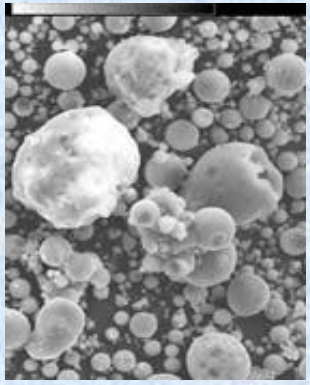
1.0 सामान्य/General

It has now been established that admixtures are substances which when added to concrete in small doses can overcome some of the drawbacks viz., poor workability, high shrinkage cracks, poor performance against chemicals, high permeability, inadequate protection of steel reinforcement from corrosion, low tensile strength and lower fracture toughness.

Admixtures can be defined as materials other than water, cement and aggregate, added to concrete immediately before or during mixing. Admixtures are used to accelerate or retard the setting time of concrete, to reduce water content and improve strength and to increase slump or reduce cement content and to improve the overall durability of concrete. Admixtures can enhance the workability of concrete.

It is generally agreed that the use of fly-ash, particularly as an admixture rather than as a replacement of cement, reduces segregation and bleeding. Flyash has proved to be less expensive and when mixed with lime (liberated during hydration process), it makes excellent binders; improves durability of concrete, particularly its resistance to sulphate attack and alkali-silica reactions.

2.0 फ्लायएश का निष्कर्षण/Extraction of Flyash



Flyash as a pulverized fuel ash (PFA) extracted from flue gases by any suitable process such as by cyclone separator or electro-static precipitator (in dry form) is fine material & possesses good pozzolanic property. The pozzolanic property of flyash makes it a resource for making cement and other ash based products. The flyash obtained from electrostatic precipitators is relatively fine having a specific surface of about 3500 cm^2/g and may be as high as 5000 cm^2/g.

3.0 पल्वराइज्ड फ्यूल एश के उपयोग क्षेत्र/ Utilization Areas of Pulverized Fuel Ash

The major utilization areas of PFA are as under:

- Manufacture of Portland Pozzolana Cement & Performance improver in Ordinary Portland Cement (OPC).
- Part replacement of OPC in cement concrete.
- High volume flyash concrete.
- Roller Compacted Concrete used for dam & pavement construction.
- Manufacture of ash bricks and other building products.
- Construction of road embankments, structural fills, low lying area development.
- As a soil amender in agriculture and wasteland development.

4.0 सीमेंट के साथ फ्लायएश की प्रतिक्रिया/ Reaction of Flyash with Cement

As a result of reactions during the hydration process of cement, lime (by-product calcium hydroxide) is released out and remains as surplus in the hydrated cement. This leached out surplus lime renders deleterious effect to concrete such as make the concrete porous, give chance to the development of micro- cracks, weakening the bond with aggregates and thus affect the durability of concrete.

If flyash is available in the mix, it chemically reacts with the surplus lime released by the chemical reaction between cement and water to form additional cementitious products [calcium-silicate-hydrate (C-S-H) gel having similar binding properties] that improve many desirable properties of concrete. Compared to cement and water, the chemical reaction between flyash and lime is typically slower resulting in delayed hardening of the concrete. The reaction of flyash with surplus lime continues as long as lime is present in the pores of liquid cement paste.

5.0 फ्लायएश की विशेषतायें/Characteristics of Flyash

- **Chemical Composition of Flyash:** The major constituents of most of the flyash are Silica (SiO_2), alumina (Al_2O_3), ferric oxide (Fe_2O_3) and calcium oxide (CaO). The other minor constituent of the flyash are MgO, Na_2O, K_2O, SO_3, 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 flyash is considered as **Siliceous flyash** or class F flyash. Such type of flyash is produced by burning of anthracite or bituminous coal and possesses pozzolanic properties. The active constituents of class F flyash is siliceous or alumino-silicate glass.
  - If the sum of these three constituent is equal or more than 50% and reactive calcium oxide is not less than 10%, flyash will be considered as Calcareous flyash also called as class C flyash. This type of flyash is commonly produced by burning of lignite or sub-bituminous coal and possesses both pozzolanic and hydraulic properties. In Calcareous flyash the active constituents are calcium alumino-silicate glass, free lime (CaO), anhydrate ($CaSO_4$), tricalcium aluminate and rarely, calcium silicate.

  The glassy materials of flyash are reactive with the calcium and alkali hydroxides released from cement flyash system and forms cementitious gel, which provide additional strength.
- **Physical Properties of Flyash:** The flyash particles are generally glassy, solid or hollow and spherical in shape. The fineness of individual flyash particle ranges from 1 µm to 150 µm size and has a significant influence on its performance

in cement concrete. Greater the surface area, more will be the fineness of flyash.

