing was 21.16, 52.42, 53.83 and 73% 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 28d was not similar as the trend of 7d. At 28d curing strength of fly ash 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 28d curing was 14, 33 and 46% 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 56d curing, strength of fly ash 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 56d curing is increased about 15% and 10.8% respectively than that of referral concrete. Decrease in strength at 56d curing was 1, 13.44, and 32.40% 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 fly ash concrete with 4% lime at different replacement level

Cube designation	Replacement level (%)	Lime content (%)	Average compressive strength(N/mm^2)		
			7 Days	28 Days	56 Days
A1	0	0	29.39	31.64	36.38
B1	30	4	24.7	34.22	41.83
B2	40	4	23.17	31.92	40.31
B3	50	4	13.67	27.31	36.13
B4	60	4	13.57	21.19	31.49
B5	70	4	8.01	16.95	24.59

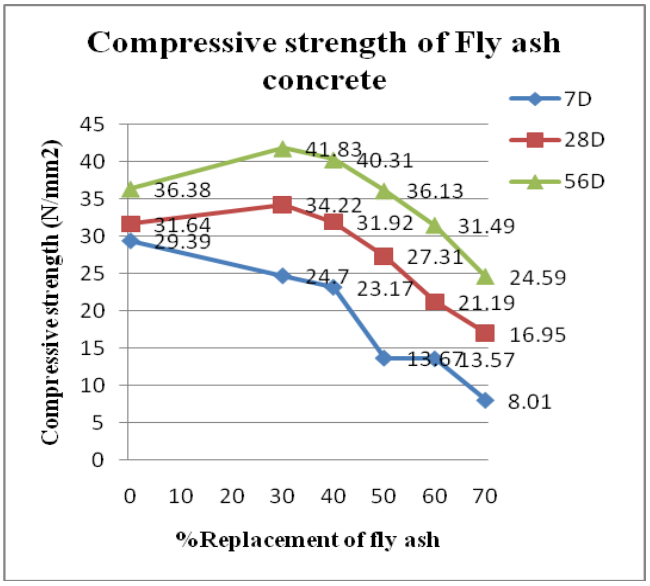

Fig-4 Variation of compressive strength (at 4% of lime) with replacement level

IV. Conclusion:-

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 3% 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.

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