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Influence of curing conditions on strength characteristics of cement stabilized fly ash bricks

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ABSTRACT:

Fly ash is a waste produced in coal-fired thermal power stations. This calls for the development of strategies to encourage and establish technological concepts which will ensure consumption of fly ash in bulk. Fly ash has pozzolonic properties and can therefore be stabilized with either cement or lime to achieve the strength required for use as base courses in pavements. This requires carrying out unconfined compression tests on stabilized fly ash specimens prepared and cured as per standard procedures. The stabilizer content is the minimum amount of the stabilizer for which the unconfined compressive strength of the specimens complies with the specified values.

The actual curing conditions of the stabilized fly ash bases in the field, however, will differ from those of the laboratory specimens. This will affect the strength development of the bases, their durability, and their performance. An experimental program is carried out to study the strength characteristics of cement stabilized fly ash, and influence of curing conditions on strength. This program comprised compaction tests, unconfined compression tests and CBR tests. Two Indian fly ashes and a commercial Portland cement were used in the study. From the experimental results it can be concluded that there will be reduction of strength at different curing methods.

1. INTRODUCTION

Coal-based thermal power plants all over the world face serious problems of handling and disposal of the ash produced. The high ash content (30–50%) of the coal in India makes this problem complex. At present, about 80 thermal power stations produce nearly 100 million tonnes of coal ash per annum. Safe disposal of the ash without adversely affecting the environment and the large storage area required are major concerns. Hence attempts are being made to utilize the ash rather than dump it. To overcome this, strong economical and environmental imperatives exist for effective use of these fly ashes.

In the past few years, researchers tried to investigate the scope of commercial utilization of different kinds of fly ashes, and a wide variety of applications for high-volume use of fly ashes have been used for decades. The fly ash can be utilized in bulk only in geotechnical engineering applications such as construction of embankments, as a backfill material, as a sub-base and base material, etc. Fly ash is a fine-grained material of mostly silt size (0.075– 0.002 mm) particles. It is nonplastic and can therefore be handled easily. Further, because of its pozzolanic properties, it can be stabilized with cement or lime to achieve the strength required for use as base and sub base courses in pavements.

1.1 FLYASH

Fly ash closely resembles volcanic ashes used in production of the earliest known hydraulic cements about 2,300 years ago. Those cements were made near the small Italian town of Pozzuoli - which later gave its name to the term "pozzolan."A pozzolan is a siliceous or siliceous / aluminous material that, when mixed with lime and water, forms a cementitious compound. Fly ash is the best known, and one of the most commonly used, pozzolans in the world. Instead of volcanoes, today's fly ash is the finely divided mineral residue resulting from the combustion of ground or powdered coal in electric generating plant (ASTM C 618). Fly ash consists of inorganic matter present in the coal that has been fused during coal combustion. This material is solidified while suspended in the exhaust gases and is collected from the exhaust gases by electrostatic precipitators. Since the particles solidify while suspended in the exhaust gases, fly ash particles are generally spherical in shape (Ferguson et. al., 1999). Fly ash particles those are collected in electrostatic precipitators are usually silt size (0.074 - 0.005 mm).

1.2 PRODUCTION OF FLY ASH

The fly ash produced from the burning of pulverized coal in a coal-fired boiler is a fine-grained, powdery particulate material that is carried off in the flue gas and usually collected from the flue gas by means of electrostatic precipitators, bag houses, or mechanical collection devices such as cyclones. In general, there are three types of coal-fired boiler furnaces used in the electric utility industry. They are referred to as dry-bottom boilers, wet-bottom boilers, and cyclone furnaces. The most common type of coal burning furnace is the dry-bottom furnace.

When pulverized coal is combusted in a dry-ash, dry-bottom boiler, about 80 percent of all the ash leaves the furnace as fly ash, entrained in the flue gas. When pulverized coal is combusted in a wet-bottom (or slag-tap) furnace, as much as 50 percent of the ash is retained in the furnace, with the other 50 percent being entrained in the flue gas. In a cyclone furnace, where crushed coal is used as a fuel, 70 to 80 percent of the ash is retained as boiler slag and only 20 to 30 percent leaves the furnace as dry ash in the flue gas.

1.3 FLYASH UTILISATION

The utilization of fly ash can be broadly grouped into three categories.

1. Low value Utilization
2. Medium Value Utilization
3. High Value Utilization

Any well planned coal utilisation project must concentrate on bulk utilisation. This is possible only through geotechnical applications such as embankment construction, back filling, pavement construction and the like. During 1996, the most recent year for which ash statistics are currently available, the electrical utility industry in the United States generated approximately 53.5 million metric tons (59.4 million the tons) of coal fly ash. Until 1996, the amount of fly ash produced annually had remained roughly the same since1977, ranging from 42.9 to 49.7 million metric tons (47.2 to 54.8 million tons).

