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Effect on Properties of Concrete by adding Fly ash

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ABSTRACT

Fly ash, a waste generated by thermal power plants is as such a big environmental concern. The investigation reported in this paper is carried out to study the utilization of fly ash in cement concrete as a partial replacement of cement as well as an additive so as to provide an environmentally consistent way of its disposal and reuse. This work is a case study for Deep Nagar thermal power plant of Jalgaon District in MS. The cement in concrete matrix is replaced from 5% to 25% by step in steps of 5%. It is observed that replacement of cement in any proportion lowers the compressive strength of concrete as well as delays its hardening. This provides an environmental friendly method of Deep Nagar fly ash disposal.

INTRODUCTION

Electricity is the key for development of any country. Coal is a major source of fuel for production of electricity in many countries in the world. In the process of electricity generation large quantity of fly ash get produced and becomes available as a byproduct of coal-based power stations. It 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). Conversion of waste into a resource material is an age-old practice of civilization. The fly ash became available in coal based thermal power station in the year 1930 in USA. For its gainful utilization, scientist started research activities and in the year 1937, R.E. Davis and his associates at university of California published research details on use of fly ash in cement concrete. This research had laid foundation for its specification, testing & usages.

LITERATURE REVIEW

Any country's economic & industrial growth depends on the availability of power. In India also, coal is a major source of fuel for power generation. About 60% power is produced using coal as fuel. Indian coal is having low calorific value (3000-3500 K cal.) & very high ash content (30-45%) resulting in huge quantity of ash is generated in the coal based thermal power stations. During 2005-06 about 112 million tonne of ash has been generated in 125 such power stations. With the present growth in power sector, it is expected that ash generation will reach to 175 million tonne per annum by 2012.

Any coal based thermal power station may have the following four kinds of ash

Fly Ash: This kind of ash is extracted from flue gases through Electrostatic Precipitator in dry form. This ash is fine material & possesses good pozzolanic property.

Bottom Ash: This kind of ash is collected in the bottom of boiler furnace. It is comparatively coarse material and contains higher unburnt carbon. It possesses zero or little pozzolanic property.

Pond Ash: When fly ash and bottom ash or both mixed together in any proportion with the large quantity of water to make it in slurry form and deposited in ponds wherein water gets drained away. The deposited ash is called as pond ash.

Mound Ash: Fly ash and bottom ash or both mixed in any proportion and deposited in dry form in the shape of a mound is termed as mound ash.

As per the Bureau of Indian Standard IS: 3812 (Part-1) all these types of ash is termed as Pulverized FuelAsh Fly ash produced in modern power stations of India is of good quality as it contains low sulphur & very low unburnt carbon i.e. less loss on ignition. In order to make fly ash available for various applications, most of the new thermal power stations have set up dry fly ash evacuation & storage system. In this system fly ash from Electrostatic Precipitators (ESP) is evacuated through pneumatic system and stored in silos. From silos, it can be loaded in open truck/ closed tankers or can be bagged through suitable bagging machine. In the ESP, there are 6 to 8 fields (rows) depending on the design of ESP. The field at the boiler end is called as first field & counted subsequently 2 , 3 onwards. The field at chimney end is called as last field. The coarse particles of fly ash are collected in first fields of ESP.

The fineness of fly ash particles increases in subsequent fields of ESP. Pulverized Fuel Ash is versatile resource material and can be utilized in variety of application. The pozzolanic property of fly ash makes it a resource for making cement and other ash based products. The Geo-technical properties of bottom ash, pond ash & coarse fly ash allow it to use in construction of embankments, structural fills, reinforced fills low lying area development etc. The physico chemical properties of pond ash is similar to soil and it contains P, K, Ca, Mg, Cu, Zn, Mo, and Fe, etc. which are essential nutrients for plant growth. These properties enable it to be used as a soil amender & source of micronutrients in Agriculture/ Soil Amendment.

The major utilization areas of PFA are as under: -

(1) Manufacture of Portland Pozzolana Cement & Performance improver in Ordinary Portland Cement (OPC).

(2) Part replacement of OPC in cement concrete.

(3) High volume fly ash concrete.

(4) Roller Compacted Concrete used for dam & pavement construction.

(5) Manufacture of ash bricks and other building products.

