iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 2 **Issue:** X **Month of publication:** October 2014

DOI:

International Journal for Research in Applied Science & Engineering Technology(IJRASET)

Enhancing the Characteristics of Fly Ash Concrete

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***Abstract*— Disposal of industrial waste is becoming a major problem in today's world. Fly Ash is one of the industrial wastes generated from the combustion of coal. The increasing need to protect the environment against pollution has accentuated the significance of developing new building materials based on industrial waste generated from coal fired thermal power station i.e. fly ash, as it is creating unmanageable disposal problems due to its potential to pollute the environment.**

Coal is among the most important sources of energy in the world. In India about 70% of the total energy consumption is generated by coal. India is among the countries with the largest reserves of coal in the world. The energy derived from coal in India is about twice that of energy derived from oil, as against the world, where energy derived from coal is about 30% lower than energy derived from oil. All the Thermal power stations produce large quantities of fly ash. The current production of fly ash is about 112 Million tonnes per year and is increasing rapidly with the increasing need of power generation. This has posed a serious disposal and ecological problem. When disposed of as waste in environment, fly ash causes air, water and soil pollution. This project is an attempt to find a suitable combination of fly ash in composite materials so that it can be utilized in this field and thus to prevent its disposal as waste in the environment. The amount of fly ash to be disposed off will be minimised and so pollution in the environment will be minimum. This fly ash can be used as a mineral addition in concrete to improve its strength and durability characteristics. It can be used either as an admixture or as a partial replacement of cement or as a partial replacement of fine aggregates or total replacement of fine aggregate and as supplementary addition to achieve different properties of concrete. In this present study the compressive strength and split tensile strength of fly ash concrete at elevated temperature up to 120˚C with a water cement ratio of 0.5 by weight was determined. Cement was replaced with three percentages (30%, 40%, and 50%) of cement weight of fly ash. Tests were performed at room temperature, 80˚C, 100˚C, and 120˚C for all types of fly ash concrete at different curing periods (28 and 56 days). Concrete without fly ash has also been used as reference.

The test results showed that the compressive strength and split tensile strength of concrete having cement replacement up to 30% was in range of that of the reference concrete without fly ash. Compressive strength and split tensile strength of concrete mixtures with 30%, 40% and 50 % of fly ash as cement replacement was lower than the control mixture at all ages. The strength of all mixtures continued to increase with the increase in age. The compressive strength of concrete mixes with 30%, 40% and 50 % of fly ash as cement replacement decreases by 11%, 30%, 29%, and 27% at 120˚C with an increase in temperature.

***Keywords*— Coal, Fly ash, Composite Materials, Aggregates, Temperature, Concrete.**

I. Introduction

Fly ash is the notorious waste product of coal- based electricity generating thermal power plants, known for its ill effects on agricultural land, surface and sub-surface water pollution, soil and air pollution and diseases to mankind. Researchers have proposed few ways of reusing fly ash for variety of application. One of the most common reuse of fly ash is in cement concrete. Fly ash particles are almost totally spherical in shape, allowing them to flow and blend freely in mixtures. That capability is one of the properties making fly ash a desirable admixture for concrete. These materials greatly improve the durability of concrete through control of high thermal gradients, pore refinement, depletion of cement alkalis, resistance to chloride and sulphate penetration, and continued micro structural development through a long-term hydration and pozzolanic reaction. The utilization of by-products as the partial replacement of cement has important economical, environmental and technical benefits such as the reduced amount of waste materials, cleaner environment, reduced energy requirement, durable service performance during service life and cost effective structures.

II. Fly Ash

Fly ash is the residue left from burning coal, which is collected on an electrostatic precipitator. It mixes with flue gases that result when powdered coal is used to produce electric power. Since the oil crisis of the 1970s, the use of coal has increased. In 1992, 460 million metric tons of coal-ash was produced worldwide. About 10 percent of this was produced as fly ash in the

