Exploratory Use of Fly Ash as Supplementary Material in Pozzolana Cement Concrete

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Abstract: The attempts have been made to reduce CO_2emissions in environment by all possible ways, but cement has not found a suitable replacement for it till date. Fly ash concrete has economical and environmental advantages. It also makes concrete sustainable. In India presently less than 50% of fly ash produced is consumed. Infrastructural Development is at its peak all over the world and is a symbol of growth for any country. Fly ash Concrete is an effort in reducing cement content of construction. The paper aims at discussing the use of fly ash concrete in construction as a solution to address two environmental problems - one, disposal of huge amounts of fly ash, by production of thermal power plants, causing environmental degradation through large areas of landfills and two, high percentage of carbon dioxide emissions in atmosphere from cement industry. The era of infrastructure increased in recent year, so the advancement of concrete technology exaggerated day by day in life. Use of concrete exaggerated the consumption of natural resources and energy sources. In recent years inordinate measure of fly ash generated in thermal industries. The previous couple of years, some cement firms have started mistreatment ash in producing cement called hydraulic cement, however, the utilization of ash remains terribly low. There's intolerably opportunity for the fly ash in cement likewise as in concrete.

This work describes the use of Non-conventional artifact (Fly ash) that is definitely our there. During this work cement and fine aggregate has been partly replaced by fly ash consequently within the range of 0% (without fly ash), 10%, 20%, 30%, 40% and 60% by weight of cement for M-25 *Mix* Concrete mixtures were moulded, tested and compared in terms of compressive and split strength.

Key Words: Cement, fly ash, Concrete, fly ash concrete, Fine Aggregate, Coarse Aggregate, Environment.

I. INTRODUCTION

The production of fly ash was 200 million ton by 2010 and now it is about 150 million per year. Research work of large number of agencies in the country and actual utilizations abroad has exhibited worth of fly ash. However, may be due to lack of local experience, utilization of fly ash did not pick up in India, till a few years ago. Fly Ash Mission, established by Government of India in 1994 is providing a focused thrust to develop local experiences and thus building up of confidence in techno-economic viability of fly ash utilizations as well as safe disposal of un-utilized ashes. Internationally fly ash is considered as a byproduct which can be used for many applications. Fly ash is a finely divided residue resulting from the combustion of bituminous coal or lignite in a thermal power plant. Indian coals have on an average 45% ash content In the present era of growth and development, progress is taking place in all the fields. But, in the light of progress, man is ignoring nature and harming it. Construction area, with the use of virgin materials like cement, is also posing the threat of global warming and environmental degradation. The challenge in front of civil engineering community is to provide sufficient, economical and comfortable infrastructure without causing any hardship for environment.

Taking sustainable development in view, an attempt has been made to reduce the use of cement in concrete by replacing it with otherwise waste materials such as fly ash, slag, silica fume and rice husk. Fly ash is one of the residues generated in combustion, and comprises the fine particles that rise with the flue gases. Fly ash consists of fine, powdery particles that are predominantly spherical in shape, either solid or hollow, and mostly glassy (amorphous) in nature. The carbonaceous material in fly ash is composed of angular particles. The particle size distribution of most bituminous coal fly ashes is generally similar to that of a silt (less than a 0.075 mm). Although sub-bituminous coal fly ashes are also silt-sized, they are generally slightly coarser than bituminous coal fly ashes. The specific gravity of fly ash usually ranges between 2.1 to 3.0, while its specific surface area (measured by the Blaine air permeability method) may range from 170 to 1000m2/kg. The use of fly ash in

concrete has been encouraged all over the world. Though this has been tried at some places in India but the percentages replacements of cement by fly ash are very small and only less than 25% of total fly ash produced is being utilized. A confidence is required to be built up in developing countries like India to make use of fly ash concrete in various fields of construction.

II. LITERATURE REVIEW

Hwang et al. (1998) examined the effects of fine aggregate replacement on the theology, compressive strength, and rate of carbonation of mortars of water to Portland cement ratio of 0.3, 0.4, and 0.5, in which the fine aggregate was replaced with fly ash at 25% and 50% levels. Test results showed that theological constants increased with higher replacement level of fly ash and that, when water to Portland cement ratio was maintained, the strength development and carbonation properties were improved.