(6) Construction of road embankments, structural fills, low lying area development.

(7) As a soil amender in agriculture and wasteland development.

Cement Concrete

Cement concrete - most widely used construction material in the world over, commonly consists of cement, aggregates (fine and coarse) and water. It is the material, which is used more than any other man made material on the earth for construction works. In the concrete, cement chemically reacts with water and produces binding gel that binds other component together and creates stone type of material. The reaction process is called 'hydration' in which water is absorbed by the cement. In this process apart from the binding gel, some amount of lime [Ca $(OH)_2$] is also liberated. The coarse and fine aggregates act as filler in the mass. The main factors which determine the strength of concrete is amount of cement used and the ratio of water to cement in the concrete mix.

However, there are some factors which limits the quantity of cement and ratio of water / cement to be used in the concrete. Hydration process of cement is exothermic and large amount of heat is liberated. Higher will be the cement content greater will be the heat liberation leading in distress to concrete. Water is the principal constituent of the concrete mix. Once the concrete is hardened, the entrapped water in the mass is used by cement mineralogy for hydration and some water is evaporated, thus leaving pores in the matrix. Some part of these pores is filled with hydrated products of cement paste. It has been observed that higher the ratio of water / cement, higher is the porosity resulting in increased permeability.

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How fly ash works in cement concrete.

Ordinary Portland Cement (OPC) is a product of four principal mineralogical phases. These phases are Tricalcium Silicate- C_3S ($3CaO.SiO_2$), Dicalcium Silicate - C_2S ($2CaO.SiO_2$), Tricalcium Aluminate- C_3A ($3CaO.Al_2O_3$) and Tetracalcium alumino-ferrite - C_4AF($4CaO. Al_2O_3. Fe_2O_3$). The setting and hardening of the OPC takes place as a result of reaction between these principal compounds and water. The reaction between these compounds and water are shown as under:

$2C_3S$	+ 6H ⟶	$C_3S_2H_3$	+ 3CH
tricalcium silicate	water	C-S-H gel	Calcium hydroxide
$2C_2S$	+4H ⟶	$C_3S_2H_3$	+CH
dicalcium silicate	+ water	C-S-H gel	Calcium hydroxide

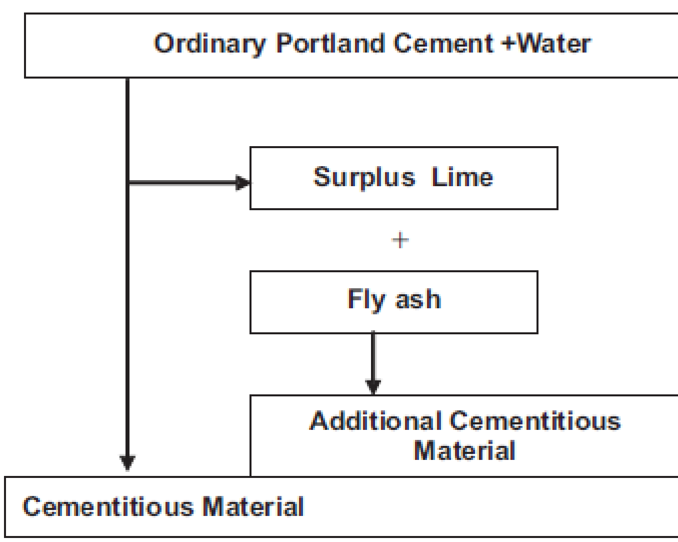
The hydration products from C_3S and C_2S are similar but quantity of calcium hydroxide (lime) released is higher in C_3S as compared to C_2S .

The reaction of C_3A with water takes place in presence of sulphate ions supplied by dissolution of gypsum present in OPC. This reaction is very fast and is shown as under:

C_3A	+ $3(CSH_2)$	+ 26H	⟶	$C_3A(CS)_3H_{32}$
tricalcium alluminate	+ gypsum	+ water	⟶	ettringite
$C_3A + CSH_2$	+ 10H		⟶	C_3ACSH_{12}
				monosulphoaluminate hydrate

Tetra calcium alumino-ferrite forms hydration product similar to those of C A, with iron substituting partially for alumina in the crystal structures of ettringite and monosulpho-aluminate hydrate. Above reactions indicate that during the hydration process of cement, lime 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 fly ash is available in the mix, this surplus lime becomes the source for pozzolanic reaction with fly ash and forms additional C-S-H gel having similar binding properties in the concrete as those produced by hydration of cement paste. The reaction of fly ash with surplus lime continues as long as lime is present in the pores of liquid cement paste. The process can also be
understood as follows:



Effect on properties of Concrete

Specific Gravity: Fly ash has a lower unit weight, which means that on a gram per gram basis, fly ash contributes roughly more percent volume of cementitious material per gram versus cement. The greater the percentage of fly ash in the paste, the better lubricated the aggregates are and the better the concrete flows.