- **Pozzolanic Properties of Flyash:** Flyash is a pozzolanic material defined as siliceous or siliceous and aluminous material which in itself possesses little or no cementitious value, chemically reacts with Calcium Hydroxide (lime) in presence of water at ordinary temperature and form soluble compound comprising of cementitious property similar to cement.

6.0 कंक्रीट में फ्लायएश का योगदान/Role of Flyash in Concrete

- **Reduced Heat of Hydration:** The large temperature rise of concrete mass exerts temperature stresses and can lead micro cracks. When flyash is present in the concrete mass, it reacts with released lime and produces binder and renders additional strength to the concrete mass. The un-reactive portion of flyash acts as micro aggregates and fills up the matrix to render packing effect and results in increased strength.

- **Workability of Concrete:** Flyash particles, generally spherical in shape reduce the water requirement for a given slump. The spherical shape helps to reduce friction between aggregates and between concrete and pump line and thus increases workability and improves flowability of concrete.

- **Permeability and Corrosion Protection:** Higher the water cement ratio, higher will be the porosity and thus higher will be the permeability. The permeability makes the ingress of moisture and air easy and is the cause for corrosion of reinforcement. Higher permeability facilitates ingress of chloride ions into concrete and is the main cause for initiation of chloride induced corrosion.

  When concrete is hardened, part of the entrapped water in the concrete mass is consumed by cement mineralogy for hydration. Some part of entrapped water evaporates, thus leaving porous channel to the extent of volume occupied by the water. Some part of this porous volume is filled by the hydrated products of the cement paste. The remaining part of the voids consists of capillary voids and gives way for ingress of water. Similarly, the liberated lime by hydration of cement is water-soluble and is leached out from hardened concrete mass, leaving capillary voids for the ingress of water.

  Additional cementitious material resulting from reaction between liberated surplus lime and flyash, blocks these capillary voids and also reduces the risk of leaching of surplus free lime and thereby reduces permeability of concrete.

- **Effect of Flyash on Carbonation of Concrete:** Carbonation phenomenon in concrete occurs when calcium hydroxides (lime) of the hydrated Portland cement react with carbon dioxide from atmospheres in the presence of moisture and form calcium carbonate. Carbonation process in concrete results in two deleterious effects (i) shrinkage may occur (ii) concrete immediately adjacent to steel reinforcement may reduce its resistance to corrosion.

  The rate of carbonation depends on permeability of concrete, quantity of surplus lime and environmental conditions such as moisture and temperature. When flyash is available in concrete; it reduces availability of surplus lime by way of pozzolanic reaction, reduces permeability and as a result improves resistance of concrete against carbonation phenomenon.

- **Sulphate Attack:** Sulphate attacks in concrete occur due to reaction between sulphate from external origins (or from atmosphere) and surplus lime leading to formation of etrringite, which causes expansion and results in volume destabilization of the concrete. Increase in sulphate resistance of flyash concrete is due to continuous reaction between flyash and leached out lime, which continue to form additional C-S-H gel. This C-S-H gel fills in capillary pores in the cement paste, reducing permeability and ingress of sulphate ions.

- **Corrosion of steel:** Corrosion of steel takes place mainly (a) due to carbonation attack and (b) due to chloride attack.

  In the carbonation attack, alkaline environment in the concrete comes down due to carbonation of free lime, which disturbs the passive iron oxide film on the reinforcement. When the concrete is permeable, the ingress of moisture and oxygen infuse to the surface of steel initiates the electrochemical process and as a result rust is formed. The transformation of steel to rust increases its volume thus resulting in the concrete expansion, cracking and distress to the structure.

  In the chloride attack, chloride ion becomes available in the concrete either through the dissociation of chlorides-associated mineralogical hydration or infusion of chloride ion. The sulphate attack in the concrete decomposes the chloride mineralogy thereby releasing chloride ion. In the presence of large amount of chloride, the concrete exhibits the tendency to hold moisture. In the presence of moisture and oxygen, the resistivity of the concrete weakens and becomes more permeable thereby inducing further distress.

  The use of flyash reduces availability of free limes and permeability thus results in corrosion prevention.

- **Reduced alkali- aggregate reaction:** Certain types of aggregates termed as reactive aggregates react with available alkalis and cause expansion and damage to concrete. It has been established that use of adequate quantity of flyash in concrete reduces the amount of alkali aggregate reaction and reduces/ eliminates harmful expansion of concrete. The reaction between the siliceous glass in flyash and the alkali hydroxide of Portland

cement paste consumes alkalis thereby reduces their availability for expansive reaction with reactive silica aggregates.