Bhanumathidas, & Kalidas, (2002) with their research on Indian fly ashes reported that the increase in ground fineness by 52% could increase the strength by 13%. Whereas, with the increase in native fineness by 64% the strength was reported to increase by 77%. Looking in to the results it was proposed that no considerable improvement of reactivity could be achieved on grinding a coarse fly ash. Authors also uphold that the study on lime reactivity strength had more relevance when fly ash is used in association with lime but preferred pozzolanic activity index in case of blending with cement.

Siddique (2003) carried out experimental investigation to evaluate mechanical properties of concrete mixes in which fine aggregate (sand) was partially replaced with class F fly ash. Fine aggregate was replaced with five percentages (10%, 20%, 30%, 40% and 50 %) of class F fly ash by weight. The test result showed that the compressive strength of fly ash concrete mixes with 10% to 50% fine aggregate replacement with fly ash were higher than control mix at all ages. Also the compressive strength of concrete mixes was increasing with increase in fly ash percentages. This increase in strength due to replacement of fine aggregate with fly ash was attributed to pozzolanic action of fly ash. The splitting tensile strength also increased with increase in percentage of fly ash as replacement of fine aggregate. The tests on flexural strength and modulus of elasticity also showed improvement in the results as compared to control concrete.

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% replacement of fine aggregate by fly ash, the compressive strength of concrete increased by 51.5 and 67.1% at 28 and 365 days respectively.

Hwang, Noguchi & Tomosawa, (2004) based on their experimental results concerning the compressive strength development of concrete containing fly ash, the authors concluded that the pores in concrete reduce by addition of fly ash as replacement of sand.

Berndt et al. (2009) concluded that addition of fly ash in concrete up to 50% gave most significant improvement in workability and required a shorter vibration time. It is also reported that addition of fly ash in concrete improves the workability

Valente et al. (2010) found that the effects of fly ash on the concrete's properties was described using the efficiency factor. In this study the fly ash efficiency factor was referred to two very important concrete properties: compressive strength and permeability to chlorides. The variability of aforesaid efficiency factors depends on cement content, fly ash content and age of concrete. The experimental data obtained in this study show that the efficiency factors suggested by European standards are much lower, especially when referred to 56-90 days aged concrete

Pofale, & Deo et al.(2010) with their study indicated about 20% increase in compressive strength and about 15% increase in flexural strength of concrete over control concrete by replacing 27% of sand with low lime fly ash. In study fly ash based Portland pozzolana cement was used. They had also reported about 25% increase in workability of the fly ash based concrete over control concrete.

Out of large number of papers studied papers only found very relevant are included for putting forward present objectives. Literature discussed has shown partial replacement of scarce sand with fly ash had shown higher strength from 3rd day as compared to control concrete. Long term strength was about 20% higher than the control concrete. Along with increase in strength, increase in workability and durability of concrete by partial replacement of sand with fly ash is very encouraging.

Analysing the results it may be seen that due to ball bearing and pore filling effect, dispersion of cement particles and pozzolanic reactivity of fly ash as partial replacement of sand workability and strength also increased. This additional strength and workability offered by partial replacement of sand with fly ash could offset loss of 28days strength of high volume fly ash concrete

Chatterjee, (2011) reported that about 50 % of fly ash generated is utilised with present efforts. He also reported that, one may achieve up to 70% replacement of cement with fly ash when high strength cement and very high reactive fly ash is used along with the sulphonated naphthalene formaldehyde superplasticizer. He reported improvement in fly ash property could be achieved by grinding and getting particles in sub microcrystalline range.

Mukherjee et al (2013) reported that the zero slump concrete shows higher compressive strength compare to workable concrete with super plasticizer up to 60% replacement with fly ash. The strength gain with time is higher compared to the OPC concrete at all replacement level of cement by fly ash and the optimum strength gain was noted at 70% replacement at 28 days.

