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STUDY ON UTILIZATION OF FLY ASH AS A REPLACEMENT OF CEMENT AND FINE AGGREGATE IN CONCRETE

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Abstract

Concrete is the most widely used construction material in civil engineering because of its high structural strength, stability, and malleability. It is a composite material made out of water, cement, fine aggregate (sand) and coarse aggregate (stones). However, the manufacturing process of raw materials used in concrete such as cement and aggregate causes environmental influences (emission of greenhouse gases and dust) and significantly consumes energy and natural resources. Fly ash a waste material that is produced as a by-product of coal combustion process. The physical and chemical properties of fly ash are similar to cement, which allows it to be used in concrete. The primary aim of this report is to determine the feasibility of using fly ash as a replacement of cement and fine aggregate in concrete and their effects on the mechanical properties of concrete. This Report presents the results of an experimental investigation carried out to evaluate the mechanical properties (workability and compressive strength) of concrete mixtures in which fine aggregate (sand) and cement were partially replaced with Fly Ash. Both fine aggregate and cement were replaced with five percentages (10%, 20%, 30%, 40%, and 50%) of fly ash by weight. Tests were conducted for properties of fresh concrete (workability), and compressive strength was determined at 7, 28 and 56 days. Test results indicate significant improvement in the strength properties of plain concrete by the inclusion of fly ash as partial replacement of either fine aggregate or cement and can be effectively used in concrete structures.

Keywords: *Concrete, Fly Ash, Cement, Workability and Compressive Strength***.**

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1. INTRODUCTION

1.1 General

Concrete plays a significant role in the construction of structures around the world. According to Construction Materials, Concrete is a composite material obtained by mixing cement, sand, gravel and water. A concrete mix can be considered to consist of two main parts, aggregates (sand and gravel) and cement paste (water and cement).

1.2 Need

The global demand of concrete is increasing significantly due to infrastructure growth worldwide. Therefore using alternative sources as replacement for cement and aggregates appears to be a challenging task. Industrial waste materials (recycled materials) can be used as alternative sources in concrete as they can assist in solving some environmental concerns , as they diminish the problem of waste disposal and reduce the intensive use of energy and natural resources. In addition; the amount of emission of gases gets reduced. There are many potential industrial waste products that have the potential to replace aggregates in concrete such as: plastic, fly ash, rubber, steel slags and leather wastes. However, fly ash is the industrial waste material that is discussed in depth in this particular report.

2. Types of material

2.1 Fly ash

2.1.1Physical and Chemical Properties of fly ash

The physical properties and the chemical compositions of fly ash are mainly controlled by the nature of coal and the processing conditions of the furnace.

The chemical composition of fly ash varies significantly between plants. However, Silicon dioxide (SiO2) occupies most of the volume of fly ash. According to

(Bremseth, 2010) the chemical composition of the coal controls the chemical contents of fly ash, American Society for Testing and Materials (ASTM) C618-03 defines two classes of fly ash, class F and class C. These two classes differ from each other in the volume of calcium. The percentage of calcium in class F is low whereas in class C is high. According to (de Brito&Saikia, 2013) larger number of unwanted chemical components such as free lime and sulphite are present in high calcium fly ash, which minimise the use of this kind of fly ash. The table below shows the chemical properties of fly ash.

Table-1: Chemical Properties of Fly ash

Sr. No.	Chemical Compound	Low Calcium Fly ash Class F	High Calcium Fly ash Class C
1.	Silicon dioxide (SiO2)	54.90	39.90
2.	Aluminium oxide (Al2O3)	25.80	16.70
3.	Iron oxide (Fe2O3)	6.90	5.80
4.	Calcium Oxide (CaO)	8.70	24.30
5.	Magnesium oxide (MgO)	1.80	4.60
6.	Sulphur Trioxide (SO3)	0.60	3.30

Fly ash particles are irregular, they are spherical in shape, their diameters range between 0.5 m to 150µ m. the sizes of fly ash particles are determined by the type of equipment that are used to remove the fly ash and it also depends on the sources. The physical properties of fly ash are shown in table below.

Table -2: : Physical Properties of Fly ash

Sr. No.	Properties	Values
1.	Specific Gravity	2.3
2.	Moisture Content	19.75%
3.	Fineness	0.001- 0.6 mm
4.	Maximum Dry Density	1.53 gm/cm^3
5.	Permeability	4.87×10^{-7} cm/sec
6.	Angle of internal friction	23°-41°
7.	Cohesion	3-34 Kpa

2.1.2Effects of Fly ash on the environment

In general fly ash is considered as a waste matter. It is a by- product that is obtained due to the combustion of coal. According to Global Coal reserves combustion of coal in India produces around 211 billion tones of fly ash per year. Approximately 60 % of fly ash is being dumped. Hence, it causes several environmental problems such as: contamination of ground water and ground pollution. Waste materials as well as fly ash specifically can be used in concrete as replacement of cement and aggregate. This kind of use has positive impacts on the environment as it reduces the problem of waste disposal and reduces the exhaustive use of energy and natural resources (aggregate mining). In addition, it reduces the amount of co_2 emission$_s$ and it saves energy when fly ash replaces some of the energy (intensive produced cement).

2.2 Cement

2.2.1 Chemical Properties of Cement

Four major oxides (CaO, SiO2, Al2O3, and Fe2O3) occupy the volume of Cement (90%). The main chemical contents of Portland Cement are tabulated below .

