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Fly Ash Concrete Pavement

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***Abstract*: The use of fly ash in concrete as a partial replacement for cement has become very important today, primarily due to its improved long-term durability and environmental benefits. Technical improvements in the operation of thermal power plants and fly ash collection systems have improved fly ash consistency. In developed countries, the use of mineral additives such as fly ash, silica fume and rice husk ash has already been established in the production of concrete. This includes large commercial applications for adding or replacing cement. In India, many alternatives have already been programmed and introduced with the introduction of ready mixed concrete, and recently the process has been accelerated to impact the construction economy. The purpose of this experimental study is to investigate physical, chemical and mechanical properties of fly ash cement concrete for road construction. Studies have observed that the use of 30% fly ash and 70% cement provides excellent performance. In addition, the use of fly ash in construction can help reduce material costs and greenhouse gas emissions. High-strength concrete can be manufactured and admixtures or alternatives can be incorporated to improve the properties of the concrete. About 7% of carbon dioxide is released into the environment for each ton of cement produced. Coal is used as a fuel in many industries, including power plants. This produces large amount of coal ash, which makes disposal very difficult and causes environmental pollution. Therefore, the production of cement and electricity leads to a large amount of carbon dioxide emissions and coal ash generation, causing environmental pollution. Fly ash contains reactive and non-reactive crystalline substances. Reactive component reacts with lime to provide hydrated minerals and give them strength. Non- reactive components give concrete a packing effect, filling pores and increasing strength. Here, we are trying to make effective use of this pollutant by using it in concrete.**

***Keywords*: Concrete, crystalline matter, fly ash, greenhouse gas, power plants.**

1. Introduction

As global warming increases, efforts are being made to reduce carbon dioxide emissions into the environment. As the cement industry is one of the major contributors to carbon dioxide emissions, the replacement of cement with materials such as fly ash, which is pozzolanic in nature, is being worked on. The use of fly ash in concrete has been promoted worldwide. This replacement is being done in various parts of India recently. Fly ash is a fine powder, generated from the combustion of powdered coal and transported in the flue gas from the boiler and then collected in electrostatic precipitators. Thus, it is possible to obtain a uniform fly ash quality from power plants. For long-term concrete strength and durability, a minimum of 28 days curing is recommended for bulk fly ash concrete. This helps to reduce hydration cracking in the concrete. Using fly ash in concrete produces denser concrete with high strength and durability. It also reduces the amount of air voids, making the concrete denser and impervious to water.

2. Literature Review

SK Kaushik (1998) discusses parameters related to Indian fly ash quality and high fly ash triple blend concrete production in general. The author's experimental results were discussed for high slump concrete with a tensile strength of 80-90 MPa and calcium fly ash content similar to that of cement. Fly ash increases fluidity, shrinks pores and strengthens them. The development of hyper plasticizers based on polycarboxylates has helped to achieve fluidity in concrete with low binder proportions containing large amounts of fly ash.

N.P. Rajamane, J. Annie Peter and S. Gopala Krishna (2000) studied concrete with compressive strengths of about 85 MPa and 105 MPa for 28 days, and the cement replacement rate was about 25%. This concrete was blended with GGBS and micro silica to maintain a total CRL of 25%. Compressive strength from 94 to 116 MPa was achieved after 90 days. Pozzolona such as blast furnace slag (GGBS) and micro silica (SF) crushed in cement concrete are used alone as mineral additives (MA).

MM. Prasad (2002) investigated the effect of replacing 17%, 22%, 27% and 32% cement with fly ash and micro silica in conventional M20 grade concrete. Concrete grade M20 was adopted as the reference mixture. After the samples are cast and cured in normal mode for 28 days, they are tested for flexural strength and tensile strength at break according to IS specifications and the results are compared. Test results show that the flexural and tensile cleavage strength of ash siliceous concrete containing up to 27% fly ash and micro silica is comparable to that of conventional concrete.