2. LITERATURE REVIEW

Rapid industrialization and urbanization exert more thrust on power generation sector. Due to the limited scope and limitations experienced by the hydroelectric power generation and atomic power generation sectors and or by virtue of limited resources or by virtue of increasing public awareness towards the safety of the environment and the society, the present day focus is more on coal based thermal power generation. With the increase in the number of coal based thermal power plants worldwide, the problems they enforce, particularly the storage and disposal of coal ashes produced during coal burning, on the environment and biosphere are also more and more acute. If appropriate preventive and corrective measures are not taken in time, a stage may reached where in the coal ash storage and disposal problem may have to be regarded as a national problem.

2.1. HIGHWAY USES AND PROCESSING REQUIREMENTS

Fly ash has been successfully used as a mineral admixture in PCC for nearly 60 years. This is the largest single use of fly ash. It can also be used as a feed material for producing Portland cement and as a component of a Portland-pozzolan blended cement.

Fly ash must be in a dry form when used as a mineral admixture. Fly ash quality must be closely monitored when the material is used in PCC. Fineness, loss on ignition, and chemical content are the most important characteristics of fly ash affecting its use in concrete. Fly ash used in concrete must also have sufficient pozzolanic reactivity and must be of consistent quality. Fly ash has been used as substitute mineral filler in asphalt paving mixtures for many years. Mineral filler in asphalt paving mixtures consists of particles, less than 0.075 mm (No. 200 sieve) in size, that fill the voids in a paving mix and serve to improve the cohesion of the binder (asphalt cement) and the stability of the mixture. Most fly ash sources are capable of meeting the gradation (minus .075 mm) requirements and other pertinent physical (nonplastic) and chemical (organic content) requirements of mineral filler specifications.

2.1.1 Stabilized Base – Supplementary Cementitious Material

Stabilized bases or sub bases are mixtures of aggregates and binders, such as Portland cement, which increase the strength, bearing capacity, and durability of a pavement substructure. Because fly ash may exhibit pozzolanic properties, or self-cementing properties, or both, it can and has been successfully used as part of the binder in stabilized base construction applications. When pozzolanic-type fly ash is used, an activator must be added to initiate the pozzolanic reaction. Self-cementing fly ash does not require an activator. The most commonly used activators or chemical binders in pozzolan-stabilized base (PSB) mixtures are lime and Portland cement, although cement kiln dusts and lime kiln dusts have also been used with varying degrees of success. Sometimes, combinations of lime, Portland cement, or kiln dusts have also been used in PSB mixtures. The successful performance of PSB mixtures depends on the development of strength within the matrix formed by the pozzolanic reaction between the fly ash and the activator. This cementitious matrix acts as a binder that holds the aggregate particles together, similar in many respects to a low-strength concrete.

2.1.2 Embankment And Fill Material

Fly ash has been used for several decades as an embankment or structural fill material, particularly in Europe. There has been relatively limited use of fly ash as an embankment material in this country, although its use in this application is becoming more widely accepted. As an embankment or fill material, fly ash is used as a substitute for natural soils. Fly ash in this application must be stockpiled and conditioned to its optimum moisture content to ensure that the material is not too dry and dusty or too wet and unmanageable.

2.3 FLY ASH PROPERTIES

2.3.1 Physical Properties

Fly ash consists of fine, powdery particles that are predominantly spherical in shape, either solid or hollow, and mostly glassy (amorphous) in nature.

The carbonaceous material in fly ash is composed of angular particles. The particle size distribution of most bituminous coal fly ashes is generally similar to that of a silt. The specific gravity of fly ash usually ranges from 2.1 to 3.0, while its specific surface area (measured by the Blaine air permeability method) may range from 170 to 1000 m2/kg. The color of fly ash can vary from tan to gray to black, depending on the amount of unburned carbon in the ash.

2.3.2 Chemical Properties

The chemical properties of fly ash are influenced to a great extent by those of the coal burned and the techniques used for handling and storage. There are basically four types, or ranks, of coal, each of which varies in terms of its heating value, its chemical composition, ash content, and geological origin. The four types, or ranks, of coal are anthracite, bituminous, sub bituminous, and lignite. In addition to being handled in a dry, conditioned, or wet form, fly ash is also classified according to the type of coal from which the ash was derived

2.4.3 FLY ASH CLASSIFICATION:

Fly ash is a pozzolanic material and has been classified into two classes, F and C, based on the chemical composition of the fly ash.

- **Class F Fly ash:** It is produced from burning anthracite and bituminous coals. This fly ash has siliceous or siliceous and aluminous material, which itself possesses little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperature to form cementitious compounds (Chu et. al., 1993).
- **Class C Fly ash:** It is produced normally from lignite and sub-bituminous coals and usually contains significant amount of Calcium Hydroxide (CaO) or lime (Cockrell et. al., 1970).

