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Hybrid Effects of Fly-Ash as an Eco Friendly Material

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Abstract—*In India, the production of fly-ash is always abundant because of the use of mainly coal in energy production. Over the last ten years, many research have been carried out to establish the use of fly-ash in various constructions out of which the main uses can be mentioned in concrete pavements and in manufacturing of bricks. Fly-ash bricks in today's scenario has almost replaced the conventional bricks. Further, the use of fly-ash in concrete pavement or more appropriately deciding an optimum percentage of fly-ash in cement for various purposes have also been established. Owing to its abundance in availability the safe use and its disposal has always been of concern to engineers and environmentalists. This paper makes an attempt to analyze various characteristics and properties of constituents of Indian coal which can generate optimum fly-ash to make it suitable to be used with cement as a cost effective measure. This paper highlights the optimum percentage in which two varieties of coal which is in abundance can be mixed to generate fly-ash and thereby conducting a regression analysis to establish a mathematical model between dependent variable as percentage of fly ash to be used and independent variables like individual percentages of Class F and Class C type fly ash. Cement is an important and not so cheap material used for civil engineering constructions. On the other hand, fly-ash is abundantly available and is a cheap waste product with some mentionable properties and specifications to treat it as an eco-friendly substance.*

Keywords*: Cement Concrete, Coal, Regression Analysis, Fly-ash*

1. INTRODUCTION

Coal is a combustible black or brownish-black sedimentary rock usually occurring in rock strata in layers or veins called coal beds or coal seams. Coal has been used as an energy source, primarily burned for the production of electricity or heat and is also used for industrial purposes, such as refining of metals. Coal is composed primarily of carbon along with variable quantities of other elements, chiefly hydrogen, sulphur, oxygen and nitrogen.Coal reserves in India is one of the largest in the world. Coal is extracted from the ground by coal mining, either underground by shaft mining, or at ground level by open pit mining extraction. Since 1983 the world top coal producer has been China. In 2011 China produced 3,520 million tonnes of coal- 49.5% of 7,695 million tonnes world coal production. As on April1, 2012, India had 293.5 billion metric tons (323.5 billion short tons) of the resource. The production of coal was 532.69 million metric tons (587.19 million short tons) in 2010-11. India ranked 3rd on world coal production. The energy derived from coal in India is about twice that of energy derived from oil, whereas world-wide,energy derived from coal is about 30% less than energy derived from oil.India can easily be self sufficient for coal and it can last for 3-4 decades (112 years).

There are mainly four main varieties of coal found in India 1) Anthracite 2) Bituminous 3) Lignite and 4) Peat. Anthracite is the highest quality hard, compact, jet black coal having semi-metallic lustre. It is best quality of coal which contains over 85 percent carbon. Anthracite coal ignites slowly and burns with a nice short blue flame. It is found in parts of Jammu and Kashmir and that too in small quantity. Bituminous coal has been buried deep and subjected to increased temperatures. It is most popular coal in commercial use and contains 50 to 85 percent carbon. It is dense, compact and brittle and is usually black in colour. Its calorific value is very high due to high proportion of carbon and low moisture content. Most of bituminous coal is found in Jharkhand, Orissa, West Bengal, Chhattisgarh and Madhya Pradesh. Lignite is low grade brown coal, which is soft with high moisture content and contains 35-50 percent carbon. It represents the intermediate stage in the alternation of woody matter into coal. The lignite reserves are in Neyveli in Tamil Nadu, Palna in Rajasthan, Lakhimpur in Assam and Karewa of Jammu and Kashmir and is used for the generation of electricity. Peat is the first stage of transformation of wood into coal and contains less than 35 percent carbon. It is seldom sufficiently compact to make good fuel without compressing into bricks. It burns like wood, gives less heat, emits more smoke and leaves a lot of ash after burning. Decaying plants in swamps produce peat, which has low carbon content with the result low heating capacity. Fly ash is one of the residues generated after coal combustion. Fly ash is very fine grey colored powder. It is as fine as and sometimes even finer than cement. It contains silica, alumina, calcium oxide, and iron oxide. It contains a small quantity of carbon. It is observed that the reactivity of fly ash depends on its fineness. Fraction of fly ash, which passes 75-micron sieve, is invariably reactive. These constituents are 80% of total quantity. The fly ash if allowed in the air with flue gases will cause large-scale pollution and other hazards. The fly ash is therefore, collected by electrical precipitators and reused for various purposes. In this paper we are going to discuss the effects of blending of the two classes of fly ash obtained from the mentioned varieties of coal and its use as an eco-friendly material.

