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Partial Replacement of Cement by Fly ash in Concrete Mix Design

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Abstract - *Concrete is the most important engineering material in construction industry because of its inherent strength properties. However, the addition of some other materials may change the properties of concrete. With increase in trend towards the wider use of concrete for pre-stressed concrete and high rise buildings there is a growing demand of concrete with higher compressive strength. The mineral admixtures with pozzolanic properties such as fly ash (FA), silica fume (SF), ground blast-furnace slag (GGBS) and metakaolin (MK) are commonly used as a partial substitution of Portland cement during construction. These admixtures are often added to modify the physical and chemical properties of cementitious mixes. In comparison to ordinary Portland cement, the collection of flyash as a by-product requires less energy and it produces less the main objective of these paper is to see the difference between strength and workability of plain concrete and concrete mix by using fly ash*

Key Words- Fly-ash, Ordinary Portland Cement, Mix Design, Workability.

1. INTRODUCTION

Fly ash is comprised of the non-combustible mineral portion of coal. When coal is consumed in the power plant, it is first ground to the fineness of powder. Blown into the power plants boiler, the carbon is consumed, leaving molten particles rich in silica alumina and calcium. These particles solidify as microscopic, glassy spheres that are collected from the power plants exhaust before they can fly away- hence the products name fly ash. There are two basic types of fly ash: Class F and Class C. According to ASTM C618, fly ash belongs to Class F if (SiO2+Al2O3+Fe2O3) > 70% and belongs to Class C if 70% > (SiO2+Al2O3+Fe2O3) > 50%. Both these fly ashes undergo pozzolanic reaction with lime (Calcium hydroxide) created by hydration of cement and water to form calcium silicate hydrate like cement. In addition, some Class C fly ashes may possess enough lime to be self-cementing in addition to the pozzolanic reaction with lime from cement hydration.

Through pozzolanic activity, fly ash combines with free lime to produce the same cementitious compounds formed by the hydration of Portland cement. Due to this series of chemical reaction, rate of strength gain for fly ash concrete is relatively slower at early ages of curing. During the last few years, some cement companies have started using fly ash in manufacturing cement, which is known as "Pozzolana Portland Cement," but the overall percentage utilization remains very low and most of the fly ash is dumped at landfills.

Fly ash is a fine, glass-like powder recovered from gases created by coal-fired electric power generation. Power plants produce millions of tons of fly ash annually, which is usually dumped in landfills. Fly ash is an inexpensive replacement for Portland cement used in concrete, while it actually improves strength, and ease of pumping of the concrete. Fly ash is also used as an ingredient in brick, block, paving, and structural fills.

2. FLY ASH

2.1 CLASSIFICATION OF FLY-ASH

There are two basic types of fly ash: Class F and Class C. Both types react in concrete in similar ways. Both Class F and Class C fly ashes undergo a "pozzolanic reaction" with the lime (calcium hydroxide) created by the hydration (chemical reaction) of cement and water, to create the same binder (calcium silicate hydrate) as cement. In addition, some Class C fly ashes may possess enough lime to be self-cementing, in addition to the pozzolanic reaction with lime from cement hydration.

2.2 PROPERTIES OF FLY-ASH

The fly ash or pulverized fuel is the residue, which is collected by the mechanical dust collector or electrostatic precipitator from the fuel gases of thermal power plants. Composition of fly ash varies with the type of fuel burnt, load on the boiler and the type of separator. Like Portland cement, fly ash contains oxides of calcium, aluminum and silicon, but the amount of calcium oxide is considerably less. The carbon contents should be as low as possible, whereas the silica content should be as high as possible. Fly ash obtained from electrostatic precipitator (ESP) may have a specific surface of about 350 to 500 m2/kg. I.e. finer than the Portland cement. Properties of fly ash in concrete are not directly related to the chemistry of fly ash. Some properties of fly ash are known by two parameters, these are fly ash mineralogy and fly ash practical size.

