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An Evaluation on the Composition of Coal Fly Ash and Its Co-Placement with Concrete

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Abstract - *Coal fly ash is an industrial by-product, produced from coal combustion in thermal power plants. It is the most complex anthropogenic materials, which consists of combination of minerals originated from different sources. Coal fly ash and its byproduct has become an environmental concern over the World. This study was intended to characterize the physical and chemical properties of a coal fly ash (CFA) from a site specific power plant and to find it helpful in improving the properties of concrete when co-placed with concrete.*

***Key Words*: Coal Fly Ash, Characteristic; Co-Placement.**

1. Introduction

Fly Ash is a byproduct of coal-fired electric generating plants. The coal is pulverized and blown into burning chamber for immediate combustion. Heavier ash particle (Bottom Ash or Slag) fall to the bottom burning chamber and the lighter ash (fly ash) fly out with exhaust gases, thus the term fly ash is used. Before leaving the stack, these fly ash particles are removed and collected by electrostatic precipitation, bag houses or other methods. According to ASTM, fly ash is classified as Class C or Class F. Class C fly ash generally has more than 20% CaO, more than 50% combined SiO2, Al2O3, and Fe2O3 content, and is normally produced from sub-bituminous or lignite coal combustion. Class F fly ash is usually produced from bituminous and anthracite coal combustion and has less than 10% CaO content and more than 70% SiO2, Al2O3, and Fe2O3 content. Coal samples tested during research conducted by EPRI showed Class C fly ashes having a 14.6% to 27.2% CaO composition and Class F having a 0.3% to 6.8% CaO composition. Approximately 40% of the fly ash produced is re-used in industrial applications.

2. Composition of Coal Fly Ash

Fly ash material solidifies while suspended in the exhaust gases and is collected by electrostatic precipitators or filter bags. Since the particles solidify while suspended in the exhaust gases, fly ash particles are generally spherical in shape and range in size from 0.5 µm to 100 µm. They consist mostly of silicon dioxide (SiO2), which is present in two forms: amorphous, which is rounded and smooth, and crystalline, which is sharp, pointed and hazardous; aluminum oxide (Al2O3) and iron oxide Fly ashes are generally highly heterogeneous, consisting of a mixture of glassy particles with various identifiable crystalline phases such as quartz, mullite, and various iron.

3. Classification of Coal Fly Ash

Two classes of fly ash are defined by ASTM C618: Class F fly ash and Class C fly ash these classes is the amount of calcium, silica, alumina, and iron content in the ash. The chemical properties of the fly ash are largely influenced by the chemical content of the coal burned. Class F fly ash: The burning of harder, older anthracite and bituminous coal typically produces Class F fly ash.

This fly ash is pozzolanic in nature, and contains less than 20% 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 Class C fly ash: Fly ash produced from the burning of younger lignite or sub-bituminous coal, in addition to having pozzolanic properties, also has some self-cementing properties. In the presence of water, Class C fly ash will harden and gain strength over time. Class C fly ash generally contains more than 20% lime (CaO).

4. Physical and Chemical Properties of CFA

The particle distribution of the CCA was shown in the Figure 2. It is observed that the CCA has the median diameter (d50) of 0.2 mm and less than 20% of fines (1%) and followed by sulfur, titanium, barium, sodium and phosphate which are less than 1%.The major constituents of most of the fly ashes are Silica (SiO), alumina ((Al O), ferric oxide (Fe O) and calcium oxide (CaO). The other minor constituent of the fly ash are MgO, Na O, K O, SO , MnO, TiO and unburnt carbon. There is wide range of variation in the principal constituents - Silica (25- 60%), Alumina (10-30%) and ferric oxide (5-25%).

When the sum of these three principal constituents is 70% or more and reactive calcium oxide is less than 10% - technically the fly ash is considered as or class F fly ash. Such type of fly ash is produced by burning of anthracite or bituminous coal and possesses pozzolanic properties. If the sum of these three constituent is equal or more than 50% and reactive calcium oxide is not less than 10%, fly ash will be considered as also called as class C fly ash.