Properties	Fly Ash Class	
	Class F	Class C
Silicon dioxide (SiO_2) plus aluminum oxide (Al_2O_3) plus iron oxide (Fe_2O_3), min, %	70	50
Sulfur trioxide (SO_3), max, %	5	5
Moisture Content, max, %	3	3
Loss on ignition, max, %	6.0*	6

Table 2.2 Chemical requirements for fly ash classification

2.4 FLY ASH STABILIZATION

Stabilization of soils and pavement bases with fly ash is an increasingly popular option for design engineers. Fly ash stabilization is used to modify the engineering properties of locally available materials and produce a structurally sound construction base. Both non-self-cementing and self-cementing coal ash can be used in stabilization applications.

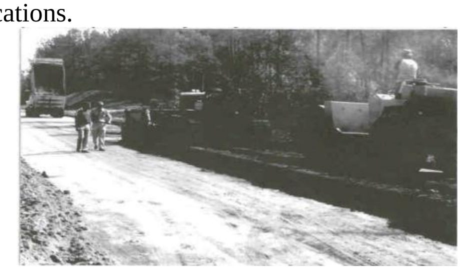

Figure: Cement treated fly ash base course

3. EXPERIMENTAL REASEARCH

31. Preliminary Tests on Flyash

3.1.1. Specific Gravity

Specific gravity is one of the important physical properties needed for the use of fly ashes for geotechnical and other applications.

3.1.2. Grain Size Distribution

The grain size analysis of fly ashes can be done in accordance with is: 2720-part IV (1985). Dry sieving can be adopted for samples retained on 4.75

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mm sieve. Wet sieving can be adopted for samples passing 4.75 mm sieve

3.1.3. Consistency Limits

Fly ashes are non-plastic materials, and hence, they do not possess liquid and plastic limits.

- Liquid limit: liquid limit can be done by cone penetration method.
- Plastic limit: fly ashes are non-plastic and hence plastic limit could not be determined.
- Shrinkage limit: it was also not possible to carry out shrinkage limit tests since the ash pats crumbled upon drying.

3.2 LIME REACTIVITY

A pozzolanic reaction is one in which a siliceous material reacts in the presence of moisture and calcium to form to form compounds exhibiting cementitious properties. The metastable silicates present in all fly ashes, even those which possess little or no cementing value, react with the calcium ions in the presence of moisture to form water insoluble calcium silicates and aluminum silicates. This property is known as the lime reactivity or pozzolanic reactivity of fly ashes.

3.3 METHODS OF CURING

To study the influence of curing conditions on strength development, the specimens were cured by the following methods for the required periods.

3.3.1 Standard Method Std

The specimens extruded from the mould were closely, individually wrapped in polyethylene bags to prevent moisture loss and placed in a desiccator. A small quantity of water was kept at the bottom of the desiccator to maintain constant humidity within the desiccator. The desiccator was closed with a lid and kept in a room the temperature. This method of curing is akin to that suggested by EPRI and is designated as STD (standard).

3.3.2 Method Atm:

In this method, the specimens were first cured for 7 days by the STD method. The specimens were then removed from the polyethylene bags and kept in the open, exposed to the natural environmental elements of heat, light, air, humidity, rain, etc., for the remainder of the curing period. t.

3.4 Unconfined Compressive Strength

At the end of the curing period, unconfined compression tests were carried out on the specimens. The tests were conducted as per relevant Indian standards (IS 2720)

4. RESULTS AND DISCUSSIONS

The unconfined compression test results show the variation of unconfined compressive strength of KFA (MDD-OMC) specimens with curing period for different cement contents.

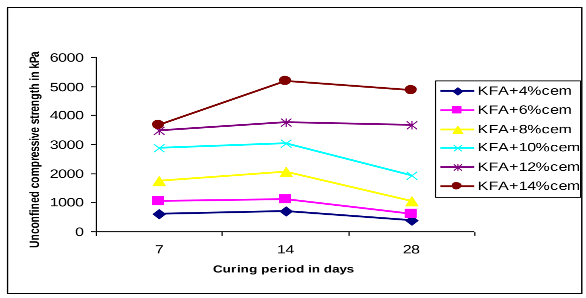

Fig: Variation of UCS in STD method of curing in kothagudem fly ash

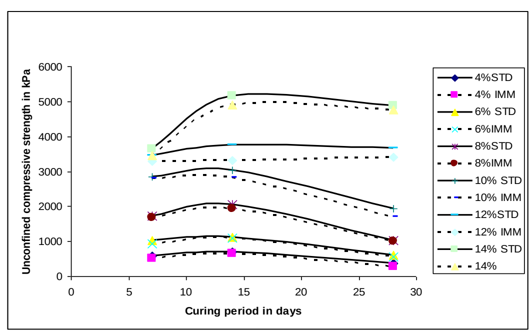

Fig: Effect of cement content and STD and IMM methods of curing in kothagudem fly ash

The rate of change unconfined compression strength in STD method and IMM method. The high strength obtained in STD method compared to IMM method. The immersion of the specimens in water before the compression test increased their water contents,

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which probably decreased the UCS of these specimens.