S. Gopala Krishna (2004) conducted a pilot study at SERC in Chennai to investigate the role of Supplementary Cementitious Material (SCM) in concrete mixtures. This article presents the properties, strength and durability properties of typical concrete mixtures of grade M40 studied, including SCM, at various cement replacement levels. Research shows that SCM available in India can be used to produce concrete mixes with desired strength and durability properties.

K. Matong and T.P. Agrawal (2012) studied the effect of the addition of fly ash on concrete properties and found that the

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normal consistency increased with cement grade and fly ash content. In addition, it was concluded that the use of fly ash improves the workability of concrete. It was also observed that the compressive strength of concrete increased with the cement grade. In all OPC grades, the strength of concrete decreases with increasing fly ash content. The decline is greater at early age than at later age. Fly ash concrete has been found to be more durable than regular OPC concrete.

A. Jatale (2013) studied the effect on compressive strength of partial replacement of cement with fly ash and found that the use of fly ash slightly slowed the setting time of concrete. Curing rates at different ages were also found to be related to the water-cement ratio and the fly ash ratio in the concrete mix. Moreover, the modulus of elasticity of fly ash concrete decreases with increasing fly ash ratio for a given water/cement ratio.

T. Sama (2014) studied the effect of partial replacement of cement with fly ash and the addition of steel fibers on the strength of concrete. Concrete grade M40 was used with a mixing ratio of 1:1.62:2.83 and a water-cement ratio of 0.45. The optimal addition rates of fly ash and steel fiber are 40% and 2%, indicating that tensile strength and bending strength are maximally improved.

R. Bansal (2015) studied the effect of partial replacement of cement with fly ash on the compressive strength of concrete. As a result, when 10% of cement was replaced with fly ash, the compressive strength decreased by 20% and 50% each at 28 days of age. Similarly, at 20% replacement, there was a 7% and 11% increase in compressive strength at 7 and 28 days of age, respectively, and at 30% replacement, there was a 23% and 25% increase in compressive strength in 7th and 28th day. In addition, it was observed that the compressive strength of fly ash replacing concrete increases with age.

3. Fly Ash in Concrete Industry

In consideration of global warming, we are working to reduce CO_2 emissions to the environment. The cement industry contributes significantly to CO_2 emissions and consumes large amounts of energy resources in the production of cement. By replacing cement with materials with pozzolanic properties such as fly ash, the cement and concrete industries can work together to meet the growing demands of the construction industry. Fly ash is a useful resource rather than a waste product, considering the benefits it imparts for the strength and durability of concrete pavements. Due to their beneficial use, scientists have begun research activities and R.E. Davis and his collaborators at the University of California published details of their work on the use of fly ash in cement concrete in 1937. In India, coal is an important fuel source for power generation. About 60% of electricity is generated from coal. In the process, a large quantity of fly ash gets produced and become available as a byproduct. Fly ash from modern thermal power plants does not require any further treatment for use as a cement binding additive. Usage of fly ash reduces cement consumption and related carbon dioxide emissions, amount of voids, crack problems, heat of hydration, bleeding etc. It provides good quality hydration and improves workability of plastic concrete, strength and durability of hardened concrete.

Table 1

S. No.	Property	Value
1	Grade	43
2	Fineness	4.6
3	Specific gravity	3.15
4	Standard consistency	35%
5	Initial setting time	70 min
6	Final setting time	Not greater than 600 min

A. *Materials used*

The physical properties of cement, fine aggregate, coarse aggregate, fly ash and water used for mix design of M30 grade of concrete were tested in laboratory and are mentioned below.

1) Cement

Ordinary Portland cement of grade 43 is used.

2) Fine aggregate

M-sand has been used as fine aggregate.

3) Coarse aggregate

Coarse aggregate of 20mm nominal size machine crushed angular granite metal from local source has been used.

Table 2

S. No.	Property	Value
1	Porosity	0.39
2	Void ratio	0.64
3	Fineness modulus	4.34
4	Bulk density	1.63 g/cm^3

4) Fly ash

Fly ash of class F is used here.

Table 3

S. No.	Property	Value
1	Specific gravity	2.1
2	Moisture content	19.48%

4. Working Procedure

1) Collection of materials

The materials mentioned above are procured and their physical properties were identified for the fly ash concrete. The materials should be of good quality.