About 43% is recycled, often used as a Pozzolana to produce hydraulic cement or hydraulic plaster and a replacement or partial replacement for Portland cement in concrete production. A supplementary cementitious material, when used in conjunction with Portland cement, contributes to the properties of the hardened concrete through hydraulic or Pozzolanic activity or both.

Controlled low strength material (CLSM)-

Fly ash can be utilized in the manufacture of CLSM. This is a fluid mixture made up of small quantity (4-6%) of Portland cement, sufficient quantity of water and large quantity of fly ash or fine aggregates or both. The CLSM is neither a concrete nor a soil cement but is has property similar to both. CLSM or fly ash slurry fill material provides many advantages as follows:

- Excellent flow-ability; can be filled with minimal efforts; fills all the voids, spaces.
- No compaction or curing required.
- Easy to produce and apply.
- No settlement after final set.
- Low unit weight.
- Can be dug back later, when required.
- Different strengths can be designed as per retirement.
- Reduced labor cost.
- Cost effective.

Special Characteristics of Fly Ash

- Low bulk density; water holding capacity; neutral to slightly alkaline pH; almost non-reactive particulates; low EC; presence of some essential elements for plant body; presence of many trace elements.
- Fly ash has a good potential for being utilized in the agriculture fields in the following manner:
  a. As a soil amendment to modify the pH of the soil.
  b. As a soil conditioner to improve the physical and chemical properties of soil. c. As a source of essential plant nutrients like P, K, Ca, Mg, Cu, Zn, Fe, Mn, etc.
- Due to comparatively medium silica content and fineness of the material, fly ash undergoes rapid weathering. During combustion of coal, the material is produced containing all the mineral constituents of coal, but with a very low cation exchange capacity (3 meg/100 g).
- The ability of fly ash particles of complex formation of trace elements with organic substances controls the concentration levels of trace elements in aquatic environment; hence lowers the toxicity of a given concentration of total metal.

Fig -1: Coal fly ash

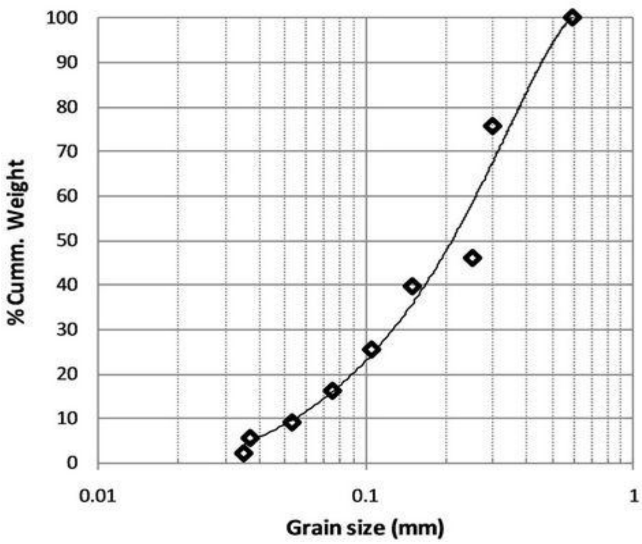

Fig -2: Particle size distribution of CFA

Major Element (Mass %)		Major Element (Mass %)	
SiO_2	32.627	Na_2O	0.206
TiO_2	0.669	K_2O	1.446
Al_2O_3	13.961	P_2O_5	0.225
FeO	6.462	S	0.969
MnO	0.019	Ba	0.400
MgO	3.045	LOI	14.36
CaO	2.67	H_2O	22.71

Table -1: Bulk element composition of sample

3. Improved Properties of Fresh Concrete

3.1 Improved workability

The spherical shaped particles of fly ash act as miniature ball bearings within the concrete mix, thus providing a lubricant effect. This same effect also improves concrete permeability by reducing frictional losses during the pumping process and flat work finish ability.

