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Behavior of FLY ASH in Cement-Concrete Pavement

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Abstract- ***Aim of study is to test and analysis compressive strength of fly ash-cement concrete in a normal way as use to determine on construction site, which can utilize in road construction in rural areas. There is a vast area of covered by industrial waste such as fly ash, so using this waste in road construction can dispose this waste and also beneficial in minimize pollution in environment due to this waste. Laboratory experiments were performed on fly ash to determine its properties, which may be used in road construction, earth dam construction, soil stabilization etc. Fly ash was collected from Kalishindh thermal power plant, Jhalawar. In present study aims preparing concrete by replacement of Ordinary Portland Cement (OPC) with fly ash in various proportion like- 10%, 20%, 30%, 40% and 50% Fly Ash by mass. The study discloses that high volume of Fly Ash in concrete reduces the water demand and improves the workability. Study also reveals that the OPCC and HVFAC exhibit similar hardened properties. Experiments such as compressive strength test, slump test for workability, std. consistency test, specific gravity test etc are done in order to determine properties of fly ash, which can take account in the construction field. A comparison is made between fly ash and cement properties which are used as sub-grade, base in Highway construction. It would have been a very good situation if common industrial wastes like fly ash can be considered as an alternative option to mix in concrete materials for highway construction with economical solution.***

1. INTRODUCTION

Road and Electricity are basic need for every human. Mainly every human creature move one place to another place and Transportation system provide them a better way to move. Major source of power generation in India are on coal-based Thermal power plant, where 75% of the total power obtained is from these plants. In the process of electricity generation, large amount of fly ash get produced and become available as a byproduct of coal-based power stations.

Fly ash is a fine powder resulting from the combustion of powdered coal - transported by the flue gases of the boiler and collected in the Electrostatic Precipitators (ESP). Fly ash is defined in Cement and Concrete Terminology (ACI Committee 116) as the 'finely divided residue resulting from the combustion of ground or powdered coal, which is transported from the fire box through the boiler by flue gases. Fly ash is fine glass powder, the particles of which are generally spherical in shape and range in size from 0.5 to 100 μ.

Fly ash particles are in general spherical in shape and range in size from 0.5 μm to 100 μm. They consist mainly of silicon dioxide (SiO_2), which is present in two forms: amorphous, which is rounded and smooth, and crystalline, which is sharp, pointed and hazardous; aluminium oxide (Al_2O_3) and iron oxide (Fe_2O_3). Fly ashes are in general highly heterogeneous, consisting of a concoction of glassy particles with various exacting crystalline phases such as quartz, mullite, and various iron oxides.

1.1 Classes of Fly ash

According to ASTM C-618 Fly ash is broadly classified into two major categories: Class F and Class C fly ash. The chief difference between these two classes is the amount of calcium, silica, alumina, and iron content. The chemical properties of the fly ash are largely influenced by the chemical content of the coal burned (i.e., anthracite, bituminous, and lignite).

- **Classes "F" fly ash**- The burning of old anthracite and bituminous coal typically produces Class F fly ash which contains less than 10% lime (CaO). Possessing pozzolanic properties, the glassy silica and alumina of Class "F" Fly ash requires a cementing agent, such as Portland cement, quicklime, or hydrated lime, with the presence of water in order to react and produce cementitious compounds. Alternatively the addition of a chemical activator such as sodium silicate (water glass) to a Class "F" ash can lead to the formation of a geo-polymer.
- **Class 'C' Fly ash** -Class "C" Fly ash produced from the burning of younger lignite or sub bituminous coal generally contains more than 20% lime (CaO). This type of ash does not require an activator & the contents of Alkali and sulfate (SO_4) are generally higher as compare to the Class "F" Fly ash.

1.2 Types of Fly ash[1]-

There are three types of fly ashes produced by thermal power plant:-

- **Fly ash**- this kind of Fly ash is exerted from flue gases through Electrostatic precipitator in dry form. This ash is fine material and possesses good pozzolanic property.
- **Bottom ash** -this kind of fly ash is collected in the bottom of boiler furnace. It is comparatively coarse

material and contains higher un-burnt carbons. It possesses zero or little pozzlanic property.

- **Pond ash**- Fly ash and bottom ash when transported and disposed to the pond it is termed as pond ash.