The materials used are cement, fine aggregate, coarse aggregate and fly ash.

2) Mixing process

Materials are weighed and mixed in proper nominal mix method. In this experimental study, M30 grade of concrete was prepared. The mix ratio is 1:2:3 and w/c ratio is 0.5. During the preparation, conventional beams, cubes and cylinders are prepared. They are also prepared using fly ash with 20% and 25% replacement of cement.

3) Molding process

Beam of size 500X100X100 cm, cylinder of 15cm diameter, 30cm length and cube of size 150cm are prepared. Concrete is mixed by hand thoroughly and placed in moulds with minimum delay. It was well compacted by rodding, tamping and vibrating to remove all air voids in them.

4) Removal of mould

After 24 hours of casting, moulds were removed. After removing mould, each specimen was marked with a identification on top and bottom using a waterproof marker.

5) Curing

The specimens were cured normally on fresh water at room temperature for 28 days. Curing plays an important role in gaining of strength of concrete. It increases strength and decreases permeability.

6) Testing process

Both conventional and fly ash replaced beams, cubes and cylinders are tested after a curing period of 28 days. They are taken out from curing and the water content is wiped off. Compressive strength test, split tensile test and flexural strength test are carried out using compressive strength testing machine.

After conducting all these tests, fly ash concrete pavement with most suitable replacement were constructed.

5. Tests Conducted

A. Compressive Strength Test

Compressive strength of concrete is the most important parameter and represents overall quality of concrete. It is used to find out the compressive strength of the specimen and is done in Compression Testing Machine. It mainly depends on the water /cement ratio, curing and age after it is casted.

$$\text{Compressive strength} = F/A$$

Where F→ force or load at point of failure
A→ cross sectional area

B. Flexural Strength Test

It is used to determine the flex or bending property of a material. It measures the force required to bend a beam of plastic material and determines the resistance to flexing or stiffness of a material.

$$F = PL/bd^2$$

Where P→ failure loads
L→ effective span
b→ breadth of specimen
d→ depth or thickness of specimen

C. Split Tensile Test

The tensile strength is one of the basic and important properties of concrete. It is used to measure the maximum stress on the tension face of an unreinforced concrete block at the point of failure in bending.

$$T = 0.637\ P/dL$$

Where P→ applied load
d→ diameter in mm
L→ length of specimen

6. Test Results

Table 4

	Compressive Strength	Flexural Strength	Split Tensile Strength
Normal	27.7 N/mm²	3.9 N/mm²	4.24 N/mm²
20% replacement	28 N/mm²	5.55 N/mm²	4.95 N/mm²
25% replacement	26.3 N/mm²	4.2 N/mm²	4.18 N/mm²

The test result shows that replacement of cement by 20% gives best value. By this study/analysis, M30 grade concrete with the replacement of 20% fly ash may be recommended for the fly ash concrete pavement. Replacement of cement by fly ash by 20-30% is safe, but 50% replacement has not enough compressive strength to be used in construction.

7. Conclusion

India has huge fly ash resources across the country. Proper segregation, collection and use of this material can solve the main problem of fly ash removal and reduce the use of cement, which consumes a lot of energy and natural resources. Many organizations, especially in India, are working to raise awareness of fly ash concrete and its benefits. The Nuclear Power Corporation of India (NPCIL) is also involved in research and development for the development of fly ash concrete and its implementation for the construction of various nuclear facilities. Fly ash concrete has economic and environmental benefits. The main reason fly ash is considered environmentally friendly when used in construction is that it is a recyclable material. It also makes concrete stable. When used in concrete, it improves the workability of ductile concrete and the strength and durability of hardened concrete. You can reduce the amount of Portland cement by adding fly ash to the concrete. Less than 5% of fly ash currently produced is consumed in India. Fly ash concrete pavement is more resistant to sulphate than conventional concrete pavement. Fly ash pavement is initially competitive compared to asphalt pavement. Infrastructure development is at its peak worldwide and is a symbol of growth in every country.

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