3.2 Decreased water demand

The replacement of cement by fly ash reduces the water demand for a given slump. When fly ash is used at about 20 percent of the total cementitious, water demand is reduced by approximately 10 percent. Higher fly ash contents will yield higher water reductions. The decreased water demand has little or no effect on drying shrinkage/cracking. Some fly ash is known to reduce drying shrinkage in certain situations.

3.3 Reduced heat of hydration

Replacing cement with the same amount of fly ash can reduce the heat of hydration of concrete. This reduction in the heat of hydration does not sacrifice long-term strength gain or durability. The reduced heat of hydration lessens heat rise problems in mass concrete placements.

3.4 Increased ultimate strength

The additional binder produced by the fly ash reaction with available lime allows fly ash concrete to continue to gain strength over time. Mixtures designed to produce equivalent strength at early ages (less than 90 days) will ultimately exceed the strength of straight cement concrete mixes.

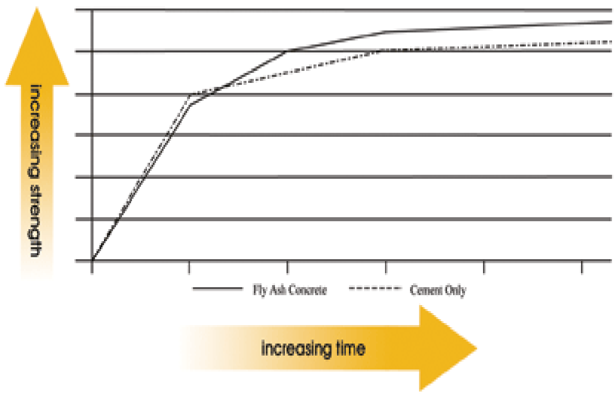

Fig -3: Typical strength gain of fly ash concrete

3.5 Reduced permeability

The decrease in water content combined with the production of additional cementitious compounds reduces the pore interconnectivity of concrete, thus decreasing permeability. The reduced permeability results in improved long-term durability and resistance to various forms of deterioration.

3.6 Improved durability

The decrease in free lime and the resulting increase in cementitious compounds, combined with the reduction impermeability enhance concrete durability. This affords several benefits improved resistance to ASR. Fly ash reacts with available alkali in the concrete, which makes them less available to react with certain silica minerals contained in it.

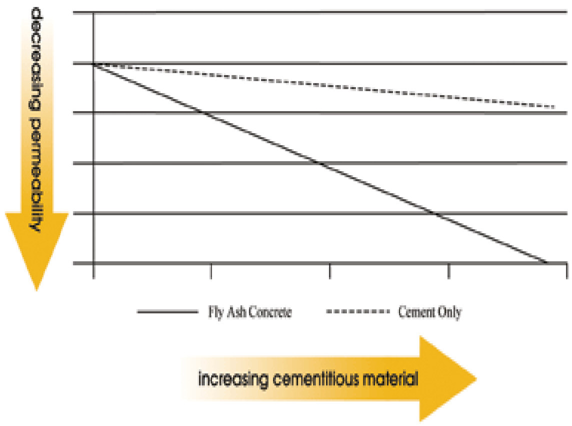

Fig -4: Permeability of fly ash concrete

4. Conclusions

As a result, it can be concluded that

- Coal ash that are used at the Thermal Power Plant Gallant Ispat Ltd. Gorakhpur contains 8.84 wt% of calcium oxide (CaO), it can be classified as C Class fly ash.
- Research results indicate that ash with high carbon content reduces the workability of mixtures, thus increasing the water demand and thereby reducing the strength of the concrete.
- No proof could be found that the particle size of ash has an effect on the strength of the concrete.
- The use of large percentages of ash replacement does result in reduced early strength, but for specific applications there could be benefits in replacing high percentages of cement with ash

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