2. MATERIALS

Fly ash material is collected by electrostatic precipitators or filter bags while suspended in the exhaust gases. Since the particles solidify rapidly while suspended in the exhaust gases, fly ash particles are generally spherical in shape and range in size from 0.5 µm to 300 µm.

Table 1: Various components of fly-ash in terms of percentage

Component	Bituminous	Subbituminous	Lignite
SiO2 (%)	20-60	40-60	15-45
Al2O3 (%)	5-35	20-30	20-25
Fe2O3 (%)	10-40	4-10	4-15
CaO (%)	1-12	5-30	15-40
LOI (%)	0-15	0-3	0-5

As per ASTM C618 fly ash can be classified into two divisions : Class F fly ash and Class C fly ash. The chief difference between these classes is the amount of calcium, silica, alumina, and iron content in the ash. The chemical properties of the fly ash are largely influenced by the chemical content of the coal burned (i.e., anthracite, bituminous, and lignite). Class F type is produced mainly by burning of anthracite and bituminous coal. This fly ash possesses pozzolanic properties and require a cementing compound such as Portland cement or hydrated lime to produce cementitious compound when mixed with water. Geopolymers can also be formed from this classby adding sodium silicate. This type of fly ash can be used in conditions where resistance to sulphate attack due to ground water level or soil conditions is of paramount importance. Also it effectively moderates heat gain during concrete curing and is therefore considered as a good cementitious material in high strength concrete.

Table 2: Chemical composition of Class F fly ash

Chemical analysis	Class F fly ash (%)	ASTM requirement C 618 (%)
Silicon Dioxide, SiO2	56.8	-
Aluminum Oxide, Al2O3	26.10	-
Ferric Oxide, Fe2O3	5.0	-
SiO2+ Al2O3+ Fe2O3	87.9	70.0 min
Calcium Oxide, CaO	3.8	
Magnesium Oxide, MgO	2.3	5.0 max
Titanium Oxide, TiO2	1.4	-
Potassium Oxide, K2O	0.6	-
Sodium Oxide, NaO 2	0.4	1.5 max
Sulfur trioxide, SO3	1.6	5.0 max
LOI (1000oC)	1.9	6.0 max
Moisture	0.3	3.0 max

Class C type fly ash is produced by burning of lignite and sub-bituminous coal. This type has self-cementing properties, It does not require an activator, hardens and gets stronger with time when mixed with water. Alkali and sulphate contents are higher in this class of fly ash. This type of fly ash is useful in conditions where early high strength is required as for examples in pre-stressed constructions and also in case of soil stabilization because of presence of high lime content.

Table 3: Chemical composition of Class C fly ash

Chemical analysis	Class C fly ash (%)	ASTM requirement C 618 (%)
Silicon Dioxide, SiO2	35.4	-
Aluminum Oxide, Al2O3	17.5	-
Ferric Oxide, Fe2O3	5.3	-
SiO2+ Al2O3+ Fe2O3	58.2	50.0 min
Calcium Oxide, CaO	26.1	
Magnesium Oxide, MgO	4.6	5.0 max
Sulfur trioxide, SO3	1.6	5.0 max
LOI (1000oC)	0.1	6.0 max
Moisture	0.4	3.0 max