Table 3: Chemical Properties of Portland Cement

Sr. No.	Chemical content	Amount (%)
1.	Calcium oxide (CaO)	60-67
2.	Silicon dioxide (SiO2)	17-25
3.	Aluminium oxide (Al2O3)	3-8
4.	Iron oxide (Fe2O3)	0.5-6
5.	Magnesium oxide (MgO)	0.1-4
6.	Sodium oxide (Na2O)	0.2-1.3
7.	Potassium oxide(K2O)	0.2-1.3
8.	Sulphur Trioxide (SO3)	1.3

It can be seen from the table below that both fly ash and cement have similar chemical contents. The same chemical compounds are present in cement and fly ash. However, their percentages differ. Portland cement is rich in Calcium oxide (CaO) but low in Silicon dioxide (SiO2). On the other hand, fly ash is rich in SiO2 but low in CaO. Therefore, it is recommended to use both fly ash and Portland cement in a concrete mixture.

Table 4: Chemical properties of Fly ash and Portland Cement.

Sr. No.	Chemical Compound	Portland Cement %	Fly Ash %	Good Cement %
1.	Silicon dioxide (SiO2)	21.82	53.39	17-25
2.	Aluminium oxide (Al2O3)	6.49	16.07	3-4
3.	Iron oxide (Fe2O3)	1.93	13.05	3-4
4.	Calcium Oxide (CaO) {Lime}	60.74	6.33	60-67
5.	Magnesium oxide (MgO)	1.08	5.48	0.5-04
6.	Sulphur Trioxide (SO3)	2.62	1.06	1-2
7.	Sodium oxide (Na2O)	0.14	1.59	2-1
8.	Free CaO	0.84	0.11	-

2.3Fine Aggregate

2.3.1 Aggregates

In a concrete mix, aggregates occupy between 60% to 80%, this high content of aggregates influences the properties of concrete both the fresh and hardened. Therefore, they must be well selected. Aggregate is classified as two different types, coarse and fine. Coarse aggregate is usually greater than 4.75 mm while fine aggregate is less than 4.75 mm. In this report only fine aggregate is discussed.

The intense usage of both Coarse and Fine aggregate in civil engineering constructions raises concerns about the preservation of natural aggregates sources. In addition, the process of extracting and processing the natural aggregate are the primary reasons of environmental concerns. In order to keep away from these concerns and to protect the natural resources alternatives materials can be used as partially or fully replacement of aggregates in concrete production.

Fly ash has common physical properties that are similar to sand, which increases the potential to use fly ash as sand replacement .

Table 5: Physical Properties of Fine Aggregate (Sand) and Fly ash

Sr. No.	Properties	Fine Aggregate (Sand)	Fly ash
1.	Specific Gravity	2.70	1.28
2.	Bulk Density (kg/m^3)	1808	838
3.	Size (mm)	Below 4.75	Below 4.75
4.	Fineness Modulus	2.68	2.70

2.3.2 Environmental Implication of Fine Aggregate

In the recent years, river sand was considered as the only alternative for the fine aggregate ingredient in concrete. However, unnecessary extraction of river sand causes the degradation of rivers. In stream mining lowers the stream bottom, which may leads to bank erosion. Reduction of sand in the streambed and along coastal areas causes the depletion of rivers and estuaries, and the extension of river mouths and coastal inlets. It may also lead to saline-water disturbance from the nearby sea. The effect of mining is compounded by the effect of sea level rise. Any volume of sand exported from streambeds and coastal areas is a loss to the system. Excessive instream sand mining is a risk to bridges, river banks and nearby structures. Sand mining also affects the adjoining groundwater system and the uses that local people make of the river.

Due to these issues, several environmental prohibitions were put in place. This increases the scarcity of natural fine aggregates and leads to search for alternate sources for its replacement.

2.4 Fly ash in concrete

2.4.1Advantages

One of the main effects that the fly ash has on concrete is improving its workability, as the percentage of fine particles in fly ash is greater than in cement. Using fly ash in concrete minimize the water demand. Fly ash increases the cohesiveness of concrete as a result both bleeding and segregation get reduced.

Concrete hardens during a chemical reaction that takes place between cement and water, this chemical reaction is known as hydration. Fly ash plays an vital role in this chemical reaction as it slows the processing of this reaction and reduces the heat of hydration, which leads to greater strength and minimize thermal cracks in concrete.

The tiny particles of fly ash fill all the small and vacant voids which make the concrete denser. Fly ash reduces the permeability of concrete. Also, it improves its durability.

2.4.2 Economic and Environmental impacts of using fly ash in concrete

1. Using fly ash in concrete produces economical and environmental benefits. Concrete mixtures with fly ash as a partially replacement of cement are considered to be cheaper than the conventional concrete.
2. Replacing cement with fly ash results in reduction of the emissions of carbon dioxide CO2, which leads to a reduction in greenhouse gases and their negative effects; also limiting the effects of global warming.
3. Moreover, using fly ash in concrete impacts significantly on the environment as it helps in solving the problem of waste disposal. It also reduces the exhaustive use of energy and natural resources.
4. Dumping fly ash may pollute the ground and contaminate the water.

3. CONCLUSION

1. Use of fly ash in concrete can save the coal & thermal industry disposal costs and produce a ‘greener’ concrete for construction.
2. This report concludes that fly ash can be innovative supplementary cementitious Construction Material but judicious decisions are to be taken by engineers.
3. It was concluded that concrete made out of fly ash and cement will have same strength as concrete made out of pure Portland cement (after a period 6 months however).
4. The pozzolanic properties of fly ash, it can be used in many engineering application such a; premixed concrete, precast concrete, concrete road pavements, concrete dams, concrete masonry, stabilised road base and asphalt concrete.

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