1.3 Use of fly ash in construction-

Fly ash is used by ancient time, initially its is used in less amount, but now a day a major production of fly ash is made so its uses and decomposes is necessary to protect environment from pollution. It is used as follow:-

- The ROMANS used naturally occurring volcanic ash from Mount Vesuvius to cement the paving stones in their roadways. Many miles of this ancient roadway although rough by our standards – still exist as useable highway.
- Fly ash concrete was first used in the U.S. in 1929 for the Hoover Dam, where engineers found that it allowed for less total cement.
- Major breakthrough in using fly ash in concrete was the construction of Hungry Horse Dam in 1948, utilizing 120,000 metric tons of fly ash.
- In January of 1974, The Federal Highway Administration indicated that "the replacement of cement with fly ash of the order of 10% to 25% can be made giving equal or better concrete strength and durability.
- In January 1983, the Environmental Protection Agency published federal procurement guidelines for cement and concrete containing fly ash which encourage the utilization of fly ash and establish compliance deadlines.
- The seven storey structure of 10780m^2 office space in Canada was constructed with HVFAC having compressive strength 30-50N/mm^2.

2. OBJECTIVE AND SCOPE OF STUDY-

The advantages of using fly ash far outweigh the disadvantages. The most important benefit is reduced permeability to water and aggressive chemicals. Properly cured concrete made with fly ash creates a denser product because the size of the pores is reduced. This increases strength and reduces permeability

1) Objective of this study-

To tests and analysis on fly ash concrete prepared by fly ash optimum replacement with cement. 28 days compressive strength of fly ash concrete is to be checked.

2) Scope of work- Following procedure to be done for this work-

- Experimental study is to be conducted on material to find out physical properties.
- Materials are to be mixed in proper proportion and molded in a cube,
- In this study, normal grade of cement have to be taken, and prepare fly ash concrete by mixing fly ash with maximum replacement of cement. Various specimen mixing proportion of cement and fly ash prepared, replacement of cement by weight 0%, 10%, 20%, 30%, 40% and 50% by fly ash.
- These various specimens of fly ash cement concrete are to be tested and normal 28 days compressive strength is to be checked.
- Analyzing tests result.

3. Experimental study: working procedure -

In this experimental study works are done as following in step:-

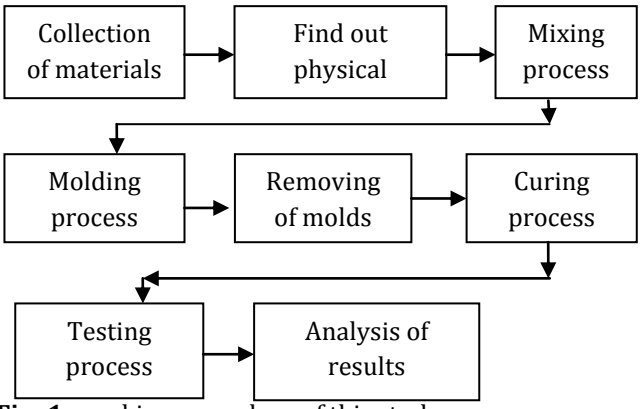

Fig -1: working procedure of this study

3.1. Collection of material: -

For fly ash concrete, materials are collected and their physical properties also to defined by conducting experiments. Materials should be qualitive and obtained from proper place. Following materials are used for preparing of fly ash cement concrete –

- **Cement**- Ordinary Portland cement of 43 grade conforming to Indian standard IS 12269(1987) was used for the present experiments.
- **Fly ash**-FLY ASH obtained from "Kalisindh thermal power plant" jhalawar. Ash collected from near the boiler.
- **Aggregates**- 20 mm to 4.75 mm aggregates taken as coarse aggregates and below 4.75 mm aggregates taken as fine aggregates. Aggregates were taken from construction site. on construction site it was brought from Nimbahera, Chhitorgarh.

3.2. Physical property of material:

Physical property as color, specific gravity, initial setting time, moisture content etc., were determined by experiments

3.3. Mixing process:

Materials are weighed in proper way and as required for mixing. After then, it mixed in proper way nominal mix method. For this experimental study M-20 grade of concrete was prepared, by nominal mix method. For present study concrete was mixed in 1:1.5:3 proportions and w/c ratio was kept 0.55. Cement was replaced with fly ash, fly ash added as 10 to 50% of cement weight which

was used in mixing concrete. Material were mixed as mentioned in table 1, as following-

Table -1: Material mixing proportions

Fly ash content	Fly ash (kg)	Cement (kg)	Sand (kg)	aggregates (kg)
0%	0.000	7.500	11.250	22.500
10%	0.750	6.750	11.250	22.500
20%	1.500	6.000	11.250	22.500
30%	2.250	5.250	11.250	22.500
40%	3.000	4.500	11.250	22.500
50%	3.750	3.750	11.250	22.500

3.4. Molding process:

Concrete mixer molded in cube sized 150*150*150 mm^3. Totally, 6 cubes were molded, in which 3 cubes tested after 7 days and rest 3 cubes tested after 28 days. Concrete is mixed by hand and thoroughly mixed and the concrete placed in cubes with the minimum delay. It was well compacted by rodding, temping and vibrating to remove all air voids after placing.