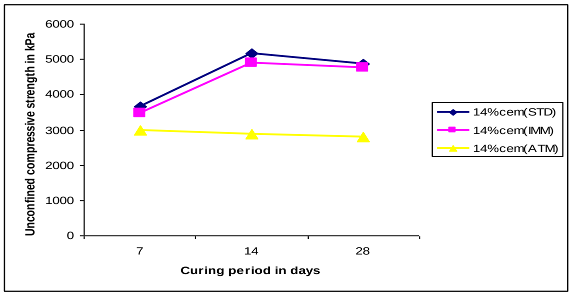

Fig: Variation of UCS in different methods of Curing for 14% of cement

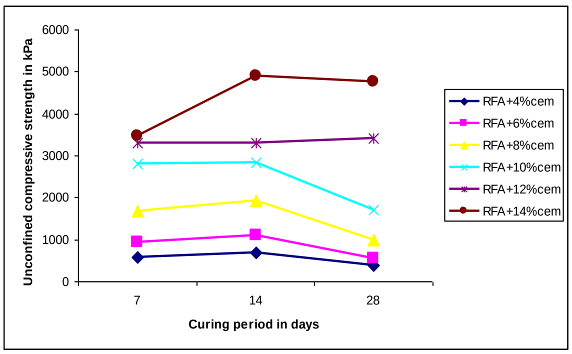

Fig: Variation of UCS in STD method of curing in Ramagundam fly ash

The unconfined compressive strength of RFA specimens increased as their cement content increased. The rate of increase of UCS high till about 14 days and decreased drastically during 28 days.

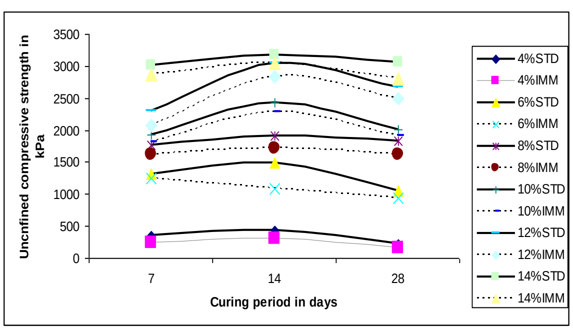

Fig: Effect of cement content and STD and IMM methods of curing in Ramagundam fly ash

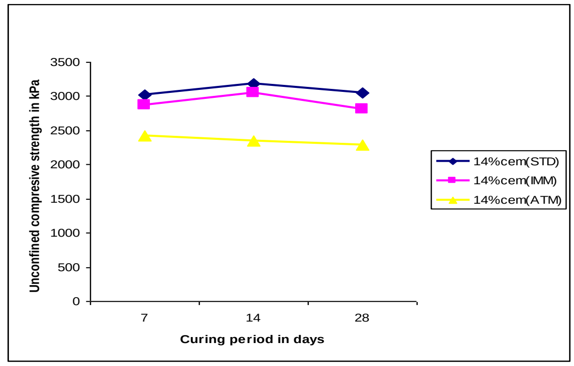

Fig: Variation of UCS in different methods of Curing for 14% of cement

CONCLUSIONS

The following conclusions are drawn based on the laboratory studies carried out in this work to find the strength characteristics of cement stabilized fly ash as a base course.

1. For any cement content, the unconfined compressive strength (UCS) increased till a certain curing period and then tended to decrease. However, for any cement content the rate of change in strength decreased as the curing period increased. The rate of increase in strength was high till about 14 days, decrease during 28 days.
2. Immersion of the specimens in water before the unconfined compression test increased their water contents and decreased their strength. The increase in water content depended on the cement content.
3. The unconfined compressive strength of the specimens depends on the method of curing. The differences between the unconfined compressive strength of the specimens cured by the STD method and the other methods were minimum in the case of ATM method of curing, where the specimens were exposed to the ambient atmospheric elements of light, temperature and humidity.

4. By observing the results of KFA and RFA, at 12%of cement content Kothagudem fly ash gained the strength as per design criteria and Ramagundam fly ash gained at 14%.
5. The Kothagudem fly ash gaining the strength at lesser cement content. Finally it may be concluded that, in practice by the economical point of view the Kothagudem fly ash is the best fly ash for the construction of a base course.

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