United States. In 1996, more than 7 million metric tons were used in concrete in the U.S. Economically, it makes sense to use as much of this low-cost ash as possible, especially if it can be used in concrete as a substitute for cement. Earlier in around 1914 it was recognized as pozzolanic ingredient for use in concrete which means it's a siliceous or siliceous-and-aluminous material that reacts with calcium hydroxide to form cement. When Portland cement reacts with water, it produces a hydrated calcium silicate (CSH) and lime. The hydrated silicate develops strength and the lime fills the voids. Properly selected fly ash reacts with the lime to form CSH–the same cementing product as in Portland cement. This reaction of fly ash with lime in concrete improves strength. Typically, fly ash is added to structural concrete at 15-35 percent by weight of the cement, but up to 70 percent is added for mass concrete used in dams, roller-compacted concrete pavements, and parking areas. Special care must be taken in selecting fly ash to ensure improved properties in concrete. The current production of fly ash is about 120 Million tonnes per year and is expected to reach around 170 Million tons by 2012 A.D (Kumar and Singh, 2006). This has posed a serious disposal and ecological problem in addition to occupying a large tract of scarce cultivable land. Although the beneficial use of fly ash in concrete, brick making, soil stabilization treatment and other applications have been recognized, only a small quantity of the total fly ash is being utilized in our country currently in such applications. There are two classes of fly ash: "F" is made from burning anthracite and/or bituminous coal, and "C" is produced from lignite or sub-bituminous coal. Till now most of the research works have been on the use of fly ash in cement and concrete.

A. Classifications and properties of Fly Ash

Fly ash is a solid, fine-grained material resulting from the combustion of pulverized coal in power station furnaces. The material is collected in mechanical or electrostatic separators .Fly ashes are classified into two categories.

1) Class C: 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, this fly ash will harden and gain strength over time. It generally contains more than 20% lime (CaO). Class C fly ash does not require an activator as it is required in case of Class F. Alkali and sulphate (SO_4) contents are generally higher in Class C fly ashes. A fly ash brick containing up to 50 percent Class C fly ash is made in US by a brick manufacturer. Testing of these fly ash bricks shows that these bricks exceed the performance standards listed in ASTM C 216 for conventional clay brick and is also within the allowable shrinkage limits for concrete brick in ASTM C 55, Standard Specification for Concrete Building Brick. The production method of these fly ash bricks can reduce the embodied energy of masonry construction by up to 90%.

2) Class F: It is produced from burning harder, older anthracite and bituminous coal. This fly ash is pozzolanic in nature and contains less than 20% lime (CaO). This fly ash requires a cementing agent such as Portland cement, quick lime, or hydrated lime to react with water and produce cementitious compounds. It is generally used in high sulphate exposure conditions. Class F fly ash is used in structural concretes, high performance concretes, or high sulphate exposure concretes. Generally high fly ash content mixtures are limited to Class F fly ash. It is generated from younger softer coal found in mid-west and western coal mines.

B. Use Of Fly Ash in Fresh Concrete

Following are the effects on Fresh Concrete Properties due to the use of fly ash in it:-

1) Increased Setting Time

Many factors influence the setting time of concrete. Concrete temperature and the chemical composition of the cement are the most important. Increasing fly ash content usually increases both initial and final set time. At room temperature each 10% increase of cement replacement with fly ash increases set time by about 5 to 20 min. At higher temperature the effect is less. At lower temperature concrete setting times can be greatly delayed and should be determined for the materials used. Some high-calcium fly ashes (i.e. ASTM Class C) lead to shorter setting times.

2) Reduced Water Content

Most fly ash particles are solid spheres with some small amount being hollow cenospheres. The spheres act as pseudo ball bearings that increase both the consistency (slump) and workability of the concrete. Their effectiveness increases in direct proportion to their surface area. Normally concrete mixtures with fly ash will require less water per cubic metre for a given slump than a mixture without fly ash.

3) Increased Workability

For mixtures with the same cementitious content, with and without fly ash, the one with fly ash will generally be noticeably more workable for a given consistency. Consequently, the coarse aggregate content usually can be increased when fly ash is used to replace cement.

4) Reduced Heat of Hydration

The exothermic reaction between cement and water can be reduced by replacing some of the cement with fly ash. Generally the early-age heat generation of a cement fly ash mixture is 30% less than that of an equivalent mass of Portland cement. When high volume fly ash concrete is used (e.g.56% fly ash with a super plasticizer) a substantial reduction in maximum temperature results frequently enabling large sections to be cast without exceeding a maximum temperature of 40°C. With all concrete, attention must be paid to the cooling rate so that temperature differentials between the surface and interior do not exceed 20 °C, so as to prevent surface cracking.

III. EXPERIMENTAL WORK

The tests done in this research work are listed in tables 1.1 and 1.2.