III. MATERIALS

A. Cement

In this work, Pozzolana Portland Cement PPC) of prism brand obtained from single batches throughout the investigation was used. The Portland cement content mainly two basic ingredients namely argillaceous and calcareous.

B. Fine aggregate

Locally available sand passed through4.75mm IS sieve is used. various properties of fine aggregates are shown in table as given below

Table 1

Properties	Value Obtained
Fineness Modulus	2.66
Specific Gravity	2.69
Water Absorption	1.45%

C. Coarse Aggregate

In this study Coarse aggregate maximum size 20mm was used. Crushed aggregate available from local sources has been used. The coarse aggregates with a maximum size of 20mm having the specific gravity value of 2.958 and fineness modulus of 7.136 are used as coarse aggregate. The loose and compacted bulk density values of coarse aggregates are 1467 and 1629 kg/m3 respectively, the water absorption of 1.26%.

D. Concrete

The concrete mix design is done in accordance with IS 10262(2009). The cement content used in the mix design is taken as 380 kg/m3 which satisfies minimum requirement of 300 kg./m3 in order to avoid the balling affect. Good stone aggregate and Natural River sand of Zone-II were used as coarse and fine aggregate respectively. Size of coarse aggregate was 20mm and 10mm. A sieve analysis conforming to IS 383-1970 was carried out for both the fine and coarse aggregates.

E. Water

Potable water is used for mixing and curing. The water cement ratio (w/c) of 0.46 has been used.

F. Fly ash

Fly ash is a by-product produced from the combustion of coal in an electrical generation station. Fly ash is a natural pozzolan, which means that it is a “siliceous or siliceous-and-aluminous material” that chemically reacts with calcium hydroxide or free lime (CH) that has evolved during reaction of cement and water to form composites having cementitous properties.

Table 2

Physical Properties		
	PPC	**Fly Ash**
Specific gravity	2.67	2.30
Mean grain size (µm)	21.5	20
Specific area (cm2/gm)	2770	2680
Colour	Grey	Grey to black

IV. EXPERIMENTAL STUDY

Compressive and split tensile strength of cubes and cylinders have been determined as per IS 516-1959 at a loading rate of about 140 kg/cm2/min (about 30 tones per minute) on 2000 tons compression testing machine. Two dial gauges in diametrically opposite directions were cast for testing are:-

The cubes size 150mm for compressive strength. The cylinder size 300mm height and dia. 150mm for split tensile strength. The details of cubes and cylinders given below.

TABLE 1: Cubes, Cement partially replaced with fly ash for compressive strength

S.No	**Cube Designation**	**Size(mm)**	**Fly Ash %age**
1	A1	150x150x150	0
2	A2	150x150x150	10
3	A3	150x150x150	20
4	A4	150x150x150	30
5	A5	150x150x150	40
6	A6	150x150x150	50
7	A7	150x150x150	60

TABLE 2: Cubes fine aggregate partially replaced with fly ash for compressive strength

S.No	**Cube Designation**	**Size(mm)**	**Fly Ash %age**
1	B1	150x150x150	0
2	B2	150x150x150	10
3	B3	150x150x150	20
4	B4	150x150x150	30
5	B5	150x150x150	40
6	B6	150x150x150	50
7	B7	150x150x150	60

TABLE- 3: Cylinders, cement replaced partially with fly ash for split tensile test

S.No	**Cube**	**Size(mm)**	**Fly Ash**

	Designation		%age
1	C1	150x150x150	0
2	C2	150x150x150	10
3	C3	150x150x150	20
4	C4	150x150x150	30
5	C5	150x150x150	40
6	C6	150x150x150	50
7	C7	150x150x150	60

V. RESULTS AND DISCUSSION

When cement replaced by Fly ash: The compressive strength of referral concrete at 7, 28 and 56 days are given in Table 4. It is evident from this table that the strength increases with the addition of fly ash. Strength increases up to 30% fly ash content and after that it decreases. However increase in strength is more prominent at 20% replacement level. The variation of compressive strength with different percentage of fly ash is shown in fig 1. These figure shows that the compressive strength of concrete with and without as function of curing time. The compressive strength of PPC is 22.7 N/mm2, 31.8 N/mm2 and 35.59 N/mm2 when water/cement ratio is 0.46 at 7, 28 and 56 days respectively.