3. METHODOLOGY

The effect on mechanical properties and durability of hardened concrete by use of fly ash depends upon the level and composition of the fly ash, composition and proportion of the other ingredients in the concrete mixture, exposure conditions and construction practices. This implies that one replacement level may not be justified for all applications. In one case it may be advisable to maximize the fly ash content and in other case it may be fruitful to minimize it. Therefore, fly ash content needs to be optimized for every application. Mainly the fly ash content selected should be sufficient to achieve the required benefit without producing any harmful effect. The minimum amount of 20% fly ash is required to achieve the desired properties.The following table shows the property of concrete, effect of fly ash, general precautionary measures and proposed regression equation with respect to each of the applications.

Table 4: Proposed regression equation for different properties of concrete

S. No	Property of concrete	Effect of Fly Ash	General Precautions	Proposed Regression Equation
1.	Fresh concrete	Improved Workability, Reduced segregation and Bleeding, Concrete is more cohesive	Cohesiveness is more for higher content of Type C Fly Ash	Y= B0+B1X1+B2X2+E, Y is total percentage of fly ash between 0.20 to 0.50, X1 is percentage of Class F type ash and X2 is percentage of Class C type Ash, B0 is a constant, B1 and B2 are coefficients, E is random error

2.	Setting time	In cold weather, fly ash retards the setting time	Fly ash, cement and admixtures is to be used for early setting time especially in cold weather.	Y= B0+B1X1+B2X2+B3X3+E, X3is the percentage of admixtures, other notations are usual as described
3.	Heat of Hydration	For critical temperature control, high use of Class F type can be safer.	Class C type fly ash may be used with less cement content to reduce the heat. Lower temperature while placing concrete may also be tried.	Y= B0+B1X1+B2X2+E X1< X2 All notations are as described
4.	Early gain in strength	Retarded when fly ash is used.	Use of accelerating admixture, silica fume is advisable for early gain in strength	Y= B0+B1X1+B2X2+B3X3+E X3 is the percentage of admixtures. All notations are as described
5.	Long term strength	Increased when fly ash is used.	Samples with fly ash may be tested for 56 days to adhere with mix-design specifications	Y= B0+B1X1+B2X2+E X1< X2 All notations are as described
6.	Permeability and Chloride Resistance	Reduced significantly during later ages	Adequate curing is required especially for upper surface or cover concrete	Y= B0+B1X1+B2X2+E X1< X2 All notations are as described
7.	Expansion due to alkali-silica reaction	With normal and non-reactive aggregate, a replacement of 20% to 30% Class F type fly ash is sufficient.	Higher replacement of Class C type fly ash up to 40% is recommended for better results.	Y= B0+B1X1+B2X2+E All notations are as described
8.	Sulfate Resistance	Reduced when Class F type fly ash is used 20% to 30%	Better results obtained when Class F type fly ash is used with sulfate-resisting Portland Cement. Use of Class C fly ash is not recommended.	Y= B0+B1X1+E All notations are as described
9.	Resistance to carbonation	Significantly reduced when fly ash is used.	Sufficient cover is to be provided and curing is to be ensured.	Y= B0+B1X1+B2X2+E All notations are as described

4. RESULT AND CONCLUSION WITH FUTURE SCOPE

The regression analysis may be used to develop a mathematical model to explain the variance in the total percentage of fly ash based on values of the percentage of Class F type fly ash, percentage of Class C type fly ash and percentage of admixtures (if used any). Depending upon the adequacy of the regression model explaining the total percentage of fly ash to be used, it can also be utilized to predict the values of the same. The regression coefficients B_1, B_2 and B_3 can be calculated using least squares method. To test the reliability of these values, validation conditions are required to be established. The next step is to implement this model in decision support system. The error in prediction is also required to be incorporated. The predicted values are then compared with the actual values as per experimental observations and the performance is required to be monitored continuously to establish a mathematical model.

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