Table 1.1 Tests done on Fly Ash Samples

Sr. No.	Tests done on Fly Ash Sample
1	Moisture Content Test
2	Specific Gravity Test

Table 1.2 Tests done on Fly Ash Concrete Samples

Sr. No.	Tests done on Fly Ash Concrete Samples
1	Compressive Strength Test
2	Split Tensile Strength Test

A. Moisture Content

The moisture condition of aggregates in concrete is very essential. If the aggregates are in a surface wet condition, meaning the moisture content is greater than the absorption, that surface water increases the water-to-cement ratio and affects strength and durability of the concrete.

Percentage of moisture = (loss in weight / wt of coal taken) * 100

The moisture content of the fly ash sample collected from Panipat Thermal Power Station is found to be 0.15 %.

B. Specific Gravity

Specific gravity is the ratio of the density of an aggregate to the density of water. Specific gravity, as it is a ratio of densities, is a dimensionless quantity; i.e. It is not expressed in units.

Specific Gravity of the fly ash sample collected from Panipat Thermal Power Station is found to be 2.35.

C. Compressive Strength Test

In this research, the values of compressive strength for different fly ash contents (0%, 30%, 40% and 50%) incorporating different temperature (40ºC, 80ºC ,100ºC, and 120ºC) at the end of different curing periods of 28 days, 56 days are given in Table 2.1.

ISSN: 2321-9653

International Journal for Research in Applied Science & Engineering Technology(IJRASET)

Table 2.1: Compressive Strength of Fly Ash Concrete

Designation of sample	Fly Ash content	Temperature, ºC	Split Tensile Strength, MPa

Designation of sample mixes	Fly Ash content %age	Temperature, ºC	Compressive Strength, MPa	
			28 days	56 days
M-0	0	N	23.0	29.4
M-1	0	80	22.9	27.0
M-2	0	100	19.3	26.5
M-3	0	120	17.6	26.0
M-4	30	N	16.2	25.2
M-5	30	80	13.3	20.5
M-6	30	100	12.1	19.7
M-7	30	120	10.8	17.6
M-8	40	N	15.4	20.4
M-9	40	80	14.3	17.9
M-10	40	100	12.9	17.8
M-11	40	120	12.8	14.5
M-12	50	N	10.8	13.3
M-13	50	80	10.5	12.2
M-14	50	100	8.9	11.3
M-15	50	120	8.4	9.6

D. Split Tensile Strength Test

It was found that split tensile strength of fly ash concrete (using 30 %, 40 % and 50 % fly ash) at different temperature depends on the percentage of fly ash used and temperature. The variation of split tensile strength was shown in table 2.2.the variation in splitting tensile strength with fly ash content and temperature was similar to that observed in case of compressive strength.

Table 2.2: Split tensile strength (MPa) of Fly Ash Concrete

			28 days	56 days
M-0	0	N	2.8	3.0
M-1	0	80	2.0	2.8
M-2	0	100	1.9	2.5
M-3	0	120	1.6	2.4
M-4	30	N	1.7	2.7
M-5	30	80	1.4	2.3
M-6	30	100	1.3	2.2
M-7	30	120	1.2	2.0
M-8	40	N	1.4	2.1
M-9	40	80	1.1	1.6
M-10	40	100	1.0	1.5
M-11	40	120	0.7	1.3
M-12	50	N	0.7	1.4
M-13	50	80	0.6	1.1
M-14	50	100	0.5	0.9
M-15	50	120	0.3	0.7

IV. CONCLUSIONS

After conducting all the experiment on fly ash concrete the following conclusions are drawn:-

- There is a decrease in Compressive strength of concrete with the increase in cement replacement with Class-F fly ash. However, with increase in age there was increase in strength at each replacement level of cement by fly ash.
- The compressive strength changed with change in temperature. When the temperature rises from room temperature to 120˚C the compressive strength decreased.
- The maximum value of compressive strength occurs at 30% fly ash replacement of cement at room temperature.
- With the increase in age the splitting tensile strength increased at each replacement level of cement by fly ash. But the splitting tensile strength decreased with increase in the volume of fly ash.
- Increase in age also increases the modulus of elasticity at each replacement level of cement with fly ash up to 50%. But the modulus of elasticity also decreased with the increase in volume of fly ash.

- With the increase in temperature up to 120 ^{0}C both splitting tensile strength and the modulus of elasticity decreased.
- Increase in curing period increases the strength at each temperature and at each level of replacement of cement by fly ash.