Table 4 Compressive strength of Fly ash concrete

S.No	Cube Designation	Compressive strength (N/mm2)			%age of fly ash
		7 days	28 Days	56 Days	
1	A1	22.7	31.8	35.90	0
2	A2	20	33.3	38.4	10
3	A3	20.6	33	38.9	20
4	A4	17.7	28.8	37.3	30
5	A5	14.2	20.7	28.5	40
6	A6	12.9	19.1	24	50
7	A7	7.4	14.9	17.3	60

When fine aggregate replaced by Fly ash : The compressive strength of referral concrete at 7, 28 and 56 days are given in table 5. It is evident from this table that the strength increases with the addition of fly ash. Strength increases continuously increases percentage of fly ash content. The variation of compressive strength with different percentage of fly ash is shown in fig 2.The compressive strength of fly ash concrete when fine aggregate partially replaced with fly ash at 50% replacement level increase in strength is 15.4% & 18% at 28 & 56 days with the reference of referral concrete cubes.

Table 5 Compressive strength of Fly ash concrete

S.No	Cube Designation	Compressive strength (N/mm2)			%age of fly ash
		7 days	28 Days	56 Days	
1	B1	22.70	31.80	35.90	0
2	B2	24.50	32.88	36.78	10
3	B3	25.11	32.97	37.78	20
4	B4	25.97	35.31	40.00	30
5	B5	26.51	35.40	40.40	40
6	B6	27.00	36.80	42.47	50

Split Tensile Strength of Fly Ash Concrete (Cement Partially Replaced With Fly Ash): The split tensile strength of referral concrete as well as fly ash concrete at 7, 28 and 56 days are given in table 6. It is evident from this table that the strength increases with the addition of fly ash. Strength increases up to 20% fly ash content and after that it decreases. However, increase in strength is more prominent at 10% replacement level. The variation of tensile strength with different percentage of fly ash is shown in fig. 3. These figure shows that the tensile strength of concrete with and without as function of curing time. The tensile strength of PPC is 4.5 N/mm2, 6.9 N/mm2 and 7.9 N/mm2 when water/cement ratio is 0.46 at 7, 28 and 56 days respectively.

Table 6. Split tensile strength of fly ash concrete

S.No	Cube Designation	Compressive strength (N/mm2)			%age of fly ash
		7 days	28 Days	56 Days	
1	C1	4.5	6.9	7.9	0
2	C2	6.0	7.8	9.9	10
3	C3	5.5	8.0	8.5	20
4	C4	3.0	5.3	6.3	30
5	C5	2.8	5.0	5.4	40
6	C6	2.3	3.7	5.3	50
7	C7	1.9	2.8	4.2	60

VI. CONCLUSIONS

From the above study following conclusions are drawn:

A. Compressive Strength (when cement replaced with fly ash)

1) The compressive strength of fly ash concrete up to 30% replacement level is slightly equal to referral concrete at 28 and 56 days.

2) Optimum replacement level of fly ash is 20%, at 20% replacement level increase in strength at 28 and 56 days is 1.9% & 3.2%.

B. Compressive strength (when fine aggregate replaced with fly ash)

3) The compressive strength of fly ash concrete at 50% replacement level increased in strength with referral concrete is 15.4% and 18% at 28 & 56 days.

C. Splitting tensile test (when cement replaced with fly ash)

4) The split tensile strength of fly ash concrete up to 20% replacement level is more than referral concrete at 7, 28 and 56 days.

5) Optimum replacement level of fly ash is 20%

6) , at 20% replacement level increase in tensile strength at 7, 28 and 56 days is 13%, 5.63% and 19.0%.

D. Cost analysis

7) By using Fly ash at 30% in concrete as cement replacement material, the material cost may decrease up to 23.34%.