2.3 ADVANTAGES OF FLY-ASH

The advantages of fly ash concrete over the corresponding plain cement concrete are:

- Improved workability
- Lower heat of hydration
- The increase in creep with fly ash content up to 15% is negligible
- Increases the modulus of elasticity of concrete when concretes of the same strength with and without fly ash are compared
- Superior resistance to freezing and thawing
- Improved sulphate resistance
- Lower water and air permeability
- Lower leaching of lime liberated during hydrated of cement
- Reduced alkali-aggregate reactions
- Greater resistance to attack of aggressive water

2.4 EFECT OF USING FLY-ASH IN FRESH & HARDENED CONCRETE

- Use of right quality fly ash, results in reduction of water demand for desired slump.
- With the reduction of unit water content, bleeding and drying shrinkage will also be reduced.
- Since fly ash is not highly reactive, the heat of hydration can be reduced through replacement of part of the cement with fly ash.
- Fly ash, when used in concrete, contributes to the strength of concrete due to its pozzolanic reactivity.
- The pozzolanic reaction also contributes to making the texture of concrete dense, resulting in decrease of water permeability & gas permeability.
- It should be noted that since pozzolanic reaction can only proceed in the presence of water, fly ash concrete should be cured for longer time.
- Dams will derive full benefits of attaining improved long term strength and water tightness.

3. MIX DESIGN

A mix is to be designed for characteristic strength of 50 N/mm^2 at 28 days having target strength of 62 N/mm^2 at 28 days. 30% of fly ash is to be included by weight of cementitious material. Maximum w/c ratio or w/c + f.a. ratio = 0.4,

Minimum cement concrete or cement + f.a. content = 400 kg/m^3. Slump: Collapsible.

Fly ash or pulverized fuel ash (PFA) is a finely divided powder thrown out as a waste material at the thermal power plants using pulverized coal for raising steam in the boilers. In the building industry, the use of fly ash a part replacement of cement in mortar and concrete at the construction site has been made all over the world including India and is well known.

A. Grade of Material:

- Cement: OPC, 53 grade, specific gravity = 3.15
- Fine aggregate: From river of Zone II Specific gravity = 2.6
- Coarse aggregate: Crushed 20 mm graded, Specific gravity = 2.6
- Fly ash: As per I.S.: 3812, Specific gravity = 2.25

B. Workability:

- Water content reduction for fly ash concrete: 5%
- Increase in cementitious material: 12%

C. Designed plain concrete of above strength and workability:

- Water (free) = 150 kg/m^3
- OP Cement = 425 kg/m^3
- Fine aggregate = 769 kg/m^3
- Coarse aggregate = 1062 kg/m^3
- Add mixture (Basf Rheoplus)= 4.3 kg/m^3 (1% of cement)
- Total = Sum of all of the above = 2410 kg/m^3 (air = 1%)

D. Fly ash concrete of above strength and workability:

Table 1. Quantities of Materials used for Fly Ash Concrete

Material	Weight (Kg/m3)	Volume (m3)
Total Cementitious Materials	476	
OPC	333	0.1057
Fly Ash	143	0.0636
Water (free)	142.5	0.1425
Admixture	4.76	0.0045
Air (1%)		0.0100
Total		0.3263
Aggregate	1-0.3263	0.6737
Coarse Aggregate	1062	0.4085
Fine Aggregate	690	0.2652
Total	2375	1

4 METHOD OF FLY ASH CONCRETE MIXING

For obtaining the best result the fly ash concrete should be prepared by the following mixing method:

- About 3/4th quantity of the mixing water should be taken in the concrete mixer. Weighted amount of the required quantity of fly ash then added to it and mixed for 30 sec. To the slurry of fly ash so obtained, weighted quantities of coarse aggregate, fine aggregate, cement and remaining quantity of the mixing water be added and mixed for 90 sec.

However, if this is not convenient normal mixing method may be adopted i.e.

- Weighted quantities of coarse aggregate, fine aggregate cement and fly ash should be put together in the concrete mixer and mixed dry for 30 sec. The required quantity of the mixing water then added and the mixing continued for 90 sec. The Admixture should be added just before discharge of the mix from mixer.

5 CONCLUSION

It may be noticed that, for the fly ash concrete the total cementitious material is greater but the OPC content is smaller, the fine aggregate content is reduced but the coarse aggregate content is deliberately the same, the water is reduced and the density is reduced because of the lower density of fly ash compared with cement

A Comparison (kg/m³)

Table 2. Comparison between Plain Concrete & Fly Ash Concrete Quantities

Materials	Plain Concrete	Fly ash Concrete
Water (free)	150	142.5
OP Cement	425	333
Fly ash	—	143
Fine aggregate	769	690
Coarse aggregate	1062	1062
Admixture	4.300	4.76
Total	2410	2375

Saving in cement 425-333 = 92 kg/m³

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