3.5. Removing of mold:

After 24 hours molds were removed. After demolding, each cube was marked with a legible identification on the top or bottom using a waterproof marker.

3.6. Curing process:

Concrete cubes were cured normally in fresh water for 7 to 28 days at room temperature. Curing plays an important role in gaining of strength of concrete. If concrete cube not properly cured then it will not gain enough strength and on other hand if concrete cubes cured for more time then also its strength decrease. Curing process in concrete increases strength and decrease permeability.

3.7. Testing process:

After removing of mould, concrete cubes are tested in laboratory. Various tastes were done.

For find physical property of material, specific gravity of cement, initial setting time, moisture content and standard consistency was determined, to check workability of concrete slump test was conducted, and for strength of concrete compressive strength was conducted by compressive strength testing machine.

3.8. Analysis and test result:

Following tested were conducted on materials and concrete-

1. **Physical property of materials-**

Physical properties determined by conducting proper experiments. After than standard consistency and initial setting time of cement and fly ash mix was determined,

Table- 2: Property of Materials

1	Physical Property of cement 1. Specific gravity 2. Moisture content 3. Initial setting time 4. Fineness modulus	 3.15 33 P 40-45 minutes 8%
2	Properties of Fly ash 1. Specific gravity 2. Moisture content	 2.27 19.48%
3	Property of Fine-aggregates 1. Standard consistency 2. Moisture Content	 2.70 8.86%

Table -3: Standard consistency of fly ash and cement mix

Content	Wt. of cement (grams)	Wt. of fly ash (grams)	consistency % (P)
0%	400	0	33.0
10%	360	40	32.0
20%	320	80	32.0
30%	280	120	31.0
40%	240	160	30.0
50%	200	200	30.0

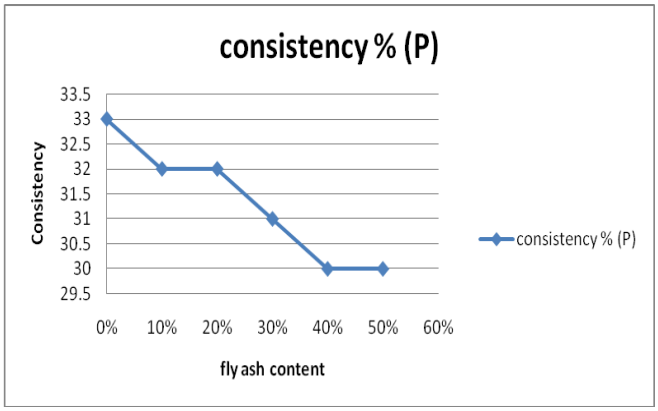

Chart- 1: Standard consistency of cement and fly ash mix

Thus by results, we can see as amount of fly ash increased consistency decreased. As amount of fly ash increased in mix, it required less water as compare to cement.

Table -4: Initial setting time of fly ash and cement mix

Content	wt. of cement (grams)	Wt. of fly ash (grams)	Initial setting time (minute)
0%	400	0	45
10%	360	40	50
20%	320	80	56
30%	280	120	65
40%	240	160	75
50%	200	200	90

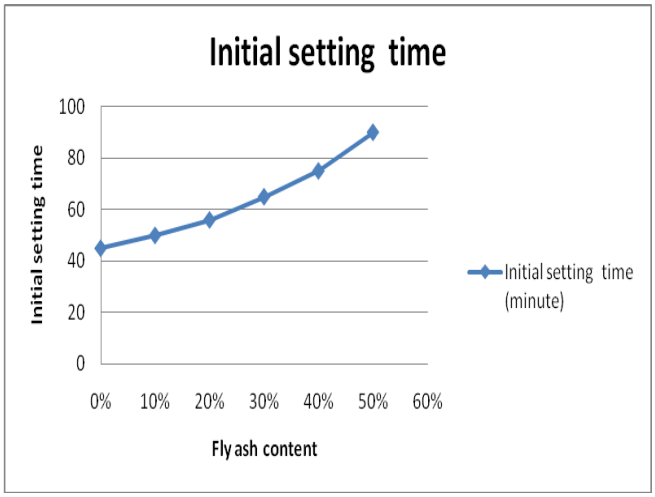

Chart- 2: Standard consistency of fly ash and cement mix

Thus by result it can see that as amount of fly ash increased in cement, initial setting time also increased and it take more time to settle.