8) It is observed that in PPC gains strength after the 56 days curing.

Increase in strength after 56 days curing showed because of slow hydration process of Fly Ash PPC concrete, Since Fly ash is a slow reactive Pozzolanic material

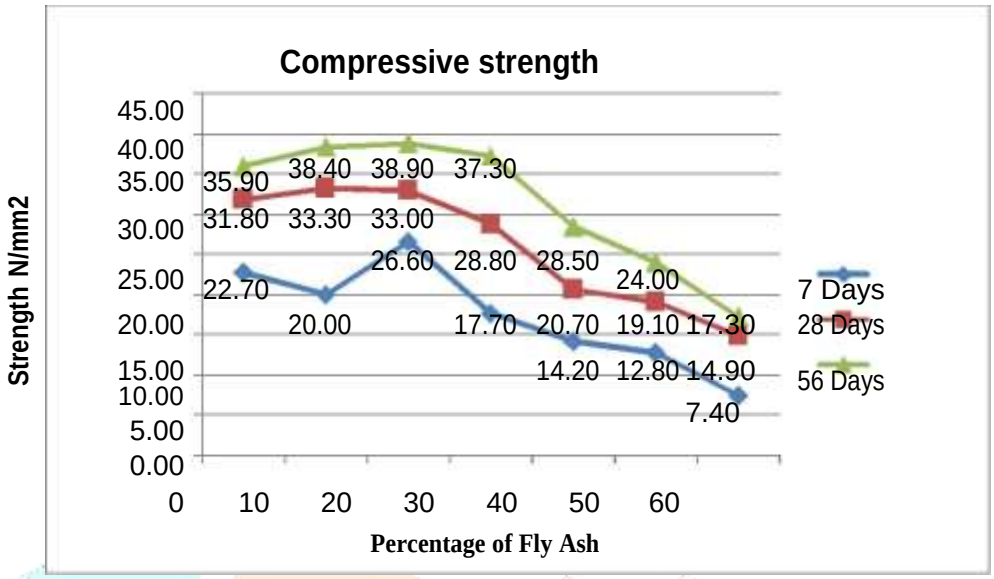

Figure 1: Compressive Strength of Fly Ash Concrete (Line chart)