V. FUTURE SCOPE

From the analysis of the test results on the samples of fly ash concrete, it can be suggested that the fly ash concretes are more economical and durable. Further research work can be done on the use of fly ash in concretes to improve its properties like strength, workability and to make it more economical as compared to normal concrete mix. Tests can be done on different proportions of fly ash as replacement of cement in concrete to make it useful in construction of buildings, dams, embankments etc.

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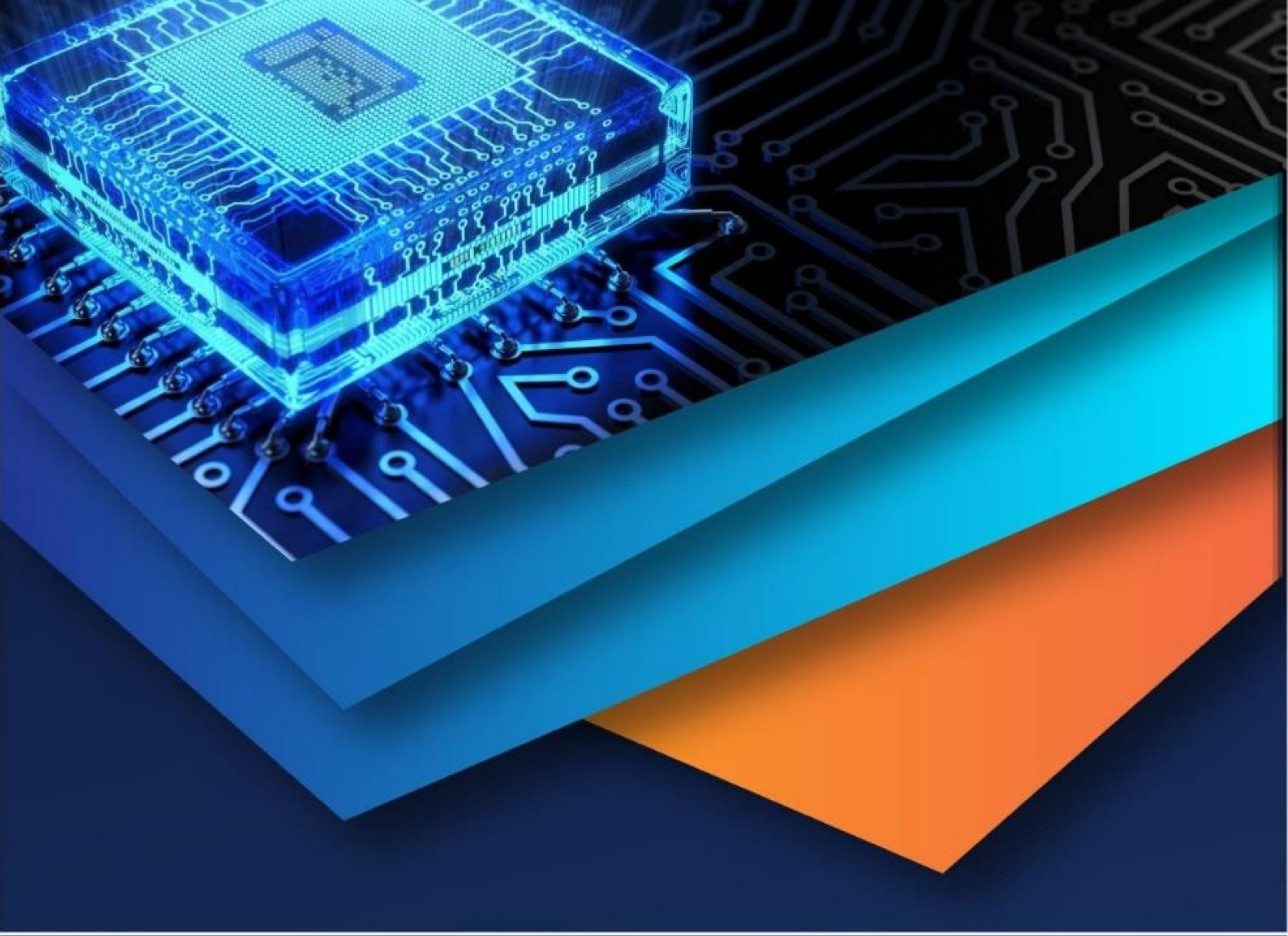

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