Consistency: Fly ash reduces the amount of water needed to produce a given slump. The spherical shape of the fly ash particles and its dispersive ability provide water reducing characteristics.

Flexural Strength: Fly ash continues to combine with the lime in cement, increasing flexural strength over time. It helps the concrete mixture achieve its maximum strength faster.

Compressive Strength: Fly ash continues to combine with the lime in cement, increasing compressive strength over time. It helps the concrete mixture achieve its maximum strength faster.

Rate of Curing: Fly ash increases the rate of curing of the concrete mixture. Fly ash chemically reacts with lime produced by the hydration of cement and water, thereby closing off their voids that allow the movement of moisture through the concrete.

The flexural strength of specimen is shown in Table given below. The flexural strength result of fly ash-cement concrete specimen is higher than the plain cement concrete. At the first testing, 7 days of curing, the fly ash cement concrete achieved twice the strength of the plain cement concrete. And until the last testing, 14 days of curing, still the fly ash-cement concrete more than twice the strength of the plain cement concrete.

Table Flexural Strength Test Result of Rectangular Specimens

	Plain Concrete		Fly Ash Cement Concrete	
Time (days)	Ultimate Load Capacity (KN)	Ultimate Strength (MPa)	Ultimate Load Capacity (KN)	Ultimate Strength (MPa)
7	3.88	0.18	4.50	0.22
	8.08	0.38	6.81	0.32
	8.66	0.41	4.16	0.22
14	8.21	0.38	8.41	0.37
	10.33	0.44	11.51	0.56
	8.57	0.42	10.7	0.47

Table Compressive Strength Test Result of Cylindrical Specimens

	Plain Concrete		Fly Ash Cement Concrete	
Time (days)	Ultimate Load Capacity (KN)	Ultimate Strength (MPa)	Ultimate Load Capacity (KN)	Ultimate Strength (MPa)
7	3.88	0.18	4.50	0.22
	8.08	0.38	6.81	0.32
	8.66	0.41	4.16	0.22
14	8.21	0.38	8.41	0.37
	10.33	0.44	11.51	0.56
	8.57	0.42	10.7	0.47

The flexural and compressive strength versus the curing period and, respectively. By comparing the results between plain concrete and fly-ash cement concrete specimen, it can be found that the strength of fly-ash cement concrete develops at a faster rate than the plain cement concrete specimen within 7 days. Fly ash increases the rate of curing of the concrete mixture. Fly ash chemically reacts with lime produced by the hydration of cement and water, thereby closing off their voids that allow the movement of moisture through the concrete.

CONCLUSION

For a given set of materials in a concrete mixture, there may be a Portland cement content that produces a maximum concrete strength. In order to obtain higher strengths one of the most practical methods is the use of fly ash in the mixture. Fly ash proportioned using the concepts suggested by this paper has been shown to give strengths significantly above those obtainable by a Portland cement concrete. The method of proportioning proposed in this paper allows for the use of a wide range of fly ashes, it has been found that it is not the quality of fly ash that is important but the variation of that quality about a mean. Good concrete can be proportioned containing a low quality fly ash as long as that quality does not vary substantially. The greatest advantage of the use of fly ash in concrete is the flexibility that it allows with the selection of the mixture proportions. By use of the fly ash, a wide range of possible mixtures can be investigated for any specification. For each situation it is possible to choose either the lowest cost mixture, or the easiest to place, or the most durable. Fly ash has a lower unit weight which means the greater the percentage of fly ash in the paste, the better lubricated the aggregates are and the better the concrete flows and continues to combine with the lime in cement, increasing compressive strength over time. It helps the concrete mixture achieve its maximum strength faster

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