- **Environmental benefits of flyash use in concrete:** Use of flyash in concrete imparts several environmental benefits and thus it is eco-friendly. It saves the cement requirement for the same strength thus saving of raw materials such as limestone, coal etc. required for manufacture of cement. In the manufacturing of one tonne of cement, about 1 tonne of CO_2 is emitted and goes to atmosphere. Less requirement of cement means less emission of CO_2 resulting in reduction in green house gas emission.

7.0 BIS के अनुसार फ्लायएश की विशेषता/ Quality of Flyash as per BIS

To utilize flyash as a Pozzolana in Cement concrete and Cement Mortar, Bureau of Indian Standard (BIS) has formulated IS: 3812 Part–1 2003. In this code quality requirement for siliceous flyash (class F flyash) and calcareous flyash (class C flyash) with respect to its chemical and physical compositions have been specified.

- **BIS stipulations for use of flyash in concrete:** As per clause 5.2 of IS 456-2000 Plain and Reinforced cement concrete code of practice, flyash (conforming to IS: 3812 Part–1) up to 35% can be used as part replacement of OPC in the concrete. As per the note of table 5 of this code of practice, addition of flyash quantity can be taken into account in the concrete composition with respect to cement content and water cement ratio.

- **Effect of quality of flyash on concrete:** The characteristics of flyash depend upon the characteristics of coal burnt in the furnace of boiler, degree of pulverization of coal, rate and temperature of combustion, fuel/ air ratio etc. The important characteristics, which affect the performance of flyash in concrete, are

  - **Loss on Ignition (LOI):** When flyash is burnt at about 1000^0C, it suffers a loss of weight through the presence of carbonates, combined water in residual clay mineral and combustion of free carbon. The combined effect is termed the LOI. The carbon contained in flyash has high porosity and a very large specific area and is able to absorb significant quantity of water as well as admixture. Thus increase of water and admixture requirement affect properties of concrete. It may be stated that lower the LOI, the better will be the flyash.
  - **Fineness:** Fineness of flyash as determined by Blaine method is represented in terms of specific surface area. Finer flyash will have more reactive surface area available to react with lime and thus more will be the pozzolanic activity of flyash.
  - **Calcium Oxide (CaO) content:** The reactivity of flyash is related to the non-crystalline phases or glass. Pozzolanic reactivity of flyash is more in high calcium flyash than low calcium flyash. The reason for high reactivity in high calcium flyash partially may be because of different chemical composition of glass than the glass of low calcium flyash.

8.0 कंक्रीट में प्रयुक्त फ्लायएश के लाभ व हानियाँ/Advantages and Disadvantages of using Flyash in Concrete

Flyash has several industrial applications and is widely found in power plant chimneys and being utilized as a significant building material for the construction purposes due to its beneficial features. It is very much vital to use only high quality flyash to prevent negative effects on the structure of the building.

Flyash is used in many countries because of its advantages. Below listed are few of the advantages and disadvantages of flyash concrete, which are described in brief:

8.1 Advantages

- Flyash in the concrete mix efficiently replaces Portland cement that in turn can aid in making big savings in concrete material prices.
- It is an environmental friendly solution, which meets the performance specifications.
- It improves the strength over time and thus, offers greater strength to the building.
- Increased density and also the long-term strengthening action of flyash that ties up with free lime and thus, results in lower bleed channels and also decreases the permeability. The reduced permeability of concrete by using flyash, also aids to keep aggressive composites on the surface where the damaging action is reduced.
- It is highly resistant to attack by mild acid, water and sulphate.
- It effectively combines with alkalis from cement, which thereby prevents the destructive expansion.
- It is helpful in reducing the heat of hydration. The pozzolanic reaction in between lime and flyash will significantly generate less heat and thus, prevents thermal cracking.
- It chemically and effectively binds salts and free lime, which can create efflorescence. The lower permeability of flyash concrete can efficiently reduce the effects of efflorescence.

8.2 Disadvantages

The quality of flyash to be utilized is very vital. Poor quality often has a negative impact on the concrete and can increase the permeability and thus damaging the building.

References:

1. ***Guidelines on use of Admixtures in Concrete - www.rdso.indianrailways.gov.in***
2. ***Flyash for Cement Concrete - www.ntpc.co.in***
3. ***IS: 3812 Part–1 2003***
4. ***Building Matrials in India: 50 Years, published by BMTPC, Ministry of Urban Affairs & Employment, Govt. of India, Nirman Bhavan, New Delhi.***

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कंक्रीट में अधिमिश्रण के रूप में फ्लायएश का उपयोग

USE OF FLYASH AS ADMIXTURE IN CONCRETE

कैमटेक/सि/2015/फ्लायएश/1.0

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फरवरी - 2015/ February – 2015

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