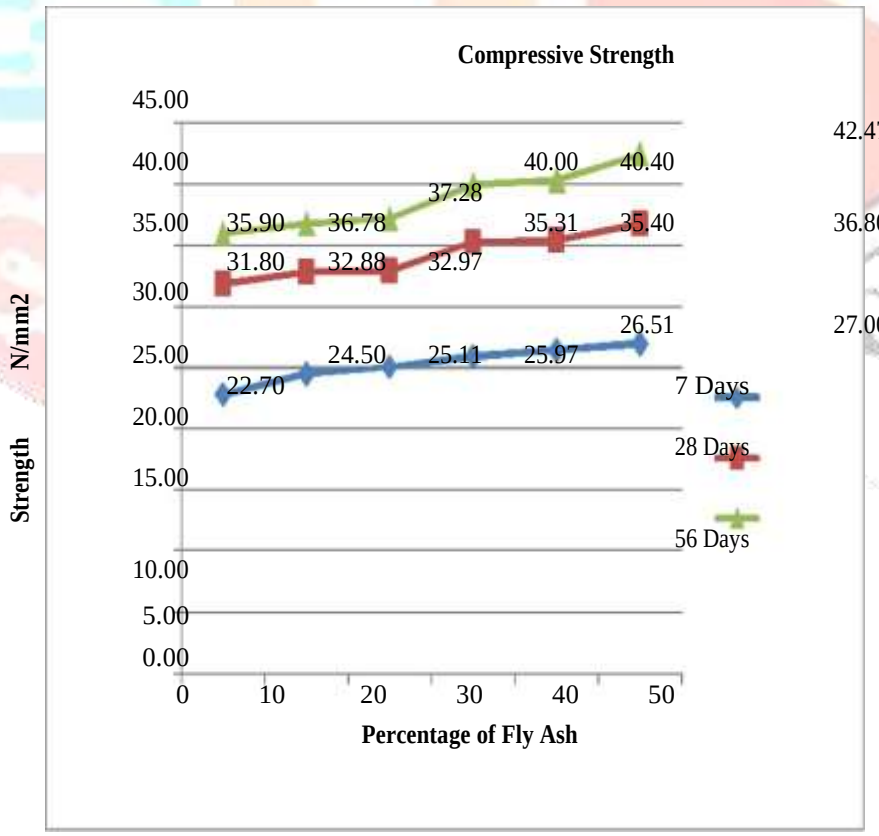

Figure 2: Compressive strength of Fly Ash Concrete (Line Chart)

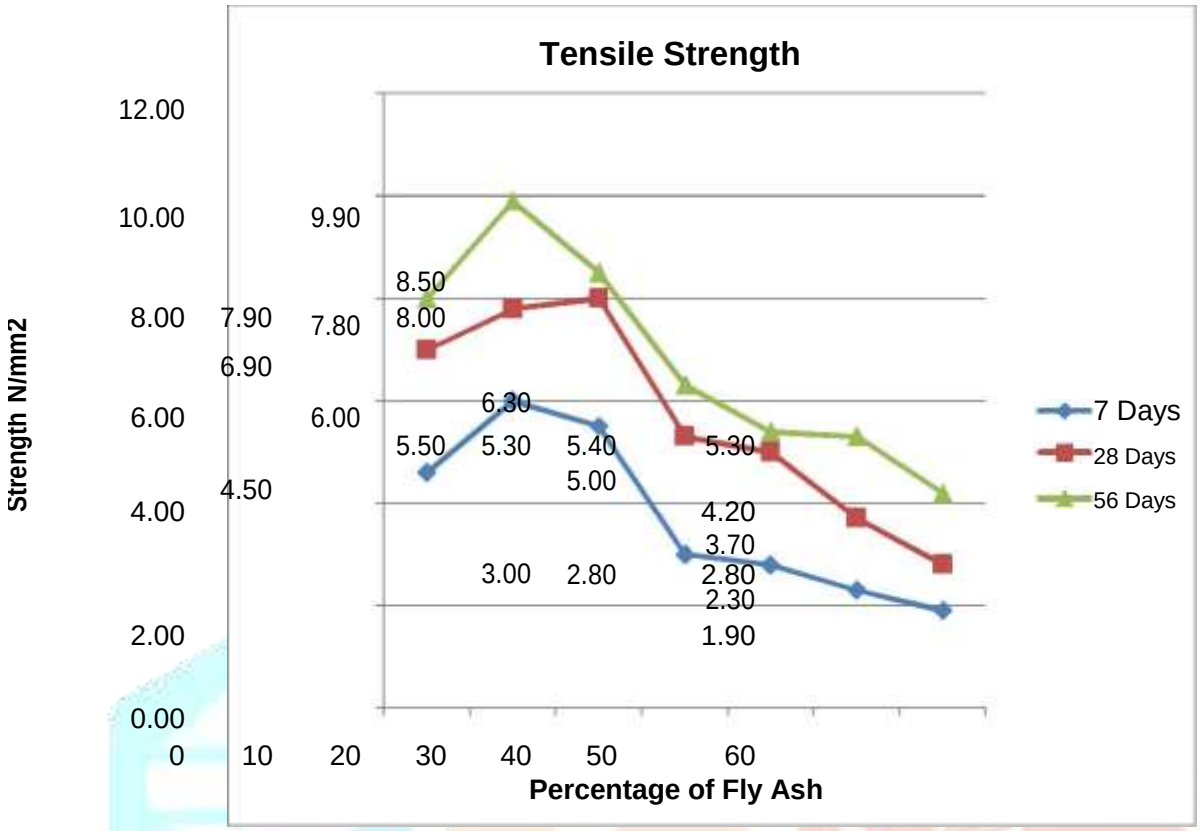

Figure 3: Split Tensile Strength of Fly Ash Concrete (Line Chart)

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