Table -5: Slump value of concrete

Fly ash content	Slump value (mm)
0%	25
10%	28
20%	33
30%	40
40%	45
50%	50

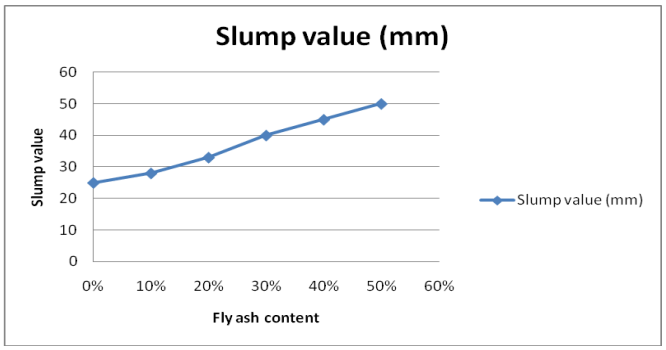

Chart- 3: Slump height of concrete mix

As amount of fly ash increased slump values increased. Fly ash also has not more binding property so slump values increased. Water/cement ratio also plays an important role in preparing of concrete, amount of water for concrete mix is can be determined according standard consistency of cement. If water is added more it will wet concrete, which have less workability and strength. If water is added less it becomes stiff which is not useful.

Table -6: compressive strength of concrete

Concrete grade	Sample content	Compressive strength (7days) N/mm2	Compressive strength (28days) N/mm2
M 20	0% (only concrete)	27.00	35.92
	10% fly ash	22.77	35.68
	20% fly ash	19.23	31.17
	30% fly ash	18.10	26.03
	40% fly ash	16.96	25.82
	50% fly ash	8.726	18.24

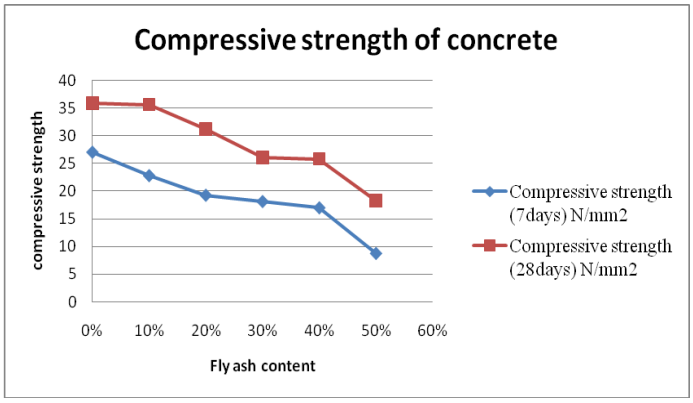

Chart -4: Compressive strength of concrete

Thus it can see that as amount of fly ash increased compressive strength decreased, up to 30-40% is safe to use in concrete mix and 50% fly ash cement concrete has not enough compressive strength to use for construction.

4. CONCLUSIONS

In present study physical properties of cement, fly ash, and fine aggregates determined, and then slump test conducted to check concrete workability, and compressive strength test to check its quality and compressive strength. Results are following-

- Specific gravity of cement was 3.148 and fly ash 2.27, so specific gravity of fly ash is less than to cement.
- Standard consistency increased as amount of fly ash increased in cement fly ash mix that means less water quantity need to make cement fly ash mix paste.
- Fly ash takes longer time to settle down as compare to ordinary Portland cement. Cement paste settle down in 45 to 50 minute. On other hand as amount of fly ash increased its settling time also increased.
- In slump test, Fly ash cement concrete has more workability as compare to normal cement concrete.
- Fly ash-cement concrete cube absorbs more water.
- Compressive strength is approximately same as normal cement concrete. As amount of fly ash increased, as compressive strength decreased. Replacement of fly ash with cement in concrete up to 30% is safe to use in road construction to